# The Carbon Neutral Design Project: Pedagogy Meets Practice

MARY GUZOWSKI
University of Minnesota

TERRI MEYER BOAKE
University of Waterloo

JIM WASLEY
University of Wisconsin-Milwaukee

## PROLOGUE

Never before have architectural educators and professionals faced the magnitude and urgency of today's ecological challenges resulting from global warming and climate change. To meet these challenges, the Society of Building Science Educators (SBSE) initiated the *Carbon Neutral Design (CND) Project* to create and disseminate the resources and tools needed to integrate carbon neutral and zero-energy design into professional architecture programs and practice.[1] This project is a direct response to the "2010 Imperative" (which is a call for architectural educators to address carbon neutral design and fossil fuel reduction in the design studio, to improve ecological literacy for design students, and to integrate related issues in the design and operations of university facilities and campuses) as well as the "Architecture 2030 Challenge" (the realization of carbon neutral architecture by the year 2030).[2] As an emerging area of design education and practice, most educators and practitioners are sorely in need of carbon neutral design resources. The project was conceived for faculty, students, and practitioners as a free online resource that would assist in supporting both those who are more technically experienced as well as those who do not presently have adequate background in the subject matter. This paper provides an overview of the *CND Project*, including discussion of the: 1) Project Goals and Outcomes; 2) Carbon Neutral Case Studies Project, 3) Carbon Neutral Studio Initiative, 4) Online Carbon Neutral Design Resources Website, and 5) Next Steps.

## PROJECT GOALS AND OUTCOMES

The *CND Project* is a multi-faceted, multi-year project designed to bring together architecture's professional and academic communities around the topic of carbon neutral design. It has been funded by and developed in collaboration with the American Institute of Architects (AIA). The goals of the project are to codify and disseminate emerging CND knowledge, methods, and tools for both practice and academia. This means not only applying the current best practices of high performance sustainable design, but also envisioning the next generation of design thinking and communicating it to the profession, faculty, and students.

Initiated at the SBSE Annual Retreat held on Bainbridge Island near Seattle in 2007, the starting point for the project was the convergence of fifty faculty members from the U.S. and Canada, many of whom were planning to integrate carbon neutral

design into their studio courses. The first phase of the project, the *Carbon Neutral Studio Initiative*, was launched to capture and share the curriculum of geographically diverse faculty who were proposing to run design studios dedicated to the exploration of carbon neutral design. Given the relative newness of the carbon neutral concept as a subset of more broad sustainable design imperatives, the majority of the studios were compelled – by necessity – to begin by clarifying and developing goals, strategies, tools and metrics with which to evaluate the CND success of the student work. It made sense to use the methods and metrics generated by the design studios to support a larger project to generate online carbon neutral design resources and tools.

During 2007-2008 the organization sought funding from a variety of agencies and foundations. Eventually the project was funded and sponsored by the AIA as an effort to help members improve their sustainable design abilities and integration of CND in professional practice. Funding was also received from an anonymous private donor whose interest lies in affordable housing. Given a newly formed partnership with professional architects, the *CND Project* team expanded the scope of the project to include resources for both design educators and practitioners. While the online resource for the *CND Project* contains a variety of materials, the project was focused around the development of several distinct bodies of information: 1) the *CND Studio Initiative*, which includes educational resources from design studios that have recently been taught throughout North America and Canada, 2) the *CND Case Studies*, which include assessment of a series of real building projects, and 3) *CND Resources*, including strategies, processes, design tools, metrics, and protocols.

**Project Outcomes**

As a direct result of the partnership between academics and practitioners, the project focused on four outcomes:

1. To continue the exposition of the *Carbon Neutral Studio Initiative*, including model curricula from diverse geographic regions and programs.
2. To add the *Carbon Neutral Case Studies Project*, which includes a series of real building case studies that demonstrate low and zero-carbon strategies, methods, and lessons for commercial, institutional, and affordable housing building types.
3. To define and develop the *Carbon Neutral Design Protocol and Metrics* needed to assess the carbon impact of design strategies.
4. To create a dedicated *CND Web Resource* to disseminate these materials.

