Back to the Basics: Improving Building Performance Using Vegetation

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Introduction and Background

- The United States is the second largest carbon emitter in the world, while residential homes account for nearly 25% of the total energy consumed by the U.S.[2]
- Residential electricity contributes 20% to total U.S. CO_2 emissions.[4]
- Equivalent CO_2 emissions associated with high performance materials are often so high that they do not actually reduce total life cycle emissions.
- Retrofit strategies with low equivalent CO_2 emissions are necessary to mitigate consequential effects of global warming.
- Phoenix receives ~ 8 in. of rain per year with an average annual temperature of 75 °F. Summer months experience extreme heat waves.

Objective

Improve building performance and sequester carbon using plant-based retrofit strategies for a single-family home in Phoenix, AZ.

Methods

- A baseline model for a residential home was created using DesignBuilder software.
- One retrofit strategy was applied per simulation. Ten simulations were completed.
- Clay, earthen materials, and shading were applied to mimic the effects of vertical greenery systems and green roofs.

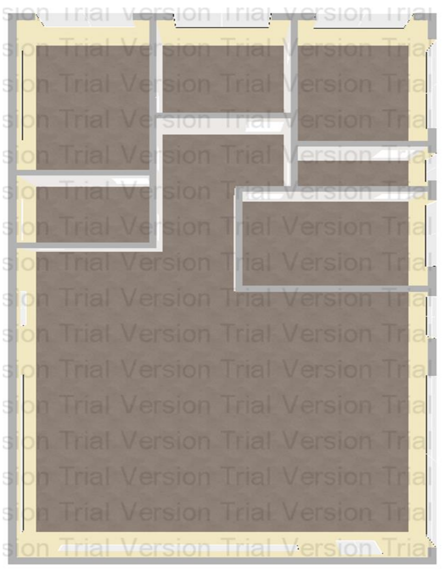

Figure 1. Floor plan for the baseline simulation Model.

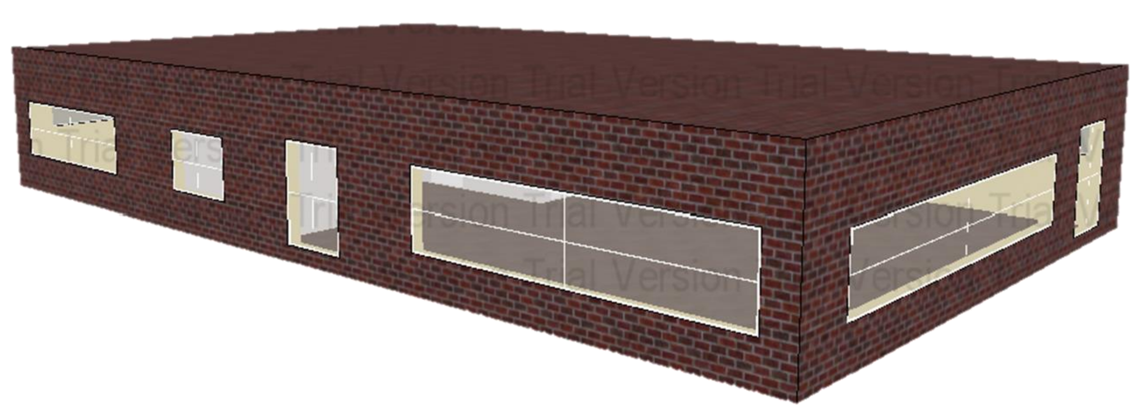

Figure 2. Rendered view of the baseline model showing the brick exterior and window to wall coverage.

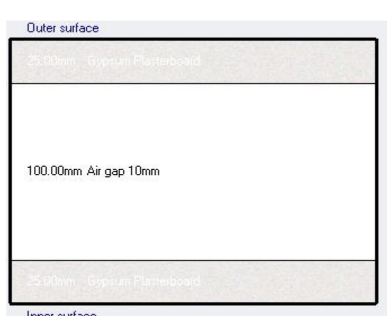

Figure 3. Baseline internal wall materials.

Figure 4. Baseline exterior wall materials.

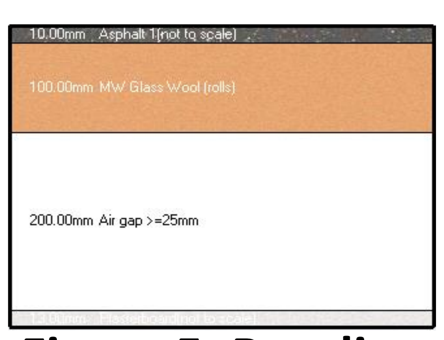

Figure 5. Baseline rooftop materials.

Results

Soil-based vertical gardens and green roofs save between 1,200 and 3,000 kWh per year, while the associated equivalent carbon emissions only increased by 1,400 kg CO_2.

Table 1. Results of ten simulations are shown below, lines are highlighted to showcase the retrofits that had improved energy efficiency with minimal increases in equivalent CO_2.

