Beyond EUI

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Fig. 1. Example student work by Ethan Walker

Abstract

To address climate change in academia, educators must equip current architecture and architectural engineering students with the knowledge and skills which enable them to contribute to transforming our current fossil-fuel-intensive energy system into a non-polluting sustainable energy system. Indeed, integration of this knowledge and skills in the undergraduate design studio plays a key role in this strategy, but due to the complex range of design responses to a given design project brief, assessing students' success can be challenging. Assessing building performance based solely on the building's Energy Use Intensity (EUI) is fair and simple, but our studio experience found it to be insufficient to assess the impact of specific design decisions, which may be considered a lost educational opportunity.

Through the support of a grant program that allowed us to award students with a monetary prize for high-performing projects, we have been able to refine a user-friendly methodology in our integrative design studio over the past three years. Over consecutive years of developing the assessment criteria, we refined how these awards categories were evaluated in a fair, simple, and meaningful fashion.

This paper will discuss the relationship between design-assisting tools and the resulting methodology for detailed assessment of building performance in the design studio. In doing so, we hope to provide insight for educators seeking to leverage the use of similar tools within the design studio. By maximizing impact on student learning, we can help our students shape their future careers to face the significant challenges posed by climate change.

Introduction

Like many schools represented in the membership of BTES, the integrative or comprehensive studio is a key component of the Bachelor of Architecture and Bachelor Architectural Engineering curriculum at Oklahoma State University (OSU). At our institution, the legacy of this course goes back to its creation in 1946, to its receiving national recognition with the NCARB Award for the Integration of Practice and Education more recently in 2004. Of course, this course has evolved significantly over time to respond to the ongoing changes in professional practice and disciplinary discourse.

One key contemporary challenge is the crisis wrought by climate change. It is a well-established fact that architecture is responsible for a significant portion of US energy consumption. According to the most recent data published by the Energy Information Administration in 2023, buildings consume 72.56% of US electricity, which represents 36.54% (34.2 quadrillion Btu) of all primary energy resources.[1] Architects and architectural engineers carry a heavy responsibility to design low-energy and/or zero-energy buildings that avoid reliance on fossil fuels.

To address the imperative for architects to meaningfully respond to climate change in academia, educators must equip current architecture and architectural engineering students with the knowledge and skills which enable them to contribute to transforming our current fossil-fuel-intensive energy system into a non-polluting sustainable energy system. Indeed, integration of this knowledge and skills in the design studio plays a key role in this strategy, but due to the complex range of design responses to a given design project brief, assessing students' success can be challenging. Assessing building performance based solely on the building's Energy Use Intensity (EUI) is fair and simple, but our studio experience found it to be insufficient to assess the impact of specific design decisions, which may be considered a lost educational opportunity.

Through expanding the ways in which building performance is assessed in the studio, we can bring focused attention to this critical aspect of design and help students to understand how to design for maximum impact. This awareness, along with the necessary knowledge and skill sets, is critical for students entering the profession.

1. Future of the Profession

The AIA and other professional societies of allied disciplines established targets to combat climate change. AIA adopted the target established by Architecture 2030; new buildings achieve zero energy by 2030 and achieve zero carbon by 2050.[2] The American Society of Civil Engineers (ASCE) target is to achieve net-zero embodied carbon in buildings by the year 2050.[3] The MEP 2040 Challenge reads as follows: "All systems engineers shall advocate for and achieve net zero carbon in their projects: operational carbon by 2030 and embodied carbon by 2040."[4] Future architects, who take up the task of addressing carbon consumption, will most probably commit to achieving the targets established by the AIA and will, most likely, collaborate with like-minded engineers. It is an obligation to help the new generation of architects and architectural engineers get prepared to tackle the challenge of climate change.

