

Proposed High-Energy Performance HVAC Solutions for the LabZero Building at the University of Brasília

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Introduction

The building sector contributes significantly to global energy consumption and carbon emissions, with buildings in Brazil using about 50% of the country's electricity. The LabZero project, part of the PROCEL EDIFICA program, aims to showcase Near Zero Energy Building (NZEB) principles through bioclimatic design and advanced HVAC strategies. This study focuses on the development and analysis of two high-efficiency HVAC solutions proposed for LabZero: a geothermal heat exchanger and a solar chimney.

Methods

This project methodology followed a multi-step approach:

- A statistical analysis of 50 global ZEBs.
- Simulations for the LabZero building in DesignBuilder.
- Geothermal heat exchanger design.
- Solar chimney design and simulation.

Data Presentation and Discussion

Geothermal Heat Exchanger Design

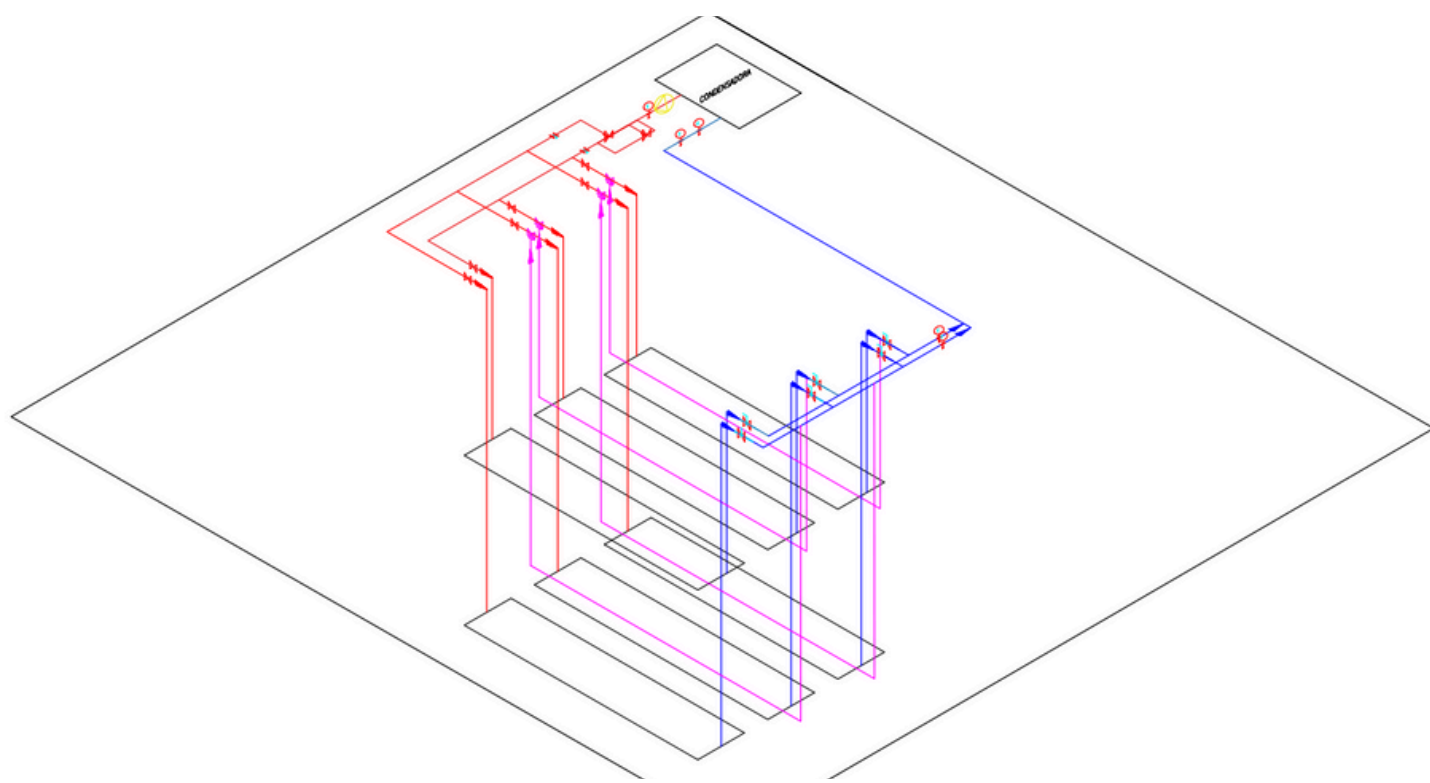
- Developed to cool the condensate water from the direct expansion air conditioning unit for LabZero.
- System design: Shallow horizontal heat exchanger with compact spiral loops.

Calculations based on the analogy between thermal and electrical resistances, with radial heat transfer equations from referenced studies applied to model the system's performance.

