Low Cost Housing Energy Modelling Project

Prepared by WSP GREEN by DESIGN

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Executive summary

1. **Study Context**

The South African Government Ministry of Human Settlements (Housing) has moved away from a housing policy based on "most houses for the lowest cost per house" to a holistic approach that focuses on the restoration of dignity, the creation of integrated communities and sustainable development. This has coincided with the growing concerns of global warming and the need for tomorrow's housing to be increasingly energy efficient.

There is a widely held perception that "through the wall" concrete block construction, while affording a lowest first cost walling solution for low cost housing, falls short in meeting anything but the very basic needs of occupants. Poor quality of construction and use inferior concrete blocks has led to structural failures and rain penetration, providing less than acceptable living conditions for many.

In response to this, the Government is encouraging the development and use of alternate construction methods in the low cost housing sector, which could offer a better quality product, perform better thermally, and do so at competitive costs.

Conventional clay brick construction is one such solution which is widely used in the middle and upper housing segments, but traditionally not for the low cost housing sector.

2. **Study Objective**

The study objective was to identify amongst a set of walling types which of these walling solutions/construction methodologies, as promoted and marketed in South Africa, provide the best balance between first cost, lifecycle cost, thermal comfort, lifecycle energy consumption and the achievement of "dignity" in a typical $40m^2$ low cost house.

3. **Study Focus**

- Using computational modelling and simulation methods, determine the effects of different walling materials and systems on energy consumption, lifecycle costs, embodied energy and indoor environmental quality for a typical $40m^2$ low cost house

- Walling materials to be compared to be limited to "through the wall" concrete block, clay brick in two leaf and cavity walling formats, and light steel frame building (LSFB) lightweight walling, the latter lightweight walling system type building being chosen in this study for its potential representation of other systems/technologies that use lightweight panel type external walling (such as timber frames). Imison and Ikhaya Futurehouse wall systems were considered in a subsequent stage of the study.

- Compare the performance and applicability of the wall types for each of the 6 major climatic zones of South Africa.

4. **Study Findings**

4.1 In each of the 6 climate zones, clay brick masonry required the lowest heating energy per annum in comparison to both concrete block walling and light steel frame building lightweight walling. (This is based on occupancy of four people, and LSFB construction to supplier spec rather than SANS 517.) In five of the zones (Kimberley excluded) the three high thermal mass clay brick walling options are the top three thermal performers ahead of concrete block, LSFB, Imison and Ikhaya.

4.2 In each of the 6 climatic zones, the clay brick masonry house was found to experience less time that occupants might experience significant thermal discomfort compared to the concrete block, Imison, Ikhaya Futurehouse and light steel frame building lightweight walling alternatives.

4.3 Notwithstanding the higher capital cost of clay brick walling versus concrete block walling, the lifecycle costs and lifecycle CO_2 emissions are considerably less for clay brick homes compared to both concrete block and light steel frame building lightweight walling alternatives. (This is based on occupancy of four people, and LSFB construction to supplier spec rather than SANS 517.) The Imison and Ikhaya Futurehouse walls sit amongst the clay brick options in lifecycle CO_2 ranking.

4.4 An additional set of simulations was done to assess a SANS 517 compliant $40m^2$ house compared to a two leaf brick construction. The clay brick in this case outperforms the LSFB construction in all climatic regions in terms of operational energy and thermal comfort.

4.4 Conventional clay brick walling with a face brick external skin has a significantly lower first built cost than the light steel frame building lightweight walling alternative.

5. National Implications of Study Finding (as an example of a possible scenario[1])

5.1 Should all the targeted 500,000 homes per annum be rolled out every year over 10 years (assuming no inflation) in the Johannesburg region, it could cost South Africa anything from about R9.6 billion more to build these homes using clay brick (two leaf) compared to concrete block, and anything from R46.4 billion more to build these homes using light steel frame building lightweight walling compared to clay brick (two leaf). (These costs are based on a house with an insulated ceiling in both cases.)

5.2 Over 10 years the additional winter peak power requirement that would be added to the South African national grid by adding 500,000 homes per annum in concrete brick rather than two leaf clay brick could cost the country anything from R 45 billion in additional power plant capacity, which makes the additional capital cost referred to under item 5.1 above negligible.

