Realizing the Future of Sustainable Design through BIM and Analysis

By Robert E Middlebrooks, AIA

In the United States, buildings are responsible for almost half of all annual green house gas emissions and they consume about three-quarters of all electricity generated by power plants[1]. And the sustainability of our built environment is particularly significant when you consider that the majority of the buildings that we will live and work in over the next thirty years have not been built. As such, reducing the carbon footprint of buildings is essential for stemming climate change.

The sustainability of a new building is based on many factors including water savings, energy efficiency, materials selection, etc. These factors are heavily influenced by a building's architectural design, site design and supporting civil infrastructure, and of course the design of the building systems. Mechanical engineers influence a building's performance in support of sustainable design by: providing early input regarding greener approaches for the building mechanical systems; designing more efficient and better-sized building mechanical systems; and by producing metrics and supporting documentation for evaluation and green certification when needed.

This article describes how building information modeling (BIM) and BIM-based design tools enable mechanical engineers to more efficiently and accurately simulate, analyze, and document their designs—and ultimately deliver greener building systems and healthier, more resource-efficient buildings.

Sustainable MEP Design

The drivers for green design are numerous, encompassing owner demand and a growing attitude towards environmental stewardship within the building industry—not to mention a host of government regulations and green-building incentives. The U.S. federal government as well as many states and local communities throughout the country have initiated programs and enacted

[1] *"Architects and Climate Change",* AIA, July 7, 2006, www.aia.org/SiteObjects/files/architectsandclimatechange.pdf

legislation regarding green building design. For example, the federal government's Energy Policy Act of 2005 provides (amongst many other things) financial incentives for sustainable building. California's Title 24 sets minimum energy efficiency standards for all new homes, additions and alterations to existing homes, and most commercial buildings within that state. And New York City's Green City Buildings Act requires that the city's new municipal buildings, as well as additions and renovations to existing municipal buildings, achieve green building standards.

Green standards and rating systems for building systems design abound. In the United States, ASHRAE 90.1 is the widely used standard that provides minimum requirements for the energy-efficient design of building systems for new or renovated buildings. And the U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED) rating system is the most prevalent scorecard used for pursing green building certification. Of the 69 total LEED credits available, approximately 25% of them can be influenced by the building systems design.

Internationally, the trend towards sustainable building design is equally strong (if not stronger). Governments around the globe are implementing new building regulations that mandate sustainable design. Many countries already require performance assessment to comply with building regulations. Additionally, countries around the world have or are adopting voluntary building rating systems similar to LEED, such as Green Globes, BREEAM, CASBEE and Green Star.

Although the building industry's interest (and owners' interest as well) in sustainable design is undeniable, it still has its challenges. Some are technical issues. Some relate to standard industry processes and practices. And cost is always a concern. But the growing market demand for sustainable design is starting to outweigh and overcome these hurdles, helping to drive fundamental process changes throughout the industry. Transformative concepts that facilitate sustainable design such as integrated project delivery and BIM are quickly becoming the standard.

Building Information Modeling

BIM is an approach to building design that that involves the use of a digital building model created from coordinated, consistent design information—

enabling whole-building analysis, faster decision-making, and better documentation.

