Reducing Carbon Dioxide (CO2) Emissions in Residential Buildings Through Envelope Renovation

Samuel Aires Master Lazaro *[1], Li Xiangyu [1], Vanessa Fathia Baba [2]

[1] College of Civil Engineering, Taiyuan University of Technology, No. 79 West Street Yingze, Taiyuan, Shanxi, PR China

[2] College of Economics & Management, Taiyuan University of Technology, No. 79 West Street Yingze, Taiyuan, Shanxi, PR China

* Corresponding author e-mail address: samuelaires01@gmail.com

Key Insights

- The construction sector significantly drives global CO_2 emissions.
- Historically, economic priorities have overshadowed sustainable design choices.
- Lifecycle-based environmental impact assessments are increasingly adopted.
- Low-carbon materials, such as sustainable concrete, reduce embodied emissions.
- Energy-efficient designs substantially lower operational carbon footprints.

Methods

1) Base Case: Developed Mozambique residential model using DesignBuilder, meeting local standards.

Figure 1. 3D Model

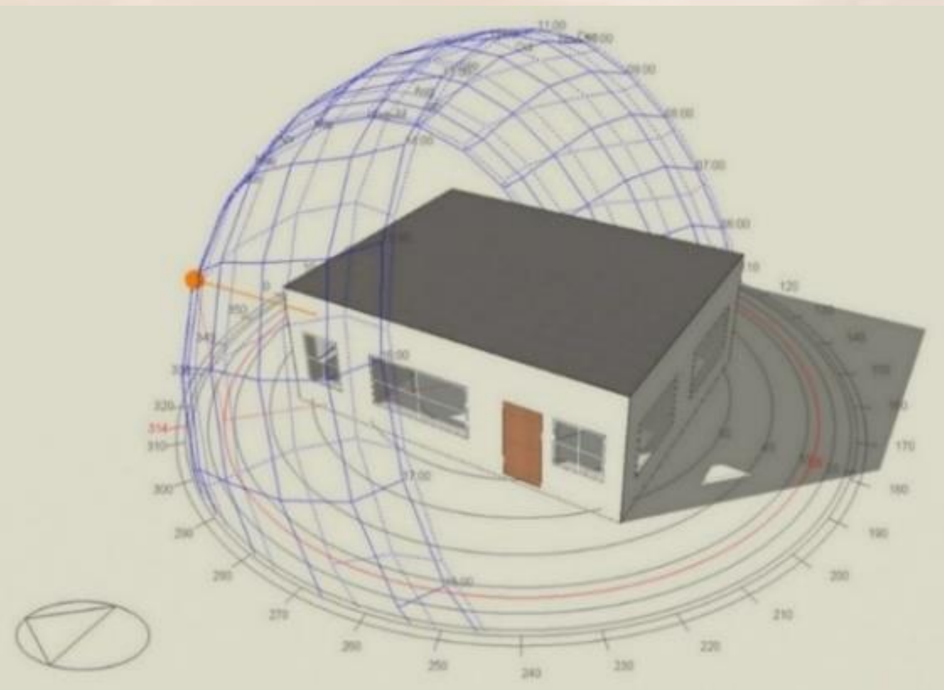


Table 1. Selected Building Characteristics

Façade and orientation	Front elevation south face
Number of floors	1
Plan shape	Rectangular
Total height	3.5 m
Floor area	80 m 2
Total volume of the building	280 m 3

2) Thermal Analysis: Evaluated building components' heat transfer for optimal performance.

Building element	Description of layers	Total thickness (mm)	U value (Wm−2 K)
External Walls	20 mm cement plaster 225 mm hollow blocks 10 mm cement plaster	255	1.862
Internal walls (partitions)	12 mm cement plaster 200 concrete hollow block 12 mm cement plaster	224	1.408
Roof (Pitched)	20.0 mm cement plaster 319.0 mm concrete, reinforced (with 2% steel) 20.0 mm ceramic/porcelain	359	3.218
Doors	3 mm plywood layer 34 mm thick foam core plywood 3 mm plywood	40	0.230
Floor (ground)	10 mm ceramic glazed tile 150 mm Concrete slab 304.8 mm Compacted soil	464,8	1.508

3) Cost-Benefit Analysis: Evaluated EPS insulation's economic viability, balancing initial costs with energy savings and HVAC cost reductions over building lifespan:

$$DPP = i_{NPV(i)=0}$$

$$NPV = \sum_{i=0}^{T} \frac{CF}{(1+r)^i} - i_0 \geq 0$$

4) Environmental Impact: Quantified CO2 emissions reduction:

$$RCDE = \frac{CDEPOP - DEPMP}{DEPMP} \times 100\,\%$$

Results

- **CO_2 Emissions:** Annual CO_2 emissions of 3.27 kg decreased by 42.20% through optimized energy-efficiency interventions.

