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Thermal simulation of different construction types in six climatic regions on heating and cooling loads

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INTRODUCTION

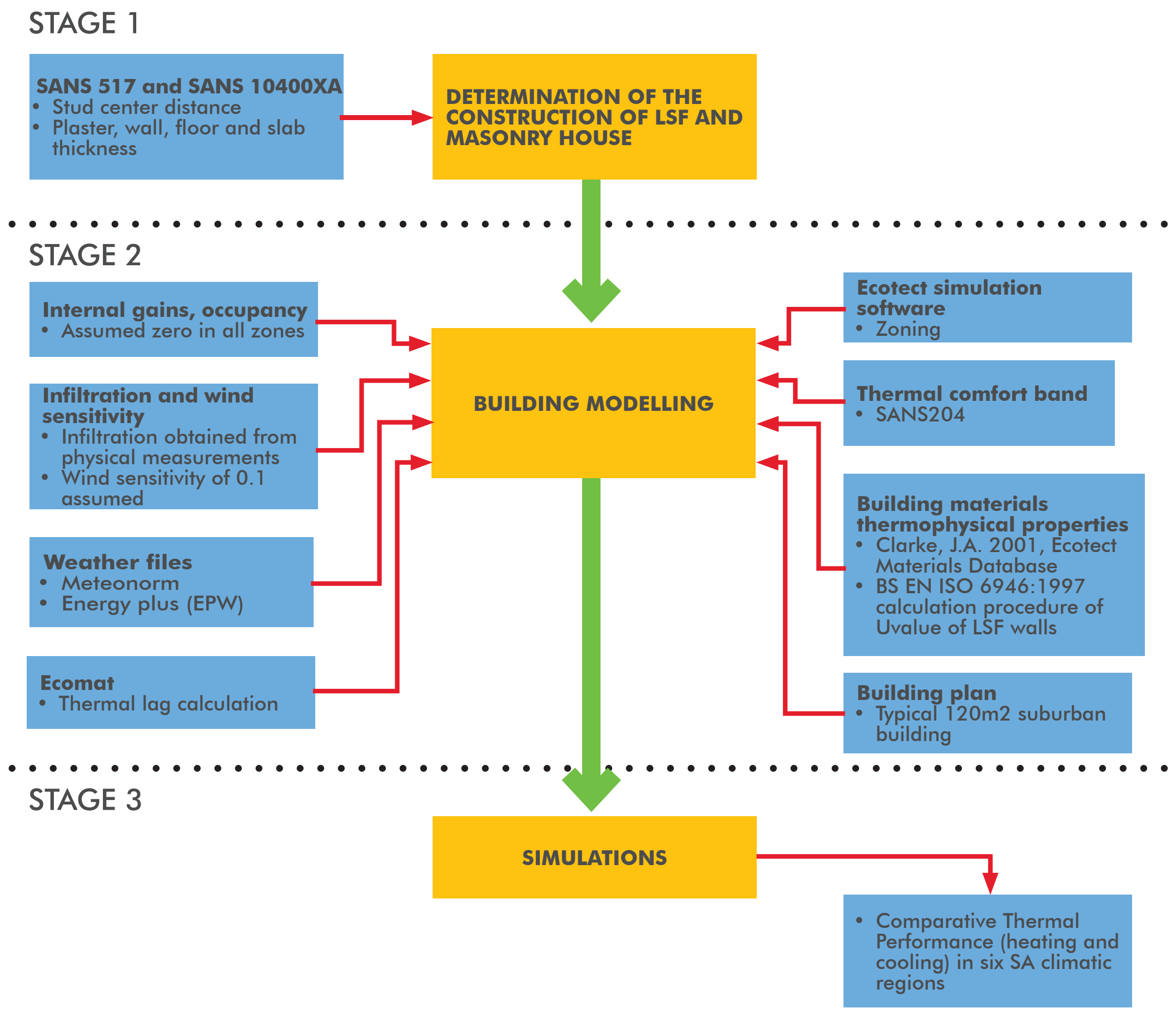
Buildings in South Africa are designed with little regard to passive heating and cooling techniques (Lombard et al., 1999); therefore indoor thermal environments are uncomfortable leading to high electrical energy consumption from heating, ventilation and air conditioning (HVAC) systems. HVAC loads require an estimated 4 000 gigawatt hours of electricity per annum (Eskom, 2010); this load could be reduced by 50–75% through the adoption of appropriate passive interventions. This, in turn, would significantly reduce the nation's energy bill and positively contribute to environmental impact and climate change mitigation, as well as alleviate uncomfortable indoor conditions experienced by many citizens (Clarke, 2001).

