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The Path to Net-Zero Carbon: Stabilizing Climate Change Takes a (Global) Village

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Firefighters battle infernos from Lake Tahoe ski lifts. A hurricane reverses the flow of the Mississippi River. Thermometers read 121 degrees Fahrenheit—in Canada. A dip in gravity is detected in the Antarctic ice sheet. Sound like some kind of futuristic dystopian disaster movie? Not quite: These scenes are real; they're happening right now; and they're fueled by climate change.

Since the Industrial Revolution, humans have sent more than 2,000 gigatons of carbon dioxide into the atmosphere. This thickening blanket of heat-trapping pollutants is the cause of global warming.

The impact of fossil fuel use is staggering: Pollution kills 8 million people annually. In the United States alone, fossil fuel use causes more than 50,000 deaths and $445 billion in economic damage each year.

The degree of global warming is directly proportional to the amount of carbon dioxide that human activities add to the atmosphere. It's a brutally simple equation: To stabilize climate change, global carbon emissions must fall to zero. The longer it takes to do that, the more the climate will change.

What Is Net-Zero Carbon?

Simply put, net zero is a state in which the amount of greenhouse gas released into the atmosphere is equal to the amount removed from the atmosphere. Net zero is achieved through carbon reduction, offsetting, and removal.

WHY IS NET-ZERO CARBON IMPORTANT?

Net-zero carbon is important because climate change is widespread and intensifying (PDF, p. 8), and experts agree that the best way to tackle it is by reducing global warming.

In 2015, the Paris Agreement outlined an international framework to limit the rise in global temperatures to less than 1.5 degrees Celsius (2.7 degrees Fahrenheit) above preindustrial levels, which would significantly limit the impacts of climate change. To meet this target, most experts agree, global carbon emissions must reach net zero by 2050. Nearly

200 countries agreed to take action, and some—including France, New Zealand, and Sweden—have ratified net zero into legislation.

Meeting midcentury net-zero goals means aggressively reducing emissions right now; actions in the next decade will be critical. "We're going to be in trouble because we're now at 1 degree Celsius rise over preindustrial temperatures," says architect and educator Ed Mazria, founder of Architecture 2030, which aims to transform the built environment from being the major emitter of greenhouse gases to a central solution to the climate emergency. Mazria, like many leading the progressive side of the movement, says 2050 is too late: "In order to keep under 1.5 degrees, we have to have a steep decline in emissions between now and 2030 and then phase them out by 2040." To have a good (67%) probability of meeting that 2040 target, Mazria says, global carbon emissions must reach a 50% reduction by 2030 and zero by 2040.

HOW DOES NET ZERO APPLY TO THE DESIGN AND BUILD INDUSTRY?

Any built structure has carbon emissions associated with it, in both the building process and the operation phase. A net-zero building balances its greenhouse gas emissions from traditional energy by reducing energy use to minimize carbon emissions, using renewable energies such as wind and solar, or purchasing carbon offsets to reach a break-even point.

Net-zero building goals are ambitious, to say the least. "By 2030, the built environment should halve its emissions, whereby 100% of new buildings must be net-zero carbon in operation, with widespread energy efficiency retrofit of existing assets well underway," says Victoria Burrows, director of Advancing Net Zero at the World Green Building Council. "Embodied carbon must be reduced by at least 40%, with leading projects achieving at least 50% reductions in embodied carbon. By 2050 at the latest, all new and existing assets must be net zero across the whole life cycle, including operational and embodied emissions."

It's difficult to overstate the built world's impact on global emissions. "We're on a path to double the amount of building floor space by 2060," says Clay Nesler, global lead, Buildings and Energy, WRI Ross Center for Sustainable Cities at the World Resources Institute. "If you do the math, that's equivalent to building another New York City every month. Those buildings will have to be heated, cooled, and lighted; provide a comfortable, healthy environment; and be resilient to the impacts of climate change.

"If cities and countries are to achieve net zero, there's no way to do it without focusing on their buildings because buildings represent 39% of global carbon emissions and even higher percentage of carbon emissions in cities," Nesler continues. "But [buildings] also represent the greatest opportunity for immediate reductions, using available technology, that are cost-effective over their life cycle."

Net-Zero Carbon: Construction's Role and Its History in the Design and Build Industry

Net zero has evolved from scientific concept to aspirational practice to policy in a very short time.

Before the Industrial Revolution, buildings were closer to net zero than they are today. Heat and light were generated by burning biomass, ventilation provided fresh air, and mechanical systems weren't widely implemented.

By the early 20th century, designers, engineers, and builders were starting to consider structures' environmental impact. In the 1970s, conflict in the Middle East led to skyrocketing oil prices and forced an energy-conservative mindset; government and industry leaders grew concerned with their economic dependency on fossil fuels.

