Green BIM:
Successful Sustainable Design with Building Information Modeling

Eddy Krygiel

Bradley Nies

Wiley Publishing, Inc.

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Compositor: Maureen Forys, Happenstance Type-O-Rama
Proofreader: Jen Larsen, Word One
Indexer: Ted Laux
Cover Designer: Ryan Sneed
Cover Image: © Assissi

Published simultaneously in Canada

ISBN: 978-0-470-23960-5

Library of Congress Cataloging-in-Publication Data

Krygiel, Eddy, 1972-
Green BIM : successful sustainable design with building information modeling / Eddy Krygiel, Brad Nies.—1st ed.
p. cm.
Includes bibliographical references and index.
ISBN-13: 978-0-470-23960-5 (paper/website)
ISBN-10: 0-470-23960-3 (paper/website)
1. Sustainable buildings—Design and construction. 2. Building information modeling. 3. Building—Data processing.
I. Nies, Brad, 1971– II. Title.
TH880.K79 2008
720'.47--dc22
2008008357

This book is printed on recycled paper.

10 9 8 7 6 5 4 3 2 1

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Best regards,

Neil Edde
Vice President and Publisher
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I would like to thank my family, especially Laura, Payton, and AJ for all their support and enthusiasm. Also, this book could not exist without the wonderful experiences we've shared with fellow BNIMers, both past and present.

—Bradley Nies

For Angiela, with and for whom all things are possible.

—Eddy Krygiel

Acknowledgments

This book, like a building, wasn't put together by a single individual. It was the work of many who came together to use their specialties to create what you have before you. We, the authoring team, get the opportunity to have our names on the cover, but this book would not have been made possible without the hard work of many others.

First, we'd like to thank our colleagues at BNIM Architects, who willingly let us tackle this endeavor and were generous in their support. A special expression of appreciation is extended to Steve McDowell, FAIA, for writing the foreword and leading the design and innovation of our firm.

We extend our gratitude to the artists and photographers whose artwork makes this book come alive. Special appreciation goes to Farshid Assassi, Lyndall Blake, Filo Castore, AIA, Jean D. Dodd, Paul Hester, Timothy Hursley, David W. Orr, Richard Payne, FAIA, Mike Sherman, and Mike Sinclair.

We would like to offer some huge thanks for the excellent support we received from the team at Sybex. Truly, not a more crack group could be had to constantly poke and prod us to use the Queen's English, write in complete sentences, and start writing at the end of a long day.

Thank you's are particularly due to our developmental editor, Jennifer Leland, who will hopefully still like us after this project is complete. Thanks to Scott Sven for his technical expertise, and to Rachel McConlogue for making us use something we've heard about called *grammar*. Thanks as well to Pete Gaughan, and last but not least, a hearty thanks to Willem Knibbe, without whose undying support, generous praise, and constant prodding none of this would have, well, they won't let me print the rest.

About the Authors

With over 10 years of professional experience, Eddy Krygiel serves as a project architect for BNIM Architects. As a well-rounded professional, his experience includes the many facets of design, construction documentation, and construction administration. In addition, Eddy is familiar with the advanced integration of technology in practice, including the latest software and program systems, which ensures maximum performance on all of his projects.

In his role as project architect, Eddy is responsible for developing the design into working details, leading the production of construction documents and specifications and construction administration. His participation is constant throughout the project, particularly during the construction documents and construction administration phases.

Eddy is responsible for implementing BIM at his firm and also consults for other architecture and contracting firms looking to implement BIM. For the last three years, he has taught BIM to practicing architects and architectural students in the Kansas City area and has lectured around the nation on the use of BIM in the construction industry. Eddy has coauthored a number of books and papers on BIM and sustainability.

Eddy's representative project experience with BNIM includes the Internal Revenue Service Kansas City Service Center, the H&R Block Service Center, Art House Townhomes, Freight House Flats, and Shook Hardy & Bacon law offices, among others. While at other firms, he has also been involved with large housing projects at Whiteman Air Force Base and Benedictine College.

Bradley Nies, AIA, LEED AP, is director of Elements, the sustainable design consulting division of BNIM Architects. He received his bachelor of architecture from the University of Kansas.

Brad has 13 years of experience and has worked on silver, gold, and platinum USGBC LEED Certified projects. He was the sustainable design consultant for the LEED Platinum Certified Heifer International Headquarters in Little Rock, Arkansas, which won a 2007 AIA Top Ten Green Project Award and a National AIA 2008 Institute Honor Award. Brad also led the team that created Implement, Seattle's online Sustainable Building Tool.

