ENERGY MODELING IN ARCHITECTURAL DESIGN

TIMOTHY L. HEMSATH
and KAVEH ALAGHEH BANDHOSSEINI

ROUTLEDGE

Energy Modeling in Architectural Design

Energy Modeling in Architectural Design demonstrates how design elements can lead to energy savings, to help you reduce the energy footprint of your buildings. In addition to identifying climate opportunities, you'll also learn fundamental passive design elements for software-agnostic energy modeling of your projects from conception. Using parametric models and testing each element during design will lead you to create beautiful and high-performance buildings. Illustrated with more than 100 color images, this book also includes a pattern guide for high-performance buildings, discusses energy and daylighting optimization, and has a glossary for easy reference.

Timothy L. Hemsath is a registered architect and an associate professor of architecture at the University of Nebraska-Lincoln, USA; as well as sustainable design leader for HDR, Inc. in Omaha, USA.

Kaveh Alagheh Bandhosseini is a doctoral candidate in architecture at the University of Nebraska-Lincoln, USA.

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Timothy L. Hemsath and
Kaveh Alagheh Bandhosseini

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With love to Sawyer and DiAnna

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Rives Taylor, FAIA

"How do things get made or built. . . How do they work. . .?"

For many, if not all, designers this lies at the heart of our attraction to the discipline and what got us into this passionate journey of creation and realization in the first place. This passion is what drives the authors to frame this valuable insight into our era's challenging design context. Design performance is the new focal point.

Perhaps now more than at any other time within the history of design do architectural designers, who are the creators of the early twenty-first-century human environment, increasingly carry the mantle of finding balance with the natural environment. In design, we have the imperative to steward the biological environment and the holistic sum of the parts. Our era elevates sustainable design, resilient strategies, resource and human stewardship practices, discussions about global impact of design to mitigate climate shift. These debates have led to calls for integrated process, regenerative, holistic, lifecycle, and net-zero project delivery. This discourse occurs from our design studios through our design practices and is ultimately displayed in the everyday environments we create, build, and operate to support our global wellbeing. Design performance is the new focal point, as Professor Hemsath notes:

> According to the Intergovernmental Panel on Climate Change (IPCC), buildings offer the lowest-cost investment potential for reducing greenhouse gases from carbon emissions. This cost capacity is twice that of any other category, with the second being industry. It helps to know that the decisions we make about a building's design early in the process actually reduce energy consumption and climate emissions—in fact, the IPCC estimates that in the building sector, recent advances in technologies, know-how and policies provide opportunities to stabilize or reduce global energy use to about current levels by mid-century.[1]

However, this is a very tall order: the design disconnect comes in our architectural discipline's seeming inability to connect cause and consequence. Endemic to much of our business thinking perhaps is that architects in the system create products that last for generations. Our profession sees through an awareness of lifecycle thinking, which creates a huge lasting global impact in the construction and operations of that built environment. For over 50 years we have been guilty of profligate energy use, often creating an adversely inhuman, sick building situation. *Energy Modeling in Architectural Design* in its initial overview of the design performance acutely documents our recent history of design and the responses, some with better outcomes than others.

It is the cause-and-effect of architectural design decisions seen in design education, through studio and technology courses at two universities and a global practice; it may be as simple as asking the designer "where is north" with drawings lacking the compass rose. How does the climate affect your design? Is accessibility a driver or simply a code requirement? How are you applying knowledge of wellbeing (much less have you even studied human factors)?

The "mystery of the design process" increasingly is hiding a lack of rigor to recognize design realization or everyday outcomes. Digital design/design virtualization has arisen from our computer-aided design, giving us virtual realization and now virtual reality. Truly incredible forms, designed through a raft of integrated coding processes, allow us to anticipate what a building looks like—but not how it will perform in the environment in a city, much less how the diversity of the human occupants will literally use it or feel about it. Will this virtual environment reflect resource stewardship or human comfort?

One of the many key elements this insightful text offers for the twenty-first-century design process is a clarity of methodology—an integrated design decision process recognizing operational outcomes. This is the best of computational design process—it is a valuable primer of what the design team needs to value in the design and delivery process for energy performance.