2. Literature Review

Scholarship published through the last several BTES conferences (dating back to 2015) identify the need for effective strategies for building energy modeling (BEM), and especially within the context of design education. Multiple papers acknowledge the pedagogical challenges of integration of building systems and improving performance. [5] In 2015, Konis and Kensek noted the barriers to provide timely, effective feedback of data within the design studio and proposed an online platform to be used as a design aid.[6] Mohsenin specifically addressed BEM in 2017 and evaluated simulation tools available at the time, ultimately focusing on Revit and DesignBuilder in their study.[7] Mojaher and Aksamija acknowledged issues of compatibility between BIM and BEM tools that impede seamless incorporation into the design studio in 2019.[8] In another paper from the 2019 conference, Minaei and Aksamija discussed techniques of optimization through a computational approach using Python scripting.[9] The literature clearly shows there are opportunities for continual improvement in the tools and techniques we use in assessing building performance in the design studio.

Cove.tool was developed in 2020 and recognized with a 2021 R&D Award from *Architect* magazine for its ability to offer "a holistic solution, freeing architects from the task of finding different software for each design parameter, such as daylighting or HVAC."[10] We have found Cove.tool to be an incredible asset within the design studio for addressing the issues noted above. In particular, it seems to be an ideal fit for undergraduate education, giving data that eliminates the barriers of "feedback, specificity, speed, and sharing" noted by Konis and Kensek.[11] Operating as a plug-in for Revit, students are able to export their models to Cove.tool with a fairly quick and easy workflow that allows ongoing assessment of the students' design proposals as they progress. The Cove.tool dashboard provides feedback on EUI, anticipated energy costs, and carbon. Especially helpful from a pedagogical perspective is the breakdown of the overall EUI into categories based on different building systems such as cooling, heating, equipment, and lighting.

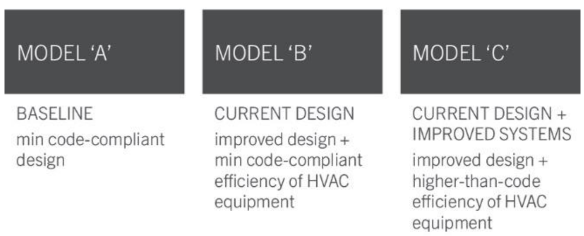
3. The Integrative Design Studio

At OSU, the integrative studio[12] is a one-semester studio that is integrated with two other three-credit courses: a seminar on design methods and a lecture course on project management. Offered within the fall of the fifth year, the studio explores integration of building systems in a design proposal for a publicly-oriented building of about 20,000-30,000 SF. This studio is structured to parallel professional practice through using typical project phases of Schematic Design (SD), Design Development (DD), and Construction Documents (CD). This studio also emphasizes collaboration, particularly through students in architecture and architectural engineering working in teams of three to four to integrate knowledge gained throughout the required building technology courses in the curriculum. For our students, this studio is the most complete opportunity for them to apply the content of the courses to their own studio project. Further, this studio is the only studio in which students (both architecture and architectural engineering) are required to apply energy conserving measures to improve the environmental performance (maximize energy savings) of their buildings using evidence-based techniques to quantify energy savings. While an emphasis on building performance is a key component of this studio, it should be noted that the studio also considers integration of building systems more broadly to address technical, functional, aesthetic, and conceptual goals for the project as well.

Through funds from a competitive grant program offered by the School of Electrical and Computer Engineering within our college, we have been able to further emphasize and refine our methodology with regards to measuring performance. The Renewable and Innovative Sustainable Energy (RAISE) Initiative, sponsored by the Martin Family Foundation, has provided funds to hire additional teaching assistant support as well as offering significant funds to award exemplary student projects with a monetary prize. The first year of this program was hugely successful, and the donors were especially impressed by the quality and output of our students' work in the studio. Our faculty team has continued to receive the RAISE grant for the course, which has allowed us to continue to offer the Performative Design Awards for three consecutive academic years. Through the three iterations of this award program (Spring 2022, Spring 2023, and Fall 2024 semesters), we have refined the methodology for assessing performance for 171 students,[13] which we will share in this paper.

