ZERO+ CAMPUS DESIGN PROJECT: INTEGRATING ENERGY AND WATER IN THE EARLY DESIGN PHASES

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ABSTRACT: The Zero+ Campus Design Project has brought together the University of Minnesota's School of Architecture, Department of Landscape Architecture, Capital Planning and Project Management (CPPM) staff, and faculty and students to explore ways in which the integration of architecture and landscape design can reduce energy and water consumption and carbon emissions on the Twin Cities campus in Minneapolis, Minnesota. The project, supported by the Office of the Provost, has developed a series of new courses that explore design methods and tools to integrate zero- and low- energy and water strategies and metrics in the early programming and predesign phases for new campus buildings and landscapes. This paper will discuss the curriculum, assessment methods and tools, project outcomes, and lessons.

Keywords: zero energy, energy, water, design tools, education

Zero+ Campus Design Project

Introduction

The University of Minnesota (UMN), like many academic institutions throughout the U.S. and world, has prioritized sustainability in campus design, planning, and operations. The UMN Board of Regents has charged the University administration and staff to "develop specific sustainability objectives and targets" in the areas of physical planning and development, including buildings and infrastructure; operations; and transportation, among other issues.[1] Ranked on the *Sustainable Endowment Institute's* "College Sustainability Report Card" as the #1 "Big Ten" institution and #4 campus institution for "Best Overall Grades" in sustainability, the University of Minnesota continues to raise the sustainability bar and to grapple with the real and urgent challenges of integrating ever more ambitious sustainability goals and performance metrics into campus planning. [2] Supported by the Office of the Provost, the *Zero+ Campus Design Project* (Zero+ Project) was launched to explore the potential ecological and economic benefits of further integrating and more effectively evaluating energy and water strategies at the building and landscape scales in the early phases of programming and predesign. While this is a seemingly straightforward goal, even a cursory survey of current architecture and landscape design strategies, evaluative tools, and performance metrics reveals a startling absence of protocols and tools for the early phases of design that would enable designers and decision-makers to bridge the issues of energy and water at the building and landscape scales to achieve greater levels of sustainable performance. While Capital Planning and Project Management (CPPM) and facilities management staff have a high level of expertise and success in reducing energy and water consumption in the later phases of design development, commissioning, and operations, the Zero+ Team is working in collaboration to extend these capabilities into the early planning and design phases for both CPPM staff and future design teams.

Fourfold Perspective

The Zero+ Project brings together the School of Architecture, Department of Landscape Architecture, the University's CPPM and facilities management staff, and faculty and students to explore campus design solutions that can reduce, and ultimately move towards net-zero energy and water consumption and greenhouse gas emissions. Framed from a fourfold perspective, the Zero+ Project is focused on the following areas of impact:

1) Curriculum Development: Develop and pilot new courses as vehicles to investigate early design strategies, metrics, and evaluative tools that can be brought back into the early phases of the CPPM planning and predesign processes.
2) Tool and Resource Development: Identify existing design tools and develop the "Zero+ Patchwork Toolkit" to support early design and decision-making processes. Pilot-test tools in the classroom and bring them back to CPPM for integration into the early design phases. Develop online design resources with strategies, project outcomes, and tools to support students, CPPM, and future design teams.
3) Demonstration Projects: Design and construct select campus demonstration projects to engage students, elevate and promote sustainability, and test and evaluate energy and water strategies and performance on campus.
4) Stakeholder Design and Decision-Making Processes: Evaluate design and decision-making processes to further and more effectively integrate energy and water strategies in the early design phases.

To date, the project has focused on the first three areas of impact and has targeted capital planning project priorities from the UMN Campus Masterplan.[3] The long-term goal of the Zero+ Project is to incrementally develop, test, and integrate related sustainable design guidelines, evaluative methods, and resources to support the CPPM staff and potential design teams in early design. The team has achieve the following outcomes: 1) development of a series of new courses exploring the design integration of energy and water in select campus projects; 2) critique of existing energy and water performance metrics and assessment tools; 3) development of a "Zero+ Patchwork Toolkit" to better integrate energy and water; 4) development of a preliminary online resource for CPPM staff and students; and 5) initiation of a demonstration project for an ecological "bike pasture" and landscape design proposed and schematically developed by architecture and landscape architecture students that is under further development with the Department of Landscape Architecture. The following discussion will focus on highlights from the project curriculum, design tools, and lessons to date.