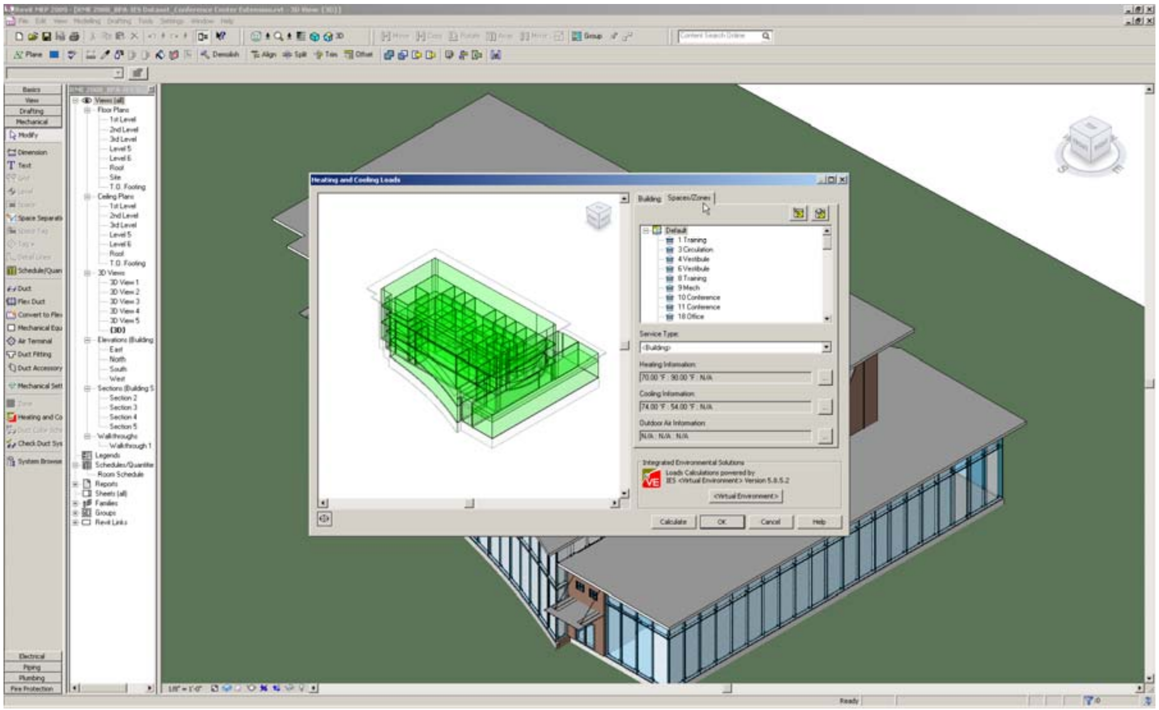
BIM software offers many benefits for general building design. State-of-the-art BIM software uses a centralized, parametric model—where all the plans and sections, the quantity takeoffs, and other related documentation are “live” views of the model and are automatically coordinated by the software. This integrated set of deliverables has an explicit relationship to each other and to the model, resulting in better coordinated construction documents that minimize errors and omissions.

The design model is also used for a variety of building analyses, for automatic clash detection, for design visualizations, and for precise quantity takeoffs. In addition, the resulting digital design model can be leveraged for a variety of related tasks such as construction sequencing, digital fabrication, and facilities management.

