Achieving Best Practice Net-Zero-Energy Building Design Instruction Methods

Thomas Spiegelhalter, MArch
[Florida International University, Miami]
tspiege@fiu.edu

Shahin Vassigh, MArch
[Florida International University, Miami]
svassigh@fiu.edu

ABSTRACT

The United Nation’s climate panel has published the third part of its long-awaited report on strategies for greenhouse gases (GHG) mitigation in 2014. The document by the Intergovernmental Panel on Climate Change (IPCC) considers the options for limiting or preventing GHG emissions and enhancing wide ranging activities that remove them from the atmosphere. For the building sector, numerous energy efficiency and GHG reduction market changes, new design and learning algorithms for more efficient simulation tools and benchmarking procedures have been developed. For example, the mandatory E.U. ‘nearly Net-Zero-Energy-Building 2018 regulation’ for all new public and privately owned buildings is now set up to help minimizing carbon emissions and reverse the negative impact. In the U.S., the American Institute of Architects (AIA) adopted the 2030 Challenge as a voluntary program, where participating buildings aim to achieve a 90% fossil fuel reduction by 2025, and carbon-neutrality by 2030. The following paper presents the outcomes from a funded project by the U.S. Department of Education under the topic of Building Literacy: the Integration of Building Technology and Design in Architectural Education. The funds supported the interdisciplinary development of a hybrid educational platform comprised of software and a hard copy textbook for advancing Net-Zero-Energy Building design. The most significant challenge was to select the best practice design variables for landscape and climate, building orientation and occupancy types, passive-active energy and climate control systems and their dynamic impact on each other. The paper will critically discuss and analyze the project implementation and the diverse feedback of multiple users from the profession and academia for further improvements for the second edition.

HYBRID PROJECT APPROACH

The instruction methods for both the book and the DVD “Best Practices for Sustainable Building Design” are developed for students, faculties, architects, engineers and everyone who is interested to apply best practice principles for Net-Zero-Energy Building designs (Figure 1). For instance, in today’s struggling economies practicing architects are faced with lower in-service training costs. For that reason with better prepared graduating students, architecture firms will not have to incur the costs of providing technical training to new hires. This book with the DVD supports and promotes a self-directed form of learning, which not only is more effective than the traditional method, because it also offers greater flexibility and links to other online animation tools. The book and the DVD are structured into seven learning modules: landscape/climate and building form, building structure and envelopes, climate building control, renewable energy and lighting. The combined text and animation modules allow the user to quickly grasp the various, but interconnected concepts of passive and active strategies influenced by microclimatic conditions, building form, envelope materials and environmental...
control systems, and other elements, ensuring an accessible step-by-step learning process. The book and DVD animation project also addresses a number of critical international issues as it aims to significantly improve the effectiveness of teaching sustainable and net-zero energy efficient design within architecture programs. In particular, the originally funded U.S. - Building Literacy pedagogy is designed to increase students’ comprehension, problem-solving capacity, and most importantly, ability to apply learned principles to carbon neutral design. The following diagrams are DVD animation excerpts about different Net-Zero-Energy building typologies in different climate zones within the Climate Control Module (Fig.1).

**Figure 1.** Excerpt of the Interactive Software: two Zero-Net-Energy building analysis tools for average hot and cold climates with passive and active building integrated renewable systems and their prospective Energy and CO2 per m2 a year performance. Source: Spiegelhalter/Ozer/Vassigh.

**DESIGN VARIABLES AND TYPICAL SELECTION CHALLENGES**

The book and software components of the educational framework have been developed as an immersive and integrated learning environment, delivering the content in a combined interactive format. Harnessing the capabilities of other advanced media, such as dynamic parametric modeling with other regular software tools, animations, interactive diagrams, and hypertext, the book DVD’s software generated environment helps to visualize and engage concepts that may be difficult to grasp in traditional learning formats. The interactive content aims to engage and compel users to participate actively in the learning process. The inclusion of the software component also responds to the proclivity of the new generation of students who are more accustomed to accessing information in such environments. The software content is organized under a graphical user interface system that serves as a vehicle for learning on demand, linking to proper information quickly and easily. All the content of the book is cross-referenced to the accompanying software with graphic icons at important reference points. The icons are used to inform the user that there are interactive diagrams, charts, and animations explaining the subject in greater depth in the accompanying software (Figure 2).
The biggest challenge is posed by the selection of the design variables in context to the interconnectivity of building systems and their impact on each other. For example, how the selection of a certain type of cooling and dehumidification system will lead to maximum efficiency when combined with a particular structural thermal mass system, or how the choice of a specific structural enclosure system can affect the levels of natural lighting within the space and therefore impact the building’s net-zero-energy profile. Since there are many building systems choices and a great number of combinations possible, leading students to learn about optimized solutions with so many variables and without a complex parametric computation seemed a difficult task to achieve. To face this challenge the authors had to limit many variables and choose strategically only those for general demonstration purposes (Figure 2).

