Out of Phase: Building Scale Analysis for Zero Energy Master Planning

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ABSTRACT

This paper presents a process for developing comparative quantitative energy and comfort analysis for a site and program before master planning begins. Loisos + Ubbelohde developed this process serving as technical experts for a public high school with zero-net-energy goals. Studying the programmatic needs of the classroom relative to the comfort needs of a classroom, energy models were used to explore the potential for passively delivering comfort with low energy approaches in this climate. Daylighting studies generated input for lighting loads and schedules for the energy use and comfort models. This information generated by the technical assistance team was then used by the Architect to efficiently begin the master plan design grounded in scientific principles, rather than less precise rule-of-thumb measures and general guidelines often employed at this early stage of master planning.

INTRODUCTION

Early design decisions often have the largest impact on a building’s energy use. These decisions, as early as the master planning stages of a project, are often made without the benefit of quantitative analysis. Later in the design process, when we typically have energy and possibly thermal comfort analyses available, changing these large-scale decisions can be difficult. This paper presents a process for developing useful quantitative energy analysis for a site and program before master planning begins. The information gained from these analyses was provided to the architectural design team at the beginning of the master planning phase of the project. The report allowed the design to commence thoughtfully with regard to energy and was essential in moving towards a zero net energy goal on a limited budget.

INTENT AND OBJECTIVES

This work was funded by Pacific Gas & Electric (PG&E), the local utility company, as part of their Zero Net Energy Pilot Program that provides technical design assistance for local projects trying to achieve Zero Net Energy performance. In addition to assisting in the creation of a number of zero net energy projects, the goal of the program was to transfer knowledge from technical assistance teams to other design team members on the projects.

Through this program, our expertise was provided to Oakland Unified School District (OUSD), a client committed to Zero Net Energy and yet without additional funds to support this level of expertise. OUSD wished to leverage the assistance offered by the program to also develop a process by which they could look at various sites throughout the school district, which contains 87 schools and over 36,000 students. The project for which OUSD received technical assistance was a master planning project for the renovation and rebuilding of Fremont High School, a campus with the potential to support up to 1,700 students.

Our team was assigned to this client and project before the architects themselves were chosen. This offered us an atypical opportunity to develop generative, energy-related information for the project before the architects started their work. By developing energy and thermal comfort analyses that had direct design implications before the architects began their design, we provided a rooted understanding of the energy potentials of this specific site paired with the particular program. Our goal was to inform the architect’s understanding of the energy considerations inherently embedded in the broad decisions that define projects early on.

CLIMATE + PROGRAMMATIC ANALYSIS

We began with an inventory and assessment of the existing campus physical conditions and energy use, followed by a study of on-site renewable potential. This was followed with a more unique investigation of the passive potential. The goal of economical zero-net-energy performance requires maximum hours of comfort delivered passively through building envelope design and control without mechanical conditioning. Our strategy was to speculatively examine potential passive retrofit and new design alternatives for the classroom and library spaces that make the bulk of campus. Simulations of various envelope configurations quantified the impact of natural ventilation, thermal mass, super-insulation, glazing specification, and daylighting controls on both the annual energy use and the hour-by-hour thermal comfort of occupants.

The process is based on the premise that the overall site organization is best informed by a detailed understanding of component performance. By finding a way to do detailed modeling before design begins, designers can use analysis specific to their climate and site in order to inform larger scale design decisions.

Climate Summary + Inventory of Existing Conditions

The climate summary and inventory of existing conditions of the buildings on the site was our first step. Master planners are tasked with determining which existing structures to maintain and which to demolish. In our inventory each existing building on campus was rated for its potential to incorporate energy saving strategies, such as thermal mass, natural ventilation, daylighting, efficient electric lighting and mechanical systems. In addition, a full inventory of all mechanical equipment was taken. The inventory included an evaluation of each existing building for its ability to provide passive comfort if it were
Ideal and Existing Classrooms

The campus was split into component parts in order to develop more detailed knowledge about how a particular program piece will interact with the climate on site. The classroom, which is repeated many times, was a starting point for investigation. We compared a typical existing classroom with an “ideal” classroom, defined as maximizing passive use of light and air with the same square footage. This allowed us to simultaneously look at a) how close the existing classroom is from a comfort perspective to what we would consider an ideal energy-use scenario, and b) to test various passive strategies for this particular site on two configurations to help the designers consider form and shape of the classroom unit.

In most integrated, sustainable design practices (see, for example, Mendler and Odell, 2000) energy analyses beyond a baseline model do not come into the process until after an initial design has been proposed. Working without a preliminary design and instead using conceptually defined “ideal” design characteristics for a repeated unit on the campus set a high bar for the design team. This strategy is well suited to any program with repeated or dominant elements.

Energy Models

We modeled the Ideal and Typical classrooms using EnergyPlus, a simulation platform that accounts for sub-hourly building envelope heat flows through conduction, convection, and radiation. The model contains envelope geometry, shading devices, and orientation as well as assumptions about ventilation strategy, construction assemblies, and internal gains. Typical meteorological year (TMY) data for Oakland International Airport (located 3 miles away) was used for the analysis.

Thermal Comfort Models

The most energy is saved if comfort is achieved passively, without active systems. We began by modeling thermal comfort conditions in the classrooms with no conditioning and no passive operations (such as operable windows). Figure 6 shows comfort levels for every hour of the year, with the color red indicating it is too hot (cooling would be required) and blue and purple indicating heating would be needed. No color signifies comfort is achieved passively for that hour. Parametric simulations enabled us to identify suites of passive strategies that minimizes need for mechanical conditioning.
Daylight Models

In order to determine the potential for reducing use of electric lighting, we modeled the classroom with Radiance, a research-grade simulation tool developed by Lawrence Berkeley Laboratory. We studied the typical existing classroom, the typical existing classroom with added skylights, the ideal classroom, and the ideal classroom with added skylights. We also used Radiance to provide hourly electric lighting use for input into the energy models.

Figure 6 (a) Annual Hourly Comfort for an unconditioned ideal classroom without insulation or passive strategies, and (b) Annual Hourly Comfort for an unconditioned ideal classroom with insulation, thermal mass, daylighting controls, and natural ventilation used when needed.

Comparing Conditioned Optimized Models

The daylighting modeling and the optimized comfort models were used to develop an optimized design that was then modeled in EnergyPlus. Energy use in the optimized retrofit design was reduced by half, from approximately 44 kBTU/SF to approximately 22 kBTU/SF in the typical classroom. In the ideal classroom, energy use was lowered to 16 kBTU/SF, requiring only 23% of roof area to be covered in PV to meet Zero Net Energy goals.

Figure 9 Optimized energy models for Existing and Ideal Classrooms in four orientations showing total energy use in kBTU/SF and the percentage of roof area required to be covered by PVs to meet Zero Net Energy.

CONCLUSION

Providing the design team with detailed analysis of the energy potential of the site and program allowed the team to move in a direction conducive to passive strategies immediately in their design process. Access to light and air became primary informants to program locations and orientations on the site at the onset. Typical and Ideal classroom studies allowed the team to understand the passive needs of the project so they could immediately begin to negotiate these with other needs of the project including mitigating outdoor air quality and acoustics. The early studies enabled the architects to quickly and effectively produce detailed master plans proposals that convinced their clients that a Zero Net Energy campus is possible.

Figure 10 Architectural scale strategies were brainstormed to resolve master planning issues in eco-charrettes.

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REFERENCES