BIM and Sustainable Design

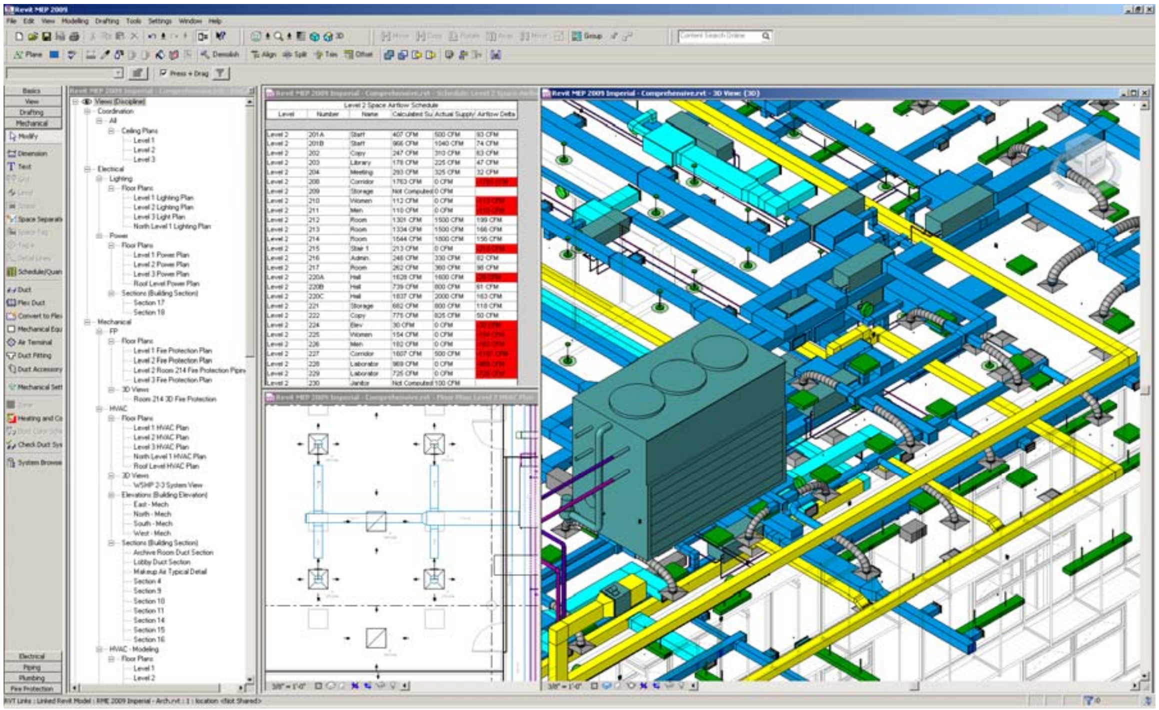
With regards to sustainable building design, perhaps the greatest advantage of BIM is for building analysis. Sustainable building design hinges on the ability to gain insight into a building’s performance through analysis and optimization of the design. But evaluating building performance based on the building representations produced by conventional CAD or object-CAD solutions requires a great deal of human intervention and interpretation—and makes the analyses unduly time-consuming and costly.

With BIM, much of the data needed for supporting performance analysis is captured naturally as design on the project proceeds. By using a building information model, designers can analyze how a building will perform—even in the very early stages of design—and armed with this information, they can quickly evaluate design alternatives and make better decisions to iterate on a greener design. By streamlining the design and analysis functions, BIM facilitates the necessary calculations needed to optimize building performance.



BIM and its reliance on a digital building model streamlines the design and analysis functions, allowing designers to quickly evaluate design alternatives and make better decisions to iterate on a greener design.

A BIM-based design model also carries a wealth of information necessary for many other aspects of sustainable design. For instance, the ability to create drawings and details directly from the model (and have the software automatically coordinate these with the model) improves the efficiency and accuracy of green certification. Schedules of building material quantities can be obtained directly from the model to determine percentages of material reuse, recycling, or salvage. Various design options for sustainability can be pursued in parallel and automatically tracked in the model. Advanced visualization techniques can be used for solar studies and to produce 3D renderings and construction animations of a green project. And a digital 3D model supports better understanding and collaborative communication with the various stakeholders in a green partnership (the architect, the owner, consultants, review bodies, and so forth).



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Sustainable Design Process

To illustrate how BIM facilitates green building systems design, let's examine a typical BIM-based workflow.

- To start the building systems design, the mechanical engineering consultant leverages the architectural design model. By using the architect's model, the mechanical engineer ensures that the building mechanical systems design is coordinated with the architectural model, and eliminates a redundant modeling effort to recreate the architect's building geometry.
- The mechanical engineer defines all the heating/cooling spaces and zones—adding information such as the number of people per room, the heat load from equipment in the room such as the number of computers, and so forth—and then exports that model to a gbXML file. In addition to the space and zone information, this file also captures all the building geometry as well as information such as lighting density, people sensible and latent load contributions, building construction thermal properties,

desired room temperature set points, required ventilation air flow, coil cooling temperature, heating coil temperature, etc. As such, it represents a more accurate thermal model of the project.

