Climate change due to increasing levels of carbon dioxide in the air is not just about the impact on the health of the planet. There are real effects on human health too.

Climate, Carbon, and Human Health

Buildings can shift from being part of the problem to part of the solution

Sponsored by Interface | *By Peter J. Arsenault, FAIA, NCARB, LEED AP*

Typically when we think about global climate change, we don't think about its impact on our human health. Rather, we may associate it with severe weather-related events, changes in plant and animal life, and other things that we perceive as separate from our bodies. However, whether we recognize it or not, the health of all people is being impacted by global climate change. In a November 2018 report published by *The Lancet* medical journal, scientists and health experts said rising heat and wilder weather linked to climate change make it "the biggest global health threat of the 21st century." They cite climate change impacts, including heatwaves, storms, floods, and fires, that are threatening to overwhelm health systems. This is evidenced by their observation that hundreds of millions of people have already been suffering health impacts from climate change effects over the past two decades.

The recognized solution to this issue is to go directly to the source, namely, reduce the amount of carbon dioxide and other air-polluting greenhouse gases (GHG) that are being released into the atmosphere. Over the past 150 years or so, there has been an observable increase in these GHGs that has been tracked, recorded, and linked directly to changes in climate and temperatures. While transportation (i.e., cars, planes, etc.) and industry (i.e., coal-fired plants) are often pointed to as the problem, they aren't the only ones. In fact, numerous sources, including the not-for-profit organization Architecture 2030, point to buildings as the source of approximately 40 percent of the annual GHG emissions globally. This is measured, in almost equal parts, in both the operations and construction of buildings. The operational carbon emissions come primarily from buildings relying on fossil-fuel-based energy sources to power the day-to-day functioning of these buildings, such as heating, cooling, and electric lighting. The construction-related emissions reflect the energy from fossil fuels that was required to produce the products and materials that go into buildings. Hence the term embodied carbon dioxide refers to the carbon dioxide emitted during the manufacture, transport, and construction of building materials, together with end-of-life emissions from disposal. This includes emissions from the raw materials used to create a building material, from the freight to transport a building material, and from the energy used in final manufacturing of a building product.

While some efforts, such as green building programs, have helped architects account for and reduce the environmental impact of the buildings that they design, there is an immediate need to do more in order to protect public health, safety, and welfare. In that regard, this course looks at climate change in light of

CONTINUING EDUCATION

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Learning Objectives

After reading this article, you should be able to:

1. Identify and recognize the direct relationship between climate change and human health.
2. Assess the impact that green building rating systems such as LEED are having on the reduction of greenhouse gas (GHG) emissions into the environment.
3. Investigate the organizations and tools available to assist design and construction professionals in determining the carbon footprint of a building.
4. Explore examples of different building and product types that can be designed and specified to work toward carbon-neutral or carbon-negative (storing) buildings.

To receive AIA credit, you are required to read the entire article and pass the test. Go to **ce.architecturalrecord.com** for complete text and to take the test for free.

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some of the specific public health concerns, solution approaches, new tools, and application strategies. It will also provide some examples of products and building projects that are helping design professionals create carbon-neutral or even carbon-negative results by reducing and potentially sequestering carbon dioxide.

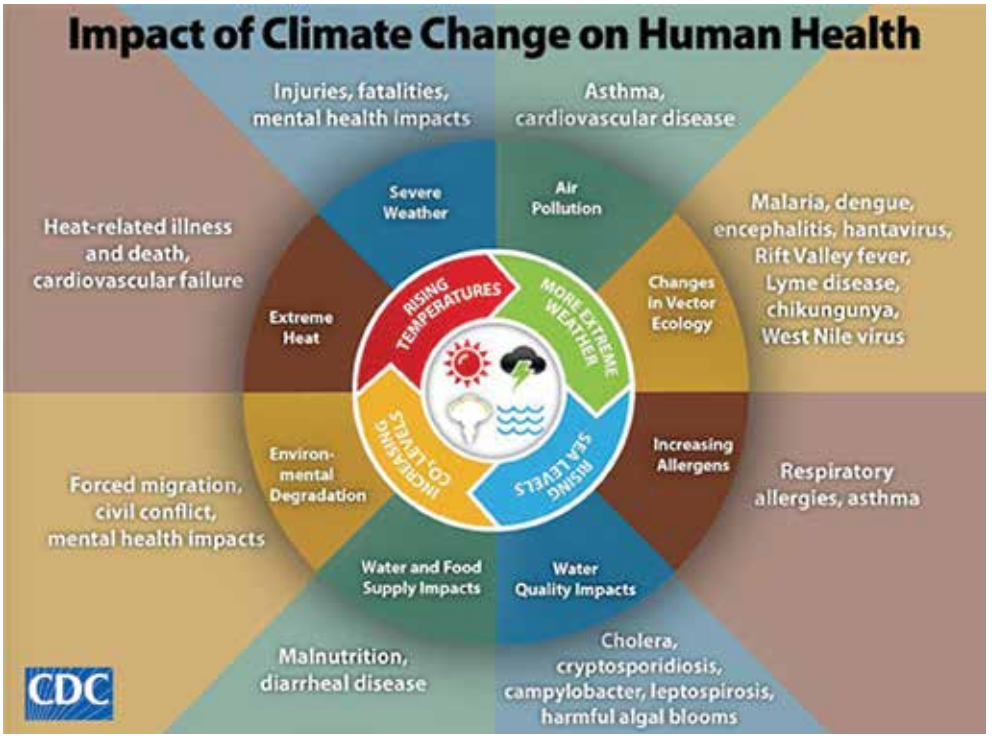
THE PROBLEM: CLIMATE CHANGE IS A PUBLIC HEALTH CONCERN

While climate change and its impacts are a worldwide issue, the United States government has been engaged in monitoring, assessing, and advising on the topic for many years. In particular, the U.S Department of Health and Human Services (HHS) Centers for Disease Control and Prevention (CDC) have teamed up with the American Public Health Administration (APHA) to look specifically at health questions related to climate change. Together, they have concluded, "Climate change poses many risks to human health. Some health impacts of climate change are already being felt in the United States."[1]