4. Pedagogical Approach

Our integrative design studio is critical for training students to design high performance buildings, which we approach through a three-legged strategy: (1) energy load reduction, (2) electrification, and (3) on-site and/or off-site electric generation from renewable resources. This strategy is pursued through identifying industry-recognized benchmarks and performance targets and creating specific metrics for assessing performance relative to those benchmarks. We utilize the Architecture 2030 benchmarks to identify the target EUI for the project type and given year of the studio, with the ultimate aim to achieve net zero performance.[14] In Fall 2024, the majority of design teams were able to reach net zero. In particular, this studio focuses efforts on the integration of passive systems (performance improvement by design only), rather than simplistically relying on selection of efficient systems and equipment to reduce energy consumption. By emphasizing envelope design, students can see the specific agency that they have as architects in reducing energy consumption. We use evidence-based techniques in the studio, especially through design-assisting tools like energy modeling (Cove.tool[15] and eQuest[16]) and experimental testing of scale models (testing daylight models under an artificial sky dome).



4.1 Whole building requirements

Starting at the beginning of the SD phase, students create three different models in Cove.tool for comparison (see Figure 2). Description of these three energy models is as follows:

- Model 'A' is the code-compliant baseline for comparison to help quantify energy savings achieved in Models 'B' and 'C.' Model 'A' represents the minimum code-compliant design (standard reference design), as defined by the International Energy Conservation Code (IECC), i.e., 30% glass ratio, no shading devices, meeting the prescriptive requirements for R- and U-values, glass properties (U-value, SHGC, and VT), light load, and minimum required efficiency of HVAC equipment.
- Model 'B' reflects the students' actual design proposal with improved envelope and overall design over the baseline. No improved HVAC systems are allowed in Model 'B'. The calculated EUI of Model 'B' is compared to EUI of Model 'A' to quantify improved performance by design only, regardless of HVAC equipment. In Fall 2024, the team who achieved the lowest EUI, also achieved 42.7% energy savings due to improved envelope design only without any improved HVAC systems. Students were able to achieve significant energy savings through the optimization of daylighting design, the use of external shading devices, and reducing the floor-to-floor height.
- Model 'C' is the exact design of Model 'B' coupled with improved HVAC systems and on-site electric generation from renewable resources like PV. Often in professional practice, HVAC system selection is driven by factors like cost and client preferences. In this studio, we allow students to select energy efficient systems such as ground-source heat pumps, chilled beams, and VRF (variable refrigerant flow) coupled with DOAS (dedicated outside air system). Students may reach zero-energy performance with the integration of photovoltaic (PV) panels, which may be able to generate enough electric power to offset the building's annual energy consumption. In Fall 2024, the majority of design teams were able to reach net zero energy through the use of efficient HVAC systems and building-integrated PV systems. The best design achieved net zero energy with a PV system that covers only 11% of the roof area.

During Schematic Design, through the comparative modeling of the entire building, students seek to improve daylight performance, reduce the building's Energy Use Intensity (EUI in kBtu/sf.year), and reduce operational carbon. Students are required to use Cove.tool for energy modeling and keep track of the performance of each design iteration. Breakdown of the EUI per end use allows students to better understand the impact of each design iteration. For example, the impact of improved daylighting performance appears in terms of lower light load and lower cooling load. External shading devices reduce the cooling load and reduce the potential of glare (ASE[17]). Additional funding allows hiring additional teaching assistants (TAs) to support the work of students. TAs check the input data used for energy simulation, energy model components correctly exported from Revit to Cove.tool per building component/category (exterior walls, roof, external shading devices, windows, skylights, floors, and interior partitions), and help interpret the simulation results. Timely TA review of students' work is necessary to ensure that students are producing correct results, getting meaningful feedback, and not wasting design time. In Fall 2024, we had 57 students and hired two graduate students as TAs who spent their time exclusively helping students with the environmental performance requirements.

