Zero net energy education: mind the gap

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ABSTRACT: Seven years after the American Institute of Architect's adoption of the 2030 Challenge, 233 architecture firms across the nation have committed to reducing energy consumption by 60% (from a baseline national average) before the year 2030. Simultaneously, 86% of A/E firms report difficulty finding employees equipped with the knowledge and skills necessary to achieve this goal. Such a gap between supply and demand begs the question: is architectural education rising to the challenge of effectively communicating energy-efficient design strategies? This paper presents a follow-up study examining the state of zero-net-energy (ZNE) education in accredited architecture schools across North America. Previous work relied upon statistical analysis of 45 syllabi for foundational building science courses; these were self-reported from instructors from 29 accredited institutions. The study showed that these instructors were dedicating approximately 25% of course time to ZNE-related topics through a combination of lecture- and project-based learning. While insightful, the limitations of the statistical methodology and narrow information from the syllabi left many questions unanswered. The study presented herein builds upon the previous work, to first re-examine the syllabi under a different lens and also to look beyond the documents to what the instructors say. Targeted surveys were used to uncover stories that cannot be easily identified through syllabus review and to reveal how "sustainable" design education is [or isn't] being handled. We hypothesized that architectural curricula have tremendous inertia, and we (faculty) are lagging in adequately preparing students for the challenges of the present and future. Survey responses revealed that fundamentals of environmental controls were being taught, but specific ZNE applications were not. Faculty perceived that students were moderately prepared to meet the 2030 Challenge. Institutional demographics revealed that environmental controls are typically taught in the third year for undergraduates and in the first year for graduate students.

KEYWORDS: ZNE (zero-net-energy), education, carbon neutral, environmental controls, 2030 Challenge

INTRODUCTION

In the spring of 2103, a very important environmental milestone was passed. Ambient CO_2 levels in the atmosphere reached 400 ppm for the first time in human history. (NASA, 2013). Such concentrations of CO_2 have occurred in the past—but only in the distant geologic past and typically as a result of some cataclysmic event. Figure 1 shows the progression of CO_2 levels since a bit before the time of the Egyptian master builders. Figure 2 shows more recent CO_2 data in greater detail.

Remarkably, although meriting some mention in the popular press (and more discussion in science circles) the 400 ppm milestone was not an issue of great concern in building design forums. This is especially quirky since buildings, in their design, construction, and operation, contribute mightily to carbon emissions that drive up ambient CO_2 concentrations. Perhaps this is a normal reaction from busy professionals who don't want to admit complicity in what many believe to be an ongoing crime-against-nature spree. This complacency feels very disingenuous, however, as Ed Mazria called us out on this issue in 2003 with the publication of "It's the architecture, stupid." (Mazria, 2003).

Mazria's contention was (and remains) that architectural design decisions affect roughly 50% of national energy consumption and, thus, roughly half of all gaseous carbon emissions. These emissions are changing the global climate (by scientific consensus) with unknown societal

impacts on the horizon. (IPCC, 2013). Buildings are literally altering the global climate in ways that are unpredictable and arguably not net-positive. For building design professionals, ignoring the problem and its root causes is irrational. Pogo was right, “We have met the enemy and he is us.”