In 2005, Brad founded a Kansas City–based volunteer construction waste management forum, which led to the development of RecycleSpot.org. Brad has served two terms on the AIA Kansas City Committee as the Environment Chair and is currently serving his second year on the Greater Kansas City USGBC Chapter Board. Brad often speaks at regional design and construction conferences throughout the Midwest and is an annual guest lecturer at the University of Kansas School of Architecture.

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Foreword

The great pyramids remain beautiful marvels of design, engineering knowledge, fabrication ability, and precision. The architect builder(s) of the great pyramids achieved seemingly impossible feats. They imagined, visualized, and realized structures of stacked stones, dwarfing design construction accomplishments still to this day. Stones were shaped and placed one by one with rudimentary tools and slave labor. It was slow-going, and each layer of stone became the scaffold for the next. Gravity was overcome with each stone as the laborers lifted and carried it to its predetermined place in the composition. Finally, every stone was at rest and carried the weight of those above, stone by stone down to the sand.

Many mysteries remain about exactly how these complex and precise structures were accomplished. How were ideas documented and communicated among the tens or maybe hundreds of thousands of laborers? In the case of Giza, what tools ensured that the lengths of the four sides varied by only 58mm? What process was in place to organize the fabrication and installation of millions of stones over decades of time by thousands of workers and achieve the parti with degrees of precision that would be considered extraordinary today?

The pyramidal form is simple and beautiful. These structures are even more beautiful as monuments to the ingenuity of the designer builders. Each is a three-dimensional diagram of the forces of gravity at work, cementing every stone in its exact position in balance with nature. We will never know if the builders understood the science of the design or simply selected the shape for its form and because it was buildable with the tools available.

Eero Saarinen understood the forces of nature. Many centuries after the pyramids, he collaborated with colleagues, engineers, a mathematician, and builders to achieve balance with gravity to realize his competition-winning design. Rising from the banks of the Mississippi River is the monument to the vision of Thomas Jefferson. The St. Louis Arch, as it is widely known, stands today as an inverted catenary curve resting in pure compression and void of all shear. Accomplishing such an undertaking demanded innovation in all aspects of design and construction.

His team approached the design utilizing mathematical formula to determine the form, sectional design, and dimensions of the entire building. High-carbon steel and concrete were combined to create a balance of form, structure, durability, aesthetics, and constructability. New elevator and other building systems were invented to provide usefulness and comfort. The design accommodated a construction approach relying on the incomplete structure to carry the weight of the workers and their tools and materials as they progressed toward the keystone piece joining the two legs of the curve. The meeting of the two legs that rise from a distance 630 feet apart to a height 630 feet above the earth demanded precision. An error greater than 1/64 inch could not be tolerated if the legs were to meet. The final section would only be allowed to slip into place with the help of nature. The only force powerful enough to align the two legs exactly into position was the sun. Solar radiation landing on the opposing legs of the arch the morning of October 28, 1965, widened the gap enough to insert the keystone section precisely and complete the arch.

The pyramids and the arch were large-scale breakthroughs in design and construction. Our era is in need of similar-scale advancements in how we realize our needs for enclosure and inspired design. We are facing a construction boom like no other in history. Over the next 20 years, we will more than double the amount of built space occupied today. Innovation is the foundation for sustaining life on earth. We are at a critical point, and the right innovations must be incorporated in the environments of the future.

Nature provides the answers—it is up to us to ask the right questions. Like the great pyramid builders centuries ago and Eero Saarinen centuries later, the authors of this book are doing just that. Eddy Krygiel and Bradley Nies are practicing a new approach to design and building that utilizes the power of building information modeling tools and integrated design thought and process with profound results. Their work has developed within BNIM Architects, a firm with a long history and commitment to sustainable design. Many new questions about the process of design and building have emerged from that experience. Those questions cover topics of sustainability, design, and construction process efficiency, construction quality, method of fabrication, roles and responsibilities of designers and builders, human health and comfort, durability, and the future of our industry.

By answering those questions and more, Krygiel and Nies have provided leadership within our firm, enabling design teams to begin the journey along a new approach to design and construction. Utilizing BIM side by side with green design principles, our projects and research undergo scientific modeling during the earliest stages of design as the parti is refined. User comfort is evaluated and the design is modeled, helping client, designer, and builder understand the quality of space and experience. Daylight and energy is studied throughout the process. Energy needs are minimized and renewable strategies found to serve the needs of the building. Water use and waste are minimized or eliminated through the modeling and design of the building and site. Fabrication and construction process is anticipated and guided as critical elements of design. Construction waste is identified and redirected as a source for other uses and products.

