A Biophilic Approach to Net-Positive Design: Studio Lessons

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This paper discusses the curricular objectives, exercises, design tools, methods, and outcomes of a seven-week graduate studio that explored a biophilic approach to net-positive design. We may be well aware of the performance and pragmatic aspects of net-positive energy in architecture, but what are the experiential and aesthetic opportunities and benefits? Could beauty, health, and well-being be as important to net-positive as are reducing waste, energy consumption, and environmental impacts? Biologist and naturalist E.O. Wilson's "Biophilia Hypothesis" suggests that there is an innate need for human connection with nature. A biophilic approach to net-positive design encourages students to investigate the intersections between regenerative design responses to natural systems, habitat, environmental and bioregional forces, passive strategies, and health and well-being. This paper discusses design objectives, methods, tools, and outcomes of six sequential exercises that developed over the course of the seven-week studio. The iterative exercises used physical and digital study models, envelope details, sketching, photography, time-lapse video, and qualitative and quantitative assessments. Students considered the poetic, pragmatic, and performance-based design issues, trade-offs, and design implications.

INTRODUCTION

We may be well aware of the performance and pragmatic aspects of net-positive energy in architecture, but what are the experiential and aesthetic opportunities and benefits? Could beauty, health, and well-being be as important to net-positive as are reducing waste, energy consumption, and environmental impacts? Might a biophilic approach help to reframe energy and carbon reductions to consider broader ecological and experiential perspectives that may not be readily apparent from a performance-based focus on net-positive? This paper discusses the curricular objectives, exercises, design tools, methods, and outcomes of a seven-week graduate studio that explored a biophilic approach to net-positive design.

A Biophilic Context for Net-Positive Design. The concept of biophilia or "love of life" was introduced by psychologist Eric Fromm in his 1973 book The Anatomy of Human Destructiveness: *"Biophilia is the passionate love of life and of all that is alive; it is the wish to further growth, whether in a person, a plant, an idea, or a social group."*[1] Biologist and naturalist E.O. Wilson popularized the term in his seminal 1984 text *Biophilia: The Human Bond with Other Species*.[2] Wilson's "Biophilia Hypothesis" suggests that there is an "innate emotional affiliation of human beings to other living organisms."[3] Over the past several decades, a body of scientific research has developed supporting the physiological and psychological benefits of human contact with nature, such as gardens, views, daylight, materials, and nature imagery.[4] In their 2008 book Biophilic Design, Stephen Kellert, Judith Heerwagen, and Martin Mador et al. establish a foundational theory, science, and proposed practice of biophilic design.[5] They suggest that biophilia is a missing component of sustainability: "Without positive benefits and associated attachment to buildings and places, people rarely exercise responsibility or stewardship to keep them in existence over the long run. Biophilic design is, thus, viewed as the largely missing link in prevailing approaches to sustainable design. Low-environmental-impact and biophilic design must, therefore, work in complementary relation to achieve true and lasting sustainability."[6]

In the 1990s, the concept of a "living building" emerged as a counterpoint to incremental improvements found in many sustainable rating systems. The "living building" standards introduced the aspirations for "net-zero" energy, water, and waste as well as focusing attention on issues such as beauty and equity.[7] In 2009, biophilia was first cited in the Living Building Challenge (LBC) 2.0 standard. In 2014, the International Living Futures Institute (ILFI) introduced LBC 3.0, which included a shifted from "net-zero" to "net-positive" energy, water, and waste. Building on Kellert's biophilic strategies, the ILFI recently published the Biophilic Design Guidebook, which is a supplemental resource for the LBC 3.1, as well as Amanda Sturgeon's book Creating Biophilic Buildings.[8 9]

In 2014, the consulting firm Terrapin Bright Green published a complementary resource entitled "Terrapin's 14 Patterns of Biophilic Design" (by William Browning, Catherine Ryan, and Joseph Clancy).[10] Building on the earlier work of Kellert et al., Terrapin's patterns provide a conceptual framework, tangible goals, and biophilic strategies to implement across design issues and scales. The 14 Patterns provide essential and complementary resources for a designer interested in integrating biophilia with net-positive energy.

