Cost-Benefit Analysis of Dwelling Retrofit Options

The objective was to study the thermal behaviour of the existing house and suggest cost effective improvements. Over recent years the energy efficiency and occupant thermal comfort of buildings in South Africa have become more important considerations to occupants. Holistic building energy modelling allows you to learn about the thermal behaviour of your new or existing building. Within the constraints of each project, building modelling engineers can determine key areas of improvement and operation of your new or existing building.

Project brief and constraints

The existing beach house in the Western Cape of South-Africa was studied to learn about possible future improvements in the facade. The owners were looking for easy cost effective solutions to improve the thermal comfort of the building.

The building and model

The building energy model was created from drawings and site measurements.

Figure 1 The house in Hermanus (South Africa), and plan drawings.

Building Façade:

- Plastered cavity walls
- Single glazing with aluminium frames
- Glass wool insulation 50mm
- Shutters on select north, east and west windows.

Other estimated building settings:

- Lighting: combination of Non-LED lights [10 W/m2]
- Infiltration: 0.75 ach before noon, 1.5 ach after noon. (Wind normally picks up)
- Temperature control: 19 - 25°C

Figure 1: Building Energy Model

The heat balance and peak cooling in summer

The building is located in a mild climate, and experiences summer conditions for most of the year. Cooling is achieved by means of natural ventilation, and overheating is reduced by movable louvres on select windows. The study focused on the effect of using the louvres and where possible cost effective future improvement can be considered. During occupied hours most heat enters as solar radiation through the windows, warm air infiltration or through the roof.

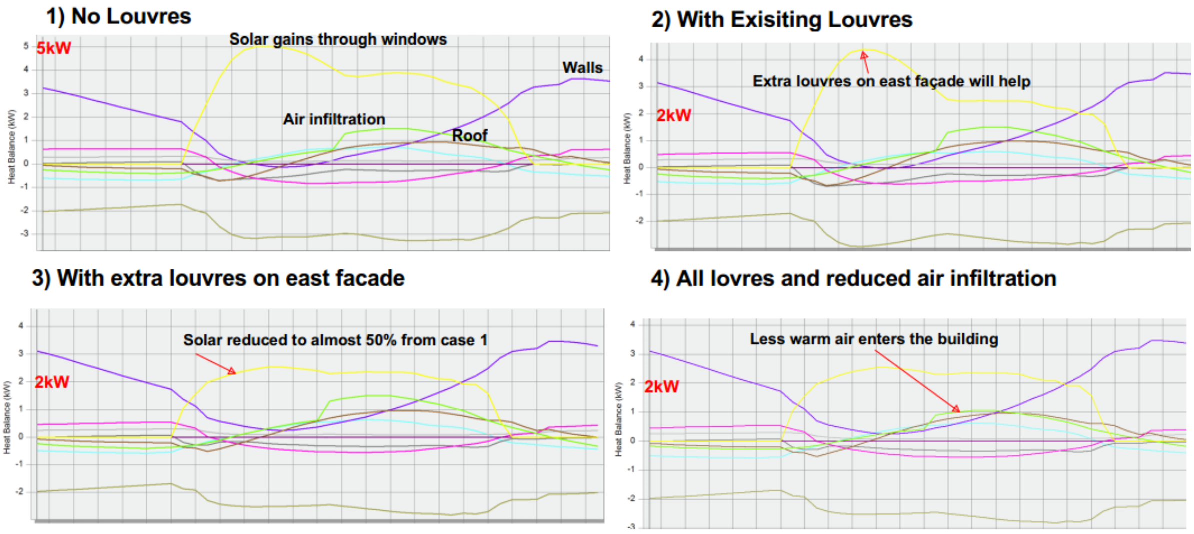


Figure 2: (1) No Louvres – existing, (2) Existing Louvres (3) Modification 1 – extra louvers on East, (4) Modification 2 Improved air-tightness

What is the maximum amount of heat that can typically be removed by natural ventilation?