Zero+ Curriculum

Curriculum Overview

During the past two academic years, five courses have been offered that investigate design strategies to reduce campus emissions and energy and water consumption. The course formats include the following: 1) Zero+ Campus Design Studio (7-week design studio, 4 credits, Architecture, graduate-level); 2) Video as an Ecological Design Tool Catalyst (1-week workshop, 1 credit, Architecture, graduate-level); 3) Integrating Architecture and Landscape Studio (3-week seminar/studio May-Term, 3 credits, Architecture & Landscape Architecture, graduate-level); 4) Whole Building Analysis Seminar (15-week seminar, 3 credits, Architecture, graduate and undergraduate-levels); and 5) Theory and Practice of Sustainable Design (15-week seminar, 3 credits, Architecture, graduate-level). Each course has provided a distinct opportunity to explore the intersection of energy and water across design scales and through different projects, program types, ecological issues, and assessment methods and tools. Table 1 includes a summary of the course formats, project and program types, and focus scales and issues.

Table 1. Summary of Course Offerings.

Course Title	Format	Level	Projects and Program Types	Focus Scales & Issues
• Zero+ Campus Design	Studio 7-week	Graduate 4-credits	• 4th Street Residence Hall new design proposals • Generic lab new design proposals	Schematic: Site and building energy and water
• Video Catalyst	Workshop 1-week	Graduate 1-credit	• Church Street corridor interventions • West Bank landscape intervention	Conceptual: Site energy or water
• Integrating Architecture and Landscape	Seminar/studio hybrid; 3-week	Graduate	• Tate Lab Renovation and Church Street Corridor interventions	Predesign: Site and building energy and water
• Whole Building Analysis	Seminar 15-weeks	Graduate and undergraduate 3-credits	• Tate Lab Renovation and Church Street Corridor analysis • Rapson Hall analysis • 4th Street Residence Hall analysis	Analysis Schematic: Building energy and water
• Theory and Practice of Sustainable Design	Seminar 15-weeks	Graduate 3-credits	• Tate Lab Renovation and Church Street Corridor interventions • Eddy Hall and Historic Knoll interventions	Conceptual: Site and building energy and water

Course Goals

The Zero+ courses have sought to: 1) develop integrated building/landscape design strategies and interventions that improve ecological design performance for the reduction of energy and water consumption and greenhouse gas emissions, 2) identify and apply integrated performance metrics and assessment methods and tools, and 3) to improve upon existing assessment tools for the early stages of design. Courses have provided a testing ground to investigate more effective predictive models for energy and water integration that will be used to inform the CPPM design and decision-making processes in the early stages of design.

Course Planning and Project and Selection Process

CPPM staff collaborated with the design team in framing the course content, selecting capital planning projects, and focusing the design and research topics. A 2-year curriculum plan was developed to identify the priority campus planning projects for each of the courses: 1) Zero+ Campus Design Studio: residence hall and generic laboratory (quantitative and qualitative assessment and design proposals); 2) Video as an Ecological Design Tool Catalyst: Church Street corridor and West Bank landscape (conceptual interventions using video as a design tool); 3) Integrating Architecture and Landscape Studio: Tate Physics Lab renovation and Church Street corridor (quantitative and qualitative assessment and strategy proposals and interventions); 4) Whole Building Analysis Seminar: Tate Physics Lab renovation and Church Street corridor, Residence Hall, and Rapson Hall energy renovation (quantitative analysis and strategy research), and 5) Theory and Practice of Sustainable Design: Tate Physics Lab renovation and Church Street corridor and Eddy Hall and Historic Knoll renovation (qualitative assessment and strategy interventions). CPPM provided performance data for the buildings and campus landscape areas that were under investigation. Water and energy data for buildings were provided for potable water, sanitary sewage, solid waste, stormwater, and energy consumption for the past 5 to 10 years as well as transit and bicycle ridership. Spatial data included infrastructure, soils/geologic formations, and surface topography.

