From Informational Barrier to Ethical Obligation: Evolving Perceptions of Teaching Energy in Architecture

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A brief history of energy modeling in architectural education

Dreaming of Energy Modeling

Energy has been a part of architecture since the beginning. The Western world's oldest extant architectural text, Vitruvius's *The Ten Books on Architecture*, includes numerous passages dedicated to energy.[1] For the purposes of the paper, however, history begins in 1973, with the OPAEC oil embargo. On October 6, 1973, a group of Arab countries led by Egypt and Syria attacked Israel on the Jewish holy day of Yom Kippur. Israel suffered some initial military setbacks, inspiring the United States to quickly resupply its ally with military equipment. Israel prevailed, and the war ended on October 25.

In response to the United States and other industrialized nations support of Israel, the members of the Organization of Arab Petroleum Exporting Countries (OAPEC, often confused with OPEC) embargoed oil exports to the United States and other specific Western countries. The embargo lasted until March 1974, but the market disruption reverberated into the mid-1980s. In the United States, the oil embargo resulted in long lines at gas stations and skyrocketing energy costs. On an unadjusted basis, a gallon of gasoline cost on average $0.36 in 1972. In 1973, the cost rose to $0.39, in 1974 it became $0.53, in 1975 it became $0.57, and it peaked in 1981 at $1.31. On an adjusted basis, gasoline spiked in 1974 and did not return to pre-oil embargo levels until 1986.[2]

The end of cheap energy was not only problematic for the transportation sector but also for the built environment. Modernist architecture often showed little regard for solar orientation or climate-appropriate design. In the era of cheap energy, heating, cooling, and lighting problems could simply be solved by engineered systems, including electric, natural gas, or fuel-oil heating systems; air conditioning systems; and fluorescent lighting.

Slowly, architects began to address the issue of energy in contemporary architecture. Like a lonely voice crying out in the wilderness, Jeffrey Cook opened his 1978 article "Thinking about Energy Education" by asking, "Must architects know anything substantial about energy?"[3] More opinion piece than traditional journal article, "Thinking about Energy Education" outlined Cook's vision of incorporating energy education into an architecture curriculum. Answering his own question, Cook argued that architects are the right professionals to manage the energy usage of buildings:

> If energy is simply a matter of hardware, perhaps the profession does need a new set of hardware specialists. But if the piece of hardware is of building size, maybe the architect must become an energy specialist. Particularly in the highly industrialized countries of the West, the adaptation of present living standards to a future of scarce energy resources may be a primary social goal.[4]

The increasing prominence of LEED, the Living Building Challenge, the (Architecture) 2030 Challenge, and the International Green Construction Code, suggests that Cook's statement about energy design becoming a

"primary social goal" is prescient. Writing in 1978, Cook not only understood the potential of energy-based design but also the challenge of such a design strategy, asking, "Can architects trained by past methods operate in such a likely future context?"[5] Cook understood that the problem involved both faculty and students. Concerning professors, Cook wrote, "For energy there are few champions in faculties. An architecture school with more than one energy champion is regarded as having a particular strength in that area."[6] The lack of faculty interest in energy education is a recurring theme in articles that discuss energy modeling from Cook forward. Concerning students, Cook noted, "Energy understanding does not come easily or quickly."[7] He argued that design based on solar orientation may be an entry point for energy consciousness in the design studio.[8] Although Cook is writing as an educator and for educators, his conclusion on the ability to teach energy in school is less than sanguine. In the end, he seemed to advocate for experience over school, writing, "Thus, the perception, visualization and projection of energy as an objective quantity and quality of the human experience seems best practiced by those professionals with the longest experience."[9]

Finding barriers to energy modeling

The 1970s ended. Jimmy Carter was out, Ronald Reagan was in, Disco was dead, New Wave dominated the airwaves, and gas (and other energy) prices began to return to "normal." Responding to the OPAEC oil embargo—in 1984, a mere 11 years after the embargo occurred—the ACSA published *Architecture, Energy & Education.* In that work, authors Robert G. Shibley and Laura Poltroneri identified four barriers to teaching and energy in architecture school:

