Advanced Building Construction Methods

The objective of this challenge is to develop an innovative solution incorporating substantial changes in building materials or construction methods, leading to benefits such as increased productivity and worker safety through reduced construction time, reduced cost and waste, improvements to occupant comfort and health, and reduced energy use.

Background

The building construction industry has been largely the same over the past century[1] but has the potential to transform thanks to recent advancements in manufacturing, fabrication, materials, and logistics. Presently, we use traditional construction methods, including transporting building components individually, for on-site construction. Advances in materials and methods have improved energy efficiency, indoor air quality, and occupant comfort, and novel construction practices could maximize the benefits from these advancements. The Department of Energy's Advanced Building Construction (ABC) initiative, which is led by the Building Technologies Office (BTO), is specifically focusing on integrating energy efficient solutions into highly productive U.S. construction practices for new buildings and retrofits. [2]

There have been significant advances in manufacturing processes and material science in recent years, and while industries such as vehicle and airline manufacturing have taken advantage of these improvements to build vehicles that are lighter, more durable, and more energy efficient, the construction industry is slower to adapt. Significant opportunities exist for radical improvements in the building construction industry, and we should look to the technologies developed in other manufacturing industries for inspiration. Dramatic changes to how buildings are built and what materials are used could lead to improvements in energy efficiency, worker safety, occupant health and comfort, new business opportunities and reduced costs, as well as more specific improvements in flexible usage or rapid on-site construction.

Recent Developments

The building construction industry has recently seen several companies modularizing the construction process and building portions of buildings (walls or apartment units) in an assembly-line-style factory.[3,4] This allows construction to occur indoors, unaffected by weather, and reduces completion time by creating tasks that can either be automated or improved by repetition. Modularization offers many new business opportunities and new jobs while simultaneously improving worker safety. In addition, the cost

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[1] Barbosa, Filipe, Jonathan Woetzel, Jan Mischke, Maria João Ribeirinho, Mukund Sridhar, Matthew Parsons, Nick Bertram, and Stephanie Brown. 2017. *Reinventing construction through a productivity revolution.* McKinsey & Company. https://www.mckinsey.com/industries/capital-projects-and-infrastructure/our-insights/reinventing-construction-through-a-productivity-revolution.

[2] EERE. 2020. "What is the Advanced Building Construction Initiative?" https://www.energy.gov/eere/buildings/what-advanced-building-construction-initiative.

[3] Modular Building Institute. "Modular Building Institute Home." https://www.modular.org/.

[4] ModX.network. "Exchanges." https://www.modx.network/mod-x.

of construction is lower—potentially up to 20% less[5]—and streamlined because of these process improvements, but companies are still generally using traditional construction materials and methods. Cost savings under current practices come from buying material in bulk and reducing on-site delays from weather, among other things.

Novel and innovative solutions for materials or manufacturing processes could lead to dramatic improvements in energy efficiency, durability, and other amenities. 3D printing and increasing the use of automation are examples of innovative methods that have been applied to buildings, but there are likely other new processes and materials that could also be used in building construction.[6,7,8] Energy savings, improved occupant comfort, and indoor environment can also be achieved by increasing the precision of the materials (less air leakage, for example) and by reducing the time that materials are exposed to the elements.

Other benefits could be realized by bringing more creativity to building construction. The COVID-19 pandemic has forced us to rethink how offices should be configured, what meets the definition of a hospital, and even how our homes are used.[9] Our buildings are currently designed and built for a single primary use, and changing that requires significant construction for remodeling. Are there ways of using novel materials and designs to make buildings more configurable, such as changes to the way interior walls (and all the embedded infrastructure) are built to be more conducive to adaptation? Another potential driver could be localized disaster response. The Federal Emergency Management Agency often delivers trailers for temporary housing following disasters such as hurricanes or forest fires.[10] What if temporary housing that is durable, energy efficient, and comfortable could be prebuilt and flat-packed, ready to be shipped to places of need with minimal notice? And then deconstructed, relocated, and repurposed as needed?