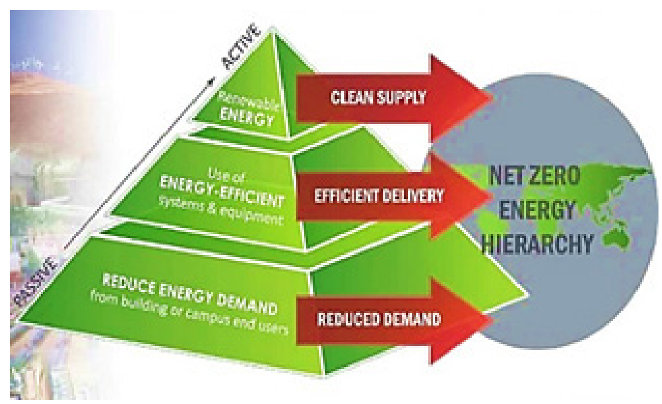
The Biophilic Net-Positive Design Studio. The required seven-week Net-Positive Design Studio is offered in the spring of the second year of the three-year M.Arch Program at the University of Minnesota. A cohort of instructors teach four parallel studios with a requirement to introduce students to the architectural opportunities and trade-offs of net-positive design, with a focus on energy and carbon goals, strategies, metrics, and assessment methods. Using Terrapin's 14 Patterns of Biophilic Design and the LBC 3.0 standard, this studio explored whether a biophilic approach to net-positive design could enhance environmental and health benefits for the planet, humans, and other species while meeting the highest standards for energy and carbon performance.

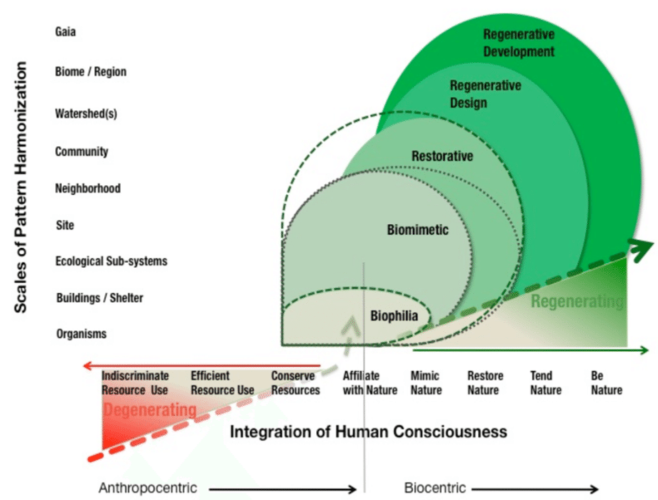
The project brief involved design of a 10,000 square foot proposed Center for Health and Well-being. Dr. MaryJo Kreitzer and Pamela Cherrey, the Director and Administrative Director, of the University of Minnesota Center for Spirituality and Healing acted as clients for the studio. They helped to frame the program (which included goals and activities for a similar project slated for future development at the university), served as guest critics, and acted as resource experts on health and well-being. A hypothetical project site was chosen in a business district on the north boundary of campus. The site afforded excellent solar and wind access, opportunities to enhance bio-diversity, and connections to the Mississippi River and proposed urban habitat within an old railway corridor.

FRAMING THE PROBLEM

Understanding the comparative attributes of net-positive and biophilic design was essential in distinguishing relative architectural opportunities, limitations, and intersections. Working with seminal texts and related design standards, small groups of students started by exploring how biophilia fits within a larger sustainable and regenerative design trajectory. During the first week, the student groups led discussions and framed questions on three related topics: 1) Defining Net-Positive Design and the Architectural Energy Hierarchy, 2) Positioning Biophilia within the Regenerative Design Trajectory, and 3) Exploring a Net-Positive Perspective on Biophilic Design.

