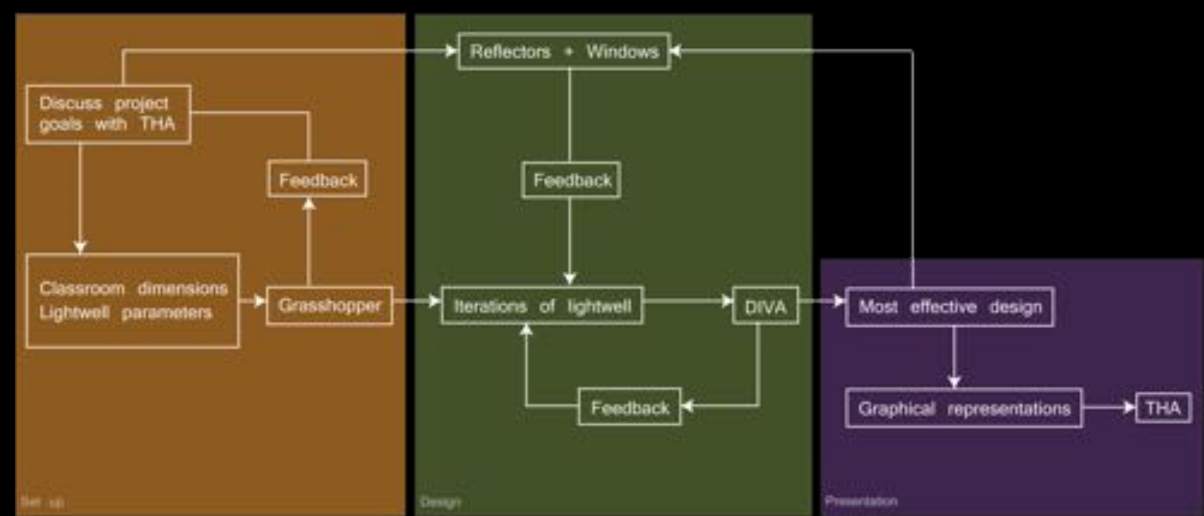
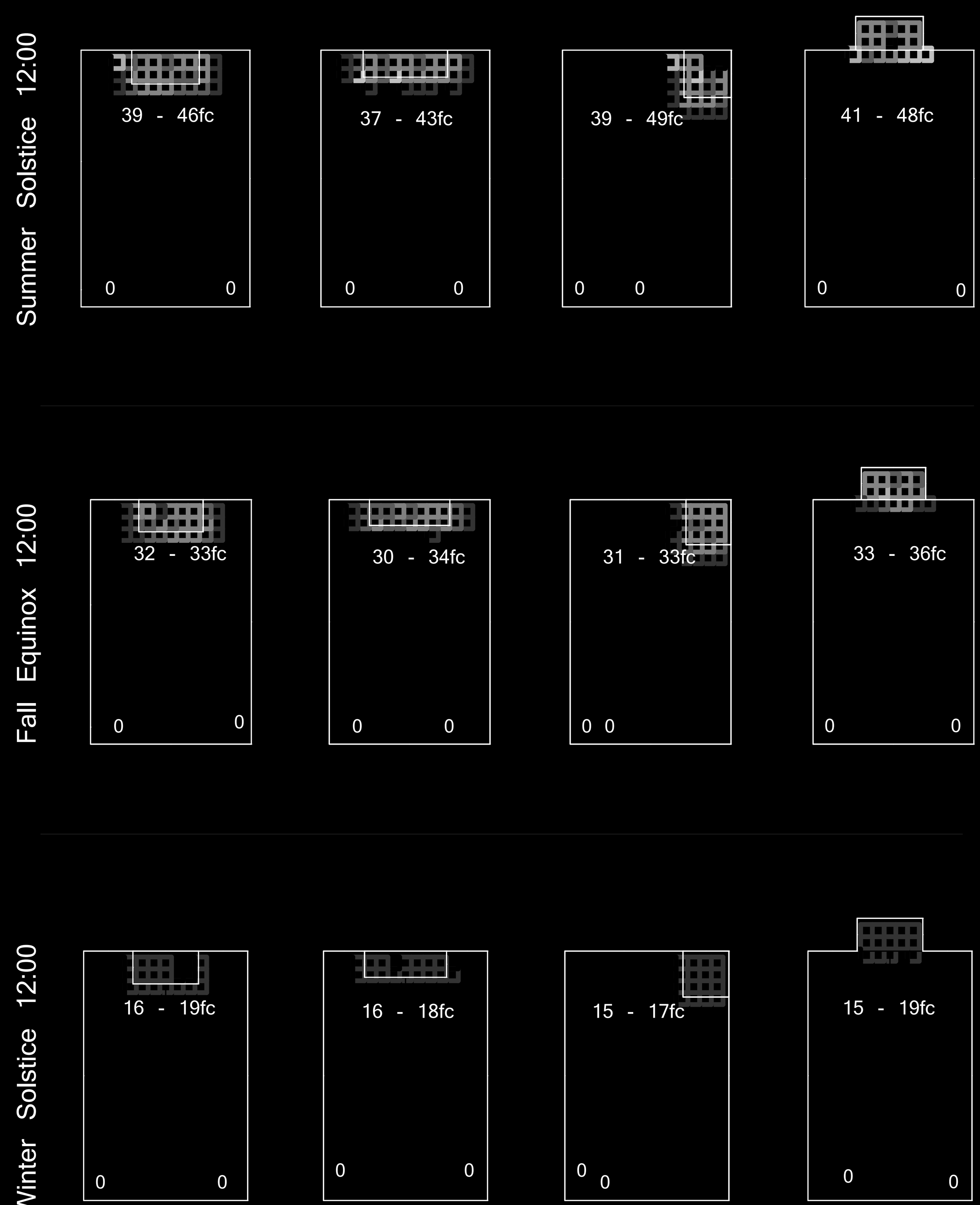
Maximixing daylight in lower level classrooms using lightwells