Retrofit Strategy	Energy Use (kWh per year)	Equivalent CO_2 (kg CO2)
Baseline	57,412.18	38,914.30
Solar rooftop installation- BIPV	54,412.18	58,914.30
Solar hot water rooftop installation	56,412.18	38,914.30
Alluvial clay, 40% sands (rooftop)	55,412.18	38,914.30
Cultivated sandy soil 25% dry-weight moisture (2cm-exterior walls)	56,972.16	39,024.00
Common earth (2cm-exterior walls)	57,293.62	38,994.40
Extra hard limestone (2cm-exterior walls)	56,970.43	39,056.90
Overhang 2m	57,412.18	38,914.30
Sage glass green window tint	57,412.18	38,914.30
Earthtube	57,491.01	38,914.30
LED lighting	57,412.18	38,914.30

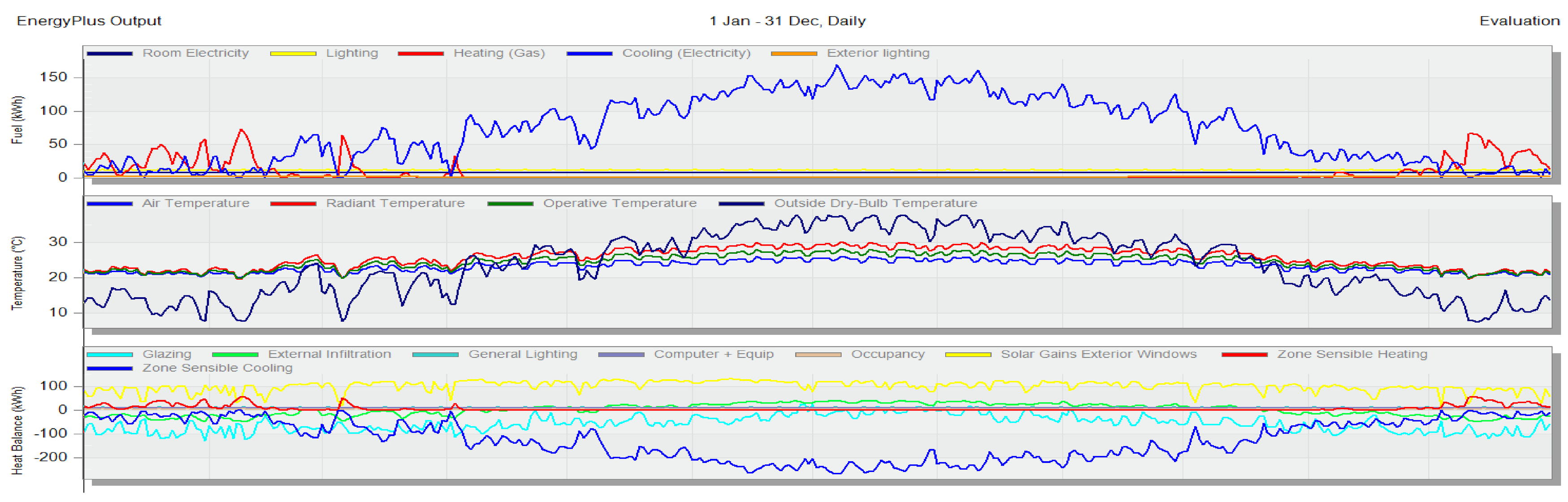

Figure 6. Correlation between cooling as the primary source for energy demand and the high temperatures of Phoenix.

As average temperature continues to rise due to climate change, so will residential demand for cooling. Soil-based greenery systems can absorb heat and provide shade to buildings, ultimately reducing heat load for HVAC systems.

Conclusion

Plant-based retrofit strategies:

- **Improve energy efficiency by providing shading and insulation.**
- **Have low associated equivalent CO_2.**
- **Improve ambient air quality, sequester carbon, and provide lively aesthetics to any home.[3]**

Future Work

Future work may entail the testing of various bioreactor designs. Algae bioreactors have the potential to turn buildings from energy consumers into energy producers. For instance, microalgae can sequester up to 3% more carbon than other plant life and supply heat to the building.[1]

Acknowledgments

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References

[1] Dutt, Florina, Steven Jige Quan, Erik Woodworth, Daniel Castro-Lacouture, Ben J. Stuart, and Perry Pei-Ju Yang. “Modeling Algae Powered Neighborhood through GIS and BIM Integration.” Energy Procedia, 8th International Conference on Applied Energy, ICAE2016, 8-11 October 2016, Beijing, China, 105 (May 1, 2017): 3830–36. https://doi.org/10.1016/j.egypro.2017.03.896.

[2] Kaza, Nikhil. “Understanding the Spectrum of Residential Energy Consumption: A Quantile Regression Approach.” Energy Policy, Energy Efficiency Policies and Strategies with regular papers., 38, no. 11 (November 1, 2010): 6574–85. https://doi.org/10.1016/j.enpol.2010.06.028.

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