4.2 Focus Space requirements

During DD students select a “Focus Space” within their team's building to conduct more detailed design and analysis while limiting the overall scope of their study. For the Focus Space, the students use manual calculations to design electric lighting, use eQuest to generate the hourly cooling load, and test physical scale models in the daylighting lab using an artificial sky dome (see Figure 3). As a result, students determine the light load (Watt/sf), space peak cooling load in the perimeter and internal thermal zones (Btuh/sf), and space peak air flow required for the peak cooling per thermal zone (in CFM/sf). They use the calculated light load as an input for the cooling load calculations and use the peak air flow to size the supply air ducts within the Focus Space. At the end of DD, they design building systems (lighting, daylighting, and HVAC) based on the reduced energy loads.

It is our observation that the design-assisting tools produce data to drive design development through the assessment of consecutive design iterations and their impact on overall building performance. Simply, this design process helps students understand the relationship between cause and effect and how to extract discrete metrics and actionable insights from that data to inform decision-making effectively. The design-assisting tools that we use generate several different data points beyond EUI. As such, we believe that more nuanced assessment can help students to see the impacts of various aspects of the building design on performance. Through effective integration, we can produce design solutions that balance the various trade-offs that often occur between the envelope design, lighting systems, and HVAC systems to optimize building performance.

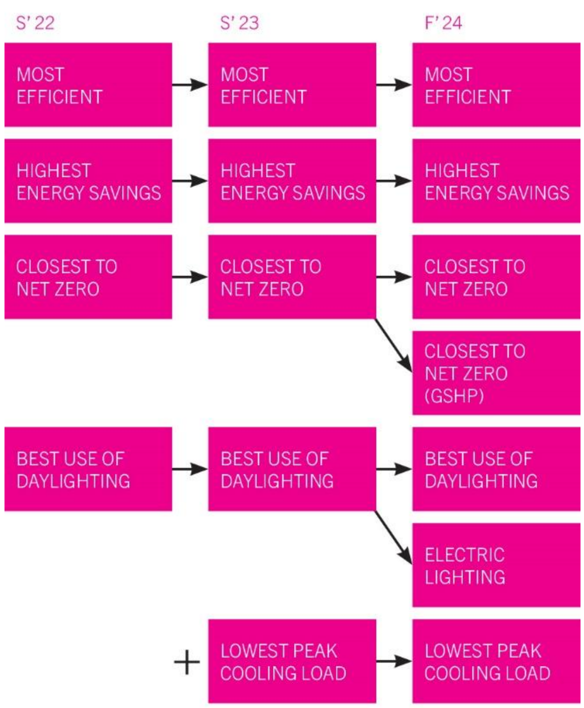
For the RAISE Performative Design Awards, the faculty assesses performance through the following categories directly related to this emphasis: (1) the most efficient building planning, (2) the best utilization of daylight, (3) the highest energy saving by design, (4) the closest to zero energy using on-site PV electric generation, and (5) the lowest peak cooling load in a Focus Space (see Figure 4). Over consecutive years of using these categories as assessment criteria, we refined how these categories were evaluated in a fair, simple, and meaningful fashion. We started with four categories, but with increased funding, we have been able to add one more category in 2023 and another in 2024.

5. Award Categories

The faculty developed award categories that align well with the educational objectives relevant to energy performance. That is why we do not assess performance solely based on EUI. We find EUI is insufficient to assess all design decisions that make a building efficient and even net zero. For example, in Fall 2024, almost all student teams achieved net zero energy (EUI of model ‘C’ = 0 kBtu/sf.yr). We want students to learn how to design efficient buildings, improve daylighting systems, reduce cooling loads, reduce peak cooling, reduce size of ducts, reduce the floor-to-floor height, reduce the size of mechanical equipment, and reduce the size of mechanical rooms. These learning objectives led us to develop several award categories and refine the criteria for some of the categories based on our experience teaching the same studio over the last three years. In the following section, we will discuss each of the award categories in more detail. First, we will define each category and its relevance to the overall goals for high performance buildings. Then we will address how the data is collected during the design process. Finally, we discuss refinements to the methodology for measuring and assessing performance to ensure fairness and reasonable comparison across the studio's various design proposals. Through the discussion of this methodology, we hope to provide insights for educators seeking to leverage the use of similar tools within the design studio.