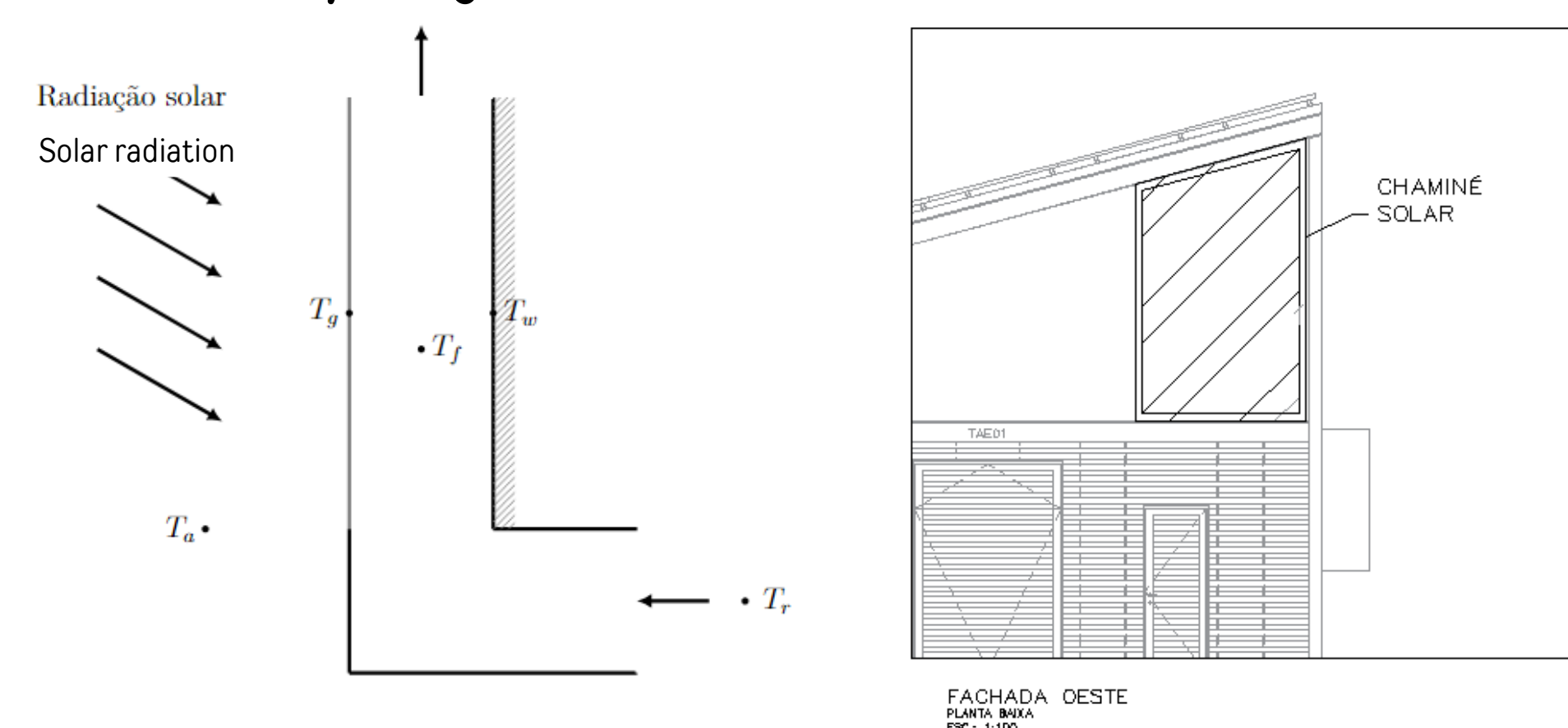
$$R_{\text{total}} = R_{\text{water}} + R_{\text{hose}} + R_{\text{soil}}$$

$$R_{\text{total}} = \frac{1}{\frac{\pi \cdot D_o \cdot L \cdot (K_{\text{water}} \cdot Nu)}{D_i} + \frac{\ln(D_o/D_i)}{2 \cdot \pi \cdot L \cdot K_{\text{hose}}} + \frac{\ln(D_o/D_i)}{2 \cdot \pi \cdot L \cdot K_{\text{soil}}}}$$

The design used a thermal conductivity value of 1.95 W/m·°C, with a thermal load of 7,320 W and rejected heat of 9,769 W (calculated in DesignBuilder). It required 640 meters of 1-inch polyethylene tubing, arranged in two spiral layers (-3 m and -6 m depths) over a 128-meter trench. The system includes valves for flexibility and experimental control.



Solar Chimney Design



- A vertical solar chimney model was chosen to be installed on the west façade.
- Design and performance analysis based on the mathematical model developed by Bansal.
- Python code developed to calculate temperatures of the absorber wall, glass wall, and air in the channel

Calculations were made to determine the generated flow rate and analyze results, using the following key equations

Energy balance equation for the glass cover:

$$S_1 A_g + h_{rwg} A_w (T_w - T_g) = h_g A_g (T_g - T_f) + U_t A_g (T_g - T_a)$$

Energy balance equation for the air between glass cover and absorber:

$$h_w A_w (T_w - T_f) + h_g A_g (T_g - T_f) = q''$$

Energy balance equation for the absorber wall:

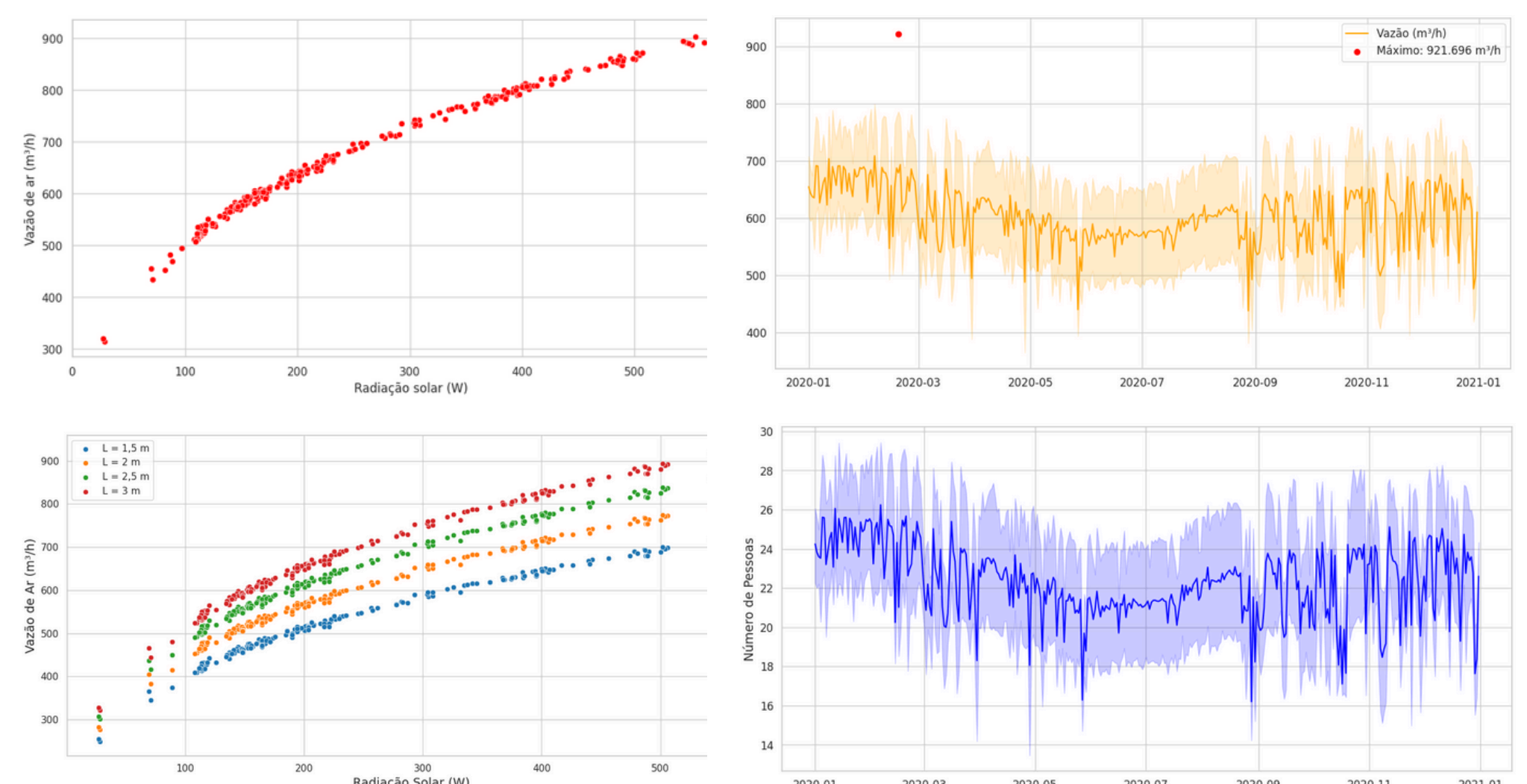
$$S_2 A_w = h_w A_w (T_w - T_f) + h_{rwg} A_w (T_w - T_g) + U_b A_w (T_w - T_r)$$

Airflow rate:

$$V = C_{\text{room}} [h H A_{\text{hot}} (T_{\text{wall}} - T_0)]^{1/3}$$

Performance Analysis:

- Solar radiation was directly proportional to airflow.
- Increasing absorber wall height (1.5 to 3.0 m) improved airflow.
- Thickness variations (0.2 to 0.4 m) showed minimal effect, optimal airflow at 0.4 m.
- Wall width (1 to 2 m) had no significant impact.
- Airflow between 9 a.m. and 5 p.m. ranged from 400 to 920 m³/h, with a maximum of 920 m³/h.
- Solar chimney met airflow requirements: 6% of hours for 30 people, 65% for 20 people, and 92% for 15 people.



Conclusion

- The research emphasizes the importance of selecting appropriate HVAC technologies for Net Zero Energy Buildings (ZEBs), based on regional climate.
- Geothermal heat exchanger for LabZero shows potential as a sustainable alternative, particularly in tropical areas.
- A Solar Chimney, when combined with other technologies, can enhance energy efficiency and support sustainable building design.

References

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