Defining Net-Positive Design and the Architectural Energy Hierarchy. Small groups considered the evolution of select architectural guidelines and standards that have developed over the past several decades to support an incremental shift from low-energy to net-zero and most recently net-positive energy targets. Student groups compared the evolving U.S. Green Building Council (USGBC) metrics and guidelines for Leadership in Energy and Environmental Design (LEED) to the incremental reductions proposed by the Architecture 2030 Challenge, and the net-positive aspiration of the LBC 3.0.[11,12,13] They reviewed the 2014 U.S. Department of Energy (DOE) "Zero Energy Buildings" (ZEB) study to define and measure an industry standard. As defined by the DOE, a zero-energy building could go beyond the "net-zero" target to reach "net-positive": ***"An energy-efficient building where, on a source energy basis, the actual annual delivered energy is less than or equal to the on-site renewable exported energy."***[14] Readings from Passive Solar Design by David Bainbridge and Ken Haggard introduced the essential role of bioclimatic and passive strategies to unite efficiency, use, and production at the building site. Their recommendations focused on 1) using on-site energy sinks and sources, 2) relying on natural energy flows with a minimum of moving parts, and 3) including energy production as an integral part of the building design.[15] Other resources such as LEED, the Architecture 2030 Palette, and the Whole Building Design Guide (WBDG) provided additional resources on bioclimatic and passive design.[16,17] As illustrated in mechanical engineer Scott West's diagram of the architecture "energy hierarchy," passive design is shown to be the foundational strategy for net-zero design by: 1) reducing energy demand and promoting energy conservation (including site design, architectural form, and bioclimatic and passive design), 2) using energy efficient and high-performance systems, and 3) integrating renewable energy systems (see Figure 1).[18] Students discussed possible strategies for the Minnesota climate to reduce energy demand through programming, site, architectural, bioclimatic, and passive design strategies. They also considered how energy strategies might simultaneously enhancing biophilic patterns and the connections between humans, other species, and natural systems.





Positioning Biophilia within the Regenerative Design Trajectory. Small groups of students also explored how biophilic design fits within a larger sustainable and regenerative design context. The definition of sustainable development in the

1987 Brundtland Commission report Our Common Future ("sustainable development meets the needs of the present without compromising the ability of future generations to meet their own need") and select articles on regenerative design helped frame discussions on the evolution of sustainable and regenerative design.[19] Included were essays by John Tillman Lyle; Ray Cole et al.; Pamela Mang and Bill Reed, Julia Africa et al.[20 21 22] This evolution is well illustrated in Reed's "regenerative design trajectory" (see figure 1).[23] The diagram illustrates the spectrum of "degenerating" to "regenerating design" practices, which helped students to position "biophilia" within a larger context.

Students also considered whether biophilia is inherently anthropocentric or whether it embraced broader biocentric and ecocentric perspectives. In the article, "Biophilic Design and Climate Change," Julia Africa et al. investigate the intersections between climate change, biophilia, and health and performance metrics. They suggest that biophilia can serve as an "interstitial tissue" that connects varied ecological scales and issues: ***"The best applications of biophilic design may be distinguished from other projects by their ability to synergistically integrate the building, site, and occupants through the creation of comprehensive "habitat." Habitat, in this context, encompasses the materials, structure and program of the building; management of site metabolism, including energy needs and waste flows; concordance with the surrounding environment, both within the building and beyond the building façade; support for on-site biodiversity, from micro to macro fauna (as appropriate); and perhaps most of all, a recognition that these features communicate habitability and community to human occupants through eons of evolutionary priming, and that this appeal is both desirable, comfortable, and health promoting."***[24] Based on their research, biophilic design can reduce energy; support improved comfort; improve mental, emotional, and social health; while increasing biodiversity.[25] They also suggest that "climate-change metrics" could serve as performance parameters for biophilic design.[26] Building on this proposition, students asked questions about how "climate-change metrics" - such as energy consumption (kBtu/square foot) or annual carbon dioxide production (lbs CO_2) - might relate to biophilic patterns and how biophilic impacts on energy and carbon might effect humans, other species, and habitats.