5.3 The concrete block option passes on anything from R2.6 billion in costs compared to two leaf clay brick to the homeowners in terms of energy costs during that 10 year period.

5.4 The CO_2 emissions over a 10 year period of the concrete block homes would be approximately 11.7 million tons more than if these homes were to be built using two leaf clay brick over the same 10 year period.

5.5 The energy savings produced by choosing clay brick over concrete block over the 10 year period would be equivalent of providing enough heating energy to another 13.5 million clay brick low cost houses for one year.

5.6 If all the 500,000 units were to be built out of concrete block, this would produce an additional 136,946 metric tons of CO_2 emitted into the atmosphere annually. This is equivalent to an additional 26,366 passenger cars on the road annually.

6. Study Conclusion

6.1 From a first cost perspective and mindful of the considerable employment opportunity masonry construction methods afford, concrete block walling is a compelling solution, however it falls considerably short, relative

[1] *This scenario involves LSFB construction to supplier spec rather than the new SANS 517 standard, four occupants per house and 3 air changes per hour peak natural ventilation rate.*

to conventional clay brick built houses in terms of operational cost (high electrical energy) and high future maintenance cost to the occupant, this also limiting the investment value in the longer term. Concrete block also falls short in terms of thermal comfort.

6.2 From both a first cost and lifecycle energy cost perspective clay brick walling outperforms light steel frame building lightweight walling for the low cost house.

6.3 Conventional two leaf clay brick construction affords a 'best fit' in terms of the Government policy intent. This together with the aesthetic and design considerations and that clay brick construction is able to maximize the long term value of properties in South Africa with minimal maintenance expenditure, and with that the relative wealth of the occupants, makes clay brick masonry with a face brick external skin the recommended walling system (building method) for sustainable low cost housing in South Africa, compared to the other walling types investigated in this study.

6.4 Ceilings with insulation should be a minimum mandatory requirement in low cost housing, as they provide a significant improvement on thermal performance of the home at a reasonable first cost.

1. INTRODUCTION

WSP Green by Design was commissioned to research the effects of a limited range of walling materials in a typical South African 40m^2 low cost house on energy consumption, energy costs, thermal comfort and embodied energy, for all six climatic regions of South Africa. Energy modelling software was used to achieve this. The intention was to provide an 'apples for apples' sound comparison whereby only the walling materials are changed, and the other properties and construction materials of the low cost house remain unchanged.

The investigation and report was not intended to solve the greater and very complex low cost housing issues, which have been researched and debated for more than sixty years in South Africa, including the debate on design and materials selection. It was not intended as an architectural study, but rather very specifically as a desktop and computer based energy modelling study on some of the walling materials available to designers of low cost houses.

The study also in no way aims to make conclusions about the greater housing market, is only relevant to the 40m^2 house modelled. It would not be appropriate to draw conclusions about a middle income house (80-150m^2) or any other kind of house based on the findings in this report – other South African studies have been done in this realm, including those by Howard Harris for the CBA and SASFA.

The report begins with the energy usage analysis, on which the comparisons of energy usage and energy cost are based. This is followed by the construction cost comparison of the various walling types and the embodied energy and life cycle comparison. After this a few aspects around indoor environmental quality and general design properties are highlighted. Lastly a discussion on the national implication of choosing clay brick over the other materials is presented.

A remodelling exercise was also conducted based on feedback from the South African Steel Frame Association. This is detailed in the relevant sections of this document. Remodelling focused on a SANS 517:2009 compliant Light Steel Frame house and the same SANS 204 compliant two leaf insulated brick house previously modelled. Occupancy and air exchange rates were increased and only insulated ceilings considered.

2. ENERGY USAGE

2.1 Background to modelling

2.1.1 *Software*

DesignBuilder: The software used to perform all energy modelling was the DesignBuilder software package. It is a front end to the EnergyPlus simulation software and includes, amongst other things, a 3D modeller and allows all materials and modelling parameters to interface with EnergyPlus.

EnergyPlus: EnergyPlus is a simulation package developed by the Department of Energy (DOE) at the Lawrence Berkeley National Laboratory in the USA. EnergyPlus models heating, cooling, lighting, ventilating, and other energy flows in buildings. EnergyPlus includes many innovative simulation capabilities, such as time steps of less than an hour, modular systems and equipment integrated with heat balance-based zone simulation, multi zone air flow, thermal comfort and natural ventilation. It is ASHRAE tested software which is recognised on an international level as leading building energy modelling software. EnergyPlus is based on an earlier product called Visual DOE (also developed by the DOE in the USA) which was the software used by Structatherm on a commission from the Clay Bick Association to investigate the thermal performance of clay brick.