These U.S. government agencies acknowledge what scientists around the world have pointed out: "When we burn fossil fuels such as coal and gas, we release carbon dioxide, which builds up in the atmosphere and causes earth's temperature to rise, much like a blanket traps in heat. This extra trapped heat disrupts many of the interconnected systems in our environment." Specifically, they have recognized four phenomena resulting from the burning of fossil fuels: 1) increased levels of carbon dioxide in the atmosphere; 2) rising air and water temperatures; 3) more extreme weather events around the country; and 4) rising sea levels. Further, they have begun to observe that each of these phenomena not only impacts the environments where people live but also human health.

The biggest direct impact on human health from emissions into the atmosphere is that the air is less healthy to breathe.

Source: Centers for Disease Control and Prevention



Climate change impacts a wide range of health outcomes. This image from the Centers for Disease Control and Prevention (CDC) illustrates the most significant climate change impacts (rising temperatures, more extreme weather, rising sea levels, and increasing carbon dioxide levels), their effect on exposures, and the subsequent health outcomes that can result from these changes in exposures.

Excerpts of some of the environmental and human health impacts that the CDC and APHA have identified and described include the following.[2]

Air Pollution

The biggest direct human health impact from emissions into the atmosphere is that the air is less healthy to breathe. According to the National Climate Assessment, climate change will affect human health by increasing ground-level ozone and/or particulate matter air pollution in some locations. Ground-level ozone (a key component of smog) is associated with many health problems, including diminished lung function, increased hospital admissions and emergency department visits for asthma, and increases in premature deaths.

There are other less-direct impacts too. Higher air temperatures generally lead to an increase in allergens and harmful air pollutants, exposure to which causes health problems for many people. When sensitive individuals are simultaneously exposed to allergens and air pollutants, allergic reactions often become more severe. People with existing pollen allergies may have increased risk for acute respiratory effects.

Similarly, more and larger wildfires linked to climate change could also significantly reduce air quality and affect people's health in a variety of ways. Smoke exposure increases acute (or sudden-onset) respiratory illness, respiratory and cardiovascular hospitalizations, and medical visits for lung illnesses. The frequency of wildfires is expected to increase as drought conditions become more prevalent.

Continues at ce.architecturalrecord.com

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Extreme Heat

Climate change also affects human health due to the increasing frequency and intensity of extreme heat events. Increases in the overall temperature of the atmosphere and oceans associated with climate change cause changes in wind, moisture, and heat-circulation patterns. These changes contribute to shifts in weather events, including extended days of extreme heat, which can be dangerous to health or even fatal.

Extreme heat and record low rainfall in Europe during the summer of 2018 led to withered fields.

Extreme heat events can trigger a variety of heat-stress conditions, such as heat stroke, which is the most serious heat-related disorder. It occurs when body temperature rises rapidly in a heat event, the sweating mechanism fails, and the body cannot cool down. This condition can cause death or permanent disability if emergency treatment is not given. People with higher risk for heat-related illness include small children, the elderly, persons with chronic diseases, low-income populations, and outdoor workers. Many cities across the United States, including St. Louis, Philadelphia, Chicago, and Cincinnati, have seen large increases in death rates during heat waves.

Precipitation Extremes: Heavy Rainfall and Drought

Increases in precipitation extremes, either heavy rainfall events at one end or droughts at the other, can impact our health. Warmer temperatures cause more water to evaporate into the air and allow that air to hold more water. This sets the stage for heavier downpours. At the same time, global temperatures influence the way heat and moisture move around the planet, meaning drier conditions will occur in some regions of the world.

Over the past several decades, we have already seen an increase in the number of heavy precipitation events in the United States. These events have contributed to more severe flooding in certain regions. Floods are one of the deadliest weather-related hazards in the United States, second only to heat.

Image courtesy of World Health Organization

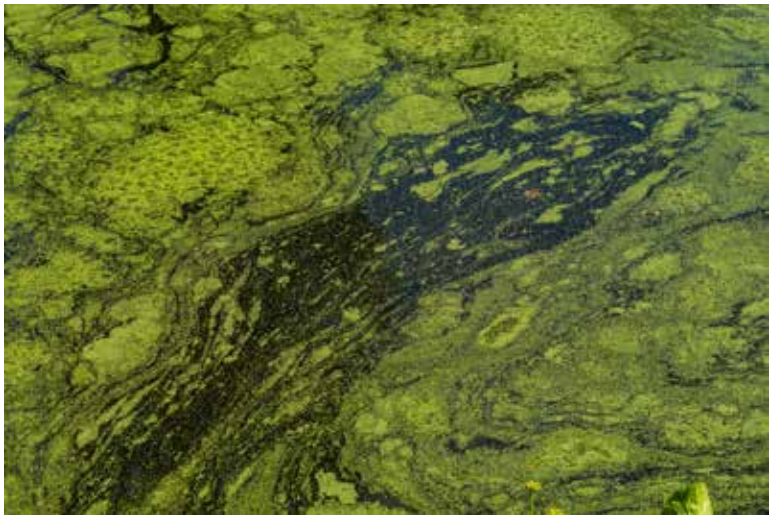
The recent floodings in Uganda is a disaster of great dimensions. More and more people are getting sick from malaria every day, the first cholera outbreaks are soon to come, and people have nothing to eat.