The CIBSE guide AM10, "Natural ventilation in non-domestic Buildings" notes the following. 'As a general rule of thumb, it is generally agreed that natural ventilation systems can meet total heat loads averaged over the day of around 30 to 40 W/m2 (i.e. solar plus internal gains)'. It can be seen that when louvres are used on warm summer days the result is close to this benchmark for most rooms except the upper living room.

		m2	Existing		Modified	
	Summary per zone		Watts/m2			
		Area	No Louvres	With Louvres	Extra Eastern Louvres	Extra Eastern Louvres and improved air tightness
Important rooms	1.KitchenAndDining:Kitchen	12	37	37	30	25
	1.KitchenAndDining:Dining	17	55	41	41	38
	2.UpperLiving:Living	29	66	66	61	57
Less important rooms	4.Garage:Bath	3	36	36	32	32
	4.Garage:Garage	38	31	31	30	30
	3.Bedrooms:Bed3	15	32	22	22	19
	3.Bedrooms:Passage	10	21	20	20	16
	3.Bedrooms:Bed1	12	43	32	32	29
	3.Bedrooms:BathEast	4	47	44	44	40
	3.Bedrooms:BathWest	4	33	33	33	33
	3.Bedrooms:Bed2	11	30	19	19	15
	Building Total		42	37	36	33
	Building % improvement			10	15	21

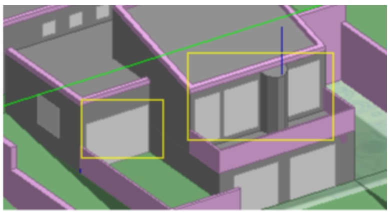
Table 1: Comparison of peak summer building cooling loads with two simple modifications considered.

What do we learn from the results (Figure 2 and Table 1)?

1. Cavity walls show the good thermal lag effect.
2. The effect of louvres reduces the solar heat entering the building (20-40% reduction).
3. Additional louvres on 3 windows on the east facade will significantly reduce heat load in early morning. This small modification reduces heat entering the whole building by 5%.
4. Improved air tightness (50% improvement) will reduce heat entering the building by an additional 10%.
5. The building is likely to be comfortable with only natural ventilation.

Heat balance and peak heating in winter

The building requires heating predominantly from July to September. In the winter we want to keep heat inside the building – especially in the living areas. The effect of new improved windows on the southern facade was studied. This will reduce unwanted air infiltration and provide better insulation.



	m2	Existing	Modified	
		Watts/m2		
	Area	Single	Single Low E	Double Low E
Dining	17	91	87	79
Living	29	116	113	107
% improvement for the whole building			3	9

Figure 3: improved glazing on the southern façade only.

Heat balance for a typical winter day shows heat predominantly being lost though the walls, roof, windows and by means of air infiltration. The replacement of southern glazing will improve the insulation of the building, and reduce loads by almost 10%.

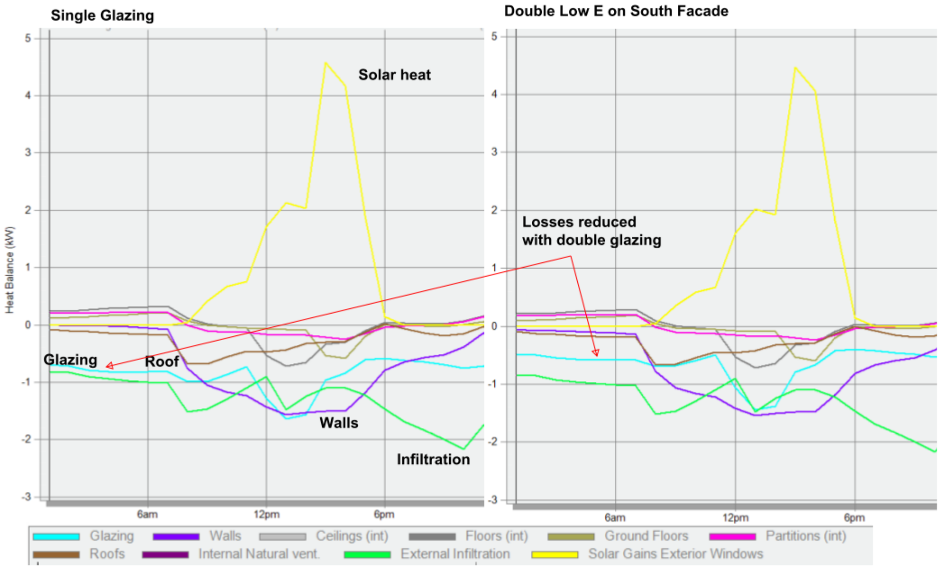


Figure 4: Building heat balance (left) only single glazing, (right) south facade replaced with double Low E glazing.

