Opaque Components Solar Heat Gain Analysis of a Passive Solar House

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Background

- The components of thermal envelope comprises of the perimeter walls, roof, floor, windows and doors.
- These components are responsible for thermal load of a house.
- The aim of this study is to analyze the solar heat gain (SHG) through the opaque components of a passive solar house in Alice, Eastern Cape.

Synopsis

- Opaque Solar Heat Gain
- Site and House Description
- Methodology
  - *Meteorological measurements*
  - *Thermal zoning*
- Results and Discussions
- Conclusions

Opaque Solar Heat Gain

- The steady and unsteady state heat gain through a wall is given in Equation (1) and (2), respectively;
- $$Q = U(t_o - t_i) \qquad (1)$$

Where Q = Heat gain (W/m^2)
U = thermal transmittance coefficient (W/m^{2}K)
t_o and t_i = Ambient and indoor temperature (°C)

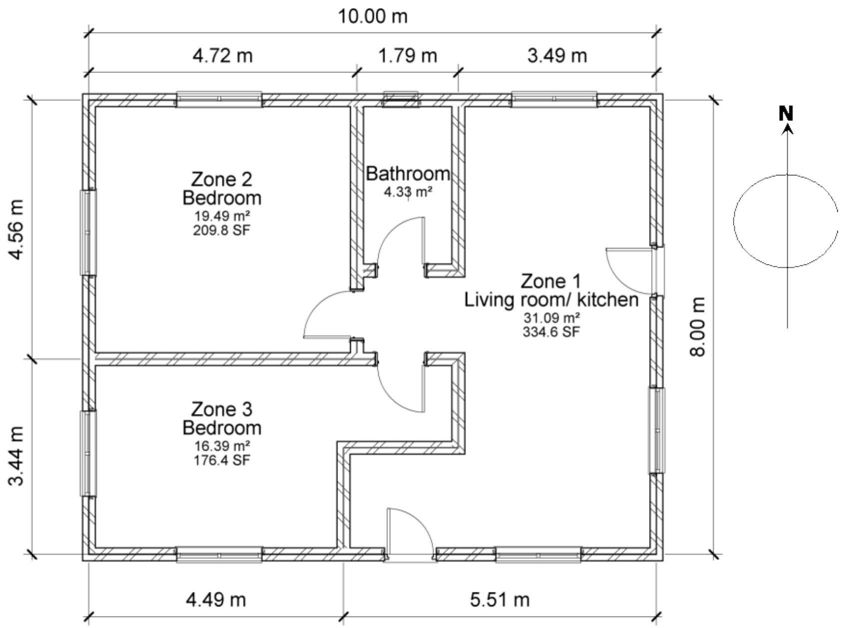
- $$Q_\theta = AU(t_{eo} - t_i) \qquad (2)$$

Where Q_θ = Solar heat gain (W)
A = Surface area of the wall exposed to solar radiation
t_{eo} = Sol-air temperature (°C)

- Sol-air temperature is given as;
- $$t_{eo} = t_o + \frac{\alpha I}{h_o} - \frac{\Delta q_{ir}}{h_o} \qquad (3)$$

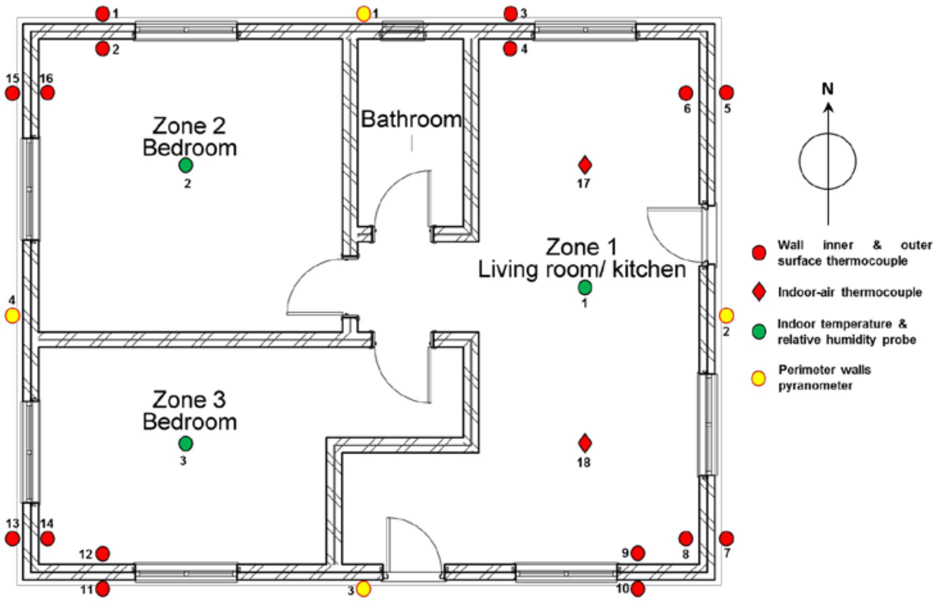
Where h_o = Surface heat transfer coefficient (W/m^{2}K)
α = Absorptance of the surface
I = Global solar irradiance on the wall surface (W/m^2)
∇q_{ir} = Correction to infrared radiation transfer between a surface and the enviroment