Figure 2. Monthly CO_2 Emissions Comparison

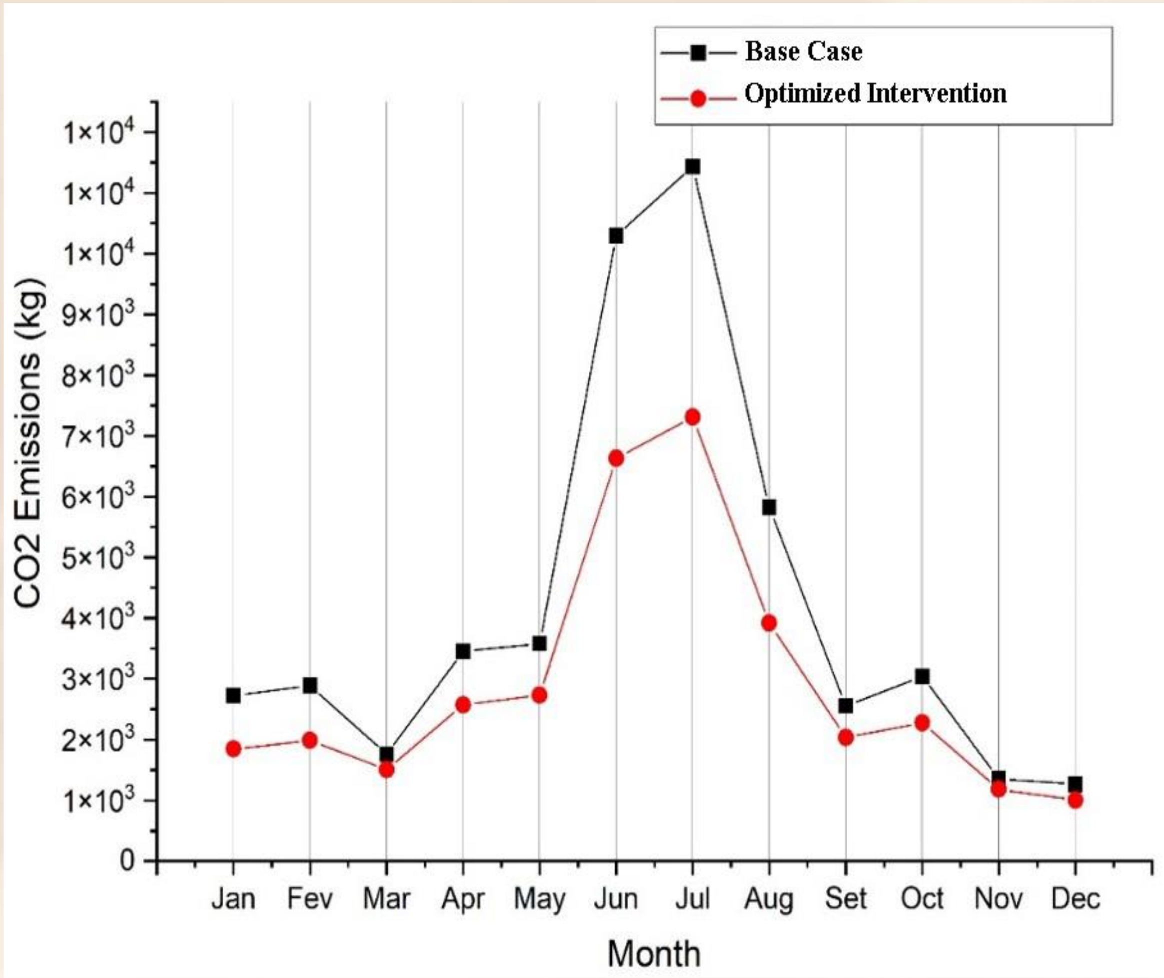
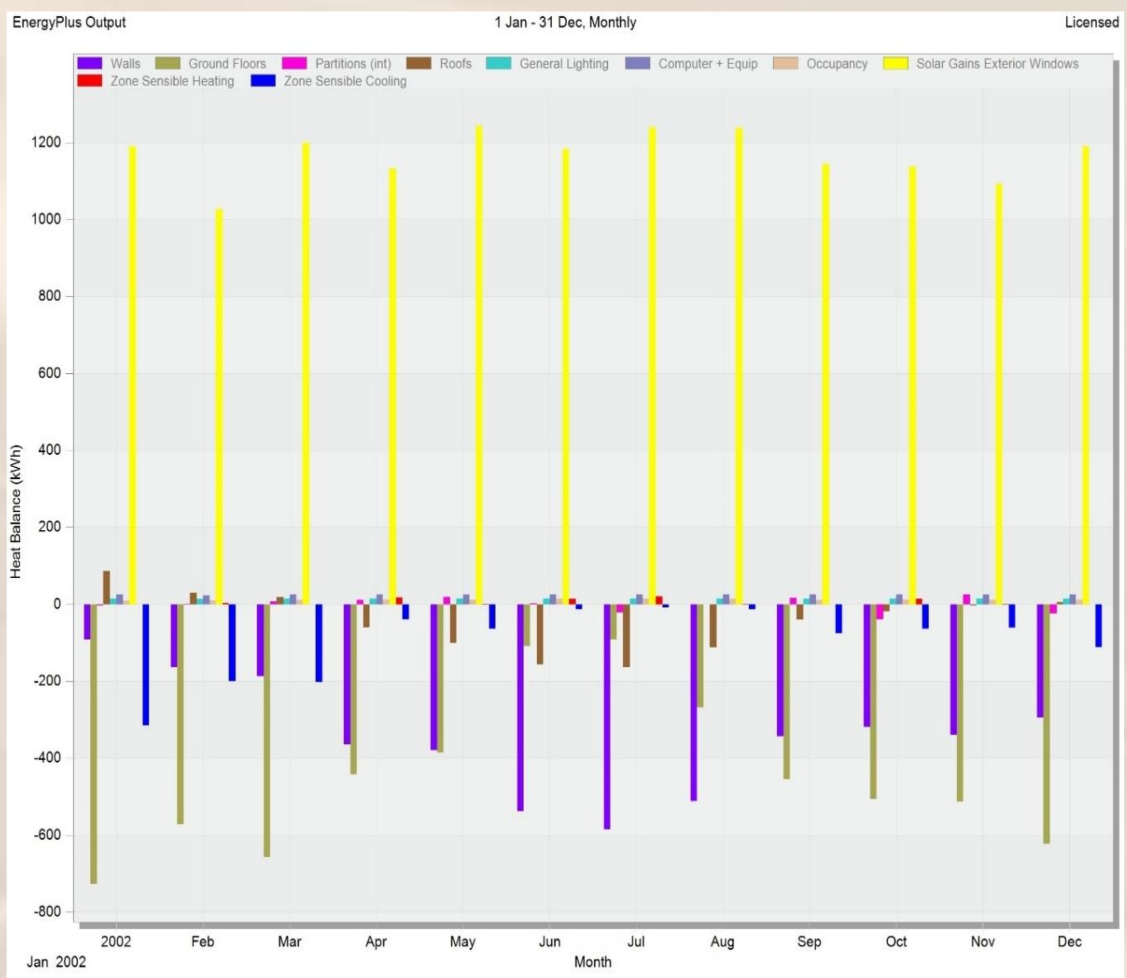