5.1 Most efficient building

Measure of performance = smallest gross area of the building with program areas ±10% of target.



A good design provides the program areas for all planned functions within the building with the least amount of added auxiliary spaces, such as circulation and service areas. Smaller buildings consume less materials, consume less energy, and cost less to build. The gross area of the building is the measure of design efficiency. The smaller the gross square footage, the more efficient the building is; hence, the functional spaces are within the reasonable range of ±10% of the required program areas.

Data collection:

- Gross square footage calculated from the students' Revit models. To ensure fairness and consistency, students were asked to calculate the gross area following the same method.

Discussion of criteria methodology:

- To address inconsistencies in method for calculating gross area, an assignment was added to the Project Management course to introduce a consistent methodology and check for compliance.
- Although smaller buildings are better, making buildings significantly smaller than required program areas should not be considered good design. To balance efficiency with qualitative requirements, overall square footage is checked relative to the program requirements to confirm spaces are within 10% of required areas.

5.2 Best optimization of daylight

Measure of performance = sDA / ASE , given sDA ≥ 20%. A good design optimizes daylighting design to allow enough daylight while reducing glare. Although natural light is free and much more desirable than artificial light, oversizing daylighting systems is counterproductive because it may increase cooling loads and the potential for visual discomfort due to discomfort and/or disabling glare. Spatial Daylight Autonomy (sDA) is the percentage of floor area (at the height of the workplane) that receives at least 30 fc for at least 50% of the annual occupied hours. The higher the sDA is, the better. Annual Solar exposure (ASE) is the percentage of space receives too much sunlight (≥ 100 fc) for at least 250 occupied hours per year. The lower the ASE is, the better. The best optimization of daylight, then, is achieving the highest sDA while reducing ASE. The measure of success is the ratio of sDA to ASE; the higher the ratio, the better the optimization of daylight is.

Data collection:

- Daylight Analysis: students include the final results of their daylight analysis from Cove.tool Model ‘B’ for each floor of their building.
- Students assume code-complaint Visible Transmittance (VT) in SD, but then select a glass in DD and use the VT of the glass selected.

Discussion of criteria methodology:

- Using the sDA as the only measure for good daylighting design sends the wrong message to the students, since it may be achieved by oversizing of windows and skylights, which increases cooling loads and may increase potential glare.

5.3 Best integration of daylight and efficient electric lighting

Measure of performance = lowest lighting EUI.

This category was introduced as a new category in fall 2024. A good design minimizes light energy consumption by means of efficient daylighting and energy efficient electric lighting systems. Successful daylighting design should minimize the time in which electric lighting is needed. Efficient electric lighting design should minimize energy consumption when electric lights are on. The lower the lighting EUI, the more efficient the building is.

Data collection:

- From Cove.tool of Model ‘B,’ through the breakdown of EUI by end use, students find the EUI for lighting only.

Discussion of criteria methodology:

- Our observation is that in some projects successful daylighting design does not result in noticeable reduction in light load, which may be the result of relatively low sDA or the design of electric lighting that complies with code but is not as efficient as in other competing projects. Since the ultimate goal is to reduce energy consumption, the lighting EUI is the primary measure of success.

5.4 Highest energy savings by design only

Measure of performance = lowest building’s EUI; using code HVAC equipment & lighting power allowance.

A good design achieves the highest energy saving by design only, regardless of mechanical and electrical systems selected. The measure of success is the lowest EUI of the building using the minimum code-compliant HVAC systems and electric power allowance (Model ‘B’). The lower the building’s EUI, the higher the energy saving by design is.

Data collection:

- From Cove.tool, the final DD results of the energy model, i.e., whole building EUI of Model ‘B’. The lower the EUI is the better.