Other hazards can appear after a storm has passed. For example, flood waters often contain a variety of contaminants or harmful pollutants, including agricultural waste, chemicals, and raw sewage. In some cases, floods can overwhelm a region's drainage or wastewater treatment systems, increasing the risk of exposure to bacteria, parasites, viruses, and other unhealthy pollutants. If a building becomes damp or flooded, it can develop mold, which affects indoor air quality. Living with poor air quality and in damp conditions has been shown to increase health problems, including aggravation of asthma and other upper respiratory tract symptoms, such as coughing and wheezing due to mold exposure. They also include lower respiratory tract infections like pneumonia.

People living in drought conditions may be more likely to encounter certain dangerous situations threatening their safety and well-being. These can range from wildfires to dust storms to flash floods.

Water Quality

Climate change affects human health by impacting the quality and safety of both our water supply and recreational water. As the earth's temperature rises, surface water temperatures in lakes and oceans also rise. Warmer waters create a more hospitable environment for the growth of some harmful algae, bacteria, and other microbes that make humans sick. For example, *Vibrio parahaemolyticus* is responsible for diarrheal illnesses linked with consuming raw or undercooked oysters from the Gulf of Mexico. *Vibrio vulnificus* causes vomiting, diarrhea, and abdominal pain in healthy adults and is the more severe of the two, believed to be responsible for most of the seafood-related deaths in the United States. Both can also cause serious infections through contact with contaminated water while swimming. *Naegleria fowleri* (sometimes referred to as a "brain-eating ameba") is a microbe that can be present in soil and warm freshwater. It usually infects people when contaminated water entera the body through the nose. Infections of these microbes are occurring farther north, and warming waters may increase this risk.

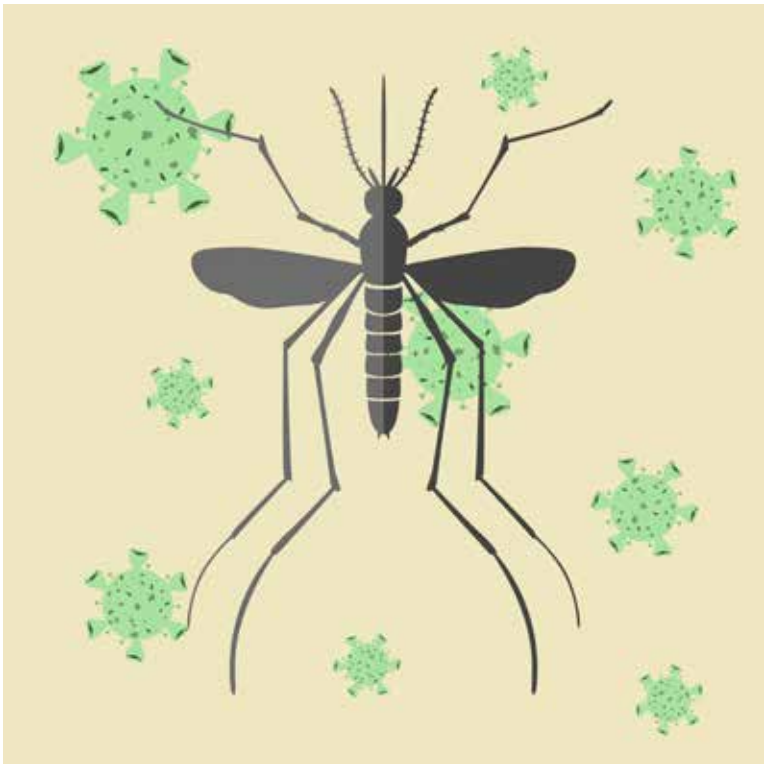


Algal blooms, like those shown here, endanger human health, the environment, and economies.

Changes in Vector Ecology

Vectors in this case are organisms such as fleas, ticks, and mosquitos that can transmit a pathogen or infectious agent from one host to another. Climate change has the potential to increase the risk of vector-borne diseases and thus impact human health. Since warmer average temperatures can mean longer warm seasons, earlier spring seasons, shorter and milder winters, and hotter summers, conditions might become more hospitable for many carriers of vector-borne diseases.

Lyme disease is a concern since the development and survival of ticks, their animal hosts (such as deer), and the bacterium that causes the disease are all strongly influenced by climatic factors, especially temperature, precipitation, and humidity. Currently, most occurrences of Lyme disease in the United States are in the Northeast, particularly the state of Connecticut. An expansion of the geographic area in which ticks can survive may lead to more people having contact with infected ticks. In regions where Lyme disease already exists, milder winters result in fewer disease-carrying ticks dying during winter. This can increase the overall tick population, which increases the risk of contracting Lyme disease in those areas.



Climate change has the potential to increase the risk of vector-borne diseases and thus impact human health.

West Nile virus is another example of a vector-borne disease (primarily through mosquitos) that may be influenced by climate change. Preventing people from contracting West Nile virus is important because there are no medications to treat or vaccines to prevent this virus in humans, and recovery from severe disease may take several weeks or months.