- Methodological barriers: the idea that energy concerns are somehow separate from design concerns
- Structural barriers: the age-old division between studio courses and technical or support courses
- Attitudinal barriers: students and faculty who believe "that energy concerns are unimportant, too complex or difficult to address, [and/or] too limiting to the designer"
- Informational barriers: lack of understanding of what energy efficiency means[10]

In 1984—or today, for that matter—there was/is no excuse for falling victim to the first three barriers. Shibley and Poltroneri's methodological, structural, and attitudinal barriers can all be corrected if educators and students decide to correct them. Methodological and structural barriers are largely the responsibility of architecture faculty, while the attitudinal barrier is shared equally by faculty and students, with the faculty having the responsibility to set a good example. Regardless of the actors, methodological, structural, and attitudinal barriers can be overcome if there is a desire to do so.

However, the informational barrier was formidable in 1984 and actually quite difficult to overcome with the computers commonly available at that time. Since the informational barrier is the barrier most relevant to this paper, it is worth quoting Shibley and Poltroneri directly: "**Informational Barriers** deal with the lack of knowledge or appropriate access to knowledge about what constitutes energy-efficiency in buildings."[11] A major component of the informational barrier was the lack of training of professors in energy-related issues. To that point, Shibley and Poltroneri wrote

> A number of schools simply state that another barrier to the integration [of energy conscious design] is faculty ignorance about energy. A particular concern was expressed by faculty of more advanced studios, that they are ill-equipped to evaluate estimated building performance of more complex solutions.[12]

How is this lack of knowledge manifested in pedagogical issues? Take, for example, a "solar cube" project. Even when a student designs and constructs a solar cube that performs well, how is that knowledge applied in design

studio? Shibley and Poltroneri argued that a "missing link" existed between projects like solar cubes and studio work.[13]

One major issue in the 1980s was the difficulty of visualizing energy flows. It may be a stereotype, but it holds a kernel of truth: architects are more comfortable with images than numbers. This is true of architecture students, also. Shibley and Poltroneri observed that "[t]he schools [participating in the study] articulate a number of emerging tactics intended to deal with the question of the 'visualization' of energy" (Shibley, Robert G.; Poltroneri, Laura; 1984, 36). Some schools had made progress on the issue. Shibley and Poltroneri noted that the research team at the University of Minnesota discovered that projects which led to a visualization of energy early in the design process were the most successful.[14]

The ACSA's response to the OPAEC oil embargo was slow in coming; so slow, in fact, that the clear mandate of the 70s had faded during the Reagan era. Writing in the preface to an issue of the *Journal of Architectural Education* dedicated to energy, one of the co-authors of *Architecture, Energy & Education*, Robert Shibley, argued, "[I]t is popular these days to dismiss energy as a fad which has passed. There is a perception that…there is nothing of importance left to do."[15] If the 1980s represent a step backward, then the 1990s represent the dawning of the modern era of sustainability, and thus, a renewed interest in teaching energy-related design. Awareness, however, did not lead quickly to application, resulting in frustration for many faculty interested in energy-related design.

Writing in 1996, Mark DeKay expressed dismay with the lack of progress. After establishing the link between the built environment and overall environmental degradation, DeKay wrote, "Architects, educators, and students recognize these issues, but *architectural education has repeatedly failed* to graduate students who can design buildings that reduce these environmental impacts."[16] DeKay specifically mentioned the four barriers identified in *Architecture, Energy & Education*, but he did not address them individually. Instead, he noted the different ways that design and technical issues are taught:

> [I]n many schools, visual and formal principles (harmony, balance, contrast, color theory, etc.) are taught as the fundamental introduction to design. This formality and visuality ignores ecology by limiting perception to small system boundaries: what is important is what can be seen, drawn, and frozen in time.[17]

The issue is compounded when the lessons in "support" classes are not validated in studio courses. DeKay wrote, "When technical, energy, and environmental issues are **not** deliberately brought into the studio course by faculty, the student's model of a dualistic world of architecture is further reinforced."[18] DeKay's proposed solution to these challenges, an "evolutionary model" of curriculum design, is intriguing, but beyond the scope of this paper.