## CARBON NEUTRAL CASE STUDY PROJECT

It was determined that the development of CND strategies and methods would be best revealed through the assessment of the strategies, methods, protocols, tools, and lessons of recently designed and constructed buildings. Carbon neutral and low-energy case studies would not only benefit other practitioners, but also design educators and students. The *CND Project* team developed a list of potential building case study candidates and design firms. Low and zero-carbon were identified and the architects and engineers associated with the buildings were contacted to see if they would be willing to provide drawings, details, and information on the selected buildings. Members of the design team were also invited to meet in a larger group to discuss the relative successes, failures, and CND procedures.[3] After a shortlist of projects was formed, a studio group at the University of Wisconsin undertook to carefully document the buildings so that they could be compared using a common graphic and quantitative CND protocol. This protocol led to the development of case study profiles and metrics that were used to reveal commonalities in the design and performance of the selected low and zero-carbon buildings. The case study protocol will also be applied to future building case studies and can be used by educators as a case study template.

Following completion of the case study analyses, a Case Study Summit was held at the University of Wisconsin in October 2008 where architects and engineers from the design firms of the case study buildings met with faculty involved in the *Carbon Neutral Studio Initiative*. The participants reviewed the case study analyses that had been prepared by the students to discern emerging themes, strategies, and practices for carbon neutral design. Based on feedback from the summit, each of the case studies was further extended and refined to include a set of common topics and lessons. (Note that not all of the case studies were able to be developed to the same degree of detail as a function of the availability of building information and post occupancy data.) Each case study is available online in html-format and as

a downloadable PDF document. The case studies are intended to provide carbon neutral design lessons for practitioners, faculty, and students across a variety of building types and geographic locations, including detailed assessment of the following topic areas (see Figure 1 for example case study):

1. Case Study Metrics
2. Climate Analysis
3. Site Analysis / Site Design
4. Massing, Building Form and Orientation
5. Envelope Design - Solar Shading, Aperture Distribution, Thermal
6. Illumination (Daylighting & Artificial Lighting)
7. Fresh Air (Natural & Mechanical Ventilation Strategies)
8. Heating (Passive Solar & Mechanical Strategies)
9. Cooling (Passive & Mechanical Strategies)
10. Renewable Energy
11. Embodied Energy
12. Water and Waste
13. Integration Strategies

## CARBON NEUTRAL STUDIO INITIATIVE

The integration of technological subjects into the design studio, the heart and soul of the architectural curriculum, has long been a contentious issue. Some schools of architecture are in an advantageous position, with faculty that have technical expertise also teaching in the design studio. Other schools separate design and technology to such an extent that those with technical expertise rarely teach in the studio. To consider exploring carbon neutral design in the studio requires a high level of integration of technical and environmental design knowledge in the foundational goals and methods of the studio. The *Carbon Neutral Studio Initiative* was implemented in Fall 2007 as a means to develop carbon neutral teaching resources and tools; to pilot those resources and tools; and to provide a means to share related educational resources and the studio outcomes. The studio initiative included a network of 50 participants from around the world with thirty-one carbon neutral studio projects taught during the 2007-2008 academic year (see Figure 2). Fourteen studios were completed in Fall 2007 and the remaining studios were completed by the summer of 2008. Ten studios were undergraduate, graduate, or mixed-level elective studios. At least four studios were designed to satisfy the U.S.