As a beautiful and powerful landmark for the vision of Thomas Jefferson, the St. Louis Arch is also a reminder of our need to always improve our approach to design and construction. The arch is in balance with nature's force of *gravity*, but also very dependent on resources that tax nature in the form of pollution, waste, global warming, and resource depletion. It is time to move forward.

The proposition of Krygiel and Nies will result in more beautiful, greener buildings, regenerative buildings, and triple bottom line results—good for all people, good for the environment, and responsible to the economics of their clients and communities. As perpetual leaders in sustainable design and building information modeling in design and construction applications, Krygiel and Nies have integrated the principles and benefits of each with innovative, high-performing results.

Today, collaborative design and construction teams are creating buildings with new aspirations. The result has been a new approach to designing and building that has given birth to buildings that strive to achieve balance with nature. These structures harvest energy, capture and clean any water that is needed, use resources efficiently, and exude maximum beauty. The term *Living Building* is associated with this approach to design and construction. These sustainable structures rely on innovation and collaborative design teams. They benefit from scientific processes to understand and model high-performing results in balance with nature and achieve the contemporary needs of building occupancy. The designer and builders are achieving these results using BIM and other design and construction tools to maximize beauty, efficiency, and functionality while minimizing or eliminating impact of the environment. This is possible utilizing the tools and design approach revealed in this book—at the scale necessary to address the impending construction boom spreading across the globe.

Steve McDowell
Principal, BNIM Architects

Introduction

Nothing is as dangerous in architecture as dealing with separated problems. If we split life into separated problems, we split the possibilities to make good building art.

—Alvar Alto

Welcome to *Green BIM: Successful Sustainable Design with Building Information Modeling*, which offers a look at two current and growing movements in the architecture, engineering, and construction industry: sustainable design and building information modeling (BIM).

As with any project, architectural or textual, or for that matter, any project that you want to turn out well, it was a lot of work. We won't lie. That said, it was also great fun, and we enjoyed the synergy as designers and collaborators to bring this project into reality. Most importantly, we were driven by a desire to do something that could help the industry universally understand how to better tackle the growing concerns about our impact on the earth's climate by using tested design methodologies together with BIM software.

As we consider the sustainable design strategies in this book, it's important to understand some key concepts about how those strategies integrate with BIM. Relative to architecture and sustainability, BIM is a fairly recent technology. Many of the tools used to measure the impact of sustainable design strategies, old or new, are not directly accessible within a BIM model itself; therefore, data needs to be exported to another application or imported from a data source.

Analysis tools can range from something more complicated like Integrated Environmental Solutions Virtual Environment (IES <VE>), a whole building energy and daylight analysis application that can take months to master, to a universal application like Microsoft Excel. In some cases a team may need to import information to the BIM model from an outside source, such as a database of weather data or material properties. Better and more seamless integration between BIM and sustainable design will come with time as the industry continues to standardize file formats, as data sets are developed, and as owners, clients, and designers begin to demand more from application developers.

We have tried hard throughout this book to avoid promoting one green building rating system or software application over another. Our purpose in this book has been to promote best practices for sustainable design and show how to use BIM to achieve the most sustainable solution. However, as it is not realistic to become an expert on every software application or rating system available on the market, it's important to note that within our own practice we do standardize on a few software programs that support our office's workflow. It is also important to acknowledge that many of our clients prefer the U.S. Green Building Council's (USGBC) Leadership in Energy and Environmental Design (LEED) green building rating system.

Many of the screen shots in this book are software specific. In our own practice, for BIM, we use Autodesk's Revit Architecture (`http://www.autodesk.com/Revit`). For applications that aid in informing our designs for sustainable solutions, we utilize a host of them at different levels and different phases of design, such as:

- IES <VE> (`http://www.iesve.com`)
- Ecotect (`http://www.ecotect.com`)
- Green Building Studio (`http://www.greenbuildingstudio.com`)
- eQUEST (`http://www.doe2.com/equest/`)
- EnergyPlus (`http://www.energyplus.gov`)
- Daysim (`http://www.daysim.com`)
- Radiance (`http://radsite.lbl.gov/radiance/index.html`)
- Climate Consultant (`http://newton.aud.ucla.edu/energy-design-tools/`)
- WUFI-ORNL/IBP (`http://web.ornl.gov/sci/btc/apps/moisture/`)

And last but not least:

- Microsoft Excel (`http://www.microsoft.com/office`)

Yes, we know that looks like an extensive list, but there are even more options available. However, throughout this book, we will be discussing ways to streamline some of that list and find the answers that work best and solve the problems that you will be facing as you reach for more sustainable designs.

