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Optimizing Building Design and Glazing for Energy Reduction

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Objective

The goal of this research is to understand the early design implications of considering building energy goals through simultaneous optimization of dynamic facade materials and building geometry.

Rational

There are many design decisions that impact the energy use of a building. Some of those include building form, thermal envelope, and local climate[a] . A study was conducted by Hinkle and Sloane[a] to determine which design variables most significantly influence building energy usage in an ASHRAE climate zone 5 suburban setting. This research extends their work, focusing on optimizing building geometry and dynamic glazing for minimum energy usage during early design. This study simulates an office building in ASHRAE climate zone 2 in an urban environment, which constricted the geometric possibilities more than the previous case study. Potential energy savings are quantified for various optimization approaches.

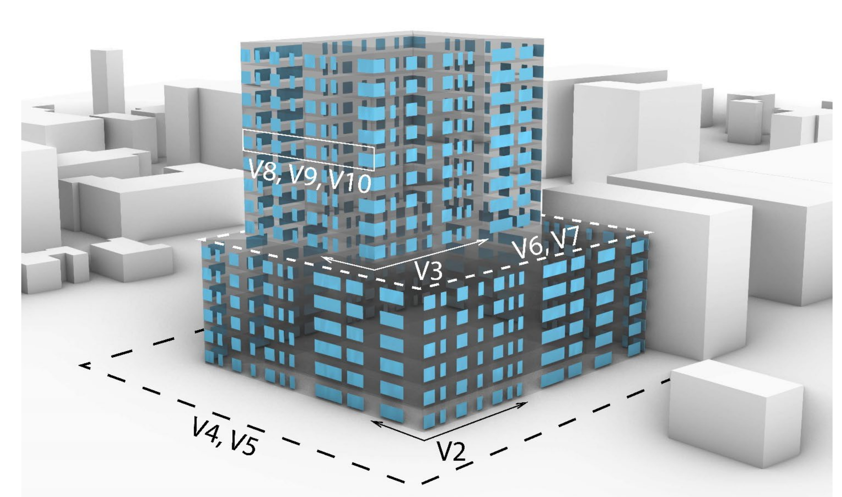
Methodology


b

Making the Model

1603 Broadway in San Antonio, was selected as the case study building. A parametric building model was generated in Grasshopper, and the energy use was simulated using EnergyPlus.

The building was designed with 10 geometric variables. For the dynamic glazing simulation The models has a custom view constraint placed on them to allow for desirable window visuals and lighting during optimization.



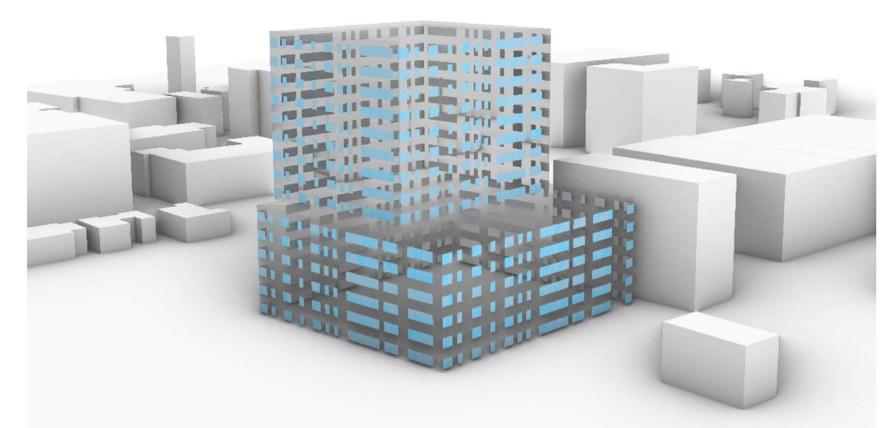
Geometric Variables
V1: distribution of building volume between tower and base
V2: base length-width aspect ratio
V3: tower length-width aspect ratio
V4: site location x
V5: site location y
V6: tower location x
V7: tower location y
V8: window sill height
V9: window head height
V10: transparent: opaque