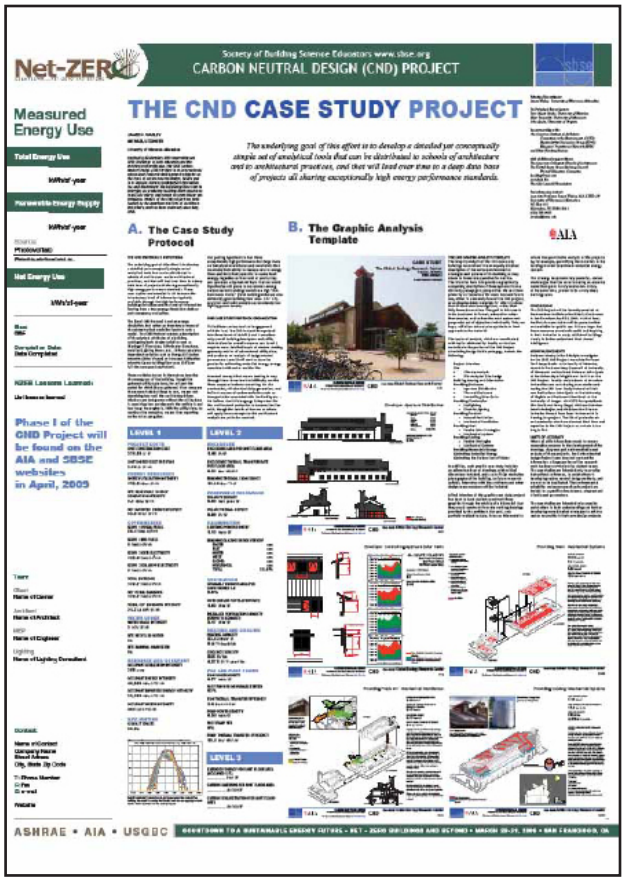



Figure 1: Example case study profile.

National Architectural Accreditation Board's "comprehensive design" requirement; and four were either capstone or thesis studios. The studio problem statements included diverse programs, including: affordable and green housing; schools; nature centres and other public facilities; high-volume retail environments; an office park/data center; other commercial programs; and several higher education projects including a mixed-use dormitory.

### Geographic and Program Distribution

As illustrated in Figure 2, the participating institutions are geographically diverse. The studios include a range of degree programs (BSAS, B.ARCH, and M.ARCH) as well as varied curricular approaches within the different programs. One segment of architectural education not well represented is the beginning design curriculum. To address this issue, the SBSE has reached out to groups such as the annual *Conference of the Beginning Design Student*, to solicit participants from early design studios.

**Participating Studio Projects by Climate and Type**

The studio projects include a wide range of building types and climates. Predictably, small buildings are favored as modestly scale projects more easily lend themselves to in-depth investigations. Also predictably, most projects are located in temperate climates, due in part to the energy challenges of cold-climate design. These biases are being analyzed during the evaluation and tool development process to insure that tools appropriate for each scale and climate type are developed. Preference will be given to the under-represented climates and project types for a proposed second round of studio evaluations to take place in during the coming academic year.

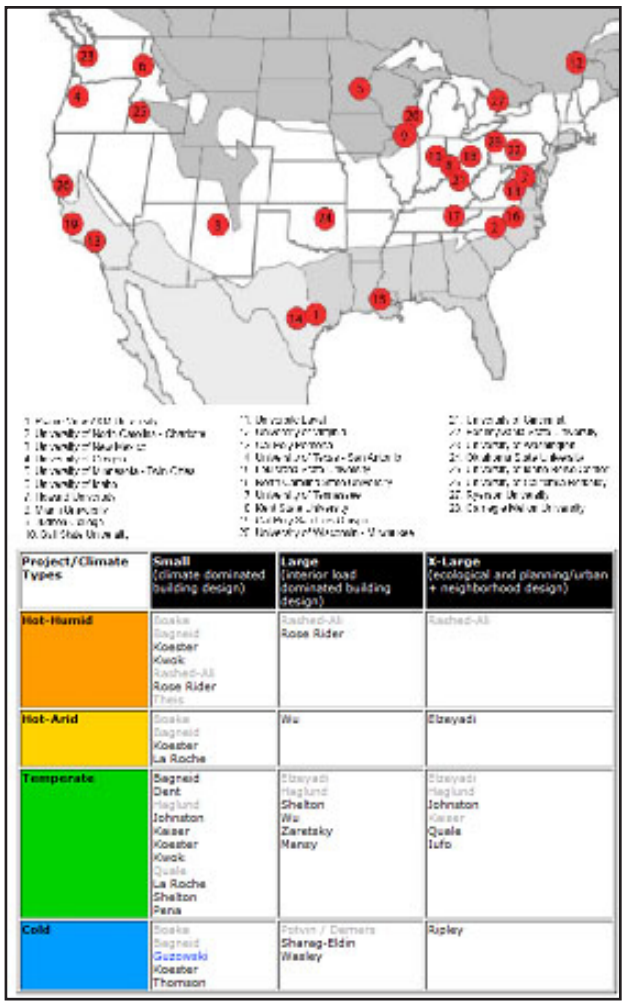
**Defining a Carbon Neutral Teaching Pedagogy**

The educators involved in the project engaged in a *CND Studio Summit*, held at the Harvard Graduate School of Design in November 2008, the purpose of which was to share experiences and outcomes of the individual studio efforts and assist in the development of a more unified methodology that could be published as part of the online resource. On review of the varying assignments and related topics, a clear alignment could be seen between the carbon-related aspects of the studio projects and the content topics in the building case studies.