Figure 3. Building Heat Gains/Losses Post-Optimized Interventions



- **Energy Performance:** The annual energy consumption of 3,118.69 kWh was reduced by 42.14% through optimized energy-efficient measures.

Figure 4. Monthly Energy Consumption Comparison

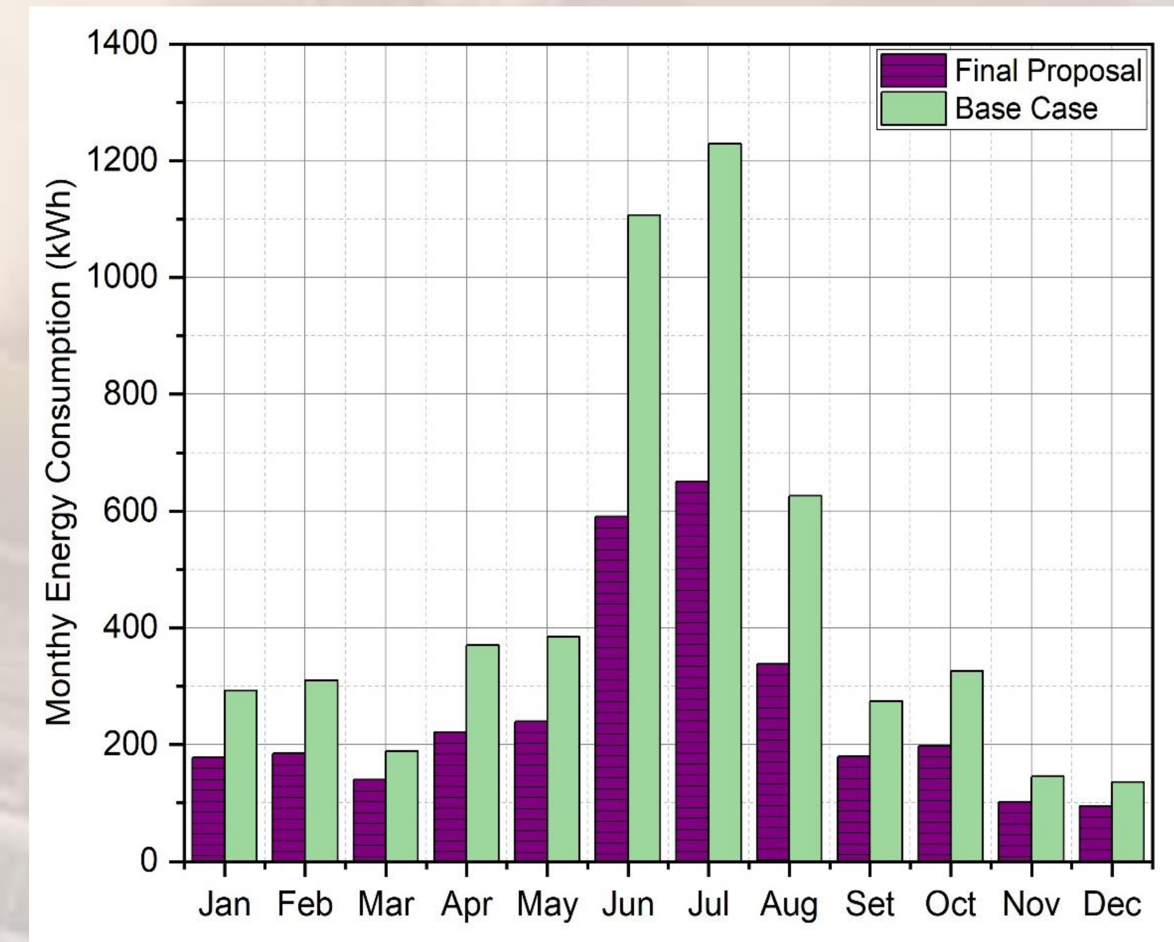


Table 3. Modifications Parameters

Parameters	Base Case	Final Proposal with Passive Design Strategies
	Exterior windows: single glazing 6 mm/wood, aluminium, and no frame	Exterior windows: Double glazing 6 mm/13 mm filled with air/wood frame
	Roof: without thermal insulation	Roofs: EPS 95 mm installed insulation
Annual electricity consumption (kWh)	5,392.04	3,118.69
Energy saving (kWh)	0.00	2,273.35
Energy saving (%)	0.0	42.14

Table 4. Modification Parameters

Exterior Window	Roof	CO2 emission reduction rate (%)
Exterior windows: single glazing 6 mm/wood, aluminium, and no frame (Base case)	20.0 mm cement plaster 319.0 mm concrete, reinforced (with 2% steel) 20.0 mm ceramic/porcelain (Base case)	0
Double Glazing 6 mm/13 mm Filled with Air/Wood Frame	20.0 mm cement plaster 319.0 mm concrete, reinforced (with 2% steel) 20.0 mm ceramic/porcelain 95 mm EPS	42.20%

- **Cost Analysis:** At a 9.95% discount rate, the 7.27-year payback period indicates a viable, moderately risky investment.

Table 5. Preliminary Investment Costs

Intervention	Unit Cost 1	Total Cost 1
Exterior windows: Double glazing 6 mm/13 mm filled with air/wood frame.	MZN 3,450/m 2	MZN 38,364.00
Roofs: These have thermal insulation	MZN 507,02 /m 2	40,561.6
Builder specialist	MZN 2,256.16/day	15,793.18 /2 weeks
		94,718.78 MZN
		Total Cost 1

1 The prices are expressed in Mozambique New Metical (MZN), 1 USD = 63.90 MZN

Conclusions & Recommendations

- Use EPS panels and double-glazed windows to reduce energy use and CO2 emissions.
- Provide subsidies to promote the adoption of sustainable construction materials.

Acknowledgements

We sincerely thank all contributors and global partners for their dedicated efforts in advancing cleaner air and sustainable environments in Mozambique and beyond.

References

[1] Adeyemi, A. B., Ohakawa, T. C., Okwandu, A. C., Iwuanyanwu, O., & Ifechukwu, G.-O. (2024). Energy-efficient building envelopes for affordable housing: design strategies and material choices. *Energy.*

[2] Iamin, E., Kamaruzaman, N., & Kamar, H. M. (2023). A pragmatic retrofitting approach to enhancing the thermal, energy and economic performance of an educational building: a case study in Malaysia. *Clean Energy.*

[3] Antonini, E., Boeri, A., & Giglio, F. (2020). Emergency driven innovation. *Innov Technol Knowl Manage.*