A thermal simulation model was prepared for a "typical" suburban building of 120m² and nine different passive designs were simulated to evaluate their impact on the heating and cooling load.

Figure 1: Construction of a Light Steel Frame (LSF) building

Figure 2: Construction of brick building

METHODOLOGY



STAGE 1

SANS 517 and SANS 10400XA
- Stud center distance
- Plaster, wall, floor and slab thickness

DETERMINATION OF THE CONSTRUCTION OF LSF AND MASONRY HOUSE

STAGE 2

Internal gains, occupancy
- Assumed zero in all zones

Infiltration and wind sensitivity
- Infiltration obtained from physical measurements
- Wind sensitivity of 0.1 assumed

Weather files
- Meteonorm
- Energy plus (EPW)

Ecomat
- Thermal lag calculation

BUILDING MODELLING

Ecotect simulation software
- Zoning

Thermal comfort band
- SANS204

Building materials thermophysical properties
- Clarke, J.A. 2001, Ecotect Materials Database
- BS EN ISO 6946:1997 calculation procedure of Uvalue of LSF walls

Building plan
- Typical 120m2 suburban building

STAGE 3

SIMULATIONS

- Comparative Thermal Performance (heating and cooling) in six SA climatic regions

Figure 3: Methodology

A "typical" 120 m² suburban building was modelled within Ecotect. As part of the model infiltration rate (obtained from infiltration rate measurements), wind sensitivity (assumed for an urban environment) and weather files (generated from Meteonorm) for the six climatic regions selected (**Figure 5**) were used. Additionally, new material composites were introduced in the materials database to represent typical building materials used in the construction of heavy and light weight buildings in South Africa. The thermal characteristics of these new materials were then calculated within Ecotect. Ecomat™ was used to calculate thermal lag which was used as an additional input into Ecotect.