Energy simulation modeling, allied with daylight modeling and other resource use mapping, is perceived by too many in the architectural profession as either an academic approach or overtly an engineering-only pursuit, often applied to align the HVAC (heating, ventilation and air conditioning) design with what the architectural team has "thrown over the transom." Many of the tools have evolved to be far friendlier than the early DOE2 versions, as Professor Hemsath notes. The lack of use, or simply using many of these simulation tools just once for the code requirement or LEED prerequisite, comes from the disconnect of the model with the design process and often the disconnect of the modeler from the rest of the team. It is the powerful insight of this text that maps the design teams, their process, and the iterative outcome of an energy simulation to deliver integrated design.

This computational design is increasingly the best practice for client value delivery; we tackle this former design dysfunction/disconnect using a design inception process called Smart Start, where projected operational and human use performance indicators are documented for continual reference and course correction. This text excels in its documentation of the clear methodology to develop the energy optimization of the owner's project requirements and the attendant integrated architectural and mechanical basis of design. This is not simply for LEED prerequisites, but is the vital tool for the lifecycle for all projects of all scales.

Like so much in the twenty-first century, the evolution of processes, ideas, and global challenges will no doubt make many of our design processes and aesthetics rapidly outdated or out of touch with our client and student demands. Professor Hemsath has delivered more than a toolkit or methodology, but a valuable mindset of performance-based design, couched in a brief but exemplary anthology of our predecessors that influenced architectural design.

Notes

1 Timothy L. Hemsath and Kaveh Alagheh Bandhosseini, *Energy Modeling in Architectural Design* (Routledge, 2018); Intergovernmental Panel on Climate Change (IPCC), *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, edited by R.K. Pachauri and L.A. Meyer (Geneva: IPCC, 2014) 102.

Preface

Why in the world am I writing this book? Because I believe that architects must lead building design into our unknown climate future. We achieve leadership through engaging our processes, designing better buildings, and demanding environmental performance. I have been an academic since 2006, when I first began teaching. New to this universe, I found it intimidating yet inspiring. I was previously involved with the U.S. Green Building Council's local chapter in Nebraska and worked briefly at Leo A. Daly.

One big disconnect we observed existed between the architect's wish to design a more sustainable building and the knowledge required to do so. We don't mean to suggest that anyone we've worked with is incompetent, of course, but this point is to identify that often our efforts to do what we think is right for the environment are at odds with our knowledge about what exactly we seek to achieve. An early example is the LEED rating system, plagued by criticism over its point system, which nonetheless moved the building industry toward greater sustainability, by awarding comparable points for often-disparate impacts on the environment. This phenomenon to quantify sustainability continues in other forms; another example is the U.S. Department of Energy-sponsored Solar Decathlon national design/build competition, where the technological value of the houses produced has greater value than their architectural quality. These efforts to measure and count something are important, though they can interfere with our ability to see the true value that design offers our built environment. This book is our attempt to connect the values of architectural design and measurable energy performance to improve the sustainability of our built environment.

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We wish to acknowledge everyone who made this book possible.

First and foremost is my life partner, best friend, and wife, DiAnna, who helped immensely by covering responsibilities, helping flesh out my grammar for the book, and pushing me to complete this effort, and also our son who has offered love whenever needed.

This book would not have been possible without my coauthor, Kaveh, who put an enormous amount of effort into simulating and writing about his work over our three-plus years working together. We began at zero, learning to understand each other and sharing the ideas that would lead to this production. I published some of our work; the rest is still sitting on my hard drive waiting for me to get to it. I compliment his ambition and persistence to push into the unknown, discover value, and question everything. Wherever he ends up after our adventure, he will surely make an impact as he has in this book.