The building requires a heating system to keep air temperatures comfortable in winter. The owner decided to install an efficient biomass heater fuelled with sustainably produced wood or invasive species.

Double glazing provides additional insulation as shown in **Figure 5**. This improves occupant thermal comfort because inside surface temperatures are more comfortable.

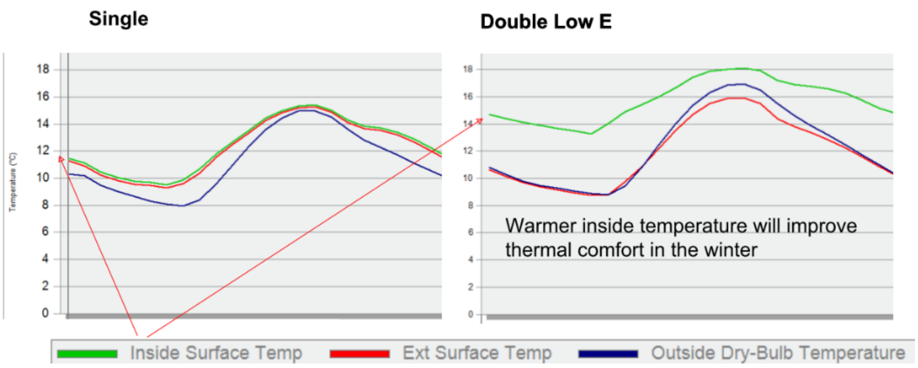


Figure 5: A comparison of glazing surface temperatures on a south facing living room window (left) single (right) Double Low E.

Thermal comfort in the living room

“That condition of the mind which expresses satisfaction with the thermal environment” [ASHRAE 55]

Winter Thermal comfort

Heating systems are typically designed to achieve thermal comfort by maintaining the air temperature above 22°C. Thermal comfort is however affected by various parameters, not only air temperature. Thermal comfort is typically measured by using the Fanger predicted mean vote (PMV) index where below (-1) is cold and above (+1) is warm.

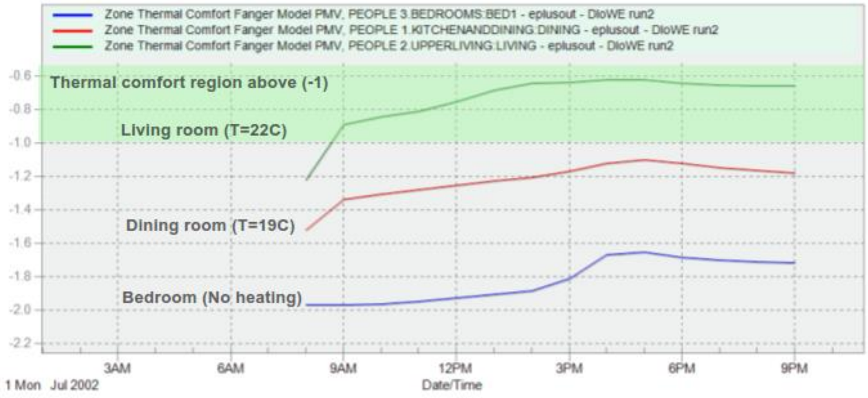


Figure 6: Fanger PMV Thermal comfort is shown with and without heating for different rooms.

Better insulated buildings, will have milder surface temperatures (or radiant temperatures) as shown previously in **Figure 5**. The mean radiant temperature is the average of all surface temperature in a space. Milder mean radiant temperatures will improve thermal comfort in a space as shown below. Therefore the thermal comfort near single glazing is worse than near double glazing due to the human perception of radiant asymmetry.