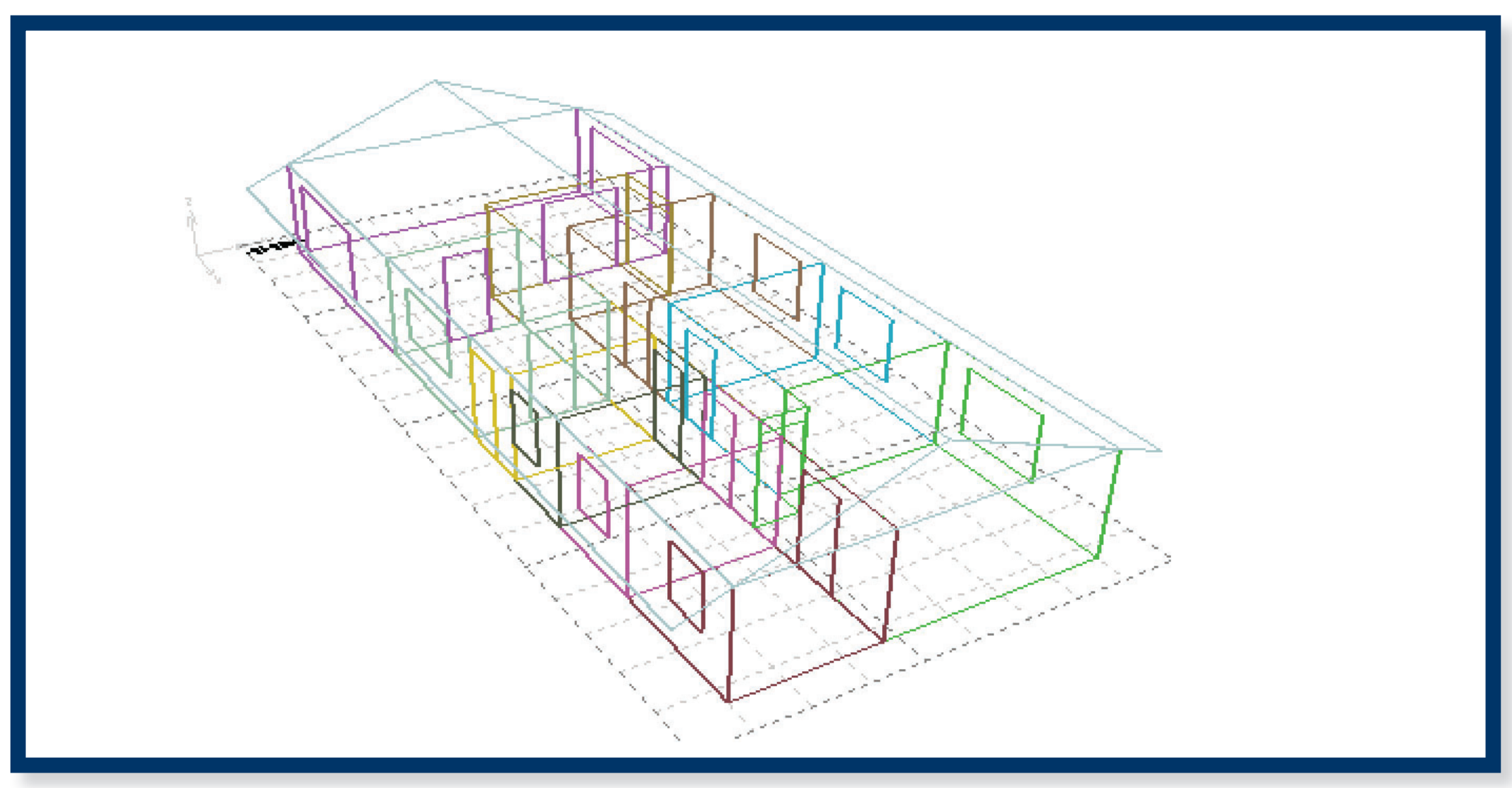


Figure 4: Building model used in thermal analysis

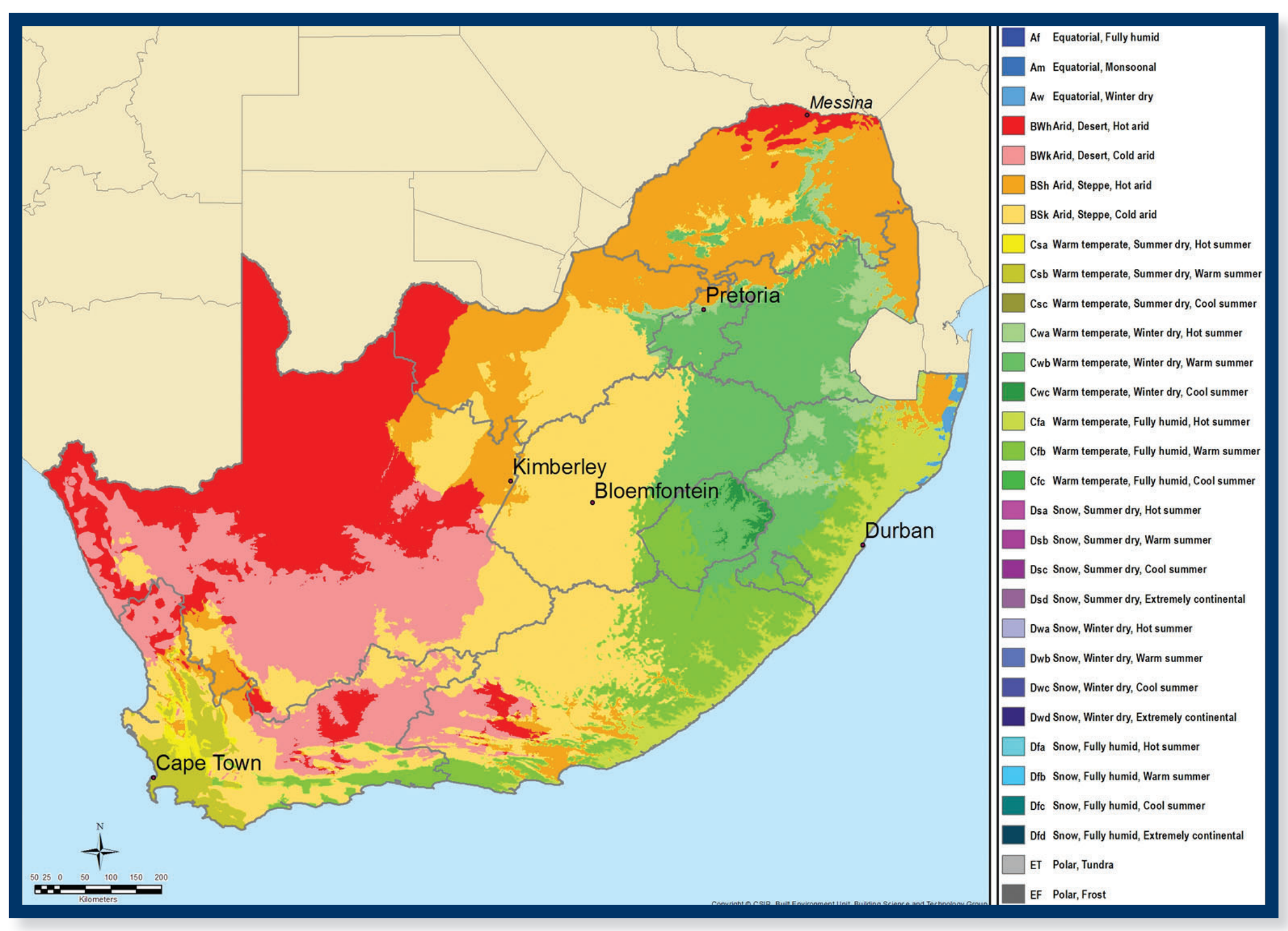


Figure 5: Map identifying regions selected

Combinations of materials with high thermal mass and high insulation were used to come up with nine different cases; the details of which are set out in **Table 1**. These cases were designed to evaluate the following:

- Case A – base case
- Case B – insulated walls
- Case C – insulated walls and insulated ceiling
- Case D – insulated walls, insulated ceiling and roof
- Case E – increased thermal mass wall and insulated ceiling
- Case F – centrally insulated wall and insulated ceiling
- Case G – double insulated wall and insulated ceiling
- Case H – increased thermal mass wall
- Case I – centrally insulated wall