Also published in 1996 was Ernest L. Boyer and Lee Mitgang's *Building Community: A New Future for Architecture Education and Practice*, a report commonly referred to as "The Boyer Report." Although it is now more than 20 years old, *Building Community* is the most recent, comprehensive, third-party examination of architectural education.[19] Reinforcing DeKay's concerns above, Boyer and Mitgang found that 55 percent of faculty believed their schools were not doing enough to integrate sustainability into design studios.[20]

Making energy modeling happen

The early 1990s represent the beginning of the "digital turn" in architecture.[21] Supporting that assertion, discussions of energy modeling in architectural education became less theoretical and more specific, often focusing on specific modeling software. Writing in 1998, University of Michigan professor Ali M. Malkawi noted

that energy modeling software had been historically difficult to use and, thus, required specialists. Designers who did not have access to energy modeling specialists because of time constraints, budget limitations, or a lack of physical access, had to "rely on intuitive methods, guidelines, or prescriptive methods" to design energy efficient buildings[22], a set of design tools with obvious limitations. Malkawi discussed his research designed to make energy simulation more accessible, particularly during "the first stages of design where the designer must make critical decisions."[23] Professor Malkawi's program used a "Graphical User Interface" and a "Building Envelope database."[24] Moreover, a project could be developed with CAD software and imported into Malkawi's program.[25] Using "Artificial Intelligence" techniques, Malkawi's program could provide "critique and advice" on potential energy saving changes to the design.[26] Malkawi's once cutting-edge features are now common features in energy modeling software, and his graphical user interfaces appear primitive compared to contemporary software. Looking back today, however, one should remember that 20 years is eons in terms of computer software development.

Building on his theoretical 1996 article, Mark DeKay returned in 1999 with a pragmatic class built around a web-based program called "Energy Scheming," which DeKay described as "a very graphical, user-friendly energy simulation tool with minimal numerical inputs."[27] Because "Energy Scheming" was created to be fast and easy to use, a designer could receive input early in the design process, which DeKay believed had important pedagogical benefits. He wrote:

> Therefore, computer simulation, which models behavior in compressed time, offers a seductive potential. Taking energy issues as a beginning point, the educational hypothesis is that students who learn using whole-building simulation will gain a good understanding of complex, higher order building/energy relationships.[28]

By inputting data early in the design process, students could make changes when they would be most impactful. Looking at the available simulation technology, DeKay developed his class with the following learning objectives in mind:

- To gain experience with a design tool that can help architects to verify the quantitative thermal implications of non-thermal design decisions, and to explore the non-thermal design potentials latent in passive design.
- To understand the complex relationships between architectural form and its energy and lighting performance.
- To experience a process of cyclic architectural design that incorporates issues to energy and lighting, and to begin to develop this process on an individual basis.[29]

Energy Scheming provided an evaluation of a student design versus a "code minimum building."[30] Today, in comparison, the goal would be net zero or regenerative design. DeKay was upbeat about the potential of Energy Scheming to address difficult problems. He wrote, "Seeing the complexity of the particular within the context of these general patterns is the essence of the recognition of the complex interdependence between structure and function, form and flow."[31] Also writing in 1999, a team of University of Oregon faculty (Brown et al.) discussed their success using Energy Scheming to power an "automated" web-based support course. Repeating concerns noted in Malkawi and DeKay, Brown et al. noted that "[f]aculty and students alike hesitate to use software that is difficult or cumbersome."[32] In contrast, the students in Brown et al.'s small test group appeared to like the simplicity and accessibility of Energy Scheming. One of the students wrote:

> The World-Wide Web interface and the exercises were helpful in learning how to use

> Energy Scheming; however inputting my own studio design was **much** more helpful. This is because of the knowledge you already have concerning your design, your site, and the materials your building is made from. It is also more interesting because you have a stake in what you are analyzing and improving—it helps your studio design.[33]

