Material and MEP system choices drove reductions in embodied carbon and operational carbon for Arizona State University's new Rob and Melani Walton Center for Planetary Health.

COURTESY MCCARTHY BUILDING COS.

BRIGHTER VISTAS: NEXT-GEN TOOLS DRIVE SUSTAINABILITY TOWARD NET ZERO LINE

LEARNING OBJECTIVES

After reading this article, you should be able to:

- **DISCUSS** how novel tools and technologies and established systems and products are facilitating net-zero and sustainable design for commercial and institutional buildings
- **EXPLAIN** how data and varied building systems can be accessed and analyzed to improve building design, construction, and operations
- **LIST** examples of new building technologies and building projects that demonstrate net zero, carbon reductions, and other sustainable building principles
- **DESCRIBE** approaches to leveraging building technology for K-12 schools, research centers, residential buildings, and mixed-use residential, among other building types

New technologies, innovations, and tools are opening doors for building teams interested in better and more socially responsible design. Supporting goals from energy efficiency and sustainability to passive design and net zero, these advances assist in the studio, on jobsites, and in building operations. Some tools help visualize outcomes, both qualitative and performance based, while others affirm material and system attributes. Still others ease the tasks of calculating metrics such as energy use intensity (EUI), lighting power density (LPD), or how project choices impact total embodied carbon or carbon emission equivalent, measured in kilograms or tons ($kgCO_2e$ or tCO_2e).

"There is a spectrum of evolving tools that have improved computation time, clarity of design direction, and ultimately sustainable performance over the last several decades," says Arathi Gowda, AIA, AICP, LEED AP BD+C, a Principal with ZGF. These deal with "foundational elements of massing, solar orientation, shading, thermal gains and losses, and carbon footprint," she adds.

The 400-student Fales Elementary School is a net-positive-energy public school in Massachusetts, producing 10% more energy than required annually using geothermal and photovoltaics.

Sorting through the best resources presents a challenge and a time drain, say experienced design and construction professionals. "For every simple, directional optimization tool, there is a deeper and more nuanced tool—and the tricky part is that we are only as good as our ability to understand the information from the tools we use," adds Gowda, who serves on the AIA COTE (Committee on the Environment) Leadership Council.

"All firms are trying to find tools to help them predict better and accomplish what they're trying to achieve, and rating systems are tools, too, helping us communicate with the owner and prioritize," says Suni Dillard, AIA, LEED AP BD+C, an Associate with HMFH Architects active in the Carbon Leadership Forum. "In some cases, longer project durations allow teams to explore these tools more, comparing what is modeled versus project reality."

Other motivations, such as owner preference or investor requirements for environmental and social governance (ESG), accelerate adoption of new approaches. For example, building teams are seeing more clients focusing on net-zero performance or "net-zero readiness," says Mark A. Winslow, CMC, REM, LEED AP BD+C, Project Executive in environmental solutions with Gilbane. This holds true especially where carbon reduction is codified in local codes or state statutes, he adds.

Even without regulations driving change, many municipal and state agencies champion processes defined to ensure best performance. "Commissioning has been a key tool for public projects in our city, inserting accountability in meeting design criteria, including envelope commissioning," says Zack Aders, AIA, LEED AP BD+C, Vice President with New York City Economic Development Corporation (EDC), a nonprofit supporting varied developments.

Before looking at specific tools and approaches, adds Nash Emrich, an Associate with sustainability consultant Paladino–a Buro Happold Company, "First understand your organizational values and identify specific sustainability goals or key performance indicators." Steps such as brainstorming in eco-charrettes with all project stakeholders early on, he says, is "a proven way to establish those targets."

In this way, decision-making can be streamlined, "selecting only optimal strategies and tactics that align most effectively to goals and desired outcomes," says Emrich. This approach united the building team for Arizona State University's new Rob and Melani Walton Center for Planetary Health, a project led by Architekton, Grimshaw, and McCarthy Building Cos., using early design-phase workshops for the collaborative design-assist and construction management at-risk delivery. Evaluation tools included energy modeling by Buro Happold and a lifecycle assessment (LCA) of building materials, with sustainability consulting by Thornton Tomasetti.

The result is a "holistic, comfortable, sustainable project," according to architect Rachel Green Rasmussen, AIA, Principal of Architekton. With 281,000 sf of lab space, classrooms, and a conference center, the $192 million building reduces global warming potential (GWP) by 26%, using water-based climate control and directing 100% of rain falling on it to landscape and aquifer recharge, according to ASU.