Another significant challenge was the complexity of the architectural design process itself. Designing a building refers normally to a wide range of socio-cultural, aesthetic, and economical constraints. For example, to address the challenge that a sustainable building could be among one of the worst socially and culturally conceived buildings and may not work for the occupants at all. Although the authors had to make a decision to deliberately exclude all these other factors and limits the project expression of architectural form within the tool. However, these constraints still evolve and engage many of the authors and book/DVD user’s discussions. The selection, development and organization of the entire content from various discipline areas of architecture, engineering and landscape architecture under one umbrella and providing instantaneous access to the vast amount of information occupied a significant amount of the project efforts. It is clear that not all topics could be covered as fore-mentioned.

![Figure 2. Screen shots from animations showing passive system choices on the left and one example of encapsulated phase changing materials as a pop up animation menu. Source: Spiegelhalter/Ozer/Vassigh.](image)

**BUILDING FORM AND ORIENTATION**

Building form has a critical impact on the well-being of the users, resource use and on the water and energy consumption. The choice of form includes the shape, volume, mass, scale, and configuration of a building. Form should also support the requirements for the users’ activities. Although building form may often be determined based on a number of other concerns outside energy efficiency and sustainability, selecting the proper form is one of the most important steps in net-zero-energy design. A properly conceived building form can mitigate the external climate in order to provide comfortable interior conditions, thereby reducing cooling, heating, ventilation, and electrical lighting demand. In
particular, the building’s environmental performance in relation to its formal configuration can be
determined based on another number of factors including plan geometry, surface area to volume ratio,
orientation, access to natural light, natural ventilation, and the location of the structural core and
circulation spaces (Figure 3). The book software interface addresses these issues in each of the climatic
zones of 1) Hot and Humid, 2) Hot and Arid, 3) Temperate and 4) Cool.

**Figure 3.** Screen shot showing thermal performance of a C-shaped building in a hot and humid climatic
zone. Source: Spiegelhalter/Ozer/Vassigh.

**BUILDING ENVELOPE AND THE LIFE CYCLE OF MATERIALS**

The building envelope is the primary interface of a building with the exterior surroundings. As a
result, the building envelope plays a critical role for the thermal comfort of the users and in the energy
management and greenhouse gases emission mitigation. The proper selection of walls, roof and floor
systems, construction materials and a rigorous, detailed development of connections and structural
joinery are important components of thermal comfort, and water and energy saving strategies. In
addition, thermal and moisture control, sound and fire insulation, and natural lighting strategies can
significantly reduce dependence on mechanical climate control systems.

**Figure 4.** Screen shots showing the environmental impact in the use of materials for construction. The
diagrams include embodied energy and water and the carbon footprint. Source: Spiegelhalter/Ozer/Vassigh.
The life cycle of materials entails the consumption of energy and water in their removal, manufacturing, transportation, maintenance and recycling and produce hazardous emissions during these processes. Approximate indicators of a material’s environmental impact are embodied energy, embodied water and carbon footprint. Designing buildings with improved environmental performance should go beyond decreasing the operational energy, and aim at reducing embodied energy, embodied water and carbon footprint during the life cycle of building materials.

BUILDING STRUCTURES

Selection of structural materials and systems for buildings is often based on material efficiency and reducing the structural components to the smallest possible size without compromising safety. Although this process promotes effective use of natural resources, other strategies that utilize materials with high-recycled content and reduced impact on the environment are significant ways in which the structure can become more effective in reducing the buildings’ carbon footprint. The concepts of structures are summarized to 1) Structural materials and their properties, 2) Horizontal Spanning Systems, and 3) Vertical Spanning Systems (Figure 5).

Figure 5. Screen shot showing a wooden structural materials and frame systems. Source: Spiegelhalter/Ozer/Vassigh.

CLIMATE CONTROL SYSTEMS

Designing resource efficient buildings with active, passive or hybrid means of achieving comfort requires a thorough understanding of climatic conditions, building occupancy types, and the availability of resources. Although there is a wide range of mechanical means for controlling the interior conditions of buildings, they present significant drawbacks to the natural resources and the environment.

While it may be unrealistic from case to case to completely move away from the active methods for climate control, investigating passive means of ventilating, daylighting, heating and cooling buildings are critical (Figure 6). The book texts and software categorizes the passive climate control systems into: 1) Natural Systems, 2) Solar Heating, 3) Passive Cooling, 4) Phase Change Materials, and 5) Building Insulation. The study of active climate control systems includes: 1) Production Systems, 2) Distribution Mediums, 3) Distribution Methods and 4) Recovery Systems.
Fossil fuels are non-renewable as they draw on finite resources that are diminishing. These fuels are becoming increasingly more expensive and produce irretrievable damage to the environment, and with that impacts, as well, human health and the survival in climate change threatened societies. In contrast, renewable energy resources are constantly replenished and their capacity to replace conventional fuels has significantly increased during the past decade at the global scale. In its various forms, renewable energy sources include natural elements such as sunlight, wind, biomass, tides and geothermal heat.