Following the *CND Studio Summit*, the studio faculty were asked to submit supporting materials that followed regularized format and topic templates in order that common threads could be identified from which other educators could learn. Part of what was found to be in common was their basic pedagogy and philosophy of teaching - as well as its relationship to the format, content and process of their instruction. The introductory overview of each professor's teaching section in the web resource begins with a statement of pedagogy and teaching philosophy as it pertains to the means that carbon neutrality has become a focal point in their teaching. To consistently and easily compare design curricula across diverse programs and geographic regions, a common format was used for each professor's "Studio Profile" as published on the web site. Studio content is organized to include the following thirteen issues:

1. 10 Common Factors:

During the *Studio Summit* faculty identified the issues that they felt were critical to teaching carbon neutral design and in establishing foundational design thinking for a carbon neutral studio problem. These differed as a function of the nature of the projects (more theoretical versus technically detailed projects), the target groups that were being taught (beginning, intermediate and senior/graduate) and whether the topics and assignments were discrete or part of a larger comprehensive studio. Each studio profile includes a list of "10 Common Factors" that the faculty felt were essential to assure a low carbon outcome.



| Project/Climate Types | Small (climate dominated building design) | Large (interior load dominated building design) | X-Large (ecological and planning/urban + neighborhood design) |
|---|---|---|---|
| Hot-Humid | Soake<br>Sagreid<br>Koester<br>Kwok<br>Rashed-Ali<br>Rose Rider<br>Theis | Rashed-Ali<br>Rose Rider | Rashed-Ali |
| Hot-Arid | Soake<br>Sagreid<br>Koester<br>La Roche | Wu | Elzeyadi |
| Temperate | Sagreid<br>Dent<br>Haglund<br>Johnston<br>Kaser<br>Koester<br>Kwok<br>Quale<br>La Roche<br>Shelton<br>Pena | Elzeyadi<br>Haglund<br>Shelton<br>Wu<br>Zaretsky<br>Mansy | Elzeyadi<br>Haglund<br>Johnston<br>Kaser<br>Quale<br>Tufo |
| Cold | Soake<br>Sagreid<br>Guzowski<br>Koester<br>Thomson | Fetvin / Demers<br>Sharag-Eldin<br>Wasley | Ripley |

Figure 2: Carbon neutral studio participating institutions by geographic location and climate zones, and scale.

2. 10 Common Mistakes (or Challenges):

Faculty also indentified common mistakes (or challenges) that they felt were impeding students from applying carbon neutral design concepts, strategies,

and methods. These might also include "misconceptions" as to the intent of low carbon design. These differed as a function of the nature of the projects (more theoretical versus technically detailed), the target group that was being taught (beginning, intermediate and senior/graduate) and whether the topics and assignments were discrete or part of a larger comprehensive studio. These are posted as a cautionary note for other instructors and students.

3. Duration of the Project:
It is understood that faculty considering adopting one of these projects or related exercises need to know how much time would be needed to complete the assignments. Studio profiles describe the time commitment of each exercise and identify whether it is part of a larger studio investigation (or a discrete study). It also outlines how exercises develop over the semester to fit within an overall studio strategy and schedule. The sequence of exercises is illustrated as a graphic key to visually represent the semester schedule (which is located on the philosophy/overview page of each studio profile).

4. Investigative Strategy:
Each faculty includes a brief explanation of investigative strategies and the methods the students used to respond to the problem statement, such as mapping, drawing, site visits, analysis, interviews, model making, computer simulation, etc. This is an abbreviated version of the project and/or exercise instructions.

5. Evaluation Process:
Evaluation processes are described for each exercise. A variety of approaches are used to assess student work, for example: quality of document format (appearance, layout, spelling, grammar, readability); clarity of graphic representations; articulation of design intentions; understanding and analysis of basic site, precedent, and program information; development and interpretation of qualitative and quantitative evaluation methods and tools; and assessment of active participation on design and/or research teams.

6. Evaluation Criteria:
Exercise evaluation criteria are outlined, including qualitative and quantitative assessments and metrics. Criteria also include discussion of the project outcomes in relation to the specific problem statement and investigative strategy employed.