Table 1: Detailed description of cases A–I

Case	Roof	External wall	Internal wall	Ceiling
A	30 mm concrete tiles, 38 mm air gap, 0.2 mm polyethylene (high density). Uvalue = 2.59 W/m².K, Thermal lag = 0.82 hrs	15 mm cement plaster, 220 mm brick normal fire clay, 15 mm cement plaster. Uvalue = 2.72 W/m².K, Thermal lag = 6.05 hrs	15 mm cement plaster, 110 mm brick normal fire clay, 15 mm cement plaster. Uvalue = 3.54 W/m².K, Thermal lag = 3.24 hrs	6.4 mm gypsum board. Uvalue = 5.58 W/m².K, Thermal lag = 0.06 hrs
B	Same as case A	9 mm fibre cement sheet, 0.2 mm vapour membrane, 30 mm OSB board, 102 mm glass wool insulation in combination with 0.8 mm steel studs, 15 mm gypsum board. Uvalue = 0.5402 W/m².K, Thermal lag = 2.6 hrs	9 mm fibre cement sheet, 0.2 mm vapour membrane, 30 mm OSB board, 102 mm glass wool insulation in combination with 0.8 mm steel studs, 15 mm gypsum board. Uvalue = 0.5402 W/m².K, Thermal lag = 2.6 hrs	Same as case A
C	Same as case A	Same as case B	Same as case B	140 mm glass wool insulation, 6.4 mm gypsum board. Uvalue = 0.26 W/m².K, Thermal lag = 0.44 hrs
D	30 mm concrete tiles, 0.2 mm polyethylene (high density) and 40 mm isotherm insulation. Uvalue = 0.93 W/m².K, Thermal lag = 0.96 hrs	Same as case B	Same as case B	Same as case C
E	Same as case A	15 mm plaster, 220 mm dense concrete and 15 mm plaster. Uvalue = 3.05 W/m².K, Thermal lag = 6.3 hrs	Same as case A	Same as case C
F	Same as case A	15 mm cement plaster, 110 mm brick normal fire clay, 50 mm mineral wool insulation, 110 mm brick normal fire and 15 mm cement plaster. Uvalue = 0.59 W/m².K, Thermal lag = 9.08 hrs	Same as case A	Same as case C
G	Same as case A	15 mm cement plaster, 50 mm mineral wool insulation, 220 mm brick normal fire clay, 50 mm mineral wool insulation and 15 mm cement plaster. Uvalue = 0.33 W/m².K, Thermal lag = 10.16 hrs	Same as case A	Same as case C
H	Same as case A	Same as case E	Same as case A	Same as case A
I	Same as case A	Same as case F	Same as case A	Same as case A

Building thermal simulation allows one to model a building before it is built or before renovations are started and various energy efficiency alternatives to be investigated and options compared to one another leading to an energy-optimized building.