In 1998, the US Green Building Council launched Leadership in Energy and Environmental Design (LEED), a rating system for material, water, and energy usage for newly constructed buildings.

In 2002, Mazria founded Architecture 2030, a nonprofit dedicated to altering the course of climate change. In 2006, Architecture 2030 issued the 2030 Challenge, which called for newly constructed buildings to be carbon neutral by 2030. The American Institute of Architects responded with the 2030 Commitment, which tracks progress toward the goals of the 2030 Challenge.

In 2006, the Living Building Challenge raised the bar for building standards and their sustainability performance.

In 2015, nearly 200 countries committed to the Paris Climate Agreement to reduce pollution over time. In 2019, the European Commission created the European Green Deal, a set of initiatives to bring Europe to climate neutrality by 2050.

Total Carbon Management: What Does It Mean?

In the context of the architecture, engineering, and construction (AEC) industry, total carbon management is the process of measuring and managing the sum of a building's embodied and operational carbon. "What's tricky is that the term net zero is often only used to describe addressing operational energy,'" says Tony Saracino, Autodesk senior manager, Sustainability Success. "Net zero in its true sense should be used to describe buildings that measure, manage, and reduce total carbon emissions—the sum of embodied carbon and operational carbon to zero or beyond."

EMBODIED CARBON

Everything that is built has a hidden climate impact due to embodied carbon—the carbon emissions generated by extracting resources, refining, manufacturing, and logistics. The embodied carbon of all the materials going into buildings and infrastructure is hard to trace but accounts for 11% of global greenhouse gas emissions. Unlike a building's operational carbon emissions, which can be reduced over time with energy-efficiency renovations and the use of renewable energies, embodied carbon emissions are locked in place as soon as a building is built.

Construction is the No. 1 consumer of raw materials in the world. According to Architecture 2030, embodied carbon will be responsible for more than half of total new construction emissions by 2030.

With a projected 2.5 trillion square feet of new buildings being constructed by 2060, it's critical to get embodied carbon under control now and achieve net-zero carbon in construction. Tools like the open-source EC3 embodied carbon calculator help stakeholders make informed choices about choosing materials with the least carbon impact.

OPERATIONAL CARBON

Operational carbon is the amount of carbon a structure emits during its use, including management and maintenance. Operational carbon makes up 28% of global emissions; that number will rise as the built world expands during the next three decades.

High-performance building design delivers buildings that are efficient, safe, and comfortable—and that exceed performance and greenhouse-gas reduction regulations. This is accomplished by combining techniques and tools to optimize energy consumption, materials usage, and occupant safety and comfort, taking advantage of renewable energy sources wherever possible.

Digital technologies such as BIM (Building Information Modeling) empower designers to simulate energy use. But while technology enhances the design process, that design process is getting more complex.

"If we're going to design these zero-carbon buildings, we not only have to make them structurally sound; we've got to analyze the lighting levels because we're using more natural lighting," Nesler says. "We have to estimate the impact of things like green roofs, white roofs. We have to figure out the best building orientation. We're going to have to do very detailed energy simulation because we're going to have to match renewable energy to the actual heating, cooling, and lighting loads of the building. And we're also going to have to control the buildings in different ways."

CARBON OFFSETS

Carbon offsets help businesses meet sustainability goals by counteracting their carbon emissions through investments in projects that avoid or reduce carbon consumption. They sometimes take the form of carbon credits, with one credit equaling the removal of 1 metric ton of carbon dioxide from the atmosphere or the avoidance of producing that carbon dioxide.

Builders can invest in third-party offset projects or start their own programs, such as tree plantings, wind farms, geothermal power plants, and solar projects.

CARBON REMOVAL

While emissions-reduction strategies are a critical step in the path to net zero, they are not enough; getting there requires strategies that actively remove carbon from the atmosphere.

Carbon-removal methods include natural strategies such as forest restoration and soil management; high-tech strategies such as direct air capture and enhanced mineralization; and hybrid strategies such as ocean-based carbon removal.

In the built world, carbon removals can include capturing carbon coming out of a chimney stack, turning industrial emissions into building materials, and storing carbon in materials like concrete.

"The most exciting developments are those that have the potential to drastically reduce the carbon footprint of concrete or even produce concrete that has net-negative carbon footprint and is therefore a carbon sink," says Dr. Claire White, associate professor of civil and environmental engineering at Princeton University. "There are alternative cements that have at least 70% lower CO_2 emissions than portland cement. We need these materials if we are to drastically cut the carbon footprint of concrete and transition to a net-zero carbon industry."