Discussion of criteria methodology:

- In the first two years, the measure for this award was the % energy savings in model ‘B’ compared to model ‘A’, which made perfect sense since improved performance (reduced energy consumption) is solely due to improved design.
- However, we observed that a high % of energy reduction may be a result of highly inefficient initial design in model ‘A’. For example, for the

same gross area, a design may have unnecessarily large volumes and high floor-to-floor heights. When the design is improved by reducing the unnecessarily large volumes, comparing Model ‘B’ to Model ‘A’ will show significant energy reduction but not necessarily low EUI. When the project begins with a grossly inefficient design (model ‘A’), it should not be simply assessed based on % savings. As such, we revised the measure of this category to the lowest EUI of Model ‘B’, regardless of % energy savings. Next time we teach the studio, we will change the award’s name as well.

5.5 Net zero with the smallest PV system

Measure of performance = net zero; with the lowest % PV area to gross area of the building.

A good design achieves net zero energy without the need for large size PV systems. The measure of success is the smaller ratio of the area of PV to the gross area of the building. The lower the ratio of PV to the gross area, the more efficient the building is.

Data collection:

- From the DD final submission, students calculate the percentage of the area of the PV system to the gross area of the building. Since almost all teams achieved net zero, it was simple to adjust the area of PV to the amount needed to make the building exactly net zero.

Discussion of criteria methodology:

- In the first two years, the measure was the closest to zero regardless of the area of the PV system. However, an inefficient building may still achieve net zero with a large and expensive PV system, with additional embodied carbon. The measure was changed from the project with EUI the closest to zero to the project achieving net zero with the smallest PV system, which provides a fair comparison of performance.

5.6 Lowest peak cooling load in the Focus Space

Measure of performance = peak cooling / (glass ratio x heigh of space); given that glass ratio ≥ 30%.

A good design minimizes the peak cooling in the Focus Space by means of envelope design. Reducing the peak cooling helps reduce the size of HVAC ducts, air handling units, fan rooms, and central sources of heating and cooling. Cooling load in the perimeter space is greatly affected by glass ratio and floor-to-ceiling height. Cooling can be reduced by passive means, such as daylighting, external shading, glass ratio, and glass selection. Larger windows maintain views to the outside and improve the quality of space. The measure of peak load reduction is the CFM/SF per glass ratio and floor-to-ceiling height.

Data collection:

- From eQuest results, the final DD results show the peak cooling in terms of Btuh/sf and CFM/sf. Documentation of the performance of design iterations show the final glass ratio and the floor-to-ceiling height of the Focus Space.

Discussion of criteria methodology:

- In the first year of this award, the measure was the lowest peak cooling regardless of glass ratio or the floor-to-floor height. Noticeably, envelope design with smaller windows results in a lower peak cooling mainly due to reduced solar heat gain. Similarly, spaces with low floor-to-ceiling height result in lower peak cooling due to less exposure to ambient conditions.
- In the second year, we did not want to send the wrong message to the students that the smaller windows are better since smaller windows hinder views to the outside. The revised measure avoids sending that wrong message to the students, as well as making it a fair

comparison between high and low floor-to-floor heights.

Conclusion

In conclusion, this paper reflects a snapshot in time, and we continue to refine the use of design-assisting tools within undergraduate design studios. We also recognize that this methodology will need to continue to be refined since the software tools continue to evolve. In January 2025, for example, Cove.tool has rebranded to simply “cove” and is now transitioning into a product called Vitras.ai to leverage the benefits of artificial intelligence in simulating building performance.

Regardless of these changes, using these tools within the studio environment is essential to our pedagogical strategies but we need to understand how to assess students’ success. Software tools like Cove.tool are readily available and able to provide an incredible amount of data through a streamlined workflow to our students. While the amount of data provided is an incredible benefit, we also need to develop and refine the ways we make that data meaningful and actionable to the students within their design process.

Moving beyond simply reducing the overall EUI is critical to this process. Through refining the award categories and how they are assessed, we have finetuned the measures of success we use to help students understand their agency as designers rather than blindly applying sustainable strategies. We have found that allowing the students to conduct design changes through trial and error with frequent feedback from BEM helps the students to understand more fully the interrelationships and trade-offs that often occur between the envelope design, lighting systems, and HVAC systems to optimize building performance.