Exploring a Net-Positive Perspective on Biophilic Design. Next, Terrapin's "14 Patterns of Biophilic Design" were used to consider biophilic dimensions of net-positive energy.[27] Students evaluated the 14 patterns through the lens of potential integration with net-positive energy and carbon strategies at the site, building, and room scales. As previously mentioned, this seven-week studio used the "hierarchy of energy" as a framework and point-of-departure for net-positive design, with an emphasis on reducing energy consumption through bioclimatic and passive strategies. With this in mind, students evaluated which of the 14 Patterns related to the "energy hierarchy" using passive strategies for daylighting, natural ventilation, and passive solar heating. A direct connection was found between biophilia and net-positive site design; building form and orientation; window size, placement, and detailing; and envelope design with four Biophilic Patterns: #1) visual connection with nature, #4) thermal and airflow variability, #6) dynamic & diffuse light, and #7) connection with natural systems. Next, students considered how other patterns might relate to net-positive design. For example, Pattern #11: Prospect could integrate with #4 Thermal and Airflow Variability and #7 Connection with Natural Systems. Finally, each student selected at least three biophilic patterns to work with for the project and to inform their own approach to a biophilic approach to net-positive. The selected patterns informed development of their individual program goals, priorities, and design strategies.

DESIGN EXERCISES AND METHODS

After framing the problem, the students used six exercises to develop the project across issues and scales. The exercises worked back-and-forth between qualitative and quantitative design methods and tools, including graphic programming, diagramming, physical and digital study models, time-lapse video and photography, envelope details, and quantitative energy and carbon analyses. Poetic, pragmatic, and performance-based design issues, trade-offs, and implications were considered, with the students defining their individual programmatic approach, design goals, and select biophilic patterns. As performance metrics for biophilia are yet emerging, the quantitative analyses focused on net-positive energy and carbon assessments using Sefaira energy software. The discussion below provides an overview of the six exercises and corresponding goals, design methods, and tools (see also Figure 2).

DISCOVERING: Exercise 1: Biophilic Journey (First Impressions of Place). The students began with iterative site visits to document and define a proposed "Biophilic Journey". Time-lapse video, photographs, diagrams, and collage illustrated the relationships between biophilic phenomena of nature and place while considering potential bioclimatic and passive response to sun, wind, and light for the site and climate (see Figure 3). They considered "existing conditions" and "potential design responses" to support the intersection of biophilic and net-positive goals. Students revisited the site each week to document changing phenomena and conditions. Next, they used their select "biophilic patterns" to inform the design of site and building massing. Students considered the seasonal and diurnal "biophilic journey" by developing iterative sketches and physical models studies to explore how the site and building spatial organization, massing, and strategies might reduce energy while enhancing habitat and connections with nature. Climate Consultant was used to analyze bioclimatic forces, the psychometric chart, solar tools, design strategies, and case study links to the architecture 2030 Palette.[28]

EXPLORING: Exercise 2: Biophilic Atmosphere and Passive Potential (Nature & Energy Matters). Using a series of iterative "atmosphere boxes" and one or two "biophilic patterns," students scale-jumped from the site studies to the interior of the main assembly room. Working from the inside-out, students developed iterative physical models using a simple ¼"=1'-0" box to explore the biophilic atmosphere (such as the degree of connection with nature, site, time, and weather) in relation to daylight, natural ventilation, and passive solar design (see Figure 3). Making only one or two design modifications per study, students developed multiple “atmosphere boxes” and photographed the incremental alterations to compare and document the changing qualities of light and material effects for select seasons. This iterative method of investigating and documenting the atmospheric quality of light and place was informally revisited in following weeks. The atmosphere studies were useful in elevating the experiential dimension of biophilia in relation to potential quantitative performance of passive strategies for net-positive.

EXPLORING: Exercise 3: Biophilic Programming and Sections (Integrating Comfort & Atmosphere). Each student next developed an initial “biophilic program” for each activity using narrative text, precedents, and seasonal photos to clarify the intersection of biophilic and net-positive goals. The program document was flexible and changed as the project evolved over the following weeks. After considering the atmosphere and programming studies, students scale-jumped back to iterative site-building massing and section physical models to explore atmospheric and seasonal response to the site forces using site-building sections and physical massing models (see Figure 3).