At the University of Nebraska-Lincoln, I wish to first thank interim deans Kim Wilson and Scott Killinger and Architecture Program Director Jeffrey Day for their monetary support for student workers. I would also have had very little luck pursuing this topic without the passion and efforts of all the students over the years who explored the ideas and tested many of the concepts this book highlights. From seminars to design studios, their work planted the seeds that have grown into this manuscript. Finally, I must specifically thank some of the graduate research assistants and undergraduate workers who spent their summers and semesters working on aspects related to this book: Bryce Willis, Brett Virgl, Adam Weise, and Adam Heier.

My strength is not writing; I relied greatly on Ian Rogers for his editorial expertise in fixing all of my grammatical issues, and appreciate the time he spent revising and suggesting changes to the manuscript. In addition, I owe my ability to rely on his support to our business administrator, Jay Penner, who found some money I had sitting around for Ian's assistance.

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Studio Twenty Seven Architecture: Todd Ray and Jim Spearman
Sustainable Engineering Group LLC: Jon Evans

To all my energy-modeling friends, I thank you for letting me bend your ears about this book and what the professional environment needs. Particular thanks to Nathan Kegel at IES for his contributions to energy modeling and my chapter on climate. I've truly enjoyed working with this group of individuals across the world who pursue this frontier of building performance simulation as it relates specifically to energy modeling.

To the academics I have spoken to at other institutions about what they are teaching, how they teach it, and what they use to educate their students with the same values I hold dear. These discussions help inspire me and open my eyes to what great things are happening. There is a lot of work to be done, and it definitely takes all of us, specifically the professionals, to push for carbon neutrality.

I should thank Peter Krebs, the mind behind Sefaira's energy modeling approach, for his brain and for speaking to me about their software plans and efforts, particularly the free educational license they provide all my students every semester to complete the coursework I thrust upon them. I should also thank the DIVA team's Alstan Jakubiec, who has helped us with many simulation issues over the years. He has been open and honest about how DIVA works and assisted in finding solutions and strategies for many of our questions. Finally, Adam Caprez, our connection to the Holland Computing Center at the University of Nebraska-Lincoln.

To conclude, I thank the editorial team at Routledge, and Grace Harrison, who was available to answer my questions. I am also grateful to Wendy Fuller and Norah Hatch for their help leading up to and at the end of the effort finalizing the manuscript.

Contributors

Timothy L. Hemsath, NCARB, AIA
Associate Professor of Architecture, College of Architecture, University of Nebraska-Lincoln

Tim is passionate about designing architecture for a sustainable built environment. As an Associate Professor in the College of Architecture, he has over 15 years of combined industry and educational experience in design, construction, and research in energy efficiency and sustainable design. His work includes establishing the Center for Urban Sustainability at the University of Nebraska-Omaha as its founding Research Fellow. He is a member of the Nebraska Community Energy Alliance and past-chair of the Nebraska Flatwater Chapter of the U.S. Green Building Council. He was the design architect for the ZNETH and ZNETH II energy-efficient prototypes working with the College of Engineering at the University of Nebraska-Lincoln, and research PI for the Nebraska Research Initiative-funded project to develop research capacity surrounding zero-net energy research at the University of Nebraska.

Kaveh Alagheh Bandhosseini, PhD
Kaveh Alagheh graduated with a Master of Architecture degree from the Khorasgan branch of Azad University in Iran. After three years of practical experience and having taught in several branches of Azad University, he left Iran to continue his education in architecture. He is a PhD candidate at the University of Nebraska-Lincoln. His extensive work on leveraging digital technologies to improve architectural performance has led to him winning the Per/Form competition, the Beetle[s] plug-in for Grasshopper, and a series of publications in cooperation with Professor Timothy Hemsath.

Rives T. Taylor, FAIA, LEED AP
Principal, Architect—Gensler

A Texas-practicing architect and educator, Rives Taylor, FAIA, LEED AP BD+C, is a Principal and Firmwide Sustainable Design Leader at Gensler, the leading global design firm. He also teaches sustainable design seminars at Rice University and technology curriculum at the UH School of Architecture. Having co-founded the U.S. Green Building Council Houston chapter, the AIA LFRT Green Committee, and engaged in AIA CEU and COTE green, and TxA SusCom efforts, Rives was elevated to his AIA Fellowship for his commitment to sustainable architectural education, mentoring, and practice.