As you read this book, bear in mind that we tried to write this for everyone. Some in our industry are knowledgeable about sustainable design and rather new to BIM. Others know a great deal about BIM but might be a little *green* regarding sustainable design. There are also some who feel as if they might need a good overview of both. In this book, we try to address all of these groups.

In the first chapters, we begin with an overview of sustainable design and an overview of BIM, discussing how the design and construction industry has arrived at this crossroads and why we need to look to new approaches and methodologies to solve the problems we've inherited. These problems are based on a number of issues that have evolved over the course of time, such as process problems like information management on larger team sizes or the specialization of the labor force and how that can negatively impact efficiency. Other issues revolve around sustainability, such as climate change, the globalization of materials, and human health and productivity. Because implementing either sustainable design or BIM or both can be drastic changes in a firm's culture and approach to design and delivery, we discuss best practices regarding workflow, integrating project teams, and offer an order of operations approach to sustainable design.

The book continues with core concepts and a deeper understanding of keys to sustainability in building design, touching on building envelope, systems, materiality, and orientation. By adding water and energy, we round out a building's needs, impacts, and opportunities for existing with the natural environment, both on a macro scale (globally) and a micro scale (locally).

Finally, we create the synergies with BIM and discuss how to use the information hosted in the BIM model to better inform the building design and share benefits with the project team.

We conclude with a brief look to the future of all the things we imagine and hope can soon be accomplished because of the value BIM brings to sustainable design.

We hope that you enjoy *Green BIM* and can capitalize on our knowledge and experience to help advance your practice and share innovations with others as we move forward to a more sustainable future.

Best,

Eddy Krygiel

Bradley Nies

Green BIM:

Successful Sustainable Design with Building Information Modeling

1 Introducing Green

The best way to predict the future is to invent it.
—Alan Kay

What you'll find in this chapter is an introduction to what it means to be green *or sustainable in the architectural profession and why this has become such an important topic both in the design and construction industry and global culture.*

Sustainability

We, the authors, started our professional careers near the beginning of what Bob Berkebile, FAIA, a founding principal of BNIM Architects, refers to as one of the greatest changes in the profession of architecture in his professional lifetime. The year was 1995 and architects were starting to use terms like *green* and *environmentally friendly* to describe their projects and project approaches. Dialogue, experience, and marketplace transition have allowed the people not only in the profession of architecture but also other professions involved in the design, construction, and operation of the built environment to garner a better understanding of what *green* means. Generally speaking, however, today we think in terms of *sustainability*.

A Brief History of Sustainable Design

The practice of sustainable thinking is in many ways ancient. If we look at the buildings from some of the North American indigenous cultures, we can see that they were highly skilled at adapting the location and materials of their structures to climate and place. For example, igloos constructed in Greenland's Thule area and by the people of Canada's Central Arctic, which were made of materials found on site, were built in a way to create thermal mass and wind resistance. Another example is the Native American teepee, built from both natural plant and animal materials found in the region. The teepee was lightweight and easy to transport for reuse and was designed utilizing natural convection flows for heating and cooling. The ancient Pueblo peoples of the southwest (who are often referred to as the Anasazi) utilized naturally formed cliffs and caves as the location for some of our first sedentary civilizations, adding structures made of earthen materials found on site (Figure 1.1). They understood the sun and natural rock formations enough to utilize passive solar techniques for cooling, heating, and lighting.

Image courtesy of Jean D. Dodd

Figure 1.1 Cliff Palace at Mesa Verde National Park

Over time as civilizations grew static, buildings took on a different significance. Civic structure and time for play and leisure developed buildings of cultural and political significance. Humankind was no longer building for survival alone. Some examples of this transitional period were the inspiring and elegant structures built by highly skilled craftsmen to last lifetimes. Buildings like St. Peter's Basilica in Vatican City, St. Basil's Cathedral in Moscow, and the Alhambra in Granada, Spain, are now centuries old and still exist today (Figure 1.2).

Image courtesy of Brad Nies

Figure 1.2 St. Peter's Basilica, Vatican City

With the Industrial Revolution came the ability to mass-produce interchangeable building materials more quickly and inexpensively than skilled laborers of the past. The goal of the Industrial Revolution was to conserve human labor while increasing production of all things needed for human society. Herein lay the beginning of prefabrication and interchangeable parts. Natural resources, in the industrial model, were rarely valued at their true cost. Most natural resources were treated as if they were abundant, unlimited, and inexpensive.

As we turned the corner into the early twentieth century, humankind started to master premanufactured materials and components, transporting materials from around the globe. At this stage, buildings were still responding to natural light and