Environmental Degradation, Food, and Water Supply

If climate change impacts are severe enough in particular areas, then it will degrade the ability of those areas to be productive and even habitable. There have already been observed impacts in the United States on food production and water supply being interrupted, sometimes for extended periods, following extreme weather events. Other places around the world are experiencing more severe impacts. These include malnutrition due to food shortages and diarrheal diseases, such as cholera, due to clean water scarcity and damaged sanitary systems. In the most extreme cases, they lead to forced migration, as happened following Hurricane Katrina in 2005 and elsewhere in the world in refugee camps. When resources needed to support lifestyles become scarce, civil conflicts often erupt, and indeed are already happening in other parts of the world. All of these conditions can impact the psychological and mental health of the people involved.

Image courtesy of World Health Organization

If climate change impacts are severe enough in particular areas, it will degrade the ability of those areas to be productive and even habitable.

While this information from the CDC and APHA paints a dire picture, the agencies also recognize that many communities are already taking significant and appropriate steps to address these issues head on. These efforts are usually contained under the umbrella of sustainability or resiliency for communities but are directly focused on reducing GHGs and preparing to bounce back from the impacts of future weather events and related climate change impacts. In so doing, they are addressing the public health issues associated with climate change and actively reducing the potential for harm to people.

FINDING SOLUTIONS: RECOGNIZING IMPACTS

We have already noted the significance of the building sector in contributing to GHG emissions, particularly carbon dioxide, both in embodied carbon and operational carbon. It has been observed that 13–18 percent of the total embodied carbon footprint of any construction project is released the year the project is built or installed.[3] Further, 100 percent of the total embodied carbon footprint of any landscape project is released during construction. Many green building experts, including Architecture 2030, make the point that these embodied carbon emissions are already impacting the climate when the building opens. Hence, it is even more urgent to address than operational carbon, which is addressable over the life of the project, typically 30 to 80 years. Operational carbon can be reduced through energy conservation, renewable energy use, and system efficiencies, but embodied carbon has already been released to the atmosphere.

Recognizing the significance of buildings and their carbon footprints is the first step in finding solutions. So is understanding the relative successes that have been observed or calculated in buildings.

Impact of the Green Building Movement

Over the past 20 years, the creation and evolution of green building programs such as LEED, GreenGlobes, the WELL Building Standard, the Living Building Challenge, Passive House, and others around the world reflect the fact that green and sustainable building is not just a trend or fad but a well-entrenched movement within the design and construction industry. Further, it is being demanded of building owners, whether for business reasons, philosophical support of their missions and values, or simple economics. It would be reasonable then to ask what the impact of this movement has been, and for our purposes here, how public health has been impacted. A team of research-

ers at the Harvard T.H. Chan School of Public Health's Environmental Health Department in Boston conducted a study to determine just that. Its findings were published in January 2018 in the *Journal of Exposure Science & Environmental Epidemiology* in a research article titled "Energy savings, emission reductions, and health co-benefits of the green building movement."[4]

This team of researchers retrieved both the floor space and designed energy efficiency of the LEED-certified projects in six different countries (the United States, China, India, Brazil, Germany, and Turkey). These six countries represent major regions around the world and account for 82 percent of LEED-certified floor space. The study included buildings certified during the years 2000–2016 representing a total of 335 million square meters of floor space. Data was obtained from the Green Building Information Gateway (GBIG) operated by the U.S. Green Building Council (USGBC).

With this information in hand, the researchers then applied Harvard's Co-Benefits of the Built Environment (Co-BE) Calculator to determine energy cost savings, emission reductions, and health co-benefits for each country studied. Their work included establishing baseline energy-use intensity (EUI) of conventional commercial and institutional buildings for each building location. They compared those baselines to the EUI of LEED-certified buildings to determine annual energy savings for each fuel source. Then they translated energy reductions into emission reductions for GHGs (CO_2, CH_4, and N_2O) and selected air pollutants (particulate matter, SO_2, and NO_x). Lastly, annual health co-benefits were calculated using the Clean Power Plan (CPP) and Social Cost of Atmospheric Release (SCAR) methodologies.

Their findings from this work included the following:

- "Based on modeled energy use, we estimate that LEED-certified buildings have yielded $13.3 billion ($9.8–$16.6 billion) in energy cost savings and health co-benefits between 2000 and 2016. $7.5 billion of this total comes from savings on energy in green buildings compared to conventional buildings. Another $1.40 billion ($0.43–$2.17 billion) comes from averting 33 megatons (MT) of CO_2 emissions and their associated climate damages. Lastly, emissions of SO_2, NO_x, and PM2.5 were reduced by 51, 38, and 10 kilotons (kt), respectively, by green buildings compared to conventional buildings, accounting for the remaining $4.35 billion."
- The U.S. health benefits derive from avoiding an estimated 172–405 premature deaths, 171 hospital admissions, 11,000 asthma exacerbations, 54,000 respiratory symptoms, 21,000 lost days of work, and 16,000 lost days of school.
- These co-benefits come from only 3.5 percent of the total commercial building floor space in the United States as of 2016, hinting at the potential for energy-efficient buildings to benefit climate and health.

Based on the extent and breadth of the positive impacts of green buildings, they further concluded that the health co-benefits of energy-efficient buildings should be considered during the drafting of policy, the design of new buildings, and the operation of existing ones.

TOOLS: REDUCING THE CARBON FOOTPRINT OF BUILDINGS

When designing and specifying buildings, architects and others can make a difference in the amount of embodied carbon in their projects by choosing products with a low carbon footprint. But how can we differentiate between products that do in fact contain low amounts of embodied carbon and those that contain more? One approach is to follow the procedures in green building rating systems such as LEED that include multiple credits conducting a whole building life-cycle assessment (LCA) of products.

