Building a Foundation For Building Decarbonization

INTERVIEWS BY MARY KATE MCGOWAN, MANAGING EDITOR

The shift as many public and corporate organizations, countries and states set goals to achieve carbon neutrality within the next 30 years is affecting buildings. Owners are making more concerted efforts to substantially change their buildings, and building design and construction firms are being asked more to provide planning and strategies to reduce or eliminate carbon consumption (decarbonize) within the business cases for owners, said Kent Peterson, P.E., Presidential Member/Fellow ASHRAE. "ASHRAE members and engineers are great at providing solutions to problems once all the issues surrounding the problem are understood," Peterson said. But some engineers are still building their foundations to understand building decarbonization.

Demystifying Decarbonization

Building decarbonization is fairly new to people, says ASHRAE Treasurer Ginger Scoggins, P.E., Fellow ASHRAE.

"In order to move forward with our discussions on decarbonizing buildings," says Scoggins, "we have to all work on the same definitions to get started," she said. The sidebar "Defining Decarbonization: Foundational Terms and Definitions" includes foundational, common terms for engineers.

"Buildings and their HVAC&R systems have direct and indirect carbon emissions from energy use, refrigerant emissions and embodied emissions," Peterson said. Energy-related direct emissions are from on-site combustion of fossil fuels. Energy-related indirect carbon emissions are from carbon released during electricity generation, or during the sourcing, processing and transportation of fuels."

Building decarbonization involves building design, construction, operation and occupancy, according to Peterson. A few primary means for reducing operating carbon emissions will be aggressive energy efficiency, electrification of building energy needs and decarbonization of the electrical grid and delivered fuels.

The key to decarbonization is having knowledge on the topic, said Doug Cochrane, P.Eng., Member ASHRAE.

"There are a lot of myths out there, and there is demand for more information on this wide-ranging topic," Cochrane said. "One of the big myths is that decarbonization is just about energy. It is so much more

Defining Decarbonization: Foundational Terms and Definitions

Carbon Metric A standard measure of carbon dioxide equivalent emissions (CO_2e) for greenhouse gases.

Carbon Dioxide Equivalent (CO_2e) A measure used to compare the impact of various greenhouse gases based on their 100-year time horizon global warming potential (GWP). CO_2e approximates the time-integrated warming effect of a unit mass of a given greenhouse gas relative to that of carbon dioxide (CO_2).

Global Warming Potential (GWP) An index for estimating the relative global warming contribution of atmospheric emissions of a particular greenhouse gas compared to emissions of an equal mass of carbon dioxide (CO_2).

Operational Carbon CO_2e emissions during the normal use of a building during its life.

Embodied Carbon All the CO_2e emitted in producing materials. It is estimated from the energy used to extract and transport raw materials as well as emissions from manufacturing processes. Embodied carbon of a building includes all the emissions from the construction materials, the building process, all the fixtures and fittings inside as well as from deconstructing and disposing of it at the end of its lifetime.

End of Life Carbon CO_2e emissions to decommission the building at its end of life.

Direct Emissions Greenhouse gas (GHG) emissions from sources that are owned or controlled by the reporting entity (primarily from on-site combustion of fossil fuels).

Indirect Emissions GHG emissions due to the activities of the reporting entity but that occur at sources owned or controlled by another entity (primarily from electricity generated off-site to power buildings).

Life Cycle Assessment (LCA) A methodology for assessing environmental impacts associated with all the stages of the life cycle of a commercial product, process or service.

Environmental Product Declaration (EPD) An independently verified and registered document that communicates transparent and comparable information about the life-cycle environmental impact of products to enable comparisons between products fulfilling the same function.

Electrification Building electrification refers to replacing direct fossil fuel use (e.g., natural gas, propane, heating oil) with electricity use in a way that reduces overall emissions while lowering other air pollutants.

Building Performance Standards (BPS) A policy that requires building owners to meet performance targets by actively improving their buildings over time. These can include energy or emissions targets buildings must meet to improve energy efficiency and reduce climate impacts.

Carbon Capture and Storage (CCS) The process that captures emitted carbon dioxide, transports it to the storage site and deposits it in such a way that it does not enter the atmosphere. It involves capturing, transporting and depositing emitted greenhouse gases from fuel power stations and industries.

Site Carbon Sequestration The process of long-term capturing and storing of carbon dioxide at the site to prevent it from entering the atmosphere. This allows the stabilization of carbon in solid and dissolved forms to avoid the increase in temperature of the atmosphere. Carbon sequestrations can be biological and geological.

including embodied carbon, refrigerant, transportation, electrification, the grid and sequestration."

One common misconception is where heat pump technology can be applied and what refrigerants should be provided, said Peterson. Heat pump technology is evolving, and ASHRAE can help with future research, while educating owners and engineers.