7. Degree of Difficulty of the Project/Topic:
In addition to outlining whether the project or exercise was given at the beginning, intermediate or senior/graduate level, each studio profile highlights required preparation and knowledge needed for the students to successfully undertake the design investigation. Some projects require significant background knowledge, while others can be done with very little advance preparation.

8. Applicability of this Topic/Project to Varying Climates:
Faculty who participated in the project teach in a wide variety of climate zones throughout the United States and Canada. Many of the projects and exercises, particularly from Comprehensive Design Studios, are site and climate specific to the location of the University offering the course. The climate zone of the University and project is noted, as well as the applicability of the project and topic approach to other climate zones. Many of the projects are climate revealing, climate responsive or climate dependent.

9. Applicability of this Topic/Project to Buildings of Varying Sizes:
The studio profiles describe the limitations of the applicability of the CND design strategies and methods in relation to project type and scale. As also found in the *Carbon Neutral Case Studies*, the studio projects are divided into interior load dominated versus skin load dominated buildings. Most of the current low carbon studio projects are less than 13,000 square feet in size and typically skin load dominated buildings. Therefore the following scalar and climate issues are identified so that other professors looking at the studio profiles can determine if the design methods are suited to a project that they are considering adopting for their studio. Projects are defined to clarify the environmental building load:

- Small- climate dominated
- Large- interior load dominated
- X-Large- ecological land planning/ urban design

10. Reference Materials - including Software and Analytical Tools:
Reference materials include textbooks, periodicals, web sites, as well as software and other analytical tools. Where possible, links to online resources are included. Software tools and their applicability, ac-

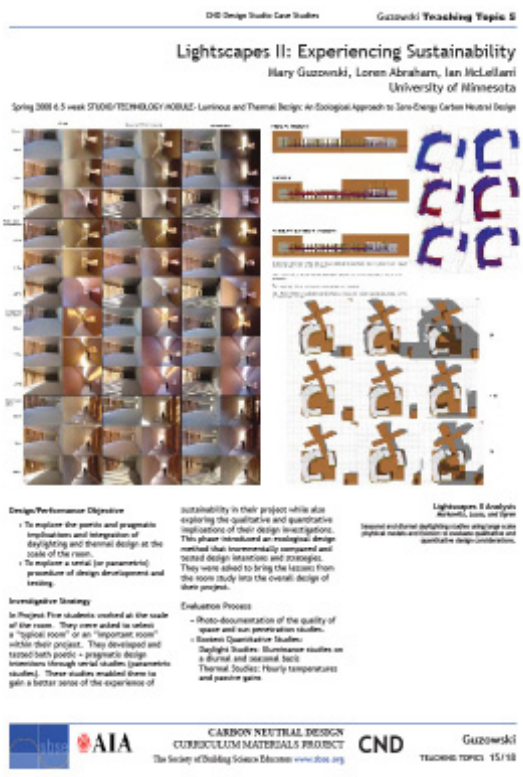



Figure 3: Example daylighting exercise from a Studio Profile.

curacy, and overall relevance to carbon neutral design are also found in the *Carbon Calculation Tools* portion of this website. Many professors share an affinity for schematic design software tools that assist students in developing and testing the validity of their solutions (e.g. HEED, Autodesk® Ecotect™, DAYSIM, and EnergyPlus, etc.). Zero-carbon is a quantitative goal, so numerical validation is important for many of the studio outcomes. This might be quite foreign in concept to the regular design studio offering. Therefore the CND web resource devotes considerable effort to providing users with an outline of available tools, links to projects and instructions on the use of these tools, as well as rating their applicability and ease of use. See Figure 3 as an example of varied design tools used for a daylighting exercise, including physical interior study models and Ecotect™.

11. Specialty Topics:
Professors were asked to report on their use of special tools or software, inclusion of affordable housing issues, or explorations with interdisciplinary teams.

12. Supporting Materials:
Syllabi and exercises for each studio are available as PDF. Faculty generously shared supporting materials such as design tools, related research, papers, and other teaching resources, which are all available online at the project web site.

13. NAAB Criteria:
Although the NAAB Criteria have recently changed, there is a brief analysis as to the NAAB Criteria that the project and assignments can assist in satisfying. It is understood that as accreditation requirements may begin to more proactively include low carbon solutions, schools will be looking for resources and exercises that can be adopted to enhance their curriculum. It is the intention to revise these sections to reflect any changes in the NAAB Criteria.