There are a number of LCA tools on w hich LEED provides guidance for proper use. Part of the process includes the use of an environmental product declaration (EPD) for each of the main products used in a building. EPDs are prepared at the request and expense of manufacturers. However, the key point is that they are carried out by independent third parties, much the same way code-compliance testing is carried out by independent third-party organizations. For a proper disclosure to be made, EPDs first rely on a product being categorized and rules established for the proper means of comparing that product to others. Simply referred to as product category rules (PCRs), these are usually prepared by trade associations taking into account industry specific data that is common across manufactured products of a particular type (i.e., masonry, roofing, etc.)

With the LCA process and PCRs as the basis, EPDs look at the specific environmental impacts of the product being assessed over its entire life cycle. Among the common reported impacts are the amounts of carbon dioxide released into the atmosphere for each unit (square foot, cubic yard, etc.) of material or product produced. This is good information and allows a specifier to compare the differences in the impact between material types (i.e., masonry versus steel) and products (i.e., some flooring types, insulation types, etc.) as long as a complete and relevant EPD has been performed and made available for those products. While the building products and materials industry is moving in this direction, the current reality is that not all product types have PCRs and not all manufacturers have prepared EPDs for their products. Nonetheless, the best way to find lower-embodied-carbon products is to look for those that are third-party certified as carbon neutral either through EPD data or similar information.

Recognizing the limited availability of EPDs and other information available to design and construction professionals, some leaders in their respective fields have come together and developed some strategies and tools for manufacturers, architects, designers, and other building industry professionals to engage in and use as follows.

Carbon Smart Materials Palette

The not-for-profit organization Architecture 2030 offers a free online public resource called the Carbon Smart Materials Palette (www.materialspalette.org). This tool takes an attribute-based approach to embodied-carbon reductions in the built environment—that is, it identifies key attributes that contribute to a material's embodied carbon impact. It also offers guidelines and options for emissions reductions. As a dynamic tool, The Carbon Smart Materials Palette is designed to support and complement LCAs and EPDs. It is also intended to provide highly impactful guidelines for low/no-carbon material selections and specifications. The creators do point out that this tool "is a living resource that reflects the best available knowledge and resources at this time. The palette will be updated as new technology, research, and data becomes available. The extent to which any or all of these guidelines and recommendations are realized in practice depends in large measure on their application, local conditions, and the extent to which the designer succeeds in understanding and applying them."

Currently, the palette addresses some high-impact materials, such as concrete, steel and insulation. It also looks at wood in terms of its potential high or reduced impacts. Similarly, it looks at materials that can be considered carbon smart in that they have low carbon or even store (i.e., sequester) carbon within them. These include hemp-crete, sheep's wool, strawbale construction, and wood.

Materials Carbon Action Network

An independent collaborative known as the Materials Carbon Action Network (materialsCAN) is comprised of "members of the global building industry that are ready to ACT on the smart prioritization of embodied carbon in building materials" (www.materialscan.org). Those members include manufacturers of ceilings, insulation, flooring, and wallboard products—some of the most common and extensively used products in building projects of all types. It also includes Gensler and Skanska representing the design and construction communities. This group aims to empower those who own, lease, design, or construct spaces with education and tools to better understand the carbon footprint of their projects, specifically through measuring the embodied carbon of specified materials. In terms of action items, materialsCAN indicates that it will 1) improve embodied carbon awareness via client, industry, and external partnerships; 2) support the creation of a methodology to enable analysis and prioritization of embodied carbon goals in specifications; and 3) highlight case studies on low-carbon, carbon-neutral, and carbon-sequestering interiors.

Lisa Conway is vice president of sustainability for the Americas at Interface, one of the founding members of materialsCAN. She points out, "When considering a newly constructed building, typically the most energy-intensive materials are concrete and steel, meaning they have the most embodied carbon. However, most projects aren't new construction, and most renovations include new flooring. For example, with carpet, from an embodied carbon perspective, up to 100-percent recycled content nylon can be specified, which drastically reduces the carbon footprint for the product category and avoids those emissions today."

Some of the basic principles that materialsCAN promotes to achieve carbon neutrality in buildings include concepts that architects and other design professionals may already be familiar with and can implement on all current projects, including the following.

- Reposition existing buildings.
- Reuse existing parts and pieces.
- Optimize choices: Do we need it? Do we need as much of it?
- Once decided it's needed: What is the carbon footprint of it, and are there lower-footprint options?
- Specify for carbon reduction.
- Don't be afraid to speak up and educate the design firm and owner as early as possible.
- Estimate carbon footprint as well as cost.
- Smart procurement: Suggest options that save emissions and don't sacrifice performance or cost.
- Engage in policy discussions and opportunities.
- Inform, educate, and push.
- Utilize LCAs.
- Target the highest carbon impacts for footprint reductions.
- Utilize renewable energy for the manufacturing process, and same for supply chain.
- Commit to recycle carbon-intensive materials.
- Work with new product development teams to ensure carbon footprint is a consideration for development process.

Kirsten Ritchie, Gensler's director of sustainable design, helps incorporate these principles into the firm's design projects and is also involved with the effort to reduce embodied carbon in buildings. "We need more ways to easily influence and impact the embodied carbon footprint of our projects," she says.

"We recently delivered a project with a 43 percent reduction in embodied carbon by replacing our typical 'go-to' products with lower-carbon-footprint options that still met performance and all other project criteria," she continues. "Our hope is that with the resources provided by materialsCAN, others will be able to easily make the same improvements."