RESULTS

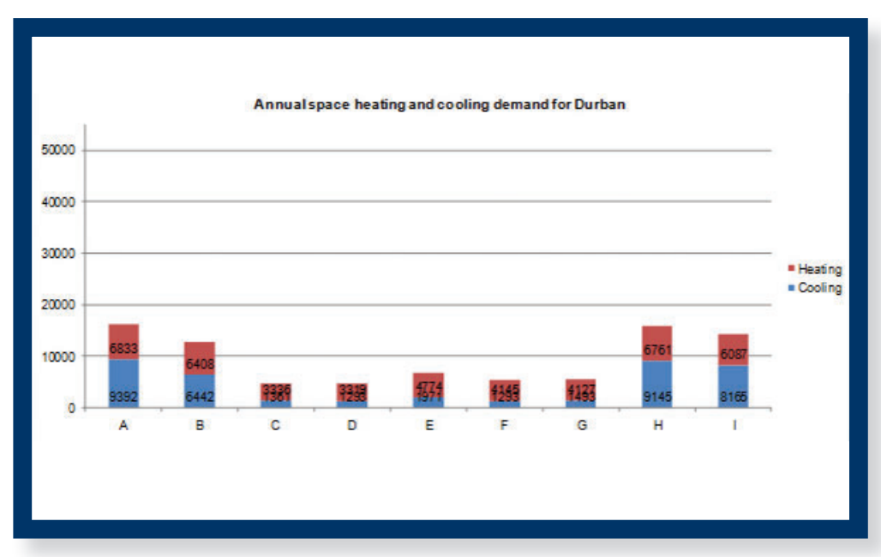


Figure 6: Annual space heating and cooling demand for Durban

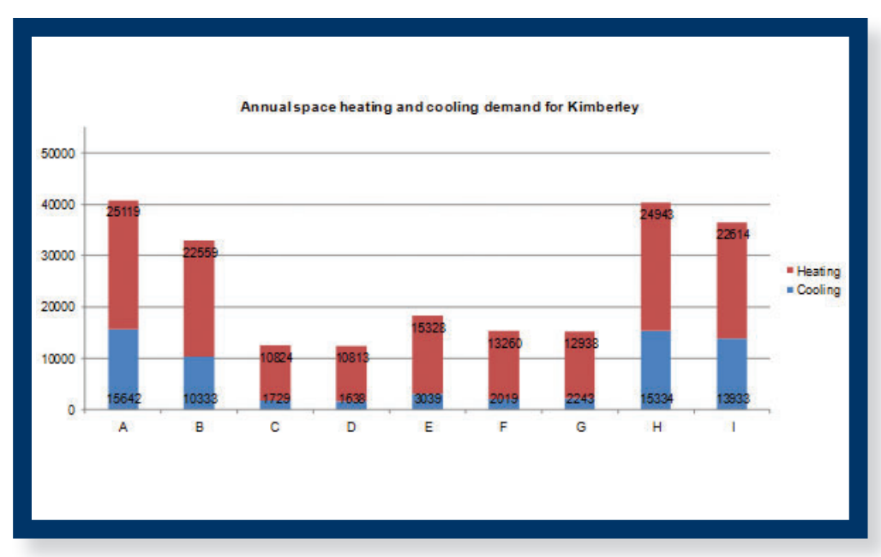


Figure 7: Annual space heating and cooling demand for Kimberly

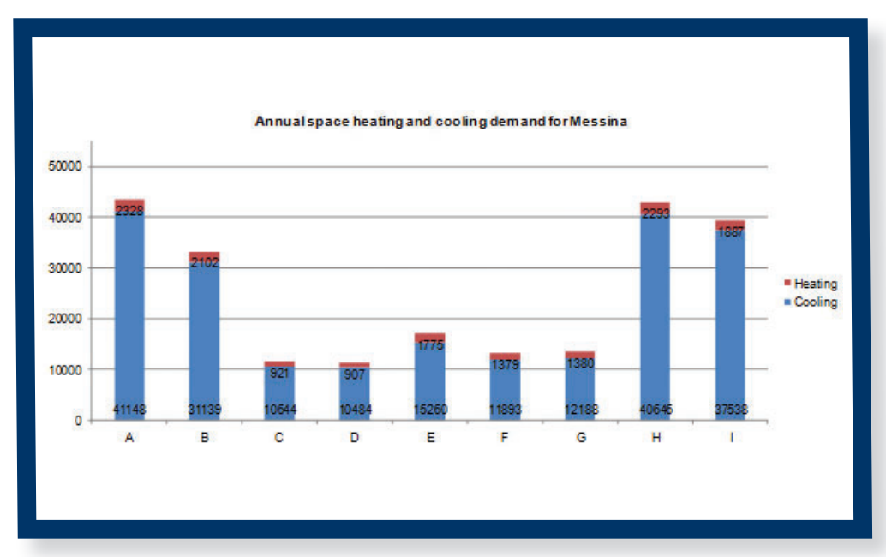


Figure 8: Annual space heating and cooling demand for Musina

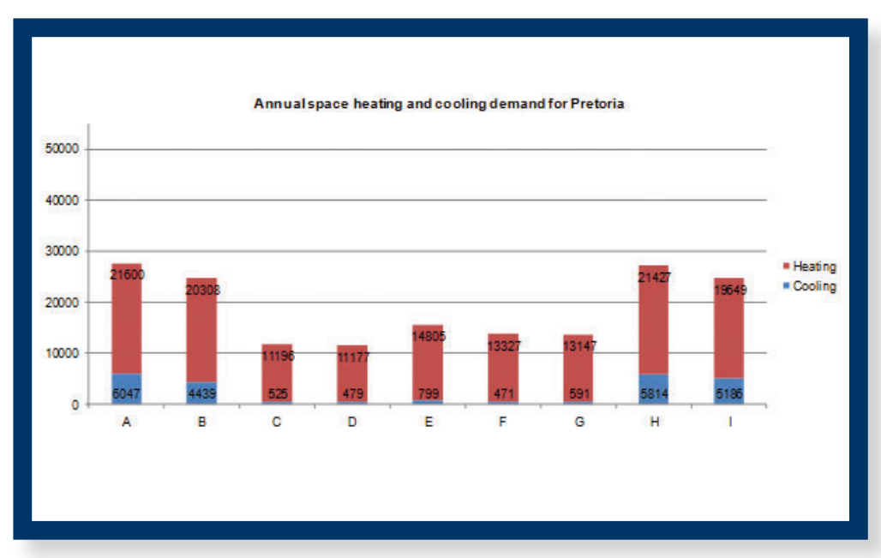


Figure 9: Annual space heating and cooling demand for Pretoria

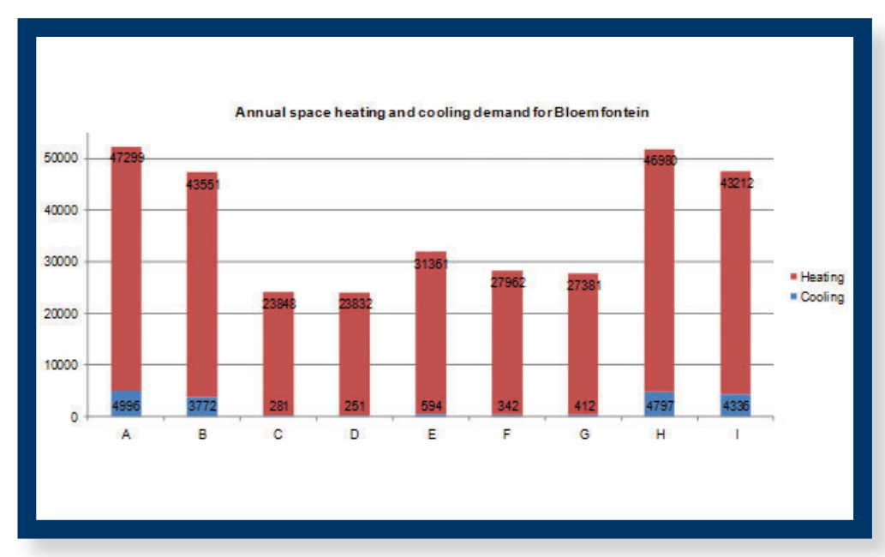


Figure 8: Annual space heating and cooling demand for Bloemfontein

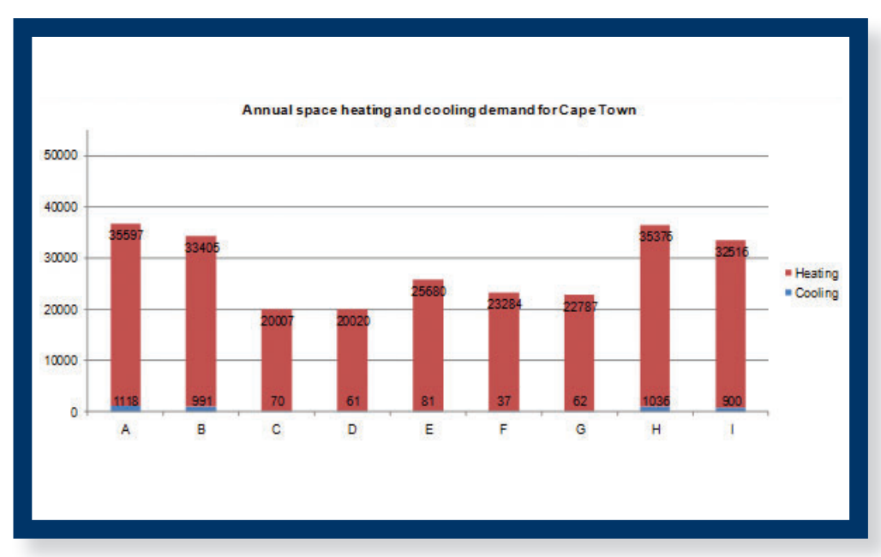


Figure 9: Annual space heating and cooling demand for Cape Town

CONCLUSIONS

1. Ceiling insulation is the most beneficial intervention that can be applied.
2. Insulating a building's ceiling and walls reduces its heating and cooling loads the most.
3. Applying both roof and ceiling insulation should always be avoided.
4. Building insulation is an effective intervention in all climatic regions.
5. Slightly increasing the thermal mass of a wall is not beneficial.
6. Positioning of insulation in a wall has a negligible effect.
7. Different designs have similar benefits across all climatic regions irrespective if heating or cooling is dominant.

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