The Challenge

If you are not limited by traditional building materials or methods, what could you do? If you do not need to build a house (or other building) at the site but could build pieces in a factory, what could you do? What materials could you incorporate that would not work well when building vertical walls? (Maybe a material that starts off as a liquid?) Could you create a totally different paradigm for buildings, such as easily reconfigurable rooms? Are there aspects to how buildings are built today that are practical but result in missed opportunities for improving health, comfort, or environmental impact?

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[5] Bertram, Nick, Steffen Fuchs, Jan Mischke, Robert Palter, Gernot Strube, and Jonathan Woetzel. 2019. *Modular construction: From projects to products.* McKinsey & Company. http://modular.org/documents/document_publication/mckinsey-report-2019.pdf.

[6] Bendix, Aria. 2019. "These 3D printed homes can be built for less than $4,000 in just 24 hours." *Business Insider.* https://www.businessinsider.com/3d-homes-that-take-24-hours-and-less-than-4000-to-print-2018-9.

[7] ORNL. 2015. "ORNL integrated energy demo connects 3D printing, vehicle." News. https://www.ornl.gov/news/ornl-integrated-energy-demo-connects-3d-printed-building-vehicle.

[8] Novotny, Rachel. 2019. "How Automation in Construction is Reshaping the Construction Industry." eSub Construction Software. https://esub.com/reshaping-the-construction-industry-automation-tools-and-technology/.

[9] McGregor, Jena. 2020. " The post-pandemic workplace will hardly look like the one we left behind." *Washington Post.* https://www.washingtonpost.com/business/2020/04/23/offices-after-coronavirus/.

[10] Keeton, Hugh. 2017. "Coast company developing temporary housing alternative to FEMA trailers." *WLOX.* https://www.wlox.com/story/34416301/coast-company-developing-temporary-housing-alternative-to-fema-trailers/.

This challenge is to develop an innovative solution incorporating substantial changes in building materials or construction methods, leading to benefits such as increased productivity through reduced construction time, brand new business models or jobs, improvements to worker safety, reduced cost and waste, improvements to occupant comfort and health, and reduced energy use. Other benefits, such as creating flexible interior spaces, can also be a key driver. The solution could include one or more of the following strategies:

- Propose the application of a new construction method. This new method does not have to be completely novel but could be an existing process used in other manufacturing sectors. The solution will include details of how this process can be applied to buildings and why it is an improvement over traditional methods.
- Propose the application of a new material in buildings. The material does not have to be completely novel but could be an existing material that has not been widely used in buildings. The solution will include details of the material, its benefits, and how it will be used in building construction, as well as a discussion around why it is an improvement over traditional materials.
- Propose a solution for buildings that will allow rooms to be more easily reconfigured, which can be beneficial during extreme circumstances like a pandemic, but will also be beneficial under normal circumstances such as an increase or decrease in on-site employees for commercial buildings or special events.
- Propose a solution that takes advantage of new construction processes, new materials, or both to substantially improve the functionality of disaster-relief housing in both design and logistics.
- Propose a solution in building materials, construction methods, or design that promotes concepts of a circular economy aimed at eliminating waste and encouraging continual use of resources, such as designing for disassembly and re-use.

All solutions must include a cost/benefit analysis. New processes, methods, and materials typically experience elevated initial costs and the following questions should be considered:

- How will costs be reduced in order to get to large-scale adoption?
- How do those costs compare to the cost of traditional best practices?
- What benefits will the new solution bring that might outweigh costs?
- Are there new business models that could be used to sell the solution?

Cost estimates should focus on those new processes, methods, and/or materials compared with current practices. Cost estimates need not be exhaustive to the entire construction process. Benefits must also be quantified, including energy efficiency, occupant comfort and health, and/or building flexibility.

Solutions may address single-family residences, multifamily housing, or commercial buildings, and should include:

- The proposed approach
- The construction method or building material and information about its current use and properties
- Details about how the proposed changes will integrate with traditional building methods and components, when necessary
- Discuss appropriate and expected impacts and benefits of the proposed solution, which could include costs, time of construction, new business models, energy usage, occupant health, worker safety, and increased productivity

- A technology-to-market plan for how to scale up this solution to make an impact on the building industry. The construction industry includes many different companies and radical change does not come easily, so the technology-to-market plan should also address how to scale-up this solution such that an impact on the building industry can be made.