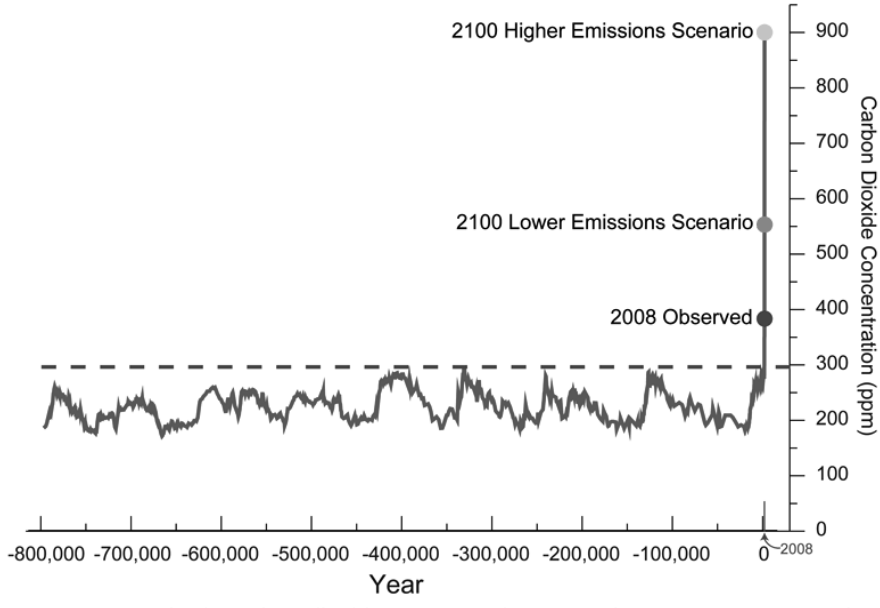

Figure 1: Atmospheric carbon dioxide concentrations over time. Source: www.ncdc.noaa.gov

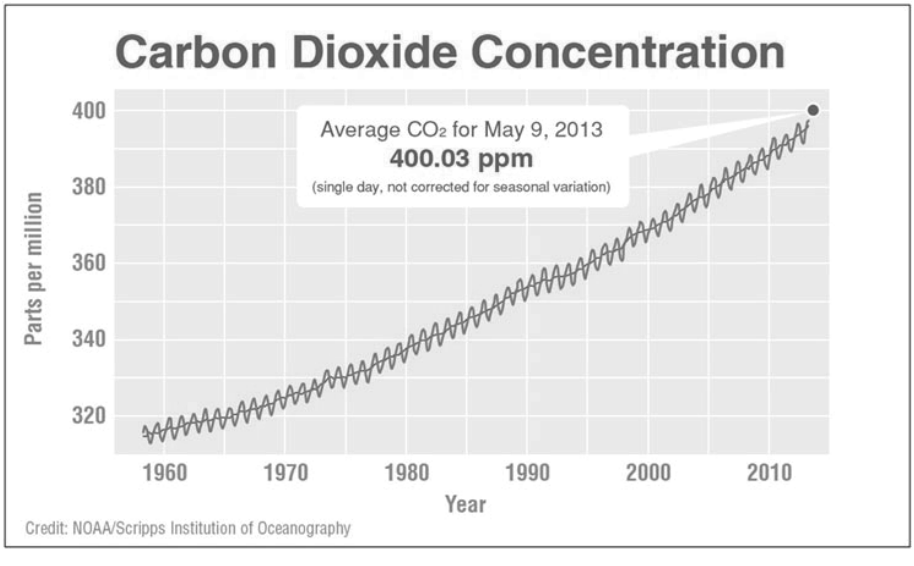

Figure 2: Recent carbon dioxide concentrations in detail. Source: climate.nasa.gov

Intriguingly, the same Mazria who pointed out architecture’s role in climate change has charted a way forward for the building professions. This is the 2030 Challenge promoted by Architecture 2030. (Architecture 2030, 2013). Philosophically the 2030 Challenge represents a

way for design professionals to step forward, take responsibility for climate change, and engage in CO_2 mitigation efforts. Technically, the Challenge provides a set of escalating targets for building energy performance that culminate in 2030 with near-carbon-neutral buildings. In the United States there seems to a preference for discussing energy efficiency in lieu of carbon neutrality. Since the vast majority of energy consumed by North American buildings is fossil-based, there is a clear and almost direct connection between decreased energy use and reduced carbon emissions. This paper essentially equates energy reductions with carbon reductions.