Site and House Description



- A passive solar house in the SolarWatt Park at the University of Fort Hare, Alice campus was used as a case study.
- Alice is located in latitude 32.8° south and longitude 26.8° east at an altitude of 540 m in the Eastern Cape of South Africa.
- The house has a floor area of 10 m x 8 m (80 m^2), an open plan living room, north and south facing bedroom.
- The two large north facing windows allow solar penetration to the living room and the north facing bedroom.
- The north facing clerestory windows channels solar radiation to the southern area of the floor space.

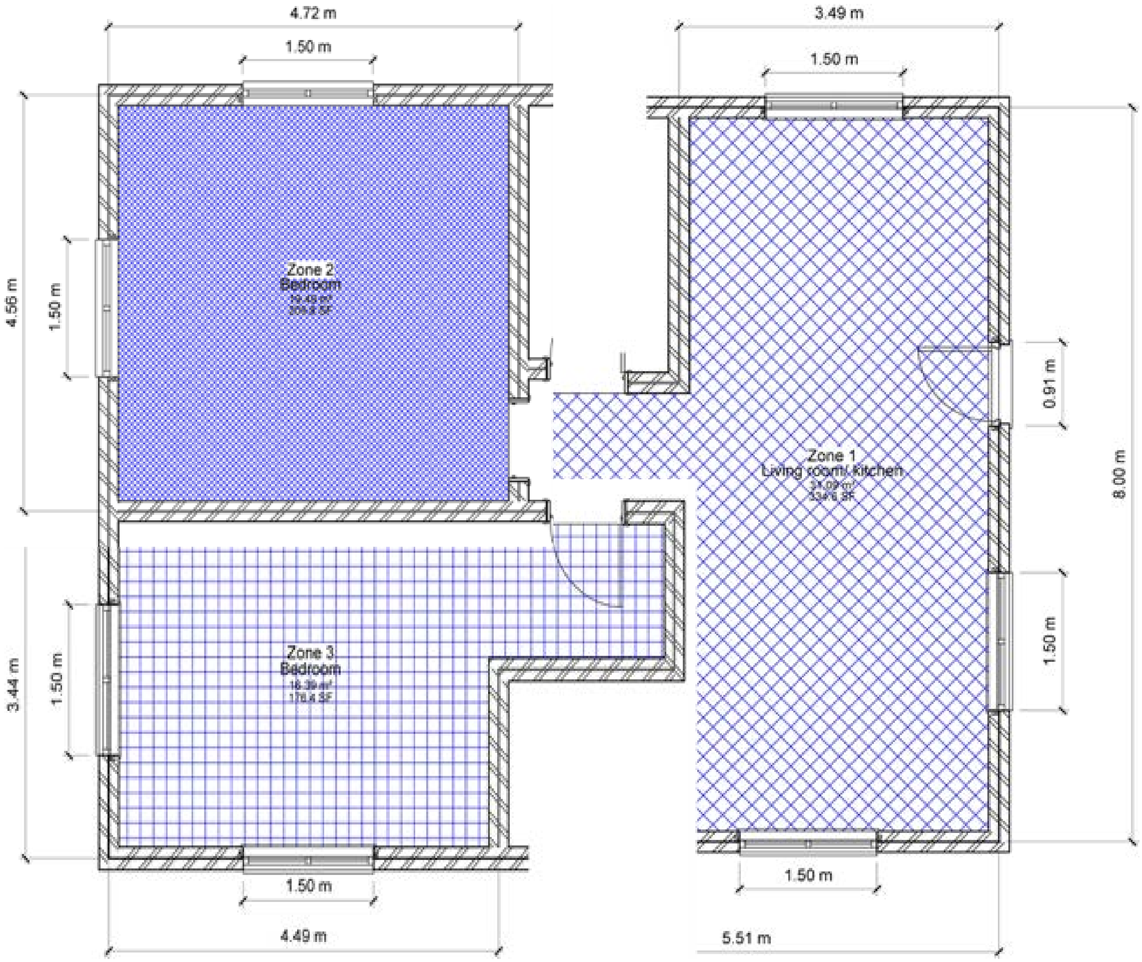
Methodology
-Meteorological measurements