The Oregon course included eight exercises, each with in a "warmup, exercise, and cooldown" format (Brown, et al. 1999, 137). The warmup component delivered content, substituting for a lecture in a traditional course. The exercise component was the problem itself, while the cooldown provided answers. In addition to the automated support course, Brown et al. discussed their plans for an upcoming studio course. To overcome the barrier of faculty not teaching energy issues in design studio because of a lack of confidence, knowledge, and/or interest, technical faculty were paired with design faculty.[34] Interestingly—and perhaps counterintuitively—the design studio exercise included three weeks of preliminary design before Energy Scheming was introduced.[35]

The shift in tone between DeKay's 1996 article and his and Brown et al.'s 1999 articles is remarkable. What is the difference? The digital turn in architecture had provided a tool that eviscerated the informational barriers to energy design. As Brown et al. note, "By speeding up the energy calculations, Energy Scheming allows students to spend more time trying out their design idea."[36] Writing in 2012, approximately 20 years after the digital turn in architecture and 35 years after Cook's article, Shen et al. are in a position to probe the effectiveness of various pieces of software to teach sustainability. Echoing Cook's seminal article on studying energy, Shen et al. wrote, "One of the technical challenges in teaching sustainable building design is enabling students to quantitatively understand how different building designs affect a building's energy performance."[37] Looking beyond digital tools, Shen et al. noted that, as of 2012, not much had been published concerning the integration of sustainability into curricula.[38] This suggests that the tools existed, but faculty and students were still not applying them to the degree they should.

Energy modeling today

When this author first taught an environmental systems support course in 2007, he continued using Energy-10, which the previous instructor had used. A DOS-based program, Energy-10 compensated for its limited abilities by being extremely buggy. Starting in 2013, this author required students to use the OpenStudio plugin for SketchUp. OpenStudio combines the powerful EnergyPlus simulation engine with SketchUp, which is visual and easy to use.[39] After hours of troubleshooting the combined software package, the author was able to help students use the software. However, the very next academic year, the university upgraded to the newest version of SketchUp, which was not compatible with the then current version of OpenStudio.

Looking for a stable energy simulation software, this author moved to Autodesk products. Autodesk has an arrangement with Ferris State University which provides free student versions of Autodesk products. To date, the combination of Revit and Green Building Studio has provided a reasonable introduction to the power of energy modeling. In the next phase, this author plans to encourage the adoption of energy modeling in subsequent design studios. However, it is important to remember that having the software does not necessarily mean that student projects are accurate in real-world scenarios. In 2009, construction management faculty looked at three pieces of building performance software—Autodesk's Ecotect, Autodesk's Green Building Studio, and Integrated Environmental Solutions' Virtual Environment—and found that students typically

overestimated energy consumption by 30-50 percent.[40] Echoing this sentiment, Cendon wrote

> An important caveat for those in the energy modeling and building science community is that energy models do not predict actual building performance. Instead, building energy models are more analogous to the miles-per-gallon sticker prominently featured on every new car. A car's estimated fuel economy….isn't an exact measurement of how much gas it will use per mile driven [which] will vary depending on speed, air-conditioner use, and whether the car is driven in the city or on the highway, but the number is useful for car-shoppers because it allows for comparisons between models.[41]

Obviously, introducing energy modeling into an architecture curriculum will be an ongoing process.

The ethical obligation to teach energy modeling

An architect not using energy modeling today is akin to a mid-19th century doctor not using anesthesia. When a technology is developed that clearly improves the human condition, an ethical obligation is imposed on the practitioner to use that technology. Just as it is hard for 21st century people to believe that 19th century people resisted the use of anesthesia, future people will likely hold our views of energy design with disdain.