Building on Past Zero+ Design Studios

While the ability to conduct performance analyses within the design context is essential to making good sustainability decisions at any phase of design, a persistent challenge to decision-making is the lack of integration between design software and performance assessment tools for programming, predesign, and schematic design. It was clear from early conversations with CPPM staff and during stakeholder meetings that a priority was to further and more effectively evaluate and weigh performance benefits of integrated strategies for energy and water in the early design phases. Without effective analytical tools it is difficult, if not impossible, to successfully compare and contrast design goals, strategies, and performance outcomes. During the past four years, a required graduate level zero-energy design studio focusing on thermal and luminous issues has been taught in the School of Architecture. The design and analytical tools used in the zero-energy studio provided a point-of-departure for the curriculum and tool resources development for the Zero+ Project. These past studios resulted in repeated testing and comparative analysis of current strengths and limitations of energy and carbon-related design and assessment tools at the building scale. To build upon the lessons of the zero-energy design studio, the team has focused on a select group of energy and water design tools and developed the “Zero+ Patchwork Toolkit” to bridge the gap between design strategies at the building and landscape scales, performance assessment, and decision-making in early design phases.

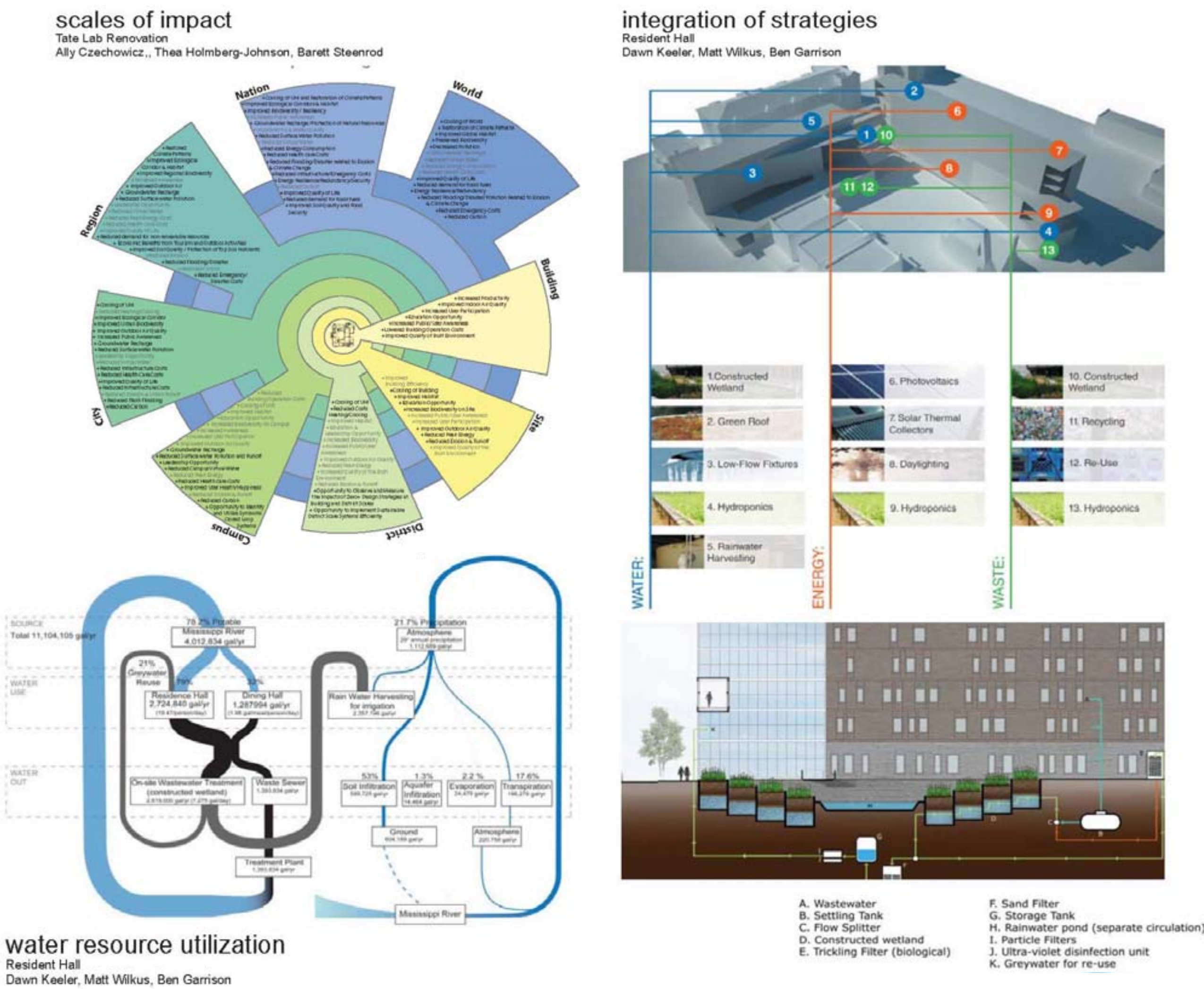
Course Methods and Outcomes

During the past two years, the Zero+ courses have tested varied curricula, course formats, evaluative methods, and tools ranging from highly analytical parametric studies of schematic designs to conceptual proposals for integrated water and energy strategies. Keep in mind that the curriculum, student work, and evaluative processes and tools are a testing ground to develop more effective methods of integrating energy and water design and analysis in early phases of decision-making. The team is currently working with CPPM to integrate the tools into their design process and to develop a curriculum plan for the coming academic year. Table 2 summarizes the various design and assessment methods and outcomes that have been investigated across the courses. For detailed materials for each course, including syllabi, assignments, student work, and tools, please see the Zero+ Design Project website at: http://zeropluscampus.umn.edu/.[4]

Table 2. Summary of Course Projects, Outcomes, and Tools.

Course Title	Projects	Student Outcomes	Evaluative Tools
• Zero+ Campus Design Studio	• Residence Hall design • Generic Lab design	Schematic design proposals: Energy and water at site and building scales; case studies; simple Z+ calculators to assess site water and building energy	• Ecotect • Version 1.0 Zero+ Calculator • Select online design guidelines, metrics, and calculators for energy and water
• Video Catalyst Workshop	• Church Street interventions • West Bank landscape interventions	Conceptual proposals: 90-second video; site energy and/or water interventions; no analysis	• Video production and editing software