- A total of 18 type K thermocouples were used to measure the inner and outer surface temperatures of the house perimeter walls.
- The indoor air temperature was measured with HMP60 temperature relative humidity probes.
- A silicon photovoltaic cosine-corrected (Li-Cor) pyranometer was used to measure the global solar irradiance on each surface of the perimeter walls.
- CMP 11 Kipp & Zonen pyranometer and sheilded HMP 60 temperature relative humidity probe were used to measure the global horizontal solar irradiance and ambient air temperature, respectively.

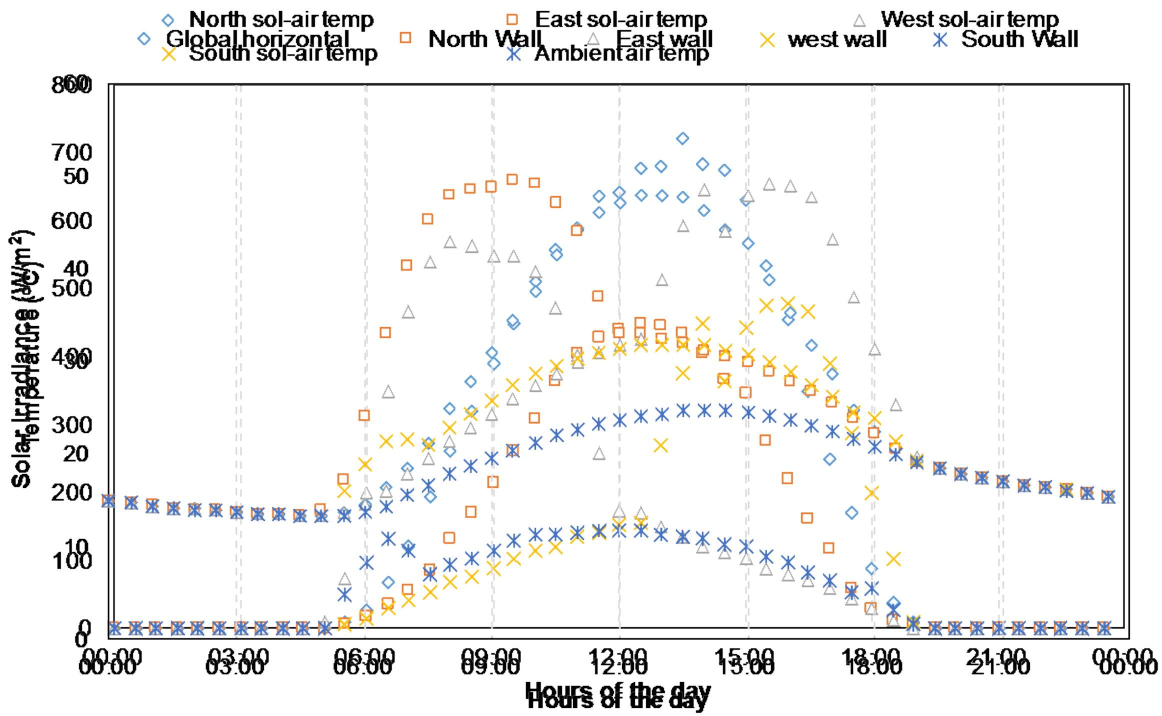
Methodology

-Thermal zoning



- According to the ISO 13790, thermal zoning is the partitioning of building into different zone, with separate thermal energy calculation for each zones.