Opportunities for future studies include comparing the methodology and results with other institutions if that information is available, as well as assessing the impact of this approach on students’ experiences after graduation. For now, we hope the insights gained along the way that we have shared in this paper can help other educators to incorporate the use of design-assisting tools in their design studio. As educators, we hold a critical role in our discipline’s collective effort to address the crisis of climate change through the design of the built environment.

Acknowledgements

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Notes:

1. Lawrance Livermore National Laboratory, 2024

2. Architecture 2030. "Architecture 2030." Accessed January 15, 2025. https://www.architecture2030.org/

3. Structural Engineering Institute. "SE 2050 Commitment." Accessed January 6, 2025. https://se2050.org/.

4. The MEP 2040 Challenge. "The MEP 2040 Challenge." Accessed January 6, 2025. https://www.mep2040.org/.

5. Works cited in this paper represent some of the findings on this topic but are not exhaustive.

6. Konis, Kyle, and Karen Kensek. “Performance as a Design Driver: A Pedagogical Approach and Online Collaborative Knowledge Network to Support High-Performance Design.” Paper presented at the *American Collegiate Schools of Architecture (ACSA) Conference*, 2014. 291–302.

7. Mohsenin, Mahsah. “Integration of Building Energy Modeling in Design Education.” Paper presented at the *Building Technology Educators' Society (BTES) Conference*, 2017. EID: 978-0-9895980-2-6.

8. Farid Mohajer, Mahsa, and Ajla Aksamija. "Integration of Building Energy Modeling (BEM) and Building Information Modeling (BIM): Workflows and Case Study." *Building Technology Educators' Society 2019* (1). https://doi.org/10.7275/bn9j-e183.

9. Minaei, Mahsa, and Ajla Aksamija. "A Framework for Performance-Based Façade Design: Approach for Multi-Objective and Automated Simulation and Optimization." *Building Technology Educators' Society 2019* (1). https://doi.org/10.7275/ye7w-nh09.

10. Bernard, Murrye. "Award: Cove.Tool, an App to Optimize Building Design for Sustainability." *Architect Magazine*, August 9, 2021. https://www.architectmagazine.com/awards/r-d-awards/award-cove-tool-an-app-to-optimize-building-design-for-sustainability_o.

11. Konis and Kensek, 292.

12. Seeking continual improvement, the faculty changed the name of the course from the Comprehensive Design Studio to the Integrative Design Studio in the Spring 2023 semester. This shift was indicative of the faculty's renewed focus on the integration of architectural thinking rather than the implicit claim of the students' work being complete (comprehensive). We especially see the emphasis on integration in the way that students explore performance and use design-assisting tools to provide feedback for making decisions.

13. The breakdown of the 171 total students by studio and by discipline (architecture and architectural engineering) is as follows: Spring '22 - 35 ARCH / 9 AE; Spring '23 - 41 ARCH / 29 AE; and Fall '24 - 38 ARCH / 19 AE.

14. EUI Benchmark and EUI Target suggested by Cove.tool refer to the Architecture 2030 baseline & target performance. The 2030 Baseline is derived from the CBECS 2003 database. CBECS is the Commercial Buildings Energy Consumption Survey conducted by the US Department of Energy. The 2030 Baseline EUI is for a similar building type (for example, Education building if you choose Education) that is built in the same climate region. 2030 Target EUI refers to the current year's EUI suggested by Architecture 2030 leading to zero energy by the year 2030.

15. Cove.tool is a Revit plug-in that is developed to run energy simulation and generate results in terms of EUI, LEED credit points, % reduction of operational carbon, comparison to Architecture 2030 target EUI, and daylight analysis.

16. eQuest is a user-friendly energy simulation computer program developed by funding from the US Department of Energy. Architecture students can quickly learn how to use it.

17. ASE is the Annual Solar exposure, which is the percentage of floor area that receives too much direct sunlight, i.e, 100 fc illuminance or more for at least 250 occupied hours per year, which may cause glare and/or increase cooling load.