1.1. Background

Seven years after the American Institute of Architect's adoption of the 2030 Challenge, 233 architecture firms across the nation have committed to reducing energy consumption—before the year 2030—by 60 percent from a baseline national average. Simultaneously, 86% of A/E firms report difficulty finding employees equipped with the knowledge and skills necessary to achieve this goal. Such a gap between supply and demand begs the question: is architectural education rising to the challenge of effectively communicating highly-energy-efficient design strategies (which would, as a direct consequence, lead to reduced carbon emissions)? This paper presents a follow-up study examining the state of Zero Net Energy (ZNE) education in accredited architecture schools across North America. Previous work by Anderson relied upon statistical analysis of 45 syllabi for foundational building science courses. These syllabi were self-reported from instructors from 29 NAAB-accredited institutions. The study showed that these instructors were dedicating approximately 25% of course time to ZNE-related topics through a combination of lecture- and project-based learning. While insightful, the limitations of the statistical methodology and the limited information provided by the syllabi left many questions unanswered. The study presented here builds upon the previous work, using qualitative analysis to look beyond what the syllabi say. A survey and several focused interviews were used to uncover stories that cannot be easily described or defined by numbers and to reveal how design education for high-energy-efficiency is [or isn't] being handled.

1.2. Objectives

AIA leadership groups recently identified four top priorities (Lazarus, 2013) when asked for perspective on the *most important sustainability priorities and trends* to meet the current and future needs of their clients and communities; these were performance metrics, design and human health, climate change, and energy. These topics were also noted as the top educational program wishes for the membership. Such results suggest a high priority need for designers well-prepared to address building energy/climate performance when they enter the profession.

The objectives of this study are to:

- determine if architectural curricula in North America are providing the students with the proper tools, skills, and resources to address zero net energy design;
- explore perceptions of student understanding of how to reduce or eliminate fossil fuels in design projects (are we properly preparing students to achieve low energy/carbon neutral solutions?)
- examine selected contextual factors surrounding building science education.

1.3. Hypotheses

We hypothesize that architectural curricula have tremendous inertia and we (faculty) are lagging in preparing students to viably contribute to reaching the Architecture 2030 targets. We also hypothesize that energy simulation and parametric analysis will be touted as common means of engaging energy efficient building design.

1.4. Previous work

A previous study (Anderson et al., 2013) collected syllabi for building science technology courses at schools of architecture, gathered public information from program websites, and reviewed/analyzed the course syllabi and schedules thus obtained. A total of 45 course syllabi and schedules were received from 38 faculty representing 29 schools of architecture (approximately one-quarter of the NAAB accredited schools). Several faculty submitted multiple syllabi (representing different courses). The acronym “ZNE” was used to broadly cover content in four categories: passive systems, active systems, benchmarks and standards, and energy. Results of the analysis suggested that ZNE topics account for approximately 28% of the time devoted to material coverage in the building science (or technology) course schedules reviewed. It was found that the majority of instructors who responded relied on exams as a primary means of student assessment. The kind of experiential activity that students were involved in (if at all) during lab sections was also investigated. Of the 45 courses reviewed in the study, approximately half were lecture-based only, and the others were lecture-lab courses. Most syllabi did not indicate the nature of the activities conducted in lab sections; the ones that did so, however, described activities such as design charrettes, tours, hands-on experiments, use of tools to gather information, games, measurement verification, calculations, and peer-to-peer collaboration. A number of inconsistencies in the data left the study with some unanswered questions at the conclusion of the document (syllabus/schedule) review process.

1.5. Methods

Syllabus Review

The course syllabi received during the prior study were reviewed through a different lens to verify the results of the Anderson study. A hierarchical approach to net-zero energy [herein designated ZNE] design was proposed by McGregor et al. Shown in Figure 3, the approach first prioritizes reducing loads, follows with the integration of passive systems, then active systems, energy recovery improvements, and concludes with integration of onsite renewable energy sources and energy offsets.

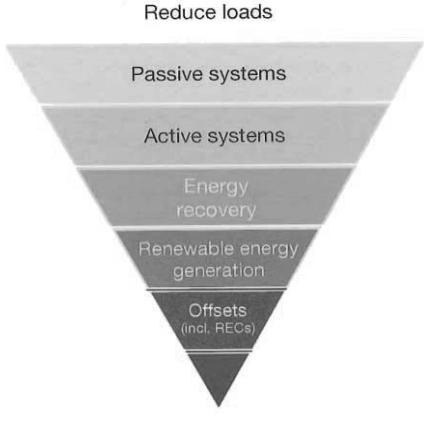

Figure 3: Hierarchical approach to achieving net-zero energy in buildings. Source: McGregor et al. 2012.