Energy harnessed from these elements can be used to produce electricity, heating and cooling energy for buildings operations. The book software investigates selected renewable energy forms in five modules of 1) Solar Thermal Convection, 2) Photovoltaic Systems, 3) Wind Energy, 4) Geothermal Energy, and 5) Energy Storage Systems. Biomass is not included and will be integrated in the next book edition.

Figure 6. Screen shot of an animation showing a latent heat process and energy exchange cycle. Source: Spiegelhalter/Ozer/Vassigh.
Figure 7. Screen shots from animations showing, a) solar façade integrated photovoltaic system. b) heat pipe conductor. Source: Spiegelhalter/Ozer/Vassigh.

NATURAL AND ARTIFICIAL LIGHTING

Since thousands of years architecture has embraced natural lighting as an important component of spiritful, healthy and inspiring aspect of buildings. Combined with daylight control systems, effective daylighting also saves energy and avoids greenhouse gases. It is well-known but not often practiced and implemented in building designs that bright, ambient living space or workplace can improve quality of life, improve user productivity and reduce buildings’ lifecycle cost, while minimizing the adverse impacts on the environment. However, using natural light as the only source of illumination is not always possible and various levels of artificial lighting are often required per occupancy type and specific building code requirements.

The use of artificial lighting in buildings can account for a significant portion of the buildings’ electric energy consumption. Using artificial lighting strategies with occupancy sensor infrastructure technology, dimmable efficient lighting systems and control devices, can reduce the electric energy demand significantly. This section therefore divides the study of light into natural lighting and artificial lighting.

LANDSCAPE DESIGN AND SYSTEMS

Landscape design should be considered as an essential and integral component of a holistic approach to sustainable net-zero-energy building design. Landscape elements and systems have a major impact on water, energy and resource management. Remarkable reductions in non-renewable resources consumption can be realized within a building and in its surrounding site by simply using landscape elements for the avoidance of heat islands, mitigation of heat transfer through shading and increase of natural ventilation strategies through soft cape designs with temperature and pressure differences. The book software interface organizes landscape systems into four major segments: Concepts, Thermal Efficiency, Hydrological Efficiency and Case Studies. The segment Thermal Efficiency concentrates on the effective use of landscape elements to mitigate climatic conditions in building projects.
CONCLUSION AND OUTLOOK

The project outlined describes a step-by-step pedagogical platform designed to teach basic resource conservation and concepts for designing carbon-neutral or nearly net-zero-energy buildings. Perhaps the real strength of the platform is the combination of book and interactive software formats. The funded project by the US Department of Education required a summative and formative project evaluation. This was accomplished through a component collected responses from the project team, faculty, and participants during the project development phase and beta testing. The information was used to provide feedback to the authors in order to improve the project. The summative evaluation measured the effectiveness of the software by analyzing comparative student performance at the State University at Buffalo (UB) and Florida International University (FIU) from 2009 to 2012. In all those tests, the animation DVD helped to visualize and engage with the exposed concepts that may otherwise be too ambiguous, too boring or too difficult to comprehend in only a text-image book format. In summary, the results showed all experimental groups exposed to the software pedagogy and tool displayed statistically significant improvement between entry and exit test scores, while the control groups not exposed to the tool showed no significant improvement. The future work to improve the next edition will include more interdisciplinary testing methods and educational games with interactive quizzes.

Another emerging question for improvement is how the future of academic and professional education will change when it comes to the increased usage of text/web-based software for tablets versus textbooks. The benefits are clear, that text/web-based software for tablets can store and process more learning materials than textbooks. Most tablets today have memories between 20GB and 100GB, which can hold hundreds of thousands of textbooks. This means a single tablet is more than capable for holding all the textbooks a learner needs plus animations, quizzes and homework. This poses the critical question if we then still need physical text books in the future? Will this lead to a fundamental paradigm change in education and practice? What are the disadvantages of digital learning with tablets and other handheld devices? Some say there are a number of health issues caused by the heavy usage of tablets: eyestrain, blurred vision and headaches, to name a few. These are symptoms which are collectively known as Computer Vision Syndrome. Or others observe disadvantages in the use of tablets that students who use them tend to get too distracted, as opposed to those who use textbooks. Some state that distractions are related to digitally connected students who are simultaneously into games, videos, emails and countless entertainment applications while they are in a learning environment. In summary, all the fore-mentioned and perhaps many more constraints would be worthwhile to further investigate to improve the pedagogy of “Achieving Best Practice Net-Zero-Energy Building Design Instruction Methods.”

REFERENCES