With today's powerful desktop computers and user-friendly software interfaces, Shibley and Poltroneri's "informational barrier" to energy design has been removed. That barrier may have been an acceptable excuse in 1984, but it is certainly not today because programs such as Revit and Green Building Studio put powerful tools in the hands of faculty and students. *Why should architectural educators care?* Increasingly, the built environment is being designed by specialists, with the architect's role often diminished to little more than a project manager (or perhaps ringmaster). But as Cook pointed out, high design is only part of an architect's skill set, since "[a]rchitects have developed skills otherwise useful to society."[42] One of these useful skills is energy design. As noted earlier in this paper, Cook argued "if the piece of hardware is of building size, maybe the architect must become an energy specialist."[43] The idea of broadening the architect's range is echoed by Boyer and Mitgang, who argued that schools of architecture should "expand their knowledge" of energy, among other factors.[44]

Buildings are complicated, multivariate problems. During the design process, ideas are winnowed from the set of all possibilities to the singular thing the building becomes. Thus, Crawley et al. note in their review of EnergyPlus that "Designers need tools that provide answers to very specific questions during design."[45] This is becoming even more relevant, as the needs to provide both comfort and sustainability collide. Cendon noted, "As the green building movement evolves, it's becoming more and more clear that the road between sustainable design intent and actual design performance is paved with data."[46]

We know that architecture is both an art and a science. In making his case for the science of architecture, Cook quoted Book 6, Chapter 2 of Alberti's treatise on architecture, which said that "All arts were begot by Chance and Observation and nursed by Use and Experience and improved and perfected by Reason and Study."[47] Writing for a modern audience, Stephen Kieran argued that "[t]o move the art of architecture forward….we need to supplement intuition with science."[48]

The digital turn in architecture is an important point milestone for the profession. Cendon argued that energy modeling is part of a "conceptual shift as dramatic as Modernism's break with traditional architectural forms."[49] In which classes will students address this conceptual shift? In support classes, certainly, but the lessons must

be repeated and augmented in studio. Cook argued that "the design studio is where energy must be taught if it is to become an integral part of the architect's vocabulary."[50] Otherwise, students lose interest in energy and other building systems and they become simply "the domain of engineering consultants."[51] This often happens, according to DeKay, because

> [T]echnology is usually approached scientifically and analytically, rather than aesthetically or integratively. Present curricula often treat energy and environmental issues as a rationally based physical science, while design students think more associatively and relationally, life artists, poets, entrepreneurs, or social activists.[52]

A successful energy curriculum will introduce the science of energy, but also the art of energy, with support classes and design studios working together.

Conclusion

Energy modeling was made both effective and accessible during the digital turn in architecture, removing the informational barrier to energy design. Those of us teaching tomorrow's practitioners are obligated to introduce this powerful technology to our students as a critical component of our students' technical and design education. And this is the lesson as technology—specifically energy modeling software—continues to evolve: in the field of architecture, continuous technological improvements lead to and ever-shifting set of ethical obligations.

[1] See Book VI, Chapter I, for example.

[2] Office of Energy Efficiency & Renewable Energy. 2016. "Fact #915: March 7, 2016 Average Historical Annual Gasoline Pump Price, 1929-2015." energy.gov. March 7. Accessed October 1, 2017. https://energy.gov/eere/vehicles/fact-915-march-7-2016-average-historical-annual-gasoline-pump-price-1929-2015.

[3] Cook, Jeffrey. 1978. "Thinking about Energy Education." *Journal of Architectural Education* 8-10: p. 8.

[4] Ibid., p. 8. Spelling error corrected.

[5] Ibid., p. 8.

[6] Ibid., p. 8.

[7] Ibid., p. 10.

[8] Ibid., p. 9.

[9] Ibid., p. 10.

[10] Shibley, Robert G.; Poltroneri, Laura. 1984. Architecture, Energy & Education: Case Studies in the Evaluation of the Teaching Passive Design in Architecture Workbook Series. Washington, D.C.: Association of Collegiate Schools of Architecture: p. 35.

[11] Ibid., p. 35.

[12] Ibid., p. 42.

[13] Ibid., p. 36.

[14] Ibid., p. 37.

[15] Shibley, Robert G. 1984. "Preface." *Journal of Architectural Education* 37 (3-4): 3.

[16] DeKay, Mark. 1996. "Possible Evolution of Technology Education in Architecture: The Case of Energy and Environmental Issues." *Constructions for Tectonics for the Postindustrial World.* Washington, D.C.: Association of Collegiate Schools of Architecture. 172-175. Emphasis in the original.