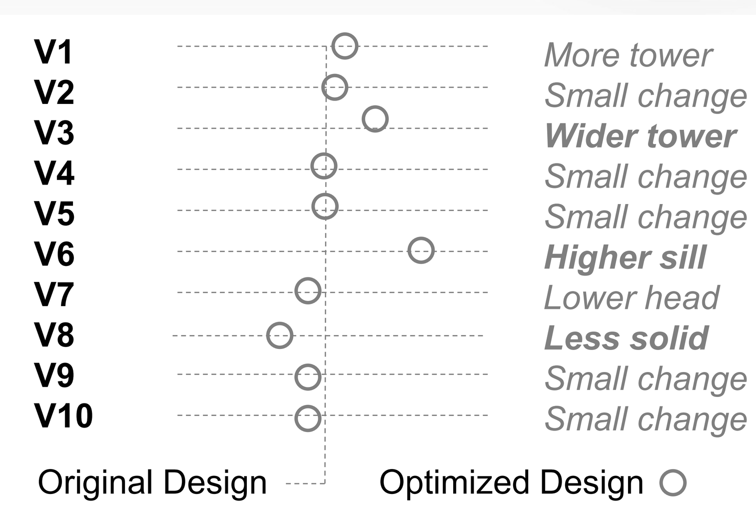
Facade Variables
SHGC
VLT
U-Factor

Results

Geometric Optimization

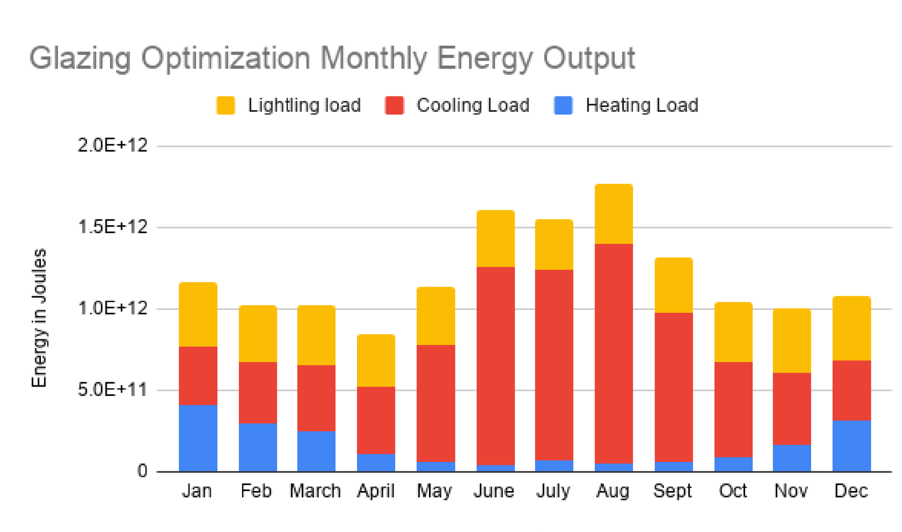
The geometric variables were optimized to find the lowest energy output based from the heating, cooling, and lighting loads. The most noticeable changes occurred in the width of the upper potion of the building, and the window sizing.