• Integrating Architecture and Landscape M-term	• Tate Lab renovation and Church Street interventions	Predesign: Site and building energy and water proposals; assessment of on-site resources for water and renewable energy; building strategies for energy reduction	• Version 1.0 Zero+ Calculator and Zero+ SketchUp Plugin • Ecotect and iTree Suite • Select online design guidelines, metrics, and calculators for energy and water
• Whole Building Analysis Seminar	• Tate Lab and Church Street analysis • Rapson Hall analysis • Residence Hall analysis	Analysis of schematic design proposals from Zero+ Studio (assigned to teams): building energy and water assessment; parametric studies using IES VS and Z+ Tools	• IES VS • Version 2.0 Zero+ Calculator and Zero+ SketchUp Plug-in, Version 1.0 Zero+ Design Analysis Tool • Select online design guidelines, metrics, and calculators for energy and water
• Theory and Practice of Sustainable Design Seminar	• Tate Lab and Church Street interventions • Eddy Hall and Historic Knoll interventions	Conceptual Proposals: Site and building energy and water integration; analysis using online calculators; focus on design goals and strategies	• Simple online calculators and metrics for energy and water • LEED, Living Building Challenge, Sustainable Sites

Figure 1: Examples of Student Work.



Zero+ Assessment Tools

Tool Inventory and Evaluation

Effective evaluative tools are essential in selecting appropriate design strategies and assessing the relative impacts of factors such as site, climate, building type, programmatic issues, and occupancy schedules. The team conducted an extensive inventory of existing design tools and online calculators that could potentially bridge energy and water at the building and landscape scales. From this inventory, four tools were chosen for further analysis based on the software ability to evaluate energy and water design strategies and performance goals. A "Tool Matrix" was developed to assist CPPM and the team in comparing the tool capacities. Four design tools were determined to have the greatest potential to support CPPM in evaluating early energy and water goals, including Integrated Environmental Solutions Virtual Environment (IES VE) [5]; i-Tree Suite[6]; Open Studio[7]; and Green Values Stormwater Toolbox[8]. Each of these tools was assessed according to the following criteria: 1) text format (text input and output); 2) applications (wind, solar, daylighting, natural ventilation, green roofs, and stormwater); 3) outputs (building energy, landscape energy, building water, runoff, water quality, CO2 emissions, among other related issues); 4) modeling (predictive or 3-D modeling); 5) Software Relationship (AutoDesk, SketchUp, ArcGIS, Macintosh, and PC; 6) Cost; and 7) Ease of Use. The software programs were also assessed according to usefulness and applicability for the following tool-related questions: 1) what does it do (e.g. scale of decision-making and scope of ecological design issues such as passive design, daylight, stormwater, etc.)?; 2) when should it be used (e.g. predesign, programming, schematic, design development, etc.)?; 3) where does it work best (building, site, regional scale)?; and 4) who should use it (target audience such as architects, planners, engineers, and planners)? For detailed information, please see "Tools" on the Zero+ Project website.