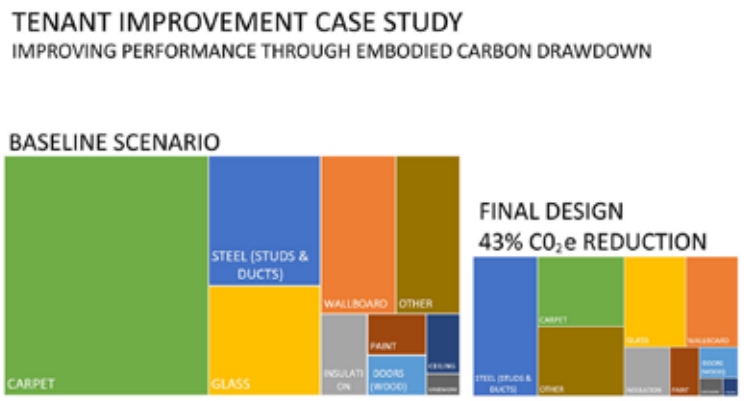


Image Courtesy of Gensler

Specifying individual products in buildings with a lower carbon footprint can add up to dramatic reductions in the total carbon dioxide emissions embodied in a completed building project.

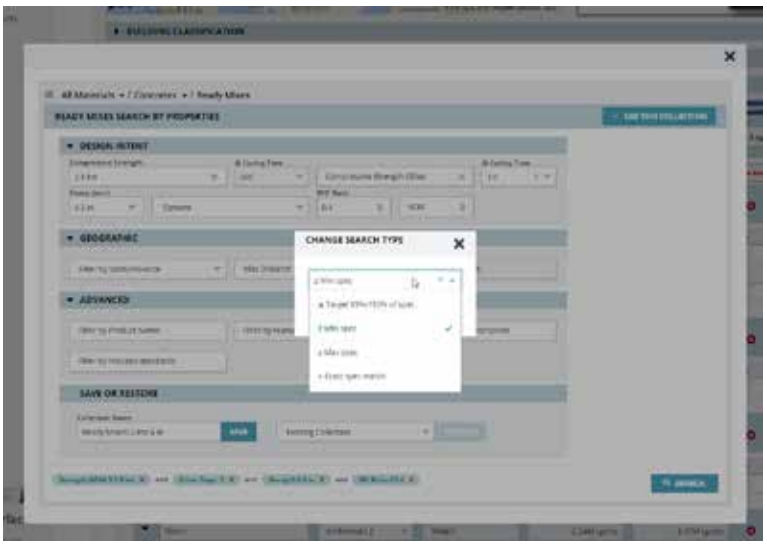
Embodied Carbon in Construction Calculator (EC3)

As a first universal step to enable anyone to measure the amount of carbon dioxide embodied in buildings, a new tool is becoming available known as the Embodied Carbon in Construction Calculator (EC3). The companies, Skanska and Microsoft, were the original seed funders for EC3, but it has now moved to the University of Washington's Carbon Leadership Forum, where it is managed and maintained. As a universal tool, EC3 will be open source, free to use, and accessible to all. It is expected to formally launch in the fourth quarter of 2019.

Stacy Smedley, a director of sustainability at Skanska USA, provides some insight into the background of this effort. "We pioneered the EC3 tool with Microsoft because of the lack of tools and product labels that reveal this information in a completely transparent and easy-to-compare way. materialsCAN, with the help of EC3, is the perfect platform for building awareness and education around an often missing but wildly impactful metric," she says.

According to the website where EC3 is in beta testing, the online EC3 tool will provide a simple, fairly straightforward way for anyone to estimate the carbon footprint of any building or space (www.buildingtransparency.org). This emerging tool will allow users to search construction materials by global warming potential (GWP) in a public, searchable database based on EPD data. Currently, there are close to 10,000 materials in the database, including concrete, steel, and gypsum. By public release, EC3 will include EPDs for products related to building enclosure and interiors. It is also expected to be able to show the variances among EPDs for products that use differing PCRs due to different iterations of PCR updates.

Reflecting on the ways this tool will empower the design and construction community, Conway says, "Carbon footprint information within our product category has been available for a long time, but it hasn't been easy for specifiers to understand how to compare it. With so many organizations having climate goals now, we need to prioritize embodied carbon in projects as part of overall carbon-reduction strategies to make a significant and measurable impact on the supply-chain emissions of buildings."



Source: www.buildingtransparency.org

The embodied carbon construction calculator (EC3) is a new tool coming available to allow anyone involved in building design and construction to estimate the carbon footprint of any project—large, small, renovation, or new construction.

SEVEN PRINCIPLES OF IMPACT REDUCTION

The people at BuildCarbonNeutral.org identify seven fundamental principles (shown below) that are the basis of reducing the impact of building design and construction on the environment, and hence on people.

1. **Site and location matter.** The location of a project will have a direct impact on the overall carbon footprint. Where you choose to build will impact the potential carbon release and the potential for carbon sequestration in the landscape. Is it a brownfield site? Is it a degraded or a pristine ecosystem? Can you restore an ecosystem in the process of developing your project?

2. **Disturbance is impact.** Protect existing soil and vegetation, and move things only when needed. Do you really need to move a pile of soil multiple times? Do you need to build a temporary structure? Can you reuse equipment and materials?

3. **Natural ecosystems sequester carbon.** Natural ecosystems sequester a lot of carbon. Most of this is stored below ground and easily released by soil disturbance. Appropriate landscaping sequesters carbon, and it can be designed and maintained to accumulate additional carbon over time. Have you minimized soil disturbance? What landscapes are best suited to your site and ecoregion? Can you use natural ecosystems to help lower your carbon footprint?