While it is essential for an architect to be proficient in each of these areas, this framework may suggest a reasonable weighting scheme for building science pedagogy. The expectation is that more time would be spent addressing the topics at the top (wide part) of the pyramid, where performance is most effectively addressed. The 45 building science course syllabi were therefore analyzed through the lens of this framework. 32 different building science topics found in the 45 course schedules were sorted into nine categories, including the six identified by McGregor. Table 1 shows how these topics were sorted. Additional categories, including

"fundamentals," "water," and "standards and best practices," were created to accommodate topics that fell outside of the McGregor framework. Course lecture schedules were used to determine the relative amounts of time dedicated to these different topics and, in turn, these nine categories.

Table 1. Building Science Course Syllabus Topic Categories

TOPICS SORTED to MCGREGOR CATEGORIES						OTHER TOPICS	
Load Reduction	Passive Systems	Active Systems	Energy Recovery	Renewable Energy	Offsets	Topics	Standards and Best Practices
Daylighting	Bioclimatic design	Active solar	n/a	Energy sources	n/a	Psychrometrics	ZNE/CND
Heat transfer/flow	Passive cooling	HVAC				Thermal comfort	LEED
Solar radiation	Passive Heating					Fire/smoke	Passive House
Electric lighting	Solar geometry					Electrical systems	Integrated design
Lighting design	Wind					Physics of light	POE
Luminaire design	Site analysis					Vertical transport	
						Acoustics	
						IAQ	
						Case studies	
						Simulation	
						Water/Waste	

Survey

Qualtrics survey software was used to administer a fifteen-question online survey. Surveys were distributed via email to adjunct, tenure-track, and tenured faculty teaching building science. Respondents included participants from the previous Anderson study, as well as additional users of the Society of Building Science Educators [SBSE] listserv, the platform through which the survey was distributed.

A total of 26 faculty responded to the survey. While the authors recognize that this dataset is in no way comprehensive, we feel that it can be used to qualitatively examine current practices in ZNE education and that it is a useful supplement to the previous syllabus review.

RESULTS

Results from the current study are described below. First, results from the follow-up syllabus review are presented, followed by results from the online survey.

2.1 Follow-up syllabus review

Figure 4 shows the percentage (by time) that each course—for which schedule information was available— allocated to each of the seven topic categories (from Table 1).

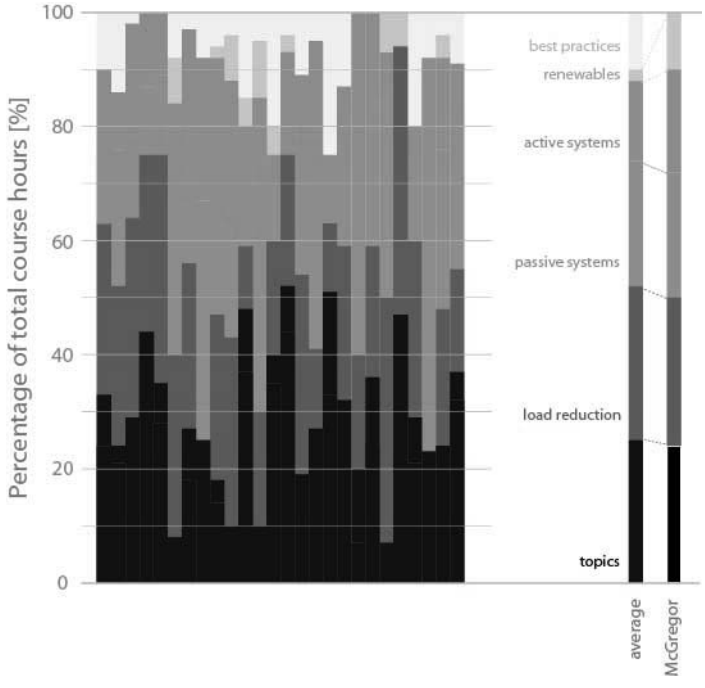

Figure 4. Percentages of lecture time dedicated to the topic categories listed in Table 1.