Building Design for a Circular Economy

The circular economy, a zero-waste mindset that focuses on the continual use and reuse of resources, is gaining ground in architecture. It's more than recycling; it's embracing the idea of upcycling in the context of design and build. Implementing this closed-loop cycle means taking a top-down approach that encompasses everything from the performance of individual materials to the purpose of the building itself.

HOW DO YOU DESIGN AND CONSTRUCT A BUILDING FOR CIRCULARITY?

Designing for circularity means accounting for a building's entire lifecycle and beyond—a "cradle-to-cradle" approach.

"Consider a simple bookcase," Saracino says. "Maybe it's in too bad a shape to repair, but the boards that made up the shelves can be used in another thing that uses that same-width and same-length wood, rather than just tearing it down. That's where smart design can lead toward circularity."

The same concept can be applied at a building scale. "Think about if you've ever gone to a loft where people have turned an old factory into housing," Saracino says. "That's a great example of circularity in a building. They've taken a building that once was a manufacturing site, and now people are living in it and sometimes with very minimal intervention—the same big redwood beams are floating through the ceilings and the columns, and the floors are still there."

To reap the most benefits of circularity in building design, end-to-end digitalization is critical, Nesler says: "You go from a crayon sketch on an iPad to a BIM model. You simulate everything; you optimize the design [for optimal energy use]; you figure out how much carbon is embodied in the materials.

"And then you download that into a system that associates data with all the sensors and the devices in the building so that we can not only optimally control the building, but we can also make the building a producer instead of a consumer of energy," he constinues. "It stores it; manages it; and, yes, it uses a little bit of hopefully clean energy. And oh, by the way, there's going to be a little tag on the concrete walls and on the steel beams so when we're tearing down that building 50 years from now, it's going to tell us what's exactly in there."

DESIGNING BUILDINGS AS MATERIALS BANKS

Today's building processes treat materials in inefficient ways; structures are designed for finite applications. What if, instead, buildings were treated as temporary storage for valuable materials and components? That's the idea behind buildings as material banks.

"A building is made up of all of this 'stuff,'" Saracino says. "There's wood on the floors; there are some concrete slabs, some copper piping. Those are all materials that are deposited in that bank of the building. Now, we can put a building together so that when it's reached its end of life, we know what's in that bank. And it's easy to take apart. You're not just hitting it with a wrecking ball."

Digitalization is an increasingly important step in designing buildings as materials banks. "Right now, we tear down a wall, we've no idea what's in it," Nesler says. "A BIM model is going to have to include everything about the materials in there and facilitate the reuse, the remanufacture, things such as that."

Examples of Projects Aiming for Net-Zero Carbon

Around the world, inspiration can be found in projects large and small that lead the way in the path to net zero.

» Build Change is constructing and strengthening houses in earthquake- and windstorm-prone nations, using locally available, climate-adapted materials.

» United Therapeutics' Unisphere building, just outside Washington, DC, is one of the world's largest net-zero buildings, at more than 134,000 square feet.

» The Skanska project team behind the Georgia Institute of Technology's Kendeda Building for Innovative Sustainable Design is meeting the performance requirements of the Living Building Challenge partly through use of salvaged materials, including two-by-fours from dismantled movie sets.

» BamCore created a system to design and manufacture hybrid bamboo panels, offering renewable materials for residential and low-rise commercial structures.

» When BuildX Studio constructed the Sachibondu Rural Health Centre in Zambia, it sourced or produced more than 80% of building materials locally, including reclaimed timber and temperature-regulating blocks made by compressing soil.

What Is the Future of Net-Zero Carbon?

Net zero is achievable, but meeting midcentury goals will take a collaborative effort among all stakeholders and must be driven by policy. But according to Nesler, the private sector also needs to be proactive. "Not all policy makers have the background of really building buildings and saving energy," he says. "The private sector can bring credibility and practicality to discussions."

As countries move toward net zero, it's critical to build resilience in the world's vulnerable communities that contribute the least to carbon emissions yet bear some of the greatest health and economic impacts. "Underserved communities have the most to lose with climate change but the most to gain from more efficient, sustainable buildings because the interventions that we make to buildings to drive their carbon emissions to zero also makes them more comfortable, makes them healthier," Nesler says.

"The trick is to find ways of being able to pay that upfront cost of higher-performance buildings or the cost of doing a major renovation and paying for it over time," he continues. "There are a number of creative business models that are private-sector oriented that can allow those communities to address that."

And that's where the AEC industry, more than any other sector, can be the biggest agent of change. "When the architecture community came to terms with the fact that they played a role in climate change, they jumped on board because, as designers, they are taught to make the world a better place," Mazria says. "That's the calling of the profession."

About the Author

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About the Article

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