"Air-source heat pumps have heating limitations in cold climates. More research and development will be needed to develop robust heat pumps to work in very cold climates. Resilience is key when it comes to ensuring there is heat in buildings at the coldest of extreme conditions—this usually means at ambient temperatures that are far below the ASHRAE 99.6% heating design

temperature," he said. "For example, the 99.6% heating temperature for Chicago is 1.9°F (–16.7°C), but the 50-year extreme temperature is –23°F (–30.6°C). The electric heating source must provide the required heat at these extreme conditions. Multiple-day electric grid outages like those experienced in Texas last year also need to be considered. These issues do not typically manifest themselves in mild climates but can present life-threatening consequences in cold climates."

"We can reduce refrigerant needs with passive design strategies to reduce active heating and cooling. Heat pumps are beginning to transition into natural (R-744) or low-GWP hydrocarbon refrigerants (e.g., R-32, R-452B). This transition will help reduce greenhouse gas emissions from refrigerants in heat pumps. Evaluating alternatives to large refrigerant distribution piping systems can also help minimize refrigerant charge and leakage," Peterson said.

Scoggins said a common question she's asked when speaking on decarbonization centers on why engineers should worry about building emissions when the electric grid is "dirty." "We do have a dirty grid—in some places it is worse than others—but we have to start somewhere," she said.

It is also a common misconception electric buildings alone will get the built environment to its carbon-neutral goal by 2050, said Peterson.

"Electrification can help decarbonize the buildings sector if the electric grids are able to decarbonize. The current electric grids will not be able to handle the increase in electric loads without substantial energy-efficiency improvements. The electric grids will need to quickly transition to very low carbon or carbon-free to reduce these indirect carbon emissions," he said.

Much of the transition is forecasted to be heavily influenced by solar and wind energy sources. "As these become a higher percentage of the total supply, we will see large deviations on carbon intensity by season and time-of-day. Carbon intensities will be lowest when the sun is out and the wind is blowing. Grid storage will be part of the solution, but buildings will also need to integrate energy-efficiency measures and demand response to create flexible building electrical loads for electrification to fully reach its full carbon reduction potential."

Another challenge is some ASHRAE members are not familiar with the impact of embodied carbon as compared to operational carbon, said Peterson. "Embodied carbon impacts can be very significant, 250 kg/m^2 to 1000 kg/m^2, when constructing a new building. While the past focus has been on major embodied carbon structural elements, embodied carbon of MEP system elements is now being considered."[1]

Net Zero Carbon vs. Net Zero Energy

Besides electrification, many decarbonization strategies align with net zero energy strategies, said Peterson. "Building heating and cooling loads can be reduced with passive efficiency strategies and optimizing waste energy."

Critical energy-efficiency upgrades can include improving the building envelope, measurement tools to provide insight into energy use and software to optimize energy use. Active energy-efficiency measures can further reduce annual energy consumption.

But low carbon strategies are different from net zero energy strategies, he said, because hourly electrical carbon emission rates vary widely throughout the year. "The difference between net zero carbon and net zero energy is the latter refers to generating energy that exceeds annual demand but does not necessarily result in annual energy that is net zero carbon. Net zero energy strategies do not account for when energy is created or used by the building. Low to zero carbon buildings will need to be demand responsive to electric grid carbon signals by utilizing thermal and/or electrical storage at the building, with smart controls that boost energy efficiency and lower emissions."

Peterson said control systems integrated into buildings can help coordinate supply and demand and shift energy use. Demand-side management systems can help save costs by optimizing use for when and where it is most needed, but they can also improve decarbonization by shifting energy use to times of the day when zero carbon energy is highest in the grid mix.

"Low carbon buildings will also focus on embodied carbon, while net zero energy strategies have focused on only operational energy," he said.

Peterson recommended using a carbon metric (CO_2e) on each project to help owners and design teams understand the carbon impacts of design decisions. "Using whole carbon life cycle assessment (LCA) on projects will allow owners and design teams to make informed decisions on trade-offs between embodied and operational carbon for new construction projects."

Resources (Available and in Development)

The decisions engineers make in design, manufacturing and building operation management have a substantial impact on building-related carbon emissions, said Peterson. "ASHRAE standards, guidance and education can significantly impact those decisions. As a result, ASHRAE and its members have an important role in responsibly decarbonizing the built environment while maintaining health and comfort."

ASHRAE's building decarbonization efforts have focused on improving building design and operation and in advancing HVAC&R technologies and applications. Peterson said ASHRAE's work to develop resources on building decarbonization include:

- Educational opportunities;
- The development of guidance materials such as the *2021 ASHRAE Handbook—Fundamentals* Chapter 36, Climate Change; and
- Continued maintenance of existing climate-specific data analysis tools, guidance materials and standards.

In addition, ASHRAE's Task Force for Building Decarbonization has enlisted the volunteer services of more than 100 members, including a group of members working to create a position document on building decarbonization. Peterson, who leads the task force's position document working group, said he expects the position document to move to the approval process in April.

Net Zero by 2050[2] is another resource to help guide engineers, as it provides some key actions for the building sector to get to near net zero carbon emissions by 2050.

References

1. CIBSE. 2021. "Technical Memoranda 65, Embodied Carbon in Building Services: A Calculation Methodology." Chartered Institution of Building Services Engineers.

2. IEA. 2021. "Net Zero by 2050: A Roadmap for the Global Energy Sector." International Energy Agency. ■