ASSESSING: Weekend Workshop #1: Daylight and Passive Optimization. On the Friday of the second week, Chris Wingate (an architect from MSR) and Pat Smith (Research Fellow at the Center for Sustainable Building Research) conducted the first Sefaira energy-modelling workshop (see Figure 3). Students from all four studios used Sefaira software and parametric analysis methods to evaluate daylighting and passive design strategies and comparative energy

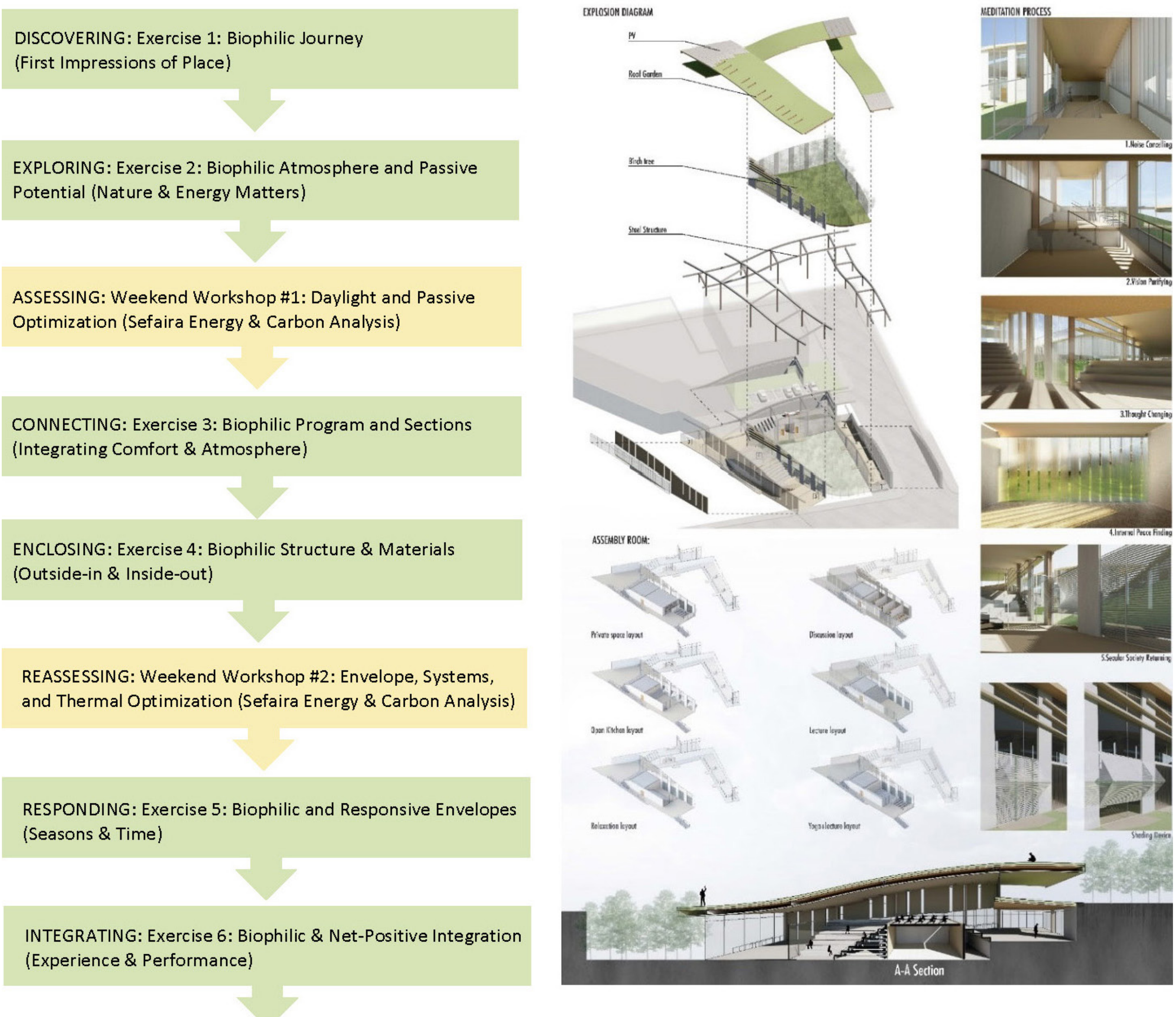


Figure 2: Left: Overview of Exercises; Right: Example Project. Credit: Yalun Chen (project).