Below are some screen shots of the model built in DesignBuilder.

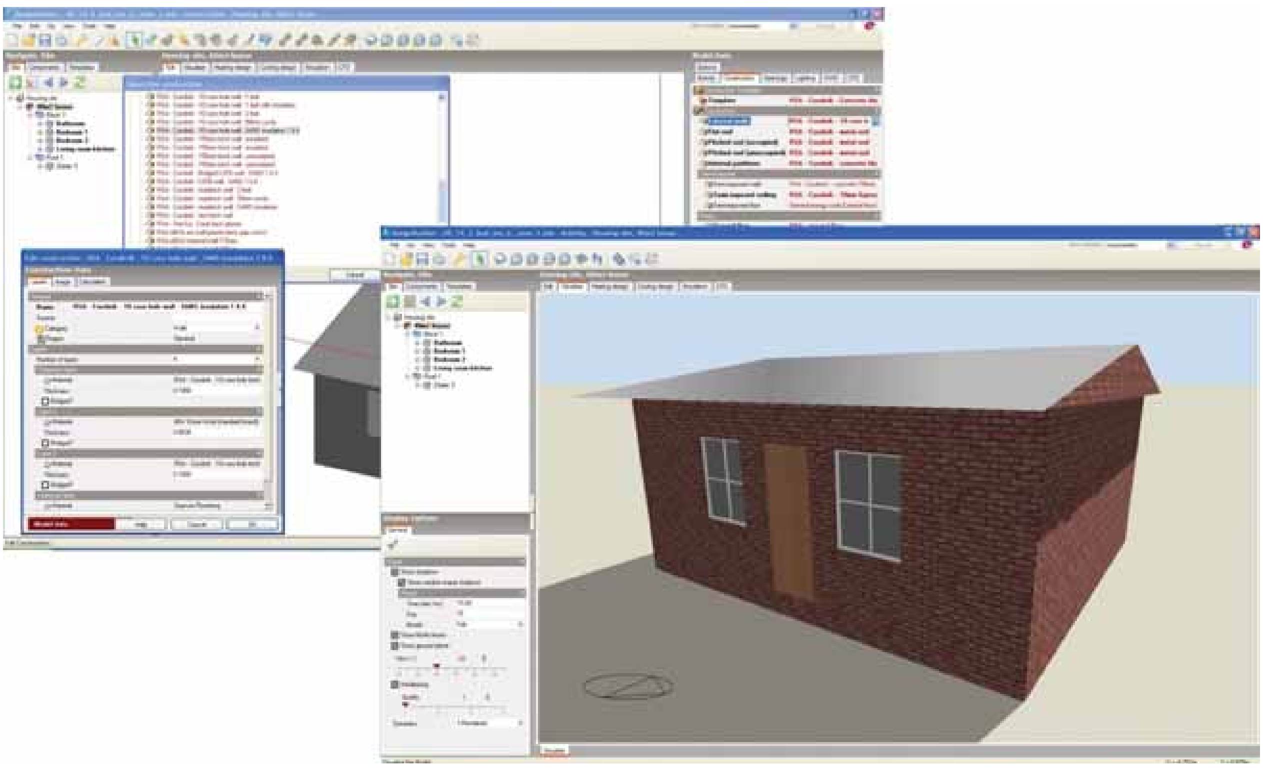

Figure 1: Screenshot of DesignBuilder

2.1.2 *Weather*

Weather data takes the form of hourly data from the software package Meteonorm. Meteonorm interpolates hourly weather and solar data, and is accepted by the Green Building Council of South Africa for simulations. Weather data from the following sites was used to represent the six climatic zones of South Africa as described by SANS 204:

Table 1: South African climatic zones

Zone	Description	Weather file used
1	Cold interior	Johannesburg
2	Temperate interior	Pretoria
3	Hot interior	Nelspruit
4	Temperate coastal	Cape Town
5	Sub-tropical coastal	Durban
6	Arid interior	Kimberley