J. Primozich, R. Weber. Portland State University, School of Architecture Professor Corey Griffin and GBRL Liasion Ben Deines : THA Architecture Alex Zelaya and Stefee Knudsen

Methodology Diagram



Point in Time Lighting Analysis (lightwell only)

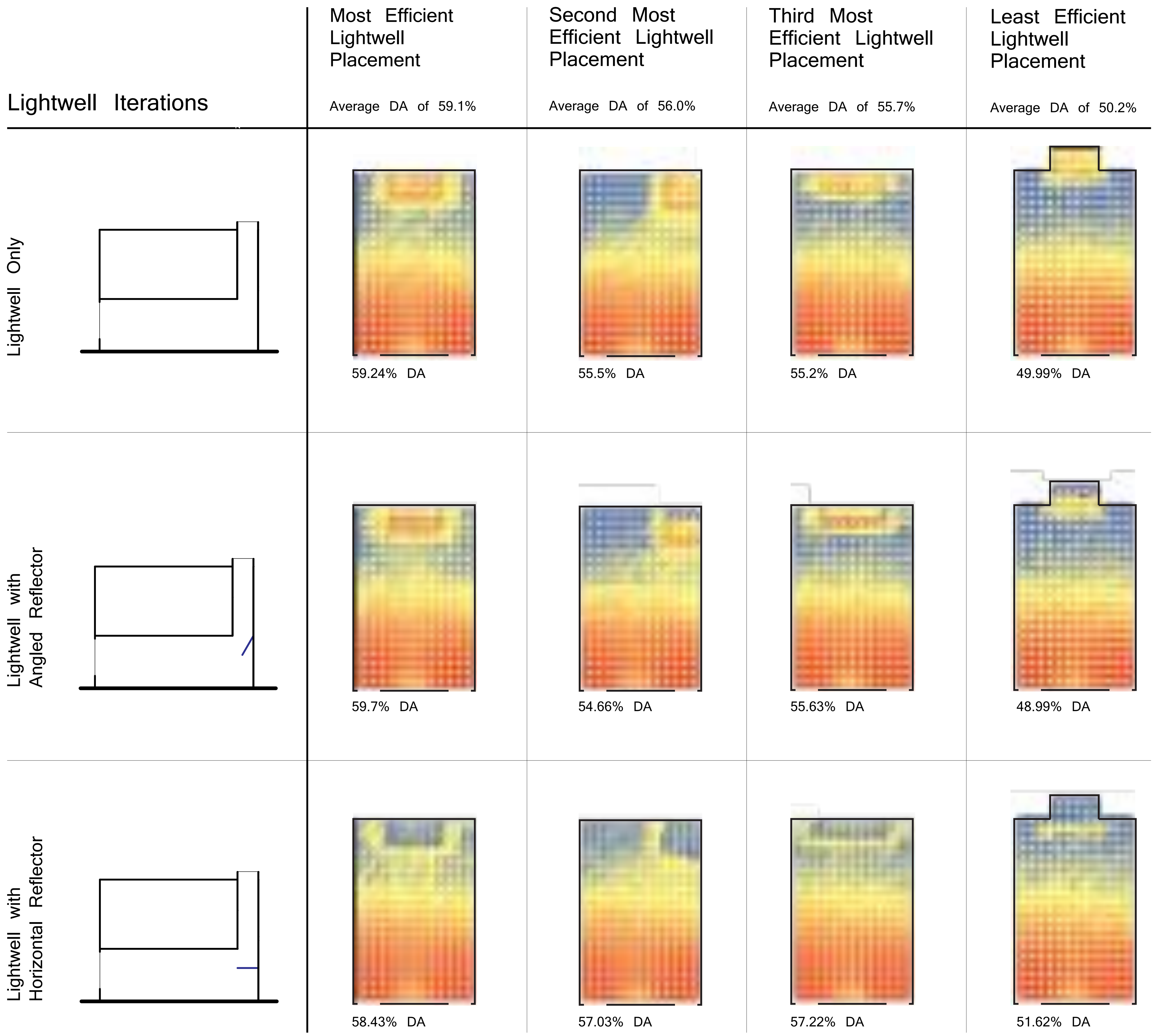


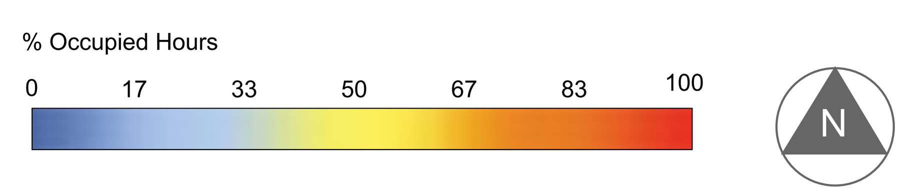
Program Workflow

"A lightwell improves the overall illuminance of the classroom by 5-10%."

"The horizontal reflector proved to be the most efficient iteration 78% of the time.

Daylight Autonomy Results : percentage of time classroom is above 30 footcandles





Introduction

Student and worker performance has been shown to share a correlation with access to natural sources of lighting (Heschong, 2002). Natural lighting also provides environmental benefits through the reduction of a building's energy dependence (Ihm, P., Nemri, A., Krarti, M., 2008). Lower-level classrooms are particularly troublesome to daylight because skylight strategies are unavailable and relying on exterior glazing increases solar heat gain as well as increased envelope costs. Lightwells offer a potential solution for daylighting without the costs associated with traditional solutions.

A lightwell is a vertical shaft extending from an opening in the roof structure to lower level rooms. The main design distinction between a lightwell and a skylight is the method of transmittance. Skylights provide direct sunlight while the lightwell has a highly reflective interior surface material that allows light entering from the roof opening to reflect down providing diffuse light into the space below. Lightwells with horizontal openings are more efficient in bringing in light in than vertical or slanted openings (Bouchet B., Fontoynont M., 1996).

This research, in coordination with Thomas Hacker Architects (THA), explores various configurations of lightwell design to maximize daylighting in the proposed classroom building on the Oregon Episcopal School campus.

The proposed building design is two levels with an allotted 950ft^2 of useable floor plan in lower level classrooms. The structural allowance for lightwell shafts is limited to 50ft^2. Ceiling height is limited to 12-½ft. This research focuses on the southern classrooms.

Methodology

Grasshopper was selected as the primary modeling software to provide researchers increased speed in generating iterations. The Grasshopper model set classroom dimension at 25ft by 38ft with a lightwell shaft height of 18-½ft for all iterations. Researchers were able to manipulate lightwell width and depth within the 50ft^2 tolerance and the lightwell position along the north wall of the classroom.