After a thorough analysis, the most promising performance-based design tool was determined to be IES VE (with the team using SketchUp as the modeling tool). To strengthen and better integrate IES VE with the early design process, the team developed the "Zero+ Patchwork Toolkit" to better support design thinking (see discussion below). As the team moved into teaching the courses, IES VE, the "Zero+ Patchwork Toolkit", and a set of select online design guides and resources were pilot-tested with students to assess the ability to integrate energy and water strategies and performance metrics. The "Zero+ Patchwork Toolkit" is now being brought back to CPPM staff for further development and to evaluate the effectiveness of the tools to support integration of energy and water design strategies in the early stages of the CPPM design process.

Zero+ Patchwork Toolkit

The goal of developing the "Zero+ Patchwork Toolkit" is to provide a means to easily conduct performance analysis for energy and water in the early phase of design, to determine the performance potential of strategic sets or "bundles" of strategies, and to quickly measure the related performance metrics. The desired outcome of the toolkit is to empower the designer (student, CPPM staff, and design teams) by providing user-friendly tools in the earliest stages of design. The "Z+ Patchwork Toolkit" includes three tools: 1) The "Z+ Shoebox Model Maker" (a Z+ SketckUp plugin for modeling); 2) The "Z+ Calculator" (an Excel spreadsheet calculator that tailors the calculations for UMN operations data (e.g. energy and water costs, fuel sources, carbon emissions, etc.); and 3) the "Z+ Design Analysis Tool" (an integrated SketchUp/Excel/IES VE analysis tool that can compare the performance of a simple "baseline model" to "bundles of design strategies" for as many as three design proposals.

A current challenge of IES VE is that, while the model can be constructed in SketchUp and imported into IES VE for the energy analysis, the performance information currently cannot be imported back into SketchUp for on-going design alterations and recalculation (without starting over by constructing a new SketchUp model and a new IES VE analysis). To make it easier for designers and decision-makers to quickly model and compare design strategies (and to work from within the SketchUp model), the "Z+ Shoebox Model Maker" (a Z+ SketchUp plugin) was developed to quickly generate "shoebox" models for a select program, geographic location, approximate building size, and design and construction assumptions to comparatively evaluate the performance and optimization across as many as three design proposals. The "Z+ Calculator," which is an Excel spreadsheet, translates the IES VS energy analyses to specific UMN water and energy costs and fuel source data. The Z+

Design Analysis Tool allows for the aggregation and integration of simulation results from IES VE, SketchUp, and Excel into an integrated set of performance data (including energy consumption in kBtu/SF, carbon footprint, lifecycle cost, and other key performance metrics). The goal of the "Zero+ Patchwork Toolkit" is to help designers to keep the performance analysis within the context of early design decisions and to make the analysis process more integrated with early planning and design decisions. While the "Zero+ Patchwork Toolkit" has been developed within the context of IES VE, the team plans to extend the toolkit to be compatible with other modeling programs as OpenStudio, Revit, and Rhino Grasshopper. The next phase of development will focus on water, including cooling energy, cooling load reduction, evapotranspiration, green roofs and living walls.

Figure 2: Zero+ Design Analysis Tool: Create and Calculate a Baseline "Shoebox Model" for Program and Location.