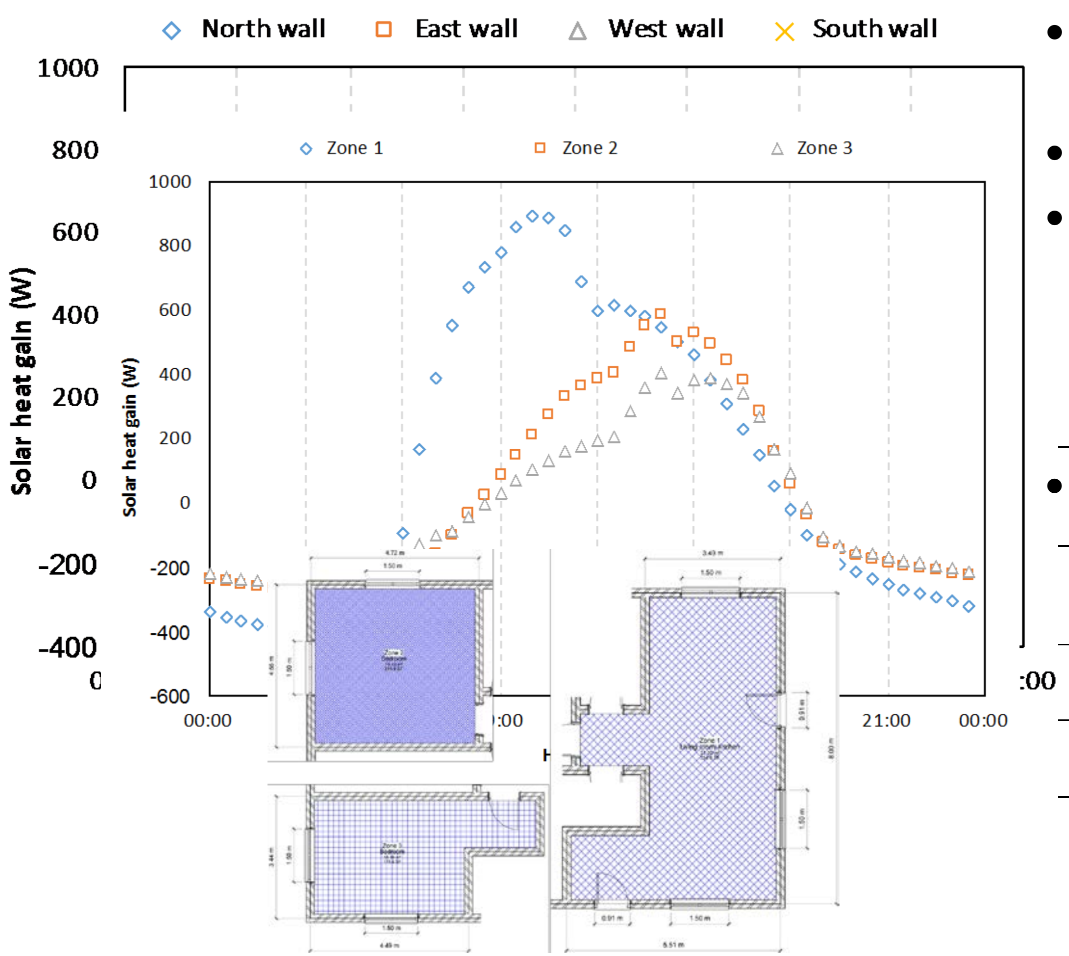
Results and Discussions



- The highest solar irradiance of 568.48 W/m² was observed on the east wall at 8h00.
- The south wall received the least solar irradiance, attaining a maximum of 145.82 W/m² at 11h30.
- The dip in the west wall solar irradiance distribution, results from the shadow of the deciduous tree planted at the west side of the house.

- Theoretically, sol-air temperature is the effect of the ambient temperature on the indoor thermal condition of a house in the present of solar radiation.
- In the absents of solar radiation, air temperatures around each of the perimeter walls were relatively equal.
- The air temperature (sol-air temperature) around each of the walls varies according to their respective surface solar irradiance.

Results and Discussions



- Zone 1 bounded by the north, east and south walls; its SHG increase rapidly from 6h00 to 11h30
- Likewise, zone 2 and 3 with the west wall as a common boundary, their SHG peaks at approximately 15h00.
- The area of the graph below indicate the amount of heat lost through the walls. While areas above zero represent amount of heat gain.
- Heat is not always lost to the out environment.

Zone	Perimeter walls	Exposured surface area (m^2)	Floor area (m^2)	Heat gain/floor area (Wh/m^2)
1	North East South	8.28 17.05 2.72	31.09	24.04
2	North West	8.57 8.05	19.49	17.42
3	West South	8.02 8.45	16.39	12.85

Conclusions

- The SHG peaks in each zone correspond with the solar irradiance peaks of the outer surface of the boundary walls
- Houses facing north; the north, east and west walls receive significant SHG, while the south wall has a relatively lower SHG.
- Spaces that do not require thermal conditioning should be located at the south or east of south end of the floorplan.
- Active area like the living room, bedrooms, etc. should occupy the north, east of north and west of north.
- Solar heat generated during the day can be utilize for space heat at night.

Acknowledgements

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