DIVA was selected as the primary daylight simulation tool to run daylight analysis on all iterations generated in Grasshopper. Researchers focused on year-round climate based daylight autonomy. While not a useful metric for understanding performance under extreme conditions--winter solstice with overcast skies and summer solstice with clear skies--daylight autonomy is useful to determine the average condition created by each lightwell design, which allowed researchers to quickly draw conclusions on the correlation between lightwell parameters and performance and hone in on the most effective design.

Researchers set DIVA parameters to calculate daylight on a 24in by 24in grid set 24in above the classroom floor. Material properties were set in DIVA with reflectance levels set as follows: lightwell rating of 90%; interior wall rating at 50%; ceiling rating at 80%; and classroom floor rating at 20%. All illuminance readings were in footcandles with the target level set at 30fc.

Once researchers had generated a set of high-performing lightwells, focus shifted to increasing performance through the addition of reflector shelves, one angled at 60° and one horizontal, placed at the bottom opening to bounce light deeper into the space. Researchers then added 30% glazing to the southern facade as two 5ft by 9ft openings and ran additional DIVA simulations to analyze total light conditions within the space.

Results

Lightwells placed fully within the classroom floor plan performed better than lightwells set back into the wall and lightwells centered along the back wall performed better than lightwells positioned in the corners--each bouncing light deeper into the space. Lightwell width had a greater correlation to light gain than did depth, distributing light more evening. From visual interpretation, horizontal reflectors performed better, spreading light more evenly throughout the space, likely as a result of bring the ceiling surface into play as a diffuser.

Conclusion

The results showed that a lightwell improves the overall illuminance by 5-10%. The optimal lightwell design was 10ft by 5ft, centered on the wall, and fully within the classroom floor plan. The placement was the same for the second most efficient lightwell, its dimensions were 4ft x 12-½ft. The horizontal reflector proved to be the most efficient iteration 78% of the time.

The data generated is limited in scope in that it does not look at extreme conditions or worst case scenarios. Discrepancy in materials used in the final design, such as wall coatings and colors, will also contribute to discrepancies in final performance. The research also does not account for room furnishings or a final glazing design for the southern facade.