Integrating green aspirations into project flows from kickoff discussions into the to pre-design phase is essential, say experienced teams. "Sustainability should be the intention from the start, and not an overlay," says Kevin Nasello, LEED AP BD+C, AIA, Senior Associate and Director of Sustainability with CetraRuddy. "Sustainable building is founded on thinking outside the box, and being able to identify priorities, as there are so many things one could attempt to do."

TOOLS FOR ENERGY AND CARBON

Today's effective tools help evaluate how project decisions impact energy and carbon budgets. Informed by data, and closely integrated with visualizations and building information modeling (BIM) platforms, project teams can move more decisively to optimize sustainability and efficiency—twin allies

in the fight against climate change. Many of these are becoming more graphic-based, three dimensional, and even immersive.

Assessing greenhouse gas (GHG) emissions for materials and structures—embodied carbon—often eclipses those from running mechanical, electrical, and plumbing (MEP) systems, or operational carbon. Examples include an Excel-based embodied carbon calculator, PHribbon, for use with the Passive House Network's PHPP modeling program, and OneClickLCA, which automates the process by importing Excel, Revit, BIM, and Green Building XML (gbXML) files. Others, such as BIM plug-ins like Revit Tally or Hawkins\Brown Emission Reduction Tool, help teams analyze and visualize embodied carbon emissions for building components.

Product selection tools also integrate carbon data or equivalents, drawing on longstanding and newer databases. "One well-established tool is NIST's software, BEES, which uses an LCA approach, and you can pull out carbon information," explains John D. Lesak, AIA, FAPT, LEED AP, with Page & Turnbull in Los Angeles, alluding to the National Institute of Standards and Technology's Building for Environmental and Economic Sustainability. The program's engine is an LCA method specified in the ISO 14040 series of standards, adds Lesak, who has presented on embodied carbon conservation for AIA California and USC.

The approach stands behind a library being adapted as the Cheech Marin Center for Chicano Art & Culture of the Riverside Art Museum, designed by WHY and Page & Turnbull and built by Hamel Contracting. Lesak's team conducted an avoided impacts analysis comparing an efficient new facility to the repurposed, rehabilitated 1960s building. The reconstruction path reduced initial embodied carbon by almost two-thirds—about 1,005 kBTUs per sf saved—and the analysis showed it would take 25.7 years for a hypothetical new building to match the reuse case in carbon savings. The building team also retrofitted the adapted building with better materials and systems for a 40% improvement in efficiency, reducing operational carbon as well.

Other tools for product selection include environmental product declarations, or EPDs, which list information on GWP allowing building teams to quantify carbon dioxide equivalent (CO_2eq)—basically, how much CO_2 would warm the earth as much as the product's constituent materials and gasses. The GWP of CO_2 is 1, the basis for measuring carbon footprint. In this way, EPDs allow a rapid comparison of products, says Page & Turnbull's Lesak. Other open-source and free software include the Embodied Carbon in Construction Calculator (EC3) for benchmarking and cutting embodied carbon in materials supply chain emissions.

Building on EC3 are databases for specific disciplines and more holistic product appraisals, says Laurel Christensen, AIA, CM-Lean, Sustainable Design Leader for Dyer Brown. "We use the mindful MATERIALS (mM) baseline criteria as a reference in vetting our physical materials library, so designers can feel confident knowing that products they select from our finish library will meet a certain standard for transparency," she says.

Many different factors should be considered in assessing the sustainability of building materials and systems, adds Christensen: "It can be widely defined as in the AIA's own Materials Pledge, which highlights five areas: human health, climate health, ecosystem health, social health, and equity, within a circular economy."

NET ZERO PROJECTS AND PRODUCTS

Often, the tools being used focus on building operations. For example, says Gilbane's Winslow, "We are seeing net-zero performance goals established as one way to control cost and address operational efficiencies." On a recent public elementary school project, he recalls, potential lifetime energy savings convinced local county constituents to approve a net-zero path, targeting LEED Gold and the 2018 framework, LEED Zero certification.

Designed by HMFH and built by Gilbane, the 400-student Annie E. Fales Elementary School, called the first net-positive-energy public school built in Massachusetts, produces 10% more energy annually than the all-electric school needs. It consumes less than two-thirds the energy of a code-compliant building, while also harnessing renewable power from on-site geothermal heating and cooling and a rooftop photovoltaic setup. It is the first new building

Four Steps to Zero

Several building teams allude to a four-step approach to achieving net-zero performance, with ideas rooted in current climate action initiatives.