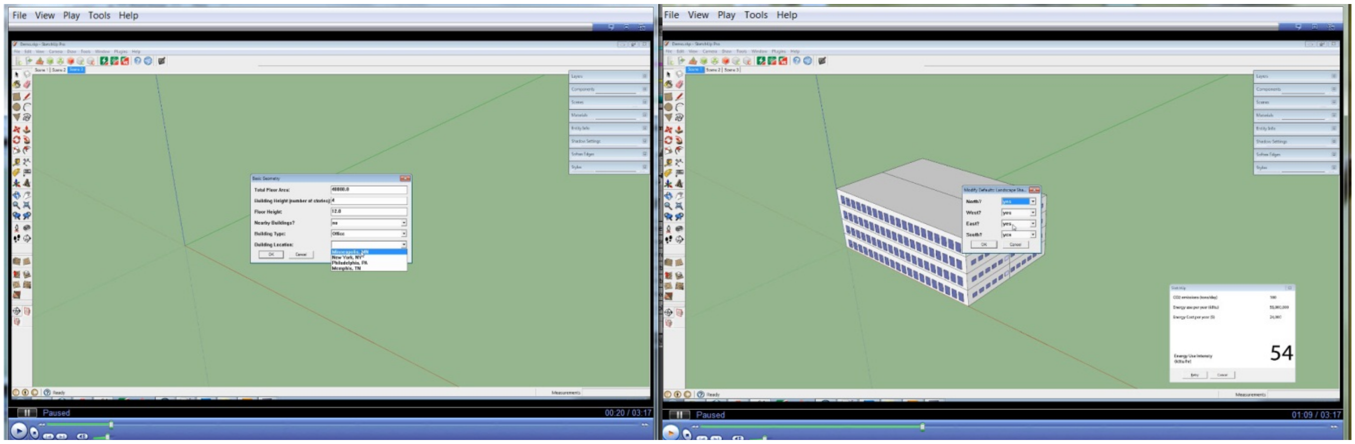


Figure 3: Zero+ Design Analysis Tool: Modify "Shoebox" to Evaluate "Bundles of Strategies" and Rank Strategies.

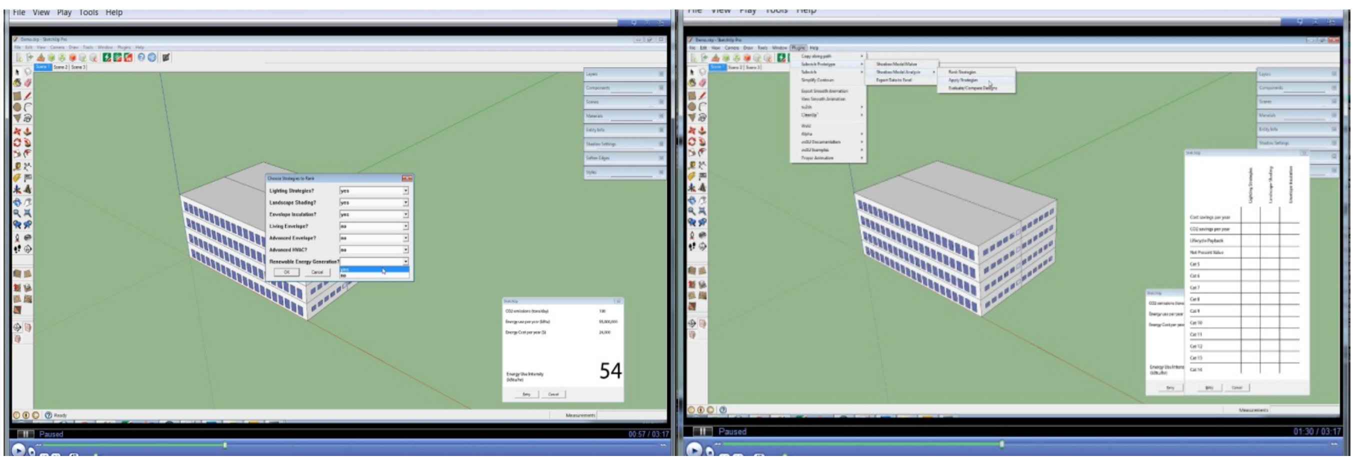
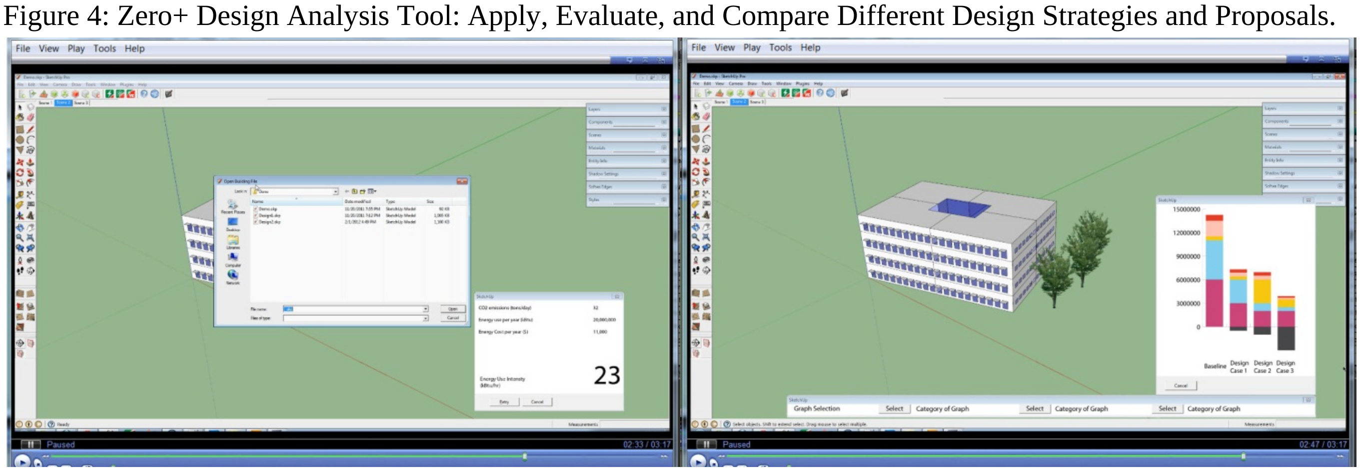