[17] Ibid., p. 172.

[18] Ibid., p. 172. Emphasis added.

[19] Long, Paul W., and Christopher L. Cosper. 2017. "105th ACSA Annual Meeting: Brooklyn says, 'Move to Detroit'." *At the Vital Center: The Small Town Studio at Ferris State University.* Washington D.C.: Association of Collegiate Schools of Architecture. 401-406.

[20] Boyer, Ernest L., and Lee D. Mitgang. 1996. *Building Community: A New Future for Architecture Education and Practice*. Princeton, NJ: The Carnegie Foundation: p. 87.

[21] Carpo, Mario. 2012. "Introduction: Twenty Years of Digital Design." In *The Digital Turn in Architecture 1992-2012*, edited by Mario Carpo, 8-14. Chichester, England: Wiley.

[22] Malkawi, Ali M. 1998. "Computer-Based Evaluation and Criticism for the Design of Energy-Efficient Buildings."

Constructing New Worlds. Washington, D.C.: Association of Collegiate Schools of Architecture. 300-305: p. 300.

[23] Ibid., p. 300.

[24] Ibid., p. 300.

[25] Ibid., p. 302

[26] Ibid.

[27] DeKay, Mark. 1999. "Learning Design + Energy Through the Whole Building Approach: Using Energy Scheming Siumlation in Lecture Courses." *Technology in Transition--Mastering the Impacts.* Washington, D.C.: Association of Collegiated Schools of Architecture. 124-133: p. 124.

[28] Ibid., p. 124.

[29] Ibid., p. 125.

[30] Ibid., p. 125.

[31] Ibid., p. 127.

[32] Brown, G.Z., Sean Fremouw, Jeff Kline, Lance Lavine, Tomoko Sekiguchi, and Russell Weiser. 1999. "Computer Enhanced Learning: New Course Materials to Teach Design of Energy-Efficient Buildings." *Technology in Transition--Mastering the Impacts.* Washington, D.C.: Association of Collegiate Schools of Architecture. 134-140: p. 137.

[33] Ibid., p. 135. Emphasis in original.

[34] Ibid., p. 139.

[35] Ibid., p. 138.

[36] Ibid., p. 135.

[37] Shen, Zhigang, Wayne Jensen, Timothy Wentz, and Bruce Fischer. 2012. "Teaching Sustainable Design Using BIM and Project-Based Energy Simulations." Education Sciences 2: 136-149: p. 136.

[38] Ibid., p. 137.

[39] Cendon, Sara Fernandez. 2011. www.aia.org. October. Accessed February 5, 2015. http://www.aia.org/practicing/AIAB089996.

[40] Azhar, Salman, Justin Brown, and Rizwan Farooqui. 2009. "BIM-based Sustainability Analysis: An Evaluation of Building Performance Analysis Software." *International Proceedings of the 45th Annual Conference.* Gainesville, FL: Associated Schools of Construction.

[41] Cendon, Sara Fernandez. 2011. *www.aia.org.* October. Accessed February 5, 2015. http://www.aia.org/practicing/AIAB089995.

[42] Cook (note 3), p. 8.

[43] Ibid., p. 8.

[44] Boyer and Mitgang (see note 19), p. 45.

[45] Crawley, D.B., R. K. Strand, C. O. Pedersen, R. J. Liesen, D. E. Fisher, L. K. Lawrie, F. C. Winkelmann, W. F. Buhl, and J. Huang. 2000. "EnergyPlus: A New-Generation Energy Analysis and Load Calculation Engine for Building Design." *ACSA Technology Conference.* Washington, D.C.: Association of Collegiate Schools of Architecture. 42-47: p. 43.

[46] Cendon (note 41).

[47] Cook (note 3), p. 8.

[48] Kieran, Stephen. 2007. "Research in Design: Planning Doing Monitoring Learning." *The Journal of Architectural Education* 27-31: p. 31.

[49] Cendon (note 39).

[50] Cook (note 3), p. 9.

[51] DeKay (note 16), 173.

[52] Ibid., p. 172.