According to Page & Turnbull's John Lesak—who has presented on embodied carbon reductions for AIA California and the University of Southern California—the path is described as:

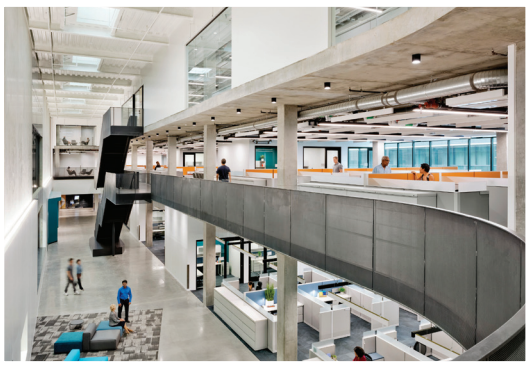
1. Begin with reducing demand, or passive strategies, which may include restoring or rehabbing existing buildings, adding insulation and ensuring good daylighting.

2. Specify and install the most efficient technology the budget allows.

3. Provide controllability as much as possible.

4. Balance with on-site renewables, he says, "to cover what you need to cover."

CONNIE ZHOU, COURTESY ZGF



The new California Air Resources Board headquarters in Riverside, Calif., is a large net-zero energy facility targeting LEED Platinum and CalGreen Tier 2 certifications.

completed as part of a Town of Westborough, Mass., pledge to be carbon-emissions free by 2035.

Deep inside Fales Elementary, high-efficiency mechanical systems optimize air quality and LED lighting responds to daylight and occupancy sensors. A building management system monitors and controls these MEP systems for maximum efficiency, says HMFH's Dillard. Triple-glazed windows, thick wall insulation, and roof enclosures specified to 40% above code allow the school to run on 40 geothermal wells and the 25,000-sf solar array.

Other teams are exploring similar paths. "Significant advances in solar technology have arrived, allowing much higher performance with fewer panels," says Mark Taylor, Assoc. AIA, AICP, Senior Project Specialist with Bray Architects and project leader on Village of McFarland (Wis.) Public Safety Building, tracking to be among the Midwest's first net-zero public safety buildings upon completion later this year. The firm also designed Forest Edge Elementary School, the first net-zero school in Wisconsin. "Geothermal systems combined with improving heat pump systems have drastically improved the potential of use on a wide range of building typologies," says Taylor.

Drilling down to building systems, heat pumps rank high among MEP system essentials in the quest for net-zero success, including air-to-air, water source, and geothermal, says Gilbane's Winslow.

Adding to the list, Emrich and Buro Happold's multidisciplinary teams advocate for integrating high-performance envelopes, heat recovery, system resiliency, and heat pumps—critical sustainability strategies, they say, especially as part of full-building electrification for "aggressive decarbonization in the built environment" to slash GHG emissions. "All-electric buildings connected to electrical grids supplied by renewable energy sources," according to the firm's recently published study, are "readily available and cost-effective solutions that will reduce or eliminate any additional strain to the electrical grid."

According to Bray Architects' Taylor, among the biggest gains in decarbonization and design flexibility have been in the improved output from photovoltaic panels. "The increase in panel output efficiency results in more power gain per square foot of space, which again helps more projects achieve net-zero goals and, in some instances, pushes them into net positive," he says.

MISSION-DRIVEN OPERATIONS

In fact, new benchmarks are set frequently, especially for unique occupancies and end-uses. For the California Air Resources Board (CARB) Southern California Headquarters in Riverside, Calif., the design-build team of ZGF, Hensel Phelps, and Affiliated Engineers Inc. targeted "the largest onsite net-zero energy facility in the country," says Shara Castillo, AIA, LEED AP BD+C, Principal with ZGF. The 403,300-sf facility supports vehicle emissions testing and research, including specialized equipment for future testing practices. No prior U.S. building offered comparable scale or function.

Engineered to operate as net-zero energy, CARB's headquarters centralizes the organization's five prior locations spread throughout the Los Angeles area into a single, 19-acre site. Planned with LEED Platinum and CalGreen Tier 2 certifications in mind, the three-story structure is both functional and memorable. "The pinwheel-shaped building strives to create a beautiful destination, a good neighbor within the city, and a compelling environment fostering a strong sense of pride and place for CARB and its 450-plus employees," says Castillo.

Operations and neighborly design emerge as themes in many sustainable design projects, not only cutting carbon impact but also smoothing out costs for energy needs, wear and tear, and future adaptability, adds Rockland Berg, AIA, ASHE, with the national architecture firm three. "Both our nonprofit and for-profit clients building senior-living

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Forest Edge Elementary School is a net-zero school in Fitchburg, Wis.

communities make major investments in repositioning and hospitality amenities also carefully address efficiency and sustainability," he says. "Their long-term view benefits from net-zero technologies and more durable materials with lower embodied carbon."