1 Introduction

In an era of climate uncertainty and pressures to reduce carbon emissions, buildings hold the largest share of energy consumption and are therefore a significant contributor of carbon into our atmosphere. We know that buildings consume energy and that conserving energy by operating a building intelligently is important. Since the primary energy source for a building is the power plant, we need to be conscientious in the use of this energy. Carbon limits on coal-fired plants place increased pressure on the use of energy in both new and existing buildings.

According to the Intergovernmental Panel on Climate Change (IPCC), buildings offer the lowest-cost investment potential for reducing greenhouse gases (GHGs) from carbon emissions. This cost capacity is twice that of any other category, with the second being industry. It helps to know that the decisions we make about a building's design early in the process actually reduce energy consumption and climate emissions—in fact, the IPCC estimates that in the building sector, recent advances in technologies, know-how, and policies provide opportunities to stabilize or reduce global energy use to about current levels by mid-century.[1] In the long term, saving energy and reducing GHGs helps save building owners and operators money and prevents wasteful energy use during operation. Energy modeling allows one to demonstrate in measurable terms the energy savings of a building's design from the very conceptualization of a project.

Fundamental decisions made by designers, architects, and engineers early in the design process represent some of the most cost efficient ones. For instance, a building's shape and orientation are decisions made with minimal project cost implications. The building blocks we begin with in design (see Figure 1.1) are essential to conserve energy and use it efficiently. This book puts measurable energy consumption numbers to a few of these design tenets, showing how impactful they are for early design decisions. We can make wiser and more energy-efficient decisions about our building design when considering energy and following a design process that incorporates building energy modeling (BEM) to simulate a building's operational energy use.

There are endless potential building sizes, shapes, and forms—not to mention a wide range of functions and uses—from those with high energy use to low energy use, making it quite a challenge to piece together the range of possibilities. BEM tools employed in architectural design help harmonize them. Using these tools early and often provides the potential to continuously track and benchmark performance against the design goals a team might have for a project. As the building evolves, the specificity of BEM closes in on a more accurate prediction of energy use. A design might start as something simple and evolve into a complex building; using BEM along the way allows us to understand its energy performance from start to finish.

One key to a successful architectural practice today is how to use BEM in the building design process. Using energy modeling is essential to making early fundamental decisions about energy. However, anyone who has attempted to learn the energy modeling process can tell you how overwhelming it can be. There are innumerable barriers to overcome: What software do I use? When should I use it? How does it work? What am I using it for? This book will answer these questions and review in a non-specific software format how to use the tools available, when to use them, and what to do with the outputs to help in the design.

Within the energy modeling field there is an increasing number of BEM professionals certified by a consortium of professional organizations. This expertise will help provide knowledge experts to transform this industry in the next decade. However, not every professional wants to specialize in BEM. If you want to design buildings and incorporate the most energy-conscious methods into the design without becoming a BEM expert, then this book is for you—yes, you—the architect who wants to make smart decisions about energy in buildings.

This book seeks to inject BEM into architectural design, helping students and professionals to understand the workflow, leverage it to make decisions, and ultimately reduce the energy footprint of their building designs. The energy modeling process is not unlike the one we use to design: You start with some basic information and a few assumptions and go. However, the difference with BEM is the amount of upfront input required to run a simulation. What energy modeling software requires one to know in advance of producing results is challenging and can hamper the productivity of the design process. In this book we will show how to combine these workflows and leverage them in concert with design to make smarter decisions about a building's performance.

As part of designing to reduce energy consumption, what the reader can take away from this book is a framework for making productive energy-saving choices during building design. Specifically, this book discusses four key concepts that designers should incorporate in their practice, and students use in their design studios. First, a fundamental review of energy efficiency and climate helps demonstrate how design elements inform energy-saving architectural design practice. We review a range of design elements common in building design for a variety of climate zones. Second, we discuss fundamental elements critical to the energy-efficient design of buildings. Using BEM, we show how these elements have the