- That gbXML file is then imported into an analysis package such as Trane TRACE and an analysis is performed to determine the building's energy usage as well as for heating and cooling load calculations. By leveraging their own design model directly for analysis, mechanical engineers can eliminate the time-consuming, error-prone task of manually entering data into the analysis solution.
- Once the analysis is done, the resulting data can be viewed in a report and also exported back to the BIM-based design model (again using the gbXML file). For example, all of the heating and cooling load requirements for each space are transferred back to the design model, enabling the mechanical engineer to view that information from inside the design environment of the BIM software and use those calculations to size equipment, ductwork, piping, etc.
- The mechanical engineer can then iterate on a better performing design using "what-if" design scenarios—changing the R-values of some walls for instance and rerunning the analysis to see how the changes affect the total energy usage of a building.
- In addition, some BIM software includes built-in heating and cooling load analysis tools that can be used to more accurately predict the peak heating and cooling loads for a building. This assists engineers in quantifying needed airflow and properly sizing the HVAC equipment, helping to ensure that energy is not wasted on powering oversized equipment.

This design/analyze/optimize workflow is typical in today's BIM-based practices. Emerging approaches for tighter integration with analysis packages are on the horizon. For example, some BIM software platforms feature programmatic links (that don't require the export/import to a neutral file-format) to analysis software solutions. By further streamlining design/analyses workflows, these integrations facilitate conceptual-stage inline analysis and enable more complete round-tripping of information. In addition, even enhancements in construction techniques—such as streamlining the workflow for direct digital fabrication of ductwork to cut material waste—are becoming more prevalent.

Sustainable Design in Practice

Design West Engineering is a full-service mechanical, electrical and plumbing (MEP) engineering consulting firm based in San Bernardino, California. Established in 2000, the firm specializes in mechanical, electrical and telecommunication engineering applications and energy efficiency projects for a wide range of building sectors, including education, medical, civic, residential and commercial.

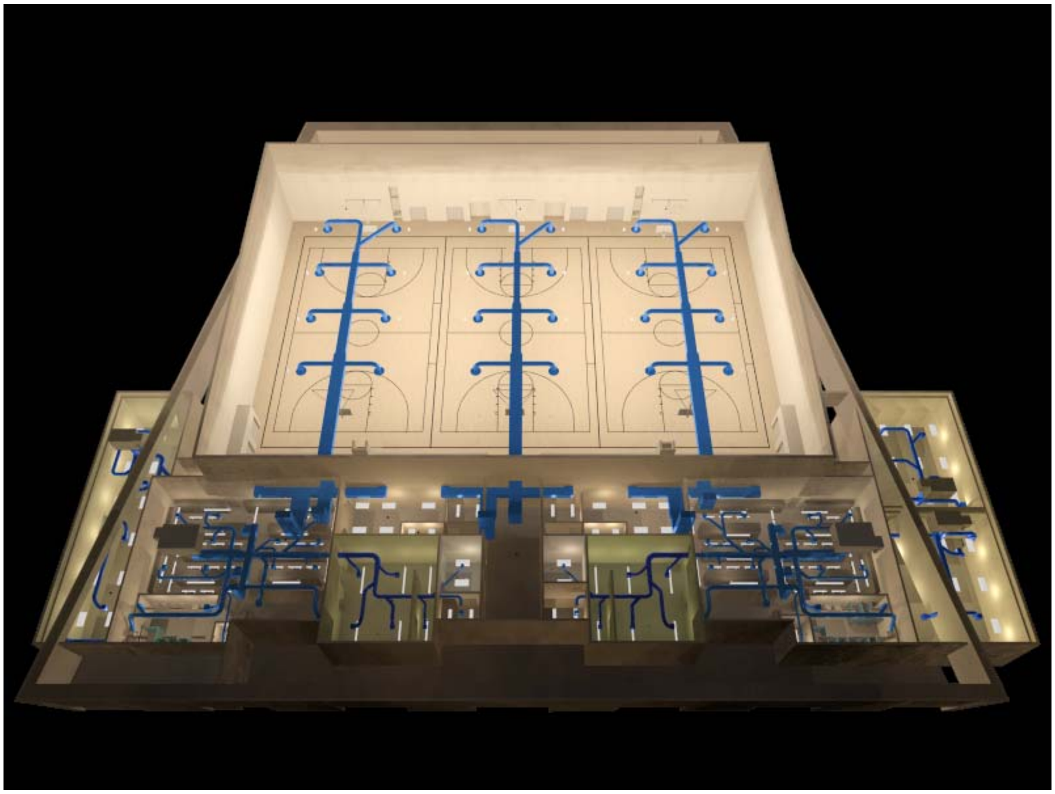
To facilitate a new level of project collaboration with their architectural clients and structural engineers, and to transform their sustainable design practices from ad-hoc to technology-based, Design West adopted BIM software in early 2007 and the firm has completed construction documentation on 12 projects using the BIM approach.