## ONLINE CARBON NEUTRAL DESIGN RESOURCE WEBSITE

Following the *Case Study* and *Studio Summits*, the materials were gathered and the web resource was authored in the Fall of 2008.[4] Much of the design and arrangement of the elements of the web site evolved out of an analysis of submitted materials, with an effort to provide users of the site and its resources with both a clear methodology to approach carbon neutral design as well as to organize the materials to create groupings and cross linkages. Given the complexity of carbon neutral design and the urgent need to apply these strategies to the design of real buildings, the *CND Project* promotes the meeting of pedagogy and practice. The building case studies and teaching resources and topics have much in common. Subsequently, the website has been designed to encourage the sharing of CND lessons across design practice and education.

The major point of agreement between the real building case studies and the design studio projects was that carbon neutral architecture was unlikely to be achieved if it did not closely respond to the dictates of its climate as well as microclimate. This is likely the major differentiating factor between carbon neutral design and most contemporary architecture. Both design studios and the case studies started with a "back to basics/design foundations" passive approach, which focuses first on the role of the architectural design (e.g. the building siting, massing, section, and detailing) to both reduce loads and harvest free onsite energy though

strategies such as daylighting, natural ventilation and passive cooling and heating.

When the architectural design strategies are coupled with high performance and innovative renewable energy systems it is possible to reach low and zero-carbon and energy goals. The bottom line that was revealed was that major reduction in the general need for energy (of any sort) in a building had to precede the incorporation of renewable energy systems. It was felt that an emphasis on the role of architectural design – with an emphasis on site, climate, and passive strategies– could be strengthened in many educational programs and most architectural practices. A major component of the website is dedicated to reintroducing these principles as a set of quick lessons that are required background knowledge.

Where some faculty might feel quite comfortable integrating the teaching topics as presented and using or modifying these for their own studio, others may need additional background material for themselves and their students. For this reason another section of the web site is devoted to the discussion of strategies to achieve carbon neutrality. The strategies section of the website expands on the following CND strategies (see Figure 4 as an example thermal exercise integrating these four facets of CND in studio):

1. Reduce loads/demand first (passive solar design, daylighting, shading, orientation, use of natural ventilation, site design and materiality, consumption, lifestyle, space planning, etc.)
2. Meet loads efficiently and effectively (energy efficient/effective lighting, high-efficiency/effective mechanical, electrical and plumbing equipment, controls, etc.)
3. Use on-site/community based generation and renewables to meet energy needs (doing the above steps to reduce loads will result in the need for much smaller renewable energy systems, making carbon neutrality achievable.)
4. Use Purchased Offsets as a *last resort* when all other means have been looked at on site.

**Common Strategies Across the Case Studies and Design Studios**

An analysis of both the *Carbon Neutral Case Studies* and the *Carbon Neutral Studio Initiative* proved that the majority of the practitioners and educators

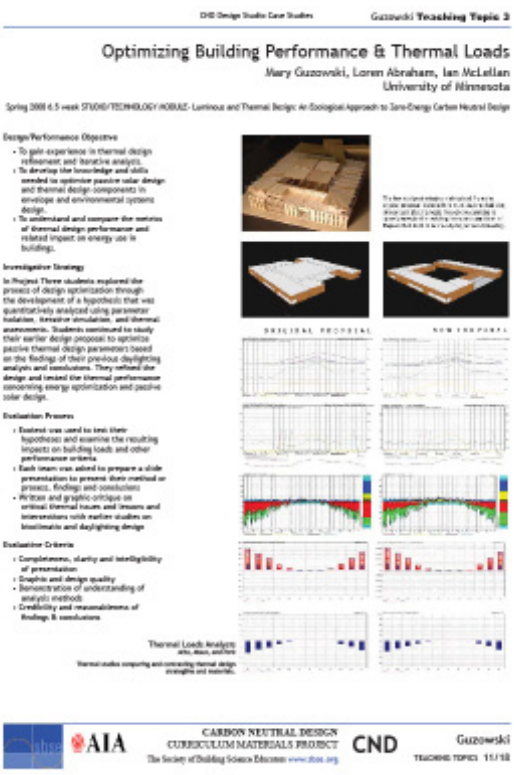



Figure 4: Example thermal exercise from a Studio Profile.

followed the above four energy and load-reducing strategies. While these steps may have been articulated in different language, the practitioners and faculty consistently sought strategies to reduce energy consumption, integrated passive design, used high-performance systems, and incorporated renewable energy systems to achieve low or zero-carbon and energy goals. Common design lessons can be found across the case studies and studio investigations. The web site seeks to facilitate an exchange of knowledge that supports both practice and academia.