According to the analysis, instructors who provided detailed course schedules dedicate roughly 72% of class time to energy-related topics, of which zero net energy, carbon neutral design, and green building practices represent at least 8%. Interestingly, the graphic demonstrates that course topic prioritization generally aligns with McGregor's hierarchy, particularly for passive and active systems and for load reduction. Such agreement between the relative effectiveness of design moves described by McGregor and current teaching emphases, while professionals report a lack of preparedness for sustainable design, suggests that lecture-class time may be appropriately allocated. Perhaps, however, the connection between fundamental principles and studio-based design thinking and solutions is not being adequately reinforced. In accreditation language, there is apparently acceptable conveyance of "understanding" (all courses in this study are from NAAB-accredited programs) but a gap between understanding and ability to use knowledge or information.

Energy offsets and energy recovery were not directly referenced in any course schedules. This is most likely due to the fact that these are technical (non-architectural) topics generally engaged in the design development phase of a project (which is rarely dealt with in design studio settings). Using lecture time as an indicator of relative priority, Figure 5 compares McGregor's hierarchy to the topic-time averages shown in Figure 4.

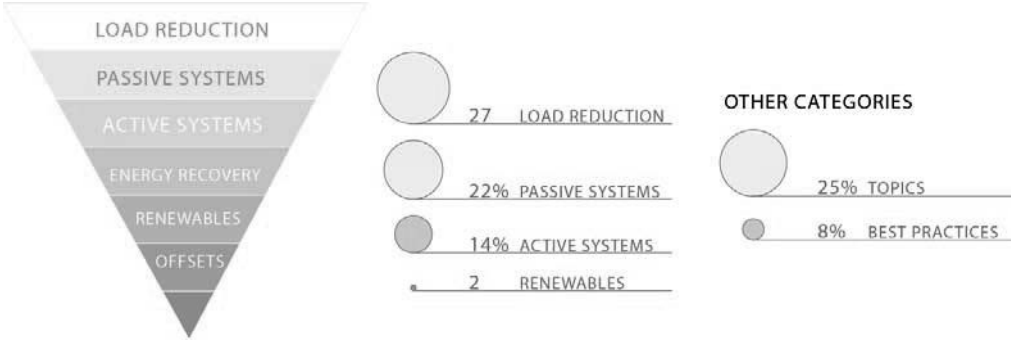

Figure 5. Comparison of McGregor's prioritized approach to zero net energy to the relative distribution of building science course class time.

2.2 Survey results

Building science courses are primarily offered during the third year of undergraduate programs and during the first year of graduate programs. Institutions that offered such courses earlier in the curriculum generally offered more electives related to energy topics. Most institutions provided teaching assistants to support the basic building science courses; on average this involved two teaching assistants (and in some of the larger programs three to five teaching assistants). Half of the building science courses were lecture-based only and the other courses offered lecture and laboratory- or discussion-section-based meetings where more experiential activities occurred.

DISCUSSION

3.1 Course content

The syllabi and schedules alone were unable to sufficiently answer all questions about whether building science courses are providing students with the experiences, skills, and abilities to address the goals of the Architecture 2030 Challenge. The close agreement, however, between the design move emphasis described by McGregor and current teaching practices reveal that class time might well be appropriately allocated, but that integration of fundamental principles and passive strategies may not be reinforced or required in studios.

It is not well reflected in the syllabi/schedules just how students are taught design integration or if these primarily lecture-based courses are even intended to provide the necessary experience to enable integrated design, in studio or once in practice. Respondents provided some comments about using the Leadership in Energy and Environmental Design (LEED) checklist as a course framework, but it is not clear that this is enough to actually provide proper preparation (and retention) of the application and integration of fundamental principles into low-energy/low-carbon building strategies.