One of Design West's current projects is a new $110 million, 340,000 square feet educational facility for the Coachella Valley Unified School District (located in Indio, California). Scheduled for occupancy in the fall of 2011, this facility will house approximately 3700 middle school and high school students. The facility will be comprised of nine structures and includes 104 classrooms in two buildings, an administrative building, two gymnasiums with basketball courts, an outdoor swimming pool with a changing facility and an outdoor stadium with two concession facilities. The campus is being designed to achieve as many points as possible towards Collaborative for High Performance Schools (CHPS)—a sustainable design rating system created specifically to address California K-12 schools. As such, the entire campus design will be rigorously analyzed to increase its energy performance.

"A large portion of the target CHPS points are related to energy efficiency," explains Joel Londenberg, Design West's Revit Project Manager. "So our mechanical design must be analyzed in the context of how the building envelope is constructed, including windows, walls, roofs, and so on." Fortunately, on this project BIM software is being used by Design West, as well as the architect, the structural engineer. So Design West can leverage the architectural and structural project models for its building systems design, as well as for cross-discipline clash detection and better coordination. "It's possible to use the architect's model in conjunction with energy analysis software to optimize the building energy performance early in the design phase of the project," reports Londenberg.

For example, the Design West's engineers need to properly account for daylighting and its effects on the heating, cooling and lighting requirements for individual spaces in the facility. The desert climate of Coachella Valley makes it particularly important to balance the desire to bring light into the classroom with the need to keep heat out. An accurate digital building model integrated with energy analysis tools greatly simplifies this daylighting analysis and helps the Design West engineers to properly size the cooling system and perform the compliance calculations that are needed to meet building codes. "By knowing accurate heating and cooling loads, we're able to right size the equipment to improve indoor air quality, improve thermal comfort and improve overall energy usage," says Londenberg.

"This sophisticated level analysis in the design phase cannot be achieved easily without BIM," remarks Londenberg. "BIM software enables us to consider the building in greater detail earlier in the design, which allows for a more thorough design process and provides a new level of design coordination and collaboration that was never possible before."



An accurate digital building model integrated with energy analysis tools greatly simplifies daylighting analysis on sustainable design projects, such as the educational facility shown here, and helps engineers to properly size building systems.

Summary

The worldwide awareness of the impact of buildings and infrastructure on the environment has increased the need for building industry professionals to embrace sustainable practices. Sustainable design is a major trend that is helping to drive process change within our industry, requiring an integrated workflow with more information brought into earlier stages of design. BIM is poised to facilitate this change since it enables an integrated design workflow that links design and analysis.

As the use of BIM in the building industry grows, building designs and outcomes will become more accurate, more buildable, more predictable, and more sustainable—enabling the cost-effective design and delivery of healthy, resource-efficient buildings and mitigating the carbon footprint of our built environment.

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