Figure 4: Zero+ Design Analysis Tool: Apply, Evaluate, and Compare Different Design Strategies and Proposals.



Lessons and Next Steps

The Zero+ courses and tool evaluation and development have attempted to bridge the existing gap between evaluating early sustainable design goals, design strategies, and performance outcomes across energy and water at the building and landscape scales. These early explorations have greatly enhanced the existing curriculum in the College of Design, with students engaging real campus projects and benefiting from the expertise and experience of CPPM and facility staff. To date, the project has also helped to elevate issues of sustainability on campus through the ecological "bike pasture" demonstration project. The next steps are to consider how the curriculum and design tools and resources can continue to evolve to support CPPM and design teams in the early phases of design. The lessons to date include the following:

- Importance of Analysis in the Early Stages of Design Decision-Making: While campuses throughout the country often have expert staff in the areas of planning, design, facilities management, systems, and performance analysis, the challenge often remains how to bring this internal (or external) expertise to the early stages of design decision making. Without dependable and easily accessible analytical tools it is difficult to move to a new level of integrated design. The Z+ team is assessing with CPPM how to develop a robust feedback loop between the tool and resource development and CPPM early design processes, which may include "Z+ Toolkit" and strategic training, workshops, and/or consulting, among other approaches.
- Integration of Curriculum and Campus Planning Priorities: Coordination between course planning and CPPM priorities is essential to effectively integrate the curriculum as a useful resource for CPPM staff. While the student work has been effective in elevating awareness of sustainability issues and has provided reports and studies that can be forwarded to future design teams, the team is working with CPPM to explore how to effectively integrate course outcomes into the planning and decision making process. The team is currently working with CPPM to develop a curriculum map for the coming academic year that will focus on target design priorities, projects, strategies, and performance metrics.
- National Alliance to Meet the Challenge of Climate Change: If campus institutions are to address the scope and scale of the climate change design challenge, there remains an urgent need for the development of reliable and accessible early decision-making tools. While the Architecture 2030 Challenge has made great progress in elevating the issue on a national scale, the tools needed to achieve this goal remain undeveloped. The level of expertise and resources needed to develop accurate and accessible early design tools requires a unified effort across public and private campus institutions, the design professions, industry, and national agencies such as the Department of Energy, National Renewable Energy Laboratory, and National Science Foundation. A national alliance is needed to meet the scope and urgency of this pressing design challenge.

Acknowledgements

The Z+ team gratefully acknowledges the contributions of the graduate research assistants Derek Schilling, Elizabeth Turner, Dawn Keeler, and Julian Lemon as well as the students who have participated in the courses. Orlyn Miller, former Director of CPPM and Monique MacKenzie, Director of CPPM, have generously contributed their time as members of the teaching/research team and have acted as the 'project client'. Jay Denny, Kathryn Bene, and Dana Donnatucci of Facilities Management and other University staff have also generously shared expertise and time as stakeholders and consultants.

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