Figure 3: Top: Example exercises 1-2 and Workshop #1: Top: Site studies, Center: Atmosphere studies, Center: Site massing, Right: Energy study, Bottom: Site and massing studies. .Credits: Mitchell Lampe, Yifan Liu, Cody Peterson, and Yalun Chen.

and carbon performance.[29] After comparing earlier studies, students selected one project (or a hybrid from the early scenarios) as a "base case" to develop a new sequence of parametric studies and design scenarios. Only architectural design variables could be incrementally altered, including: building massing, number of stories, orientation, glazing area, glazing orientation and percentage in each orientation, presence or absence of shading, and presence or absence of natural ventilation. Summaries of the parametric studies included site-building massing diagrams and performance data, including: 1) Annual Energy Use per Gross Internal Area: kBtu/square foot (vs Architecture 2030 targets); 2) Annual CO2 Production: lbs CO2; 3) Spatial Daylight Autonomy (sDA) and 4) Annual Sun Exposure (ASE). While students were not required to attain a "net-positive energy target," they were asked to investigate "how low they could go" by only reducing energy through site and architectural design. The second workshop introduced additional reductions through envelope variables, building systems, and renewable energy. Students compared the advantages and disadvantages of different bioclimatic and passive design scenarios in relation to their net-positive and biophilic goals. One project scenario was selected to move forward in the next phase of the studio.

ENCLOSING: Exercise 4: Biophilic Structure & Materials (Outside-in & Inside-out). A detailed envelope program was developed to consider the biophilic and net-positive design concepts and goals for the facades in the four cardinal orientations and the zenith (with the roof as the fifth façade). Based on the envelope program, students considered early envelope concepts, structure, and materials from the interior quality of spaces and the exterior facades (see Figure 4). Iterative scenarios were developed using exploded axonometric diagrams. Each façade was considered in terms of the effect of orientation, activities, and the site relationships from the outside-in and the inside-out. Students developed time-lapse digital videos to compare biophilic strategies with the seasonal qualities of daylight, passive solar, and shading considerations. Atmosphere boxes were encouraged to experiment with the interaction of structure, materials, and light in time.

REASSESSING: Weekend Workshop #2: Envelope, Systems, and Thermal Optimization. Each student brought a selection of site-building massing and envelope scenarios to the second Sefaira workshop, which focused on energy and thermal optimization of the building envelope and systems integration (see Figure 4). After initial comparison of previous studies, students selected one proposal (or a hybrid of strategies) to use as a "base case design" for parametric analysis. Using Sefaira, a series of iterative design alterations were developed to compare the "base case" to at least three additional proposals. The design variables that could be altered included massing, size and location of glazing, shading, envelope thermal parameters, glazing parameters, and HVAC and renewable energy systems. A summary of comparative graphics and performance data was developed to assess each design scenario, including: 1) Annual Energy Use per Gross Building Area: kBtu/square foot, 2) Annual CO2 Production from energy use (lbs CO2); 3) Spatial Daylight Autonomy (sDA) and Annual Sun Exposure (ASE); 4) Total energy breakout from Sefaira; 5) HVAC system type selected; 6) Amount of photovoltaic panels (in square feet) needed to meet the 2019 performance targets for Architecture 2030 Challenge (70% carbon reduction below the regional average for that building type); and 7) Amount of photovoltaic panels needed to achieve net-positive design. Again, students were not required to reach a "net-positive target," but rather, they revisited the question of "how low they could go," with additional energy and carbon reductions met through high performance and renewable energy systems. They considered possible trade-offs and compromises to reach design and performance goals. Based on the analyses, students selected one proposal for development over the remaining three weeks of the studio. Following the parametric analysis phase, students considered how the select scenarios could further enhance biophilic patterns and net-positive goals.