**Slicing and Linking Information**

Although both the *Carbon Neutral Case Studies* and the *Carbon Neutral Studio Initiative* resources are available as PDF downloads on the web site, an effort has been made to also use the web interface to organize material in diverse ways. The flexibility and interactivity of this medium allows information to be structured to create different synergies and relationships. Sorting by topic and creating hotlinks through the site can, for instance, let the user

find all of the studio projects that have a unit on "microclimate analysis," as well as easily see the range of software that is being used to investigate a given topical area.

As the finishing touches are being put on these linkages during the 2009-2010 academic year, the intention is to provide keywords that will take the user to all elements on a particular topic. For example to enter the keyword "photovoltaics" and provide links to how it was used on each of the case study buildings as well as links to all studio project elements devoted to the study and incorporation of photovoltaics. The site also provides links to the newly completed AIA 50-to-50 Wiki on Sustainable Design.[5] The *CND Project* web site is organized to access information in a way that provides the most benefit to the user, whether they are searching for specific technical information on carbon neutral design, or trying to understand and apply the basic principles of passive design that will allow the building to better achieve carbon related goals.

## NEXT STEPS

Additional funding is being sought to expand and develop phase two of the *CND Project*. It is hoped that such funding will permit further development of the current web site, the addition of more building case studies that address a wider range of climate and building types, as well as additional carbon neutral Studio Profiles, with specific focus on beginning design. The notion of "pedagogy meets practice" is central to the development of these teaching resources. The long term plan for the *CND Project* includes a series of "Teach the Teacher" training sessions as well as workshops and charrettes in real buildings. Although it is hoped that this can be formalized on a national basis, two such events have already been held and a book published as their proceedings, including *Zero-Net Energy Workshop* and *Design Charrettes* which were held in Portland, Oregon in March 2009 and in San Francisco, California in April 2009.[6]

The SBSE annual summer retreats also provide additional opportunities for design educators to participate in expanding the *CND Project* and to share the lessons of their attempts to integrate this material in their curriculum. A recent SBSE summer retreat that was held in Quebec City in June 2009 was titled "The Leap to Zero Carbon" and allowed participants to further share and develop their teaching resources and pedagogies. While some of the outcomes of the next phase of the *CND Project* will be further development of quantitative design and research tools, there is also a need for more subjective and qualitative resources to support design decision making process.

Carbon neutral design is an emerging practice which is yet to be fully defined and articulated for both architectural practice and design education. Given the emerging nature of the topic, it is only through an on-going collaboration between the design professions and academia that the necessary design resources, methods, processes, and tools will develop and evolve. It is intended that the *Carbon Neutral Design Project* web resource will continue to grow and reflect the on-going evolution of carbon neutral design. The thoughtful merging of pedagogy and practice will enable the next generation of sustainable design thinking to inspire design professionals, educators, and students. The SBSE welcomes participation in the *CND Project* from faculty, students, administrators, practitioners, allied organizations, and the building industries. For more information on the related carbon neutral design efforts please see the AIA/SBSE website at http://www.aia.org/carbonneutraldesignproject.

## ENDNOTES

1. Society of Building Science Educators, http://www.sbse.org.
2. Architecture 2030. www.architecture2030.org.
3. Potential candidate buildings were sought from the American Institute of Architects (AIA) Committee on the Environment "Top Ten Green Projects": http://www.aiatopten.org, as well as from the U.S. Department of Energy's "Energy Efficient and Renewable Energy" (EERE) "Zero Energy Buildings Database": http://zeb.buildinggreen.com.
4. The finishing touches are being put on the web site during the Fall Semester of 2009 in anticipation of transferring the site from its current temporary location to the main AIA web site: http://www.aia.org/carbonneutraldesignproject.
5. AIA, 50-to-50 Wiki on Sustainable Design, http://wiki.aia.org/Wiki%20Pages/Home.aspx.
6. Proceedings are available as a free PDF document and as a book for purchase from lulu.com: http://www.lulu.com/content/paperback-book/zero-net-energy-workshop-and-design-charrette/7297327.