Increasingly, high-performance passive design informs affordable housing for seniors and others, according to Nate Thomas, a Phius-certified Passive House consultant, or CPHC, and Project Manager with The Architectural Team (TAT). An example comes as part of the third phase for the Anne M. Lynch Homes at Old Colony in South Boston, Mass., the 51,000-sf affordable Passive House complex for seniors developed by Beacon Communities in association with the Boston Housing Authority.

"With such a clear national need for more housing, building to Passive House standards is a valuable and arguably necessary step in reducing GHG emissions and tackling climate change," says Thomas, who has presented on passive design to the Boston Society of Architects. "The benefits for owners and developers are clear: lower ongoing operating costs, healthier interior environments for residents, and a growing number of incentives from states and cities."

Covid and Carbon: Overseas Inspirations

For reducing demand, two-plus years of pandemic have led more institutional owners to seek passive solutions—many seen elsewhere in the world—that reduce carbon emissions and energy use while boosting occupant well-being.

"Given Covid-19, some of our U.S. clients at K-12 schools and universities agree there are more opportunities to now adopt more of the passive strategies from the schools we've designed in southwest India, for example," says Theresa Genovese, AIA, LEED AP, Principal with CetraRuddy.

"Every good school design should have fresh air, open classrooms, and more indoor-outdoor environments," says Genovese. "We're all getting back to the basics."

MATERIALS AND SYSTEM CHOICES

Building teams also see evolving choices of materials, systems, and finishes, says Dyer Brown's Christensen. "Materials with recycled content are typically going to be better, lower embodied carbon solutions than those using raw materials," she says. "If they can't be reused, recycled, or reconstructed after their installation, the carbon benefits are short lived." Christensen points to a cement and concrete block alternative, BioMason, grown in a lab and produced without high temperatures or fossil fuels, for example, and carpet or acoustic tile manufacturers with established, successful "takeback programs."

Buro Happold's Emrich recommends conducting LCAs and energy models on every project. This step helps balance high-energy materials, such as selecting steel and aluminum products with lower emissions in the production cycle, or creating a case for timber structures or vegetated roofs. A close analysis could raise the case for composting toilets, adds HMFH's Dillard, pointing to their use at Bristol County (Mass.) Agricultural High School. "Water has a huge energy cost not only on site but also the source, and then there are maintenance costs" she says, adding that even New England has drought periods.

Another strategy is "doubling the EPDs through a thoughtful submittal process," says McCarthy's Keith Cameron, Regional Environmental Manager, Southwest region. "We seek substitutions on specified items, and our trade partners support this by investigating and identifying alternate materials that meet specs but are more environmentally responsible," he says, citing examples in concrete and BubbleDeck. For the Terminal 4 expansion of Phoenix Sky Harbor International Airport, the process supported electrochromic glazing to reduce energy usage—and EV tug vehicles for airfield baggage handling.

For ASU's Walton Center, "the team utilized several cutting-edge energy-saving MEP design innovations," according to McCarthy's team, noting that Buro Happold and the architects employ adiabatic cooling to cut cooling energy in the laboratories, typically an end-use with very high power demands. The HVAC design captures energy with an adiabatic run-around coil on the exhaust and outside airflows, and with adiabatic cooling on supply fans for reduced cooling loads. In office zones, the team

utilizes radiant panels and radiant sails, slashing fan energy needs while boosting comfort.

Adding psychological comfort, biophilic design elements such as water features and interior plantings are seen as enhancing occupant experience through direct connection to nature. These also include natural materials such as cross-laminated timber, solid wood or stone flooring, and timber-backed curtain wall systems, says Emrich, also reducing off-gassing as they minimize carbon footprint.

On the project site, says Allen Gershenson, Vice President with McCarthy Building Cos., more action is needed to improve performance and slim down carbon footprints. "With remote construction sites, and the lack of EV construction vehicles along with the absence of a national infrastructure program for managing charging, this part of the industry in its early stages," he says, even as construction companies continually upgrade and modernizing equipment fleets and investigating means and methods to improve energy efficiencies, including through operational processes.

For design professionals, new technologies to streamline and automated analysis address similar goals. To meet the Architecture 2030 Challenge, adopted by AIA to prioritize building energy performance and lessen environmental impacts, says CetraRuddy's Nasello, some firms are adopting cove. tool to ease the standardized reporting for the AIA 2030 Design Data Exchange (or DDx). This allows design firms to compete to meet annual energy-use percent reduction targets, generating data for the 2030 DDx including baseline and predicted EUI, renewable energy, LPDs and embodied carbon.

"It's a fairly straightforward tool we have brought into our work, and firms should know there is some learning curve involved," says Nasello. "But using all its modeling abilities and graphics can inform everything from massing and daylighting studies to Covid considerations and LEED certifications—in addition to being a part of this industrywide push to be as socially responsible as we can." +