RESPONDING: Exercise 5: Biophilic and Responsive Envelopes (Seasons & Time). Using an in-class charette, the site-building massing and envelope scenarios were revisited to integrate the lessons of the second Sefaira energy analysis workshop. Annotated seasonal site-building section drawings were used to further develop net-positive and biophilic strategies for summer versus winter. Following the charette, students selected "one important room" to develop two ½"=1'-0" physical envelope detail models of select wall conditions. Envelope detail drawings further illustrated seasonal responses to daylight, natural ventilation, passive solar and connections to site, views, habitat, natural systems and other select biophilic patterns (see Figure 4).

INTEGRATING: Exercise 6: Biophilic & Net-Positive Integration (Experience & Performance). In the last two weeks, students illustrated the integration of biophilic patterns and net-positive design strategies at the site, building, room, and envelope scales. One select room was studied using a ½"=1'-0" detailed physical model to illustrate the quality of space and envelope. The group selected the required drawings and models for the final review, including concept diagrams, seasonal rendered site-building sections and/or axonometric drawings, structure and envelope exploded axonometric or detail drawings, Sefaira performance assessments, and a client summary (see Figure 5). Required physical models included the final room model, envelope detail studies, and all process models.

DESIGN LESSONS AND CONCLUSIONS

Several lessons and questions arise from the Biophilic Net-Positive Studio:

1. Bioclimatic and passive approaches to net-positive and biophilic design: The outcomes of the studio suggest

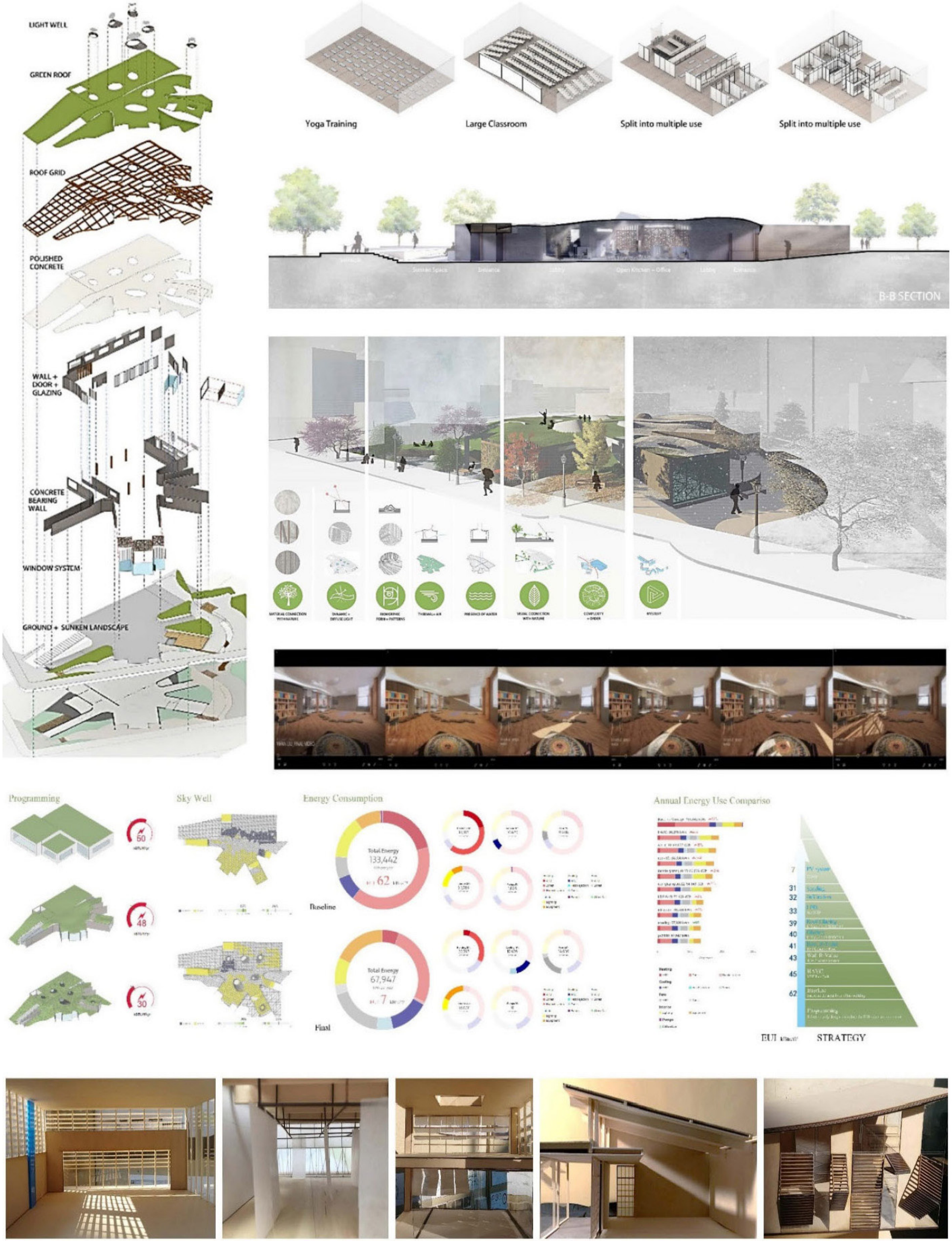


Figure 4: Top: Example exercises 3-5 and Workshop #2: Structure, materials, and envelope. Credits: Yifan Liu, Cody Peteson, Brandon Thompson, Emma Rutkowski, Yutong Yang, and Jacob Ernst.

bioclimatic and passive strategies can be combined to simultaneously reduce energy consumption for net-positive design while integrating biophilic patterns to foster human interactions with the site, environmental forces, and natural systems while enhancing habitat and biodiversity. Strategic intersections between biophilic patterns and net-positive strategies can leverage energy and carbon reductions while enhancing human-nature connections.

2. Beyond an anthropocentric perspective: While the "biophilia hypothesis" is inherently anthropocentric (focusing on the innate need to connect with nature), it does not preclude broader ecocentric aspirations to support the inherent value of living and non-living elements of an ecosystem. Designers can use biophilic and net-positive strategies to address human comfort and well-being while supporting other species and natural systems.

3. Strengths and limitations of net-positive analysis and performance metrics: Sefaira (or related) schematic design software is essential in enabling students to compare early design analyses for energy, carbon, daylight, natural ventilation, passive solar, and comfort. The next studio offering will consider the proposition by Africa et al. in their essay "Biophilia and

Figure 5: Example project: wall details, interior simulations, and Sefaira energy and carbon studies. Credit: Zixing He.

Climate Change," that suggests metrics for climate analysis could be used as "a dimension of performance analysis for biophilic design practices."[30] Further exploration will consider the biophilic implications of net-positive and climate metrics for energy and carbon.

4. Need for standardized biophilic metrics and analysis tools: While quantitative metrics for net-positive performance such as energy, carbon, daylight and thermal comfort are standardized (albeit evolving), biophilic metrics are nascent and related assessment tools have yet to develop. The recent publication of the Well Building Standard and Fitwel System have elevated discussion and research on health and well-being metrics and standards to inform design and practice.[31] [32] Growing interest in biophilic design promises further developments, standards, and tools.

5. Next steps: In the coming year, the project will be developed over a 15-week period (rather than seven weeks), using back-to-back seven-week studio modules taught be separate instructors. The first seven-week module will start with the Biophilic Net-Positive Studio to focus on the bioclimatic and passive design strategies to inform schematic site, building, and envelope design. Students will move with their project to a second seven-week module for the Integrated Design Studio, with an emphasis on materials, construction systems, detailing, and systems integration. This extended timeline will enable students a full 15-week period to develop the project in greater depth and to integrate the strategies, tools, and lessons from the Biophilic Net-Positive Studio into the Integrated Design Studio.

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