3.2 Department-level commitment

The study examined a few institutional factors surrounding teaching technical subjects and integrating building science topics and design. A look at the percentage of the total number of faculty who teach technology courses (often considered "technology faculty") revealed that 20% of the faculty teach technical subjects (e.g., 2 out of 10). The term "technology" includes environmental control systems, construction and materials, and structures.

Who teaches these courses, adjuncts or tenure-related faculty? The survey showed that 52% of the technology courses are taught by tenure-related faculty; 12% by adjuncts; and 36% are taught by both adjuncts and tenure-related faculty. Is there a split between faculty that teach design studio versus those that teach technical subjects? Sixty percent of the institutions represented in the survey are in this category and 36% of the institutions have faculty that regularly teach both design studio and technical subjects.

The sampling conducted for the survey may be too narrow to derive conclusive results. Limitations include the sample size and the pool from which respondents were drawn—the Society of Building Science Educators listserv (an already "committed to the cause" group). It also may be problematic to assume that topics not included in course documents are not covered in the course content. For instance, a lecture topic or title may not specifically mention passive design, but the course may still cover such strategies. The syllabus and schedule review provided more accurate and detailed information than the website review, but additional data collection may be necessary for a more nuanced look at course coverage of zero-net-energy design issues. This study did not consider information from complementary documents (such as project requirements, assignments, activities, or exams) which might provide a more qualitative understanding of course content

3.3 Student preparedness and enthusiasm

Faculty were queried on their perceptions of student preparedness for the energy/carbon challenges of the profession on a scale of 1 to 5 (with 5 being well-prepared)—the faculty response averaged 3.1. When asked about perceived student enthusiasm for ZNE topics, the response was slightly more positive at 3.4.

Follow up interviews with several faculty yielded anecdotal stories ranging from frustration with department culture (administrative and collegial support); at not having attention placed on student work in the technical areas. On the other hand, there were reports of courses where students rose to the challenge and ended up in well-known firms. Though the results from these perceptions are interesting, the results are weakened by not having an equivalent survey of student perceptions.

3.4 Remaining questions

During the course of this study, additional questions about related topics and educational vehicles came up to address in future studies:

- how do building science and architecture programs adapt to the world of MOOCs; and what does this mean for ZNE?
- when do we shift to emphasize water and water conservation; materials, health, and IEQ?
- do professors and practitioners value the same knowledge and skillsets; how do we find out; how do we (collectively) align these goals?
- will curricula change in light of the recent proposed changes to NAAB student performance criteria, which essentially remove the current "sustainability" criteria?
- is anyone talking (in their classes) about commissioning and aftercare; do we know that buildings are actually performing as designed?
- most courses have teaching assistants who primarily do administrative tasks; are these human resources underutilized

CONCLUSIONS

From this limited snapshot of syllabi from 29 institutions we found a number of intriguing facts, trends, and relationships. On average, roughly 72% of class time is devoted to energy-related topics, of which ZNE/CND and green building practices represent at least 8%. Topics are taught through lectures and project-based learning and faculty are generally placing emphasis on fundamentals, load reduction, and passive systems.

The courses examined in this review appear to maintain a division between traditional design and integrated design. Since extracting information from building science syllabi and faculty surveys is not an exhaustive way of evaluating content or the uptake of ZNE topics, there is a real need to expand this study to look at coverage of high-energy-efficiency goals in design studios. The syllabi, schedules, and survey were unable to sufficiently answer all questions about whether courses are providing students with the experiences, skills, and design abilities to address the goals of the Architecture 2030 Challenge.

At this point, our first hypothesis appears to be correct (students are not prepared to viably contribute to a low-energy/low-carbon future), but future research should address student impressions of their own abilities and preparedness for low-carbon design challenges. Only one response (by telephone interview) mentioned energy simulation and parametric analysis as the answer to sustainability. In this respect, our second hypothesis was incorrect.

The movement within the profession is toward sustainable design, including zero-net-energy issues. This study was intended to begin a conversation about how building science courses across a number of schools of architecture are preparing students to design buildings that address the very real concerns of global climate change. We expect that additional data collection and analysis methods can be used to build upon this initial exploration and to better reveal the true state of building science education in North America.

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