4. **Smaller is better.** Less building results in less embodied carbon. What is your building program? How do you use space? Can you take advantage of outdoor space? How much building do you really need?

5. **Buildings can sequester carbon.** This is part of a "love carbon" strategy intended to go beyond low embodied carbon to help reverse global warming. It is based on building that uses products and materials with carbon-storing (sequestering) capability and therefore reduces your carbon footprint. Wood from certified renewable sources, or wood

salvaged from demolition and saved from the landfill, can often be considered net-carbon sinks. Planting new trees can compensate for the carbon released during material transport.

6. **Material choice matters.** Material choice can reduce your building's embodied carbon footprint. Where did the material come from? Is it local? Did it require a lot of energy to extract it or get it to your building? Can it be replaced at the source? Was it recycled? Can it be recycled or reused easily? Is the material durable, or will it need to be replaced?

7. **Reuse to reduce impact.** It is possible to avoid new embodied carbon by reusing a site or structure. Make the changes necessary to improve the operational carbon footprint of an old building before building new. Is there an existing building or site that suits your needs? Can you adapt a building with minimal change?

Find out more at www.buildcarbonneutral.org/about.php.

APPLICATIONS: INFLUENCE ON BUILDING TYPES

Making it a priority to reduce embodied carbon in buildings is an approach that has been shown to make dramatic improvements in a variety of building types (i.e., residential, commercial, institutional, industrial) and all project types (i.e., new construction, renovations, tenant improvements, additions, remodeling, and even major infrastructure). The impacts will then be felt not only on the environment but also in very real ways on human health. In so doing, design professionals are at the forefront of protecting the health, safety, and welfare of the general public from the harmful effects of climate change identified by CDC and APHA. Some examples of the possible impacts of this proactive approach include the following.

- **Health-care buildings:** Health-care organizations and designers pride themselves on leading the way on interior environmental health, and, in many cases, they do just that by using materials and systems that have little or no negative impact on human health. However, it is exactly these facilities that will be most stressed when climate change events and disorders occur. By designing these facilities with reduced carbon, the health impacts of climate change can be lessened, and the health-care system in general will undergo less stress.

- **Schools:** As embodied carbon is reduced in buildings, the health effects of climate change on students and staff can be expected to reduce as well. Healthier students means better performance and educational outcomes, which is what schools generally desire. This creates better learning environments for students, faculty, and staff.

- **Office/corporate:** If there is less carbon dioxide and particulate matter in the air, then it follows that there are fewer illnesses and conditions related to air pollution, such as respiratory and cardiac conditions. For office and corporate settings, this means less absenteeism due to illness and potentially more productivity stemming from healthier employees. It also means there is less disruption of business due to weather-related events and other conditions of climate change.

- **Retail/ hospitality:** Overcoming the effects of climate change means the economy can be more robust. When the economy is healthy, there is more consumer and commercial activity, with more travel opportunities motivated both by business and leisure.

Clearly the impact of reducing carbon emissions and reducing the degree of climate change is far-reaching. And as shown in the discussion above, it has direct impacts on many different building types and the people who use them.

PROOF POSITIVE TILE

A Proof-of-Concept Prototype of a Carbon-Storing Building Product

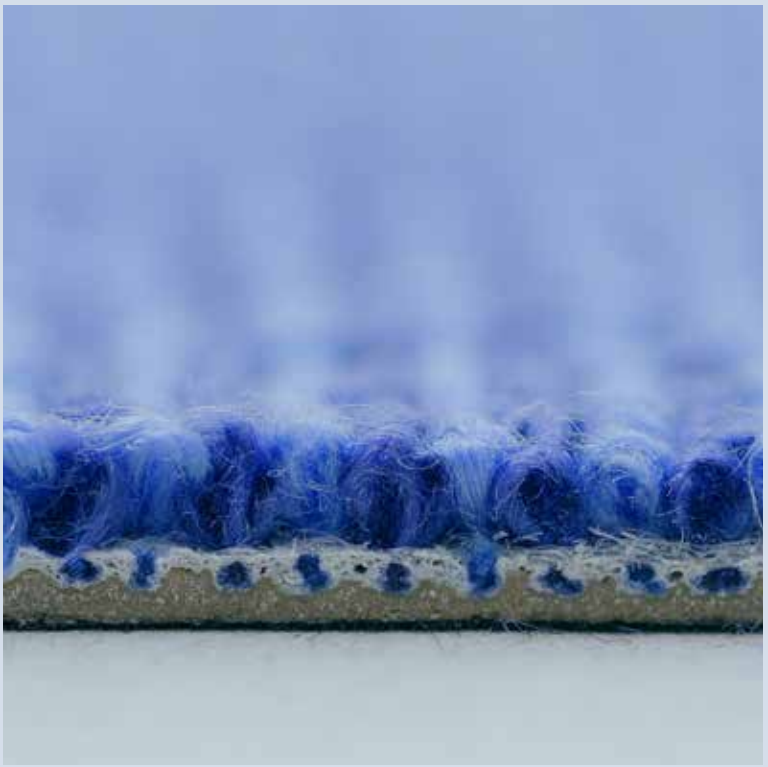


Photo courtesy of Interface, Inc.

Manufacturing building products typically results in an increase in carbon dioxide into the atmosphere. One manufacturer of carpet tiles has taken the initiative to not only reduce the amount of carbon dioxide released by its operations but also to go a step farther. After some years of research and development, it has created a prototype carpet tile that, after it is made, is responsible for less carbon dioxide being in the atmosphere than if it had not been manufactured in the first place.