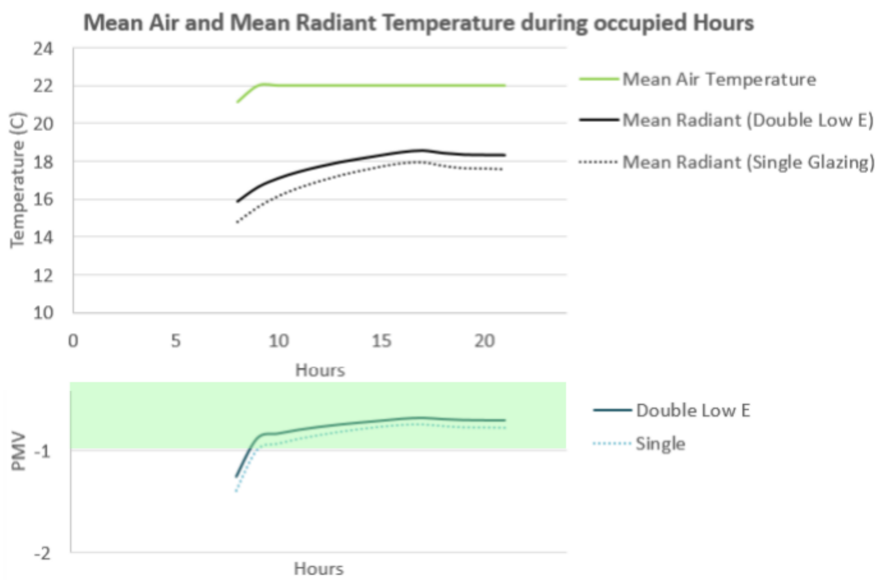


Figure 7: Typical winter day - Southern side of living room shows milder radiant temperature and improved thermal comfort when using double glazing instead of single glazing. Results are displayed for occupied hours.

A well-insulated facade with higher performance glazing reduces winter heat loss and improves thermal comfort in the winter. Therefore it can be considered in the main living spaces, especially for a new building. However, due to the mild South African climate single glazing is likely to often take advantage in the cost-benefit analysis over double glazing options for residential buildings.

Below is a CFD representation of the heated living room with single glazing. It shows mostly comfortable conditions (PMV >-0.8) except near the large eastern window which is further away from the heater.

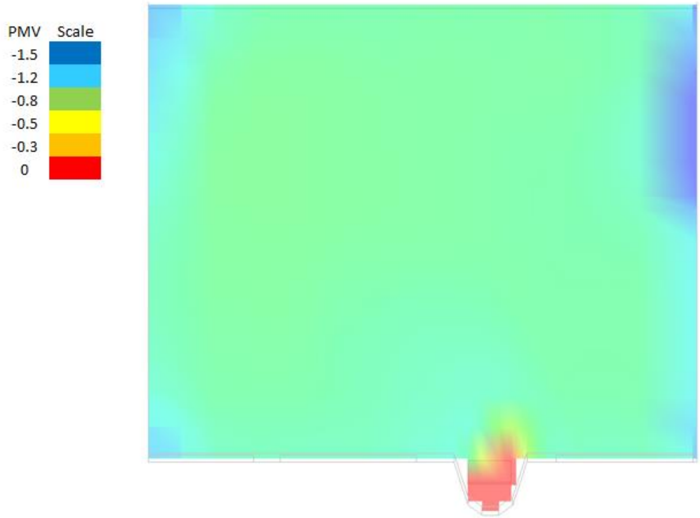


Figure 8: CFD representation of the predicted thermal comfort of the heated living room with air temperature maintained at 22°C, at 10:00 in the morning.

Summer thermal comfort

A typical summer day with free floating temperatures in the living room is shown in **Figure 9**. When outdoor temperatures are lower, natural ventilation can further reduce the air temperatures in the room.