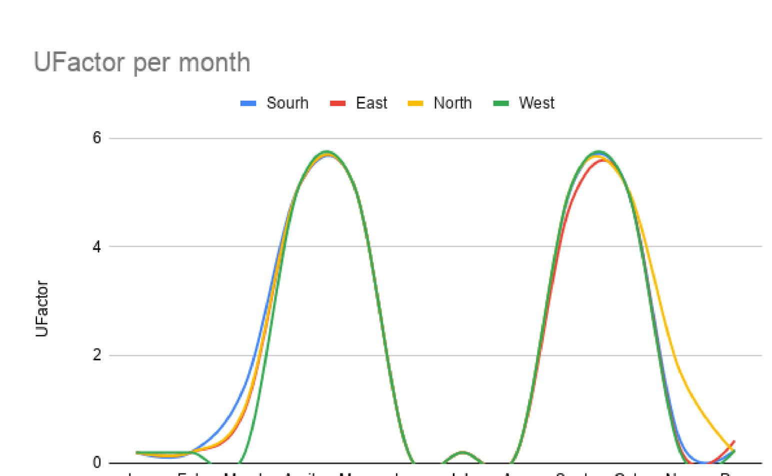


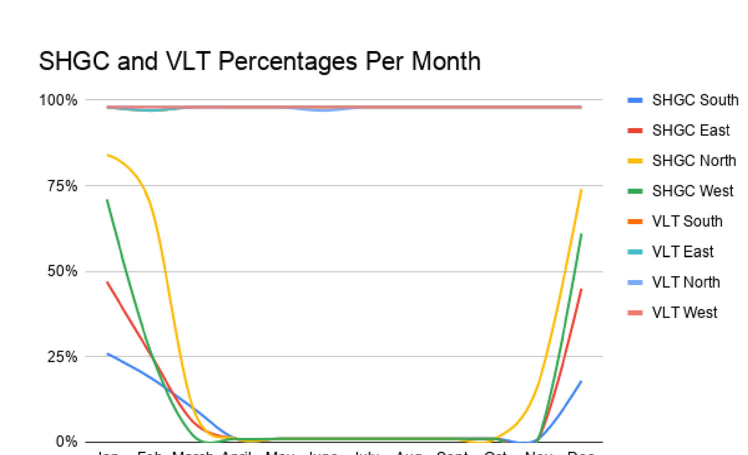


Dynamic Glazing Optimization

The dynamic glazing optimization found high SHGC in the winter, low SHGC in the summer, and a higher U-factor in shoulder months.

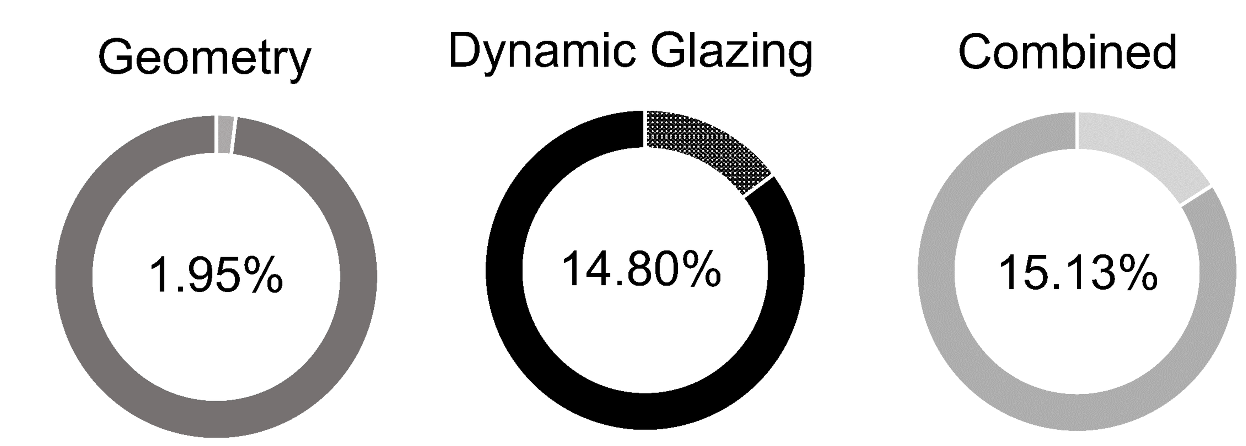






Summary

By optimizing the geometry, we were able to find slight savings on energy usage, which suggests some limitations of energy usage as a "form-giving" design strategy. Dynamic glazing yielded larger energy savings compared to 2019 ASHRAE standards. Combining the optimal settings from each optimization gained additional savings, but not as much as the geometry and dynamic glazing savings added together.



Conclusions

- Dynamic glazing has a greater impact on a building's energy use than geometry.
- Running geometric and dynamic glazing optimization simultaneously may result in increased energy savings.
- In comparing to the previous study, building orientation appears to have a strong impact on potential savings in geometry optimization, which is often inflexible in cities.

Future Work

Work toward an efficient way to optimize geometry and dynamic glazing simultaneously would allow for architects and designers to focus on designs that both were energy efficient and visually appealing to the clients. Future studies can also focus on the orientation of the upper level of the building when the footprint of a building can not be changed and constrain possible façade variable combinations to existing or emerging technologies.

References

a L. Hinkle and J. Sloane "Computational Design Optimization" AE 597 05/01/2020 – Spring 2020 Dr. Nathan Brown

b Glenser "1603 Broadway Project" https://www.gensler.com/projects/1603-broadway

F. Favoino, M. Overend, Q. Jin, The optimal thermo-optical properties and energy saving potential of adaptive glazing technologies, Appl. Energy. 156 (2015) 1–15. https://doi.org/10.1016/j.apenergy.2015.05.065.

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