How is this possible? First, the manufacturer recognized that plants can be a more sustainable resource for manufacturing than alternatives. Plants pull carbon dioxide out of the atmosphere through photosynthesis, which means the more plants and trees, the better it is for the environment and people. But when the plants and trees die, they decompose and release all of that stored carbon dioxide back into the atmosphere. In order to prevent that from happening, the manufacturer has selected plant materials that contain this absorbed carbon dioxide to make the raw material for the prototype carpet tile. In so doing, the carbon dioxide is thus stored (i.e., sequestered) harmlessly in the finished product and is not released back into the atmosphere.

When the useful life of the carpet tile is coming to an end, the entire tile can be reclaimed and recycled by the manufacturer to make new products, still keeping the carbon dioxide contained. The overall result is that the product is not just carbon neutral but actually carbon negative—it takes more carbon dioxide out of the atmosphere than the manufacturing process creates. All of these attributes are important because while other natural products sequester carbon dioxide too, they are not necessarily suitable for commercial use as building products.

While only a prototype currently, this experimental carpet tile has proven that the concept works and a manufacturing process can be developed

around it. At a full-scale, mainstream volume, products like this could become a critical solution to reversing global warming over the long term. If other manufacturers follow this one's lead, it will help move the industry toward making carbon-storing products the rule rather than the exception. All of this is consistent with the sustainability mission of this manufacturer, which is based on what its calls the "four pillars of climate take back," as follows.

- **Live Zero:** Aim for zero negative impact on the environment.
- **Love Carbon:** Stop seeing carbon as the enemy and start using it as a resource.
- **Let Nature Cool:** Support our biosphere's ability to regulate the climate.
- **Lead the Industrial Re-Revolution:** Transform industry into a force for the future that we want.

CONCLUSION

Climate change and buildings are inextricably entwined with each other. The creation and operation of buildings produces GHG emissions that in turn effect the climate. which then affects the people who live, work, and play in those buildings. The highest and best opportunity for carbon neutrality, if not carbon reduction, is for everyone involved (architects, designers, construction teams, and product manufacturers) to take full responsibility for the full life cycle of the products they create, specify, or procure. For design professionals in particular, the best way to reduce the embodied carbon in a building is to specify low-carbon materials. Currently, we have some tools to assess the carbon footprint of products and buildings to help us work to reduce it. With the emergence of new tools and the creation of carbon-storing materials, buildings can progress toward becoming part of the solution to global warming instead of part of the problem.

END NOTES

[1]"Special Report: Global warming of 1.5 °C." The Intergovernmental Panel on Climate Change. Revised on January 2019 by the IPCC, Switzerland. Web. 9 May 2019. <www.ipcc.ch/sr15>.

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[4]MacNaughton, Piers et al. "Energy savings, emission reductions, and health co-benefits of the green building movement." Journal of Exposure Science & Environmental Epidemiology. International Society of Exposure Analysis. January 2018. Web. 9 May 2019. <www.researchgate.net/publication/322799465_Energy_savings_emission_reductions_and_health_co-benefits_of_the_green_building_movement>.

QUIZ

1. Public health experts believe the number-one threat to public health in the 21st century is:
   a. disease epidemics.
   b. toxic chemicals.
   c. nuclear waste.
   d. global warming.

ONLINE PORTION

2. What is embodied carbon?
   a. The carbon dioxide emitted during the life of a building
   b. The carbon dioxide emitted during the manufacture, transport, and construction of building materials, together with end-of-life emissions
   c. The carbon dioxide emitted directly from a building material
   d. The carbon dioxide emitted from only the manufacture of building materials

3. What is an example of embodied carbon?
   a. Emissions from the raw materials used to create a building material
   b. Emissions from the freight to transport a building material
   c. Emissions from the energy used in final manufacturing of a building product
   d. All of the above

4. What is an example of operational carbon emissions?
   a. Emissions from the heating of a building
   b. Emissions from the cooling of a building
   c. Emissions from the energy used by the lighting of a building
   d. All of the above

5. Why do many green building experts consider embodied carbon even more urgent to reduce than operational carbon?
   a. Embodied carbon emissions are toxic to breathe.
   b. Embodied carbon emissions are already impacting the climate when the building opens.
   c. Operational carbon emissions are already as low as they can be.
   d. None of the above

6. What should you look for to find lower-embodied-carbon products?
   a. Products that are third-party certified carbon neutral
   b. Product with recycled mineral fillers
   c. Products made with 5 percent renewable energy
   d. All of the above

7. What is an example of a "love carbon" strategy intended to go beyond low embodied carbon to help reverse global warming?
   a. Use at least 50 percent renewable energy.
   b. Eliminate waste sent to landfills.
   c. Build using products and materials with carbon-storing (sequestering) capability.
   d. None of the above

8. Tools for identifying low-embodied-carbon products include:
   a. environmental product declarations (EPDs).
   b. Embodied Carbon in Construction Calculator (EC3).
   c. Carbon Smart Materials Palette.
   d. All of the above

9. Dramatic reductions in embodied carbon of materials have been shown to be effective in:
   a. tenant improvement (TI) , renovation, and addition projects.
   b. major infrastructure projects.
   c. new construction of buildings of all types.
   d. All of the above

10. How can you reduce the embodied carbon of a project?
    a. Specify low-carbon building materials.
    b. Manufacture your own building materials.
    c. Use a more a more efficient HVAC system.
    d. Call your senators.