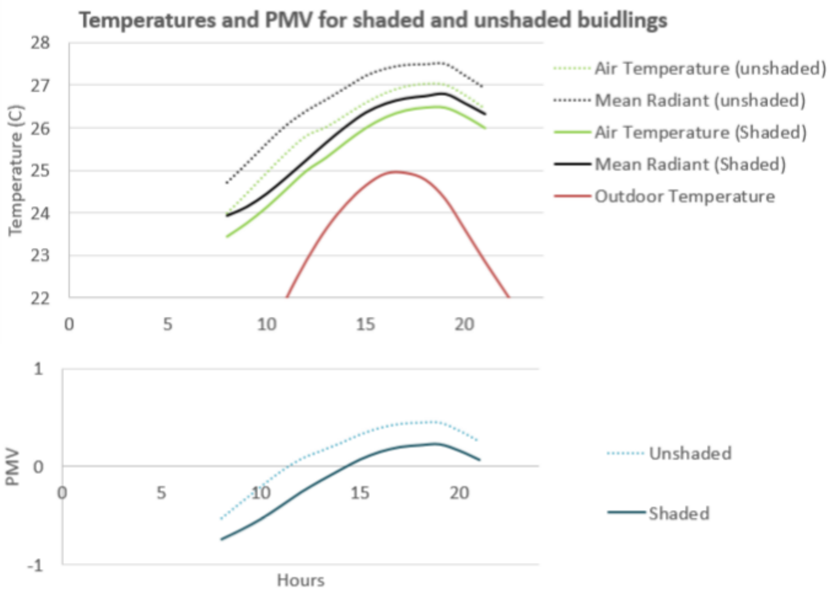


Figure 9: Typical summer day – with free floating temperatures in the living room. The results are shown with and without shading devices on. Results are displayed for occupied hours.

Below is a CFD representation of the naturally ventilated living room. It shows comfortable conditions (mostly PMV <0.4) except near the large eastern wall which was heated by the early morning sun.

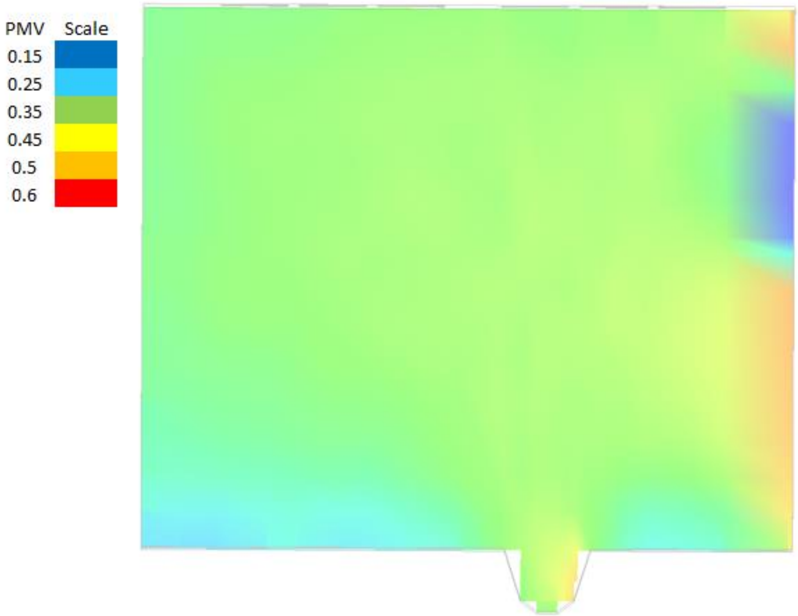


Figure 10: CFD representation of the predicted thermal comfort of the unshaded naturally ventilated living room at 15:00 in the afternoon.

Final remarks on annual thermal comfort improvement

The results from an annual thermal simulation showed that by adding additional shading devices (for summer) and a suitable heating system (maintaining winter temperatures above 22°C) improved thermal comfort from 70% to 98% on the PMV scale during occupied hours in the living room.

Greenplan consultants

Greenplan Consultants is a consulting engineering firm and DesignBuilder reseller in South Africa. We offer specialized building performance modelling services, mainly on indoor comfort and energy sustainability, for small and large scale projects. We conduct assessment modelling for Green Star SA and local government regulation (SANS 10400 XA). Our focus is on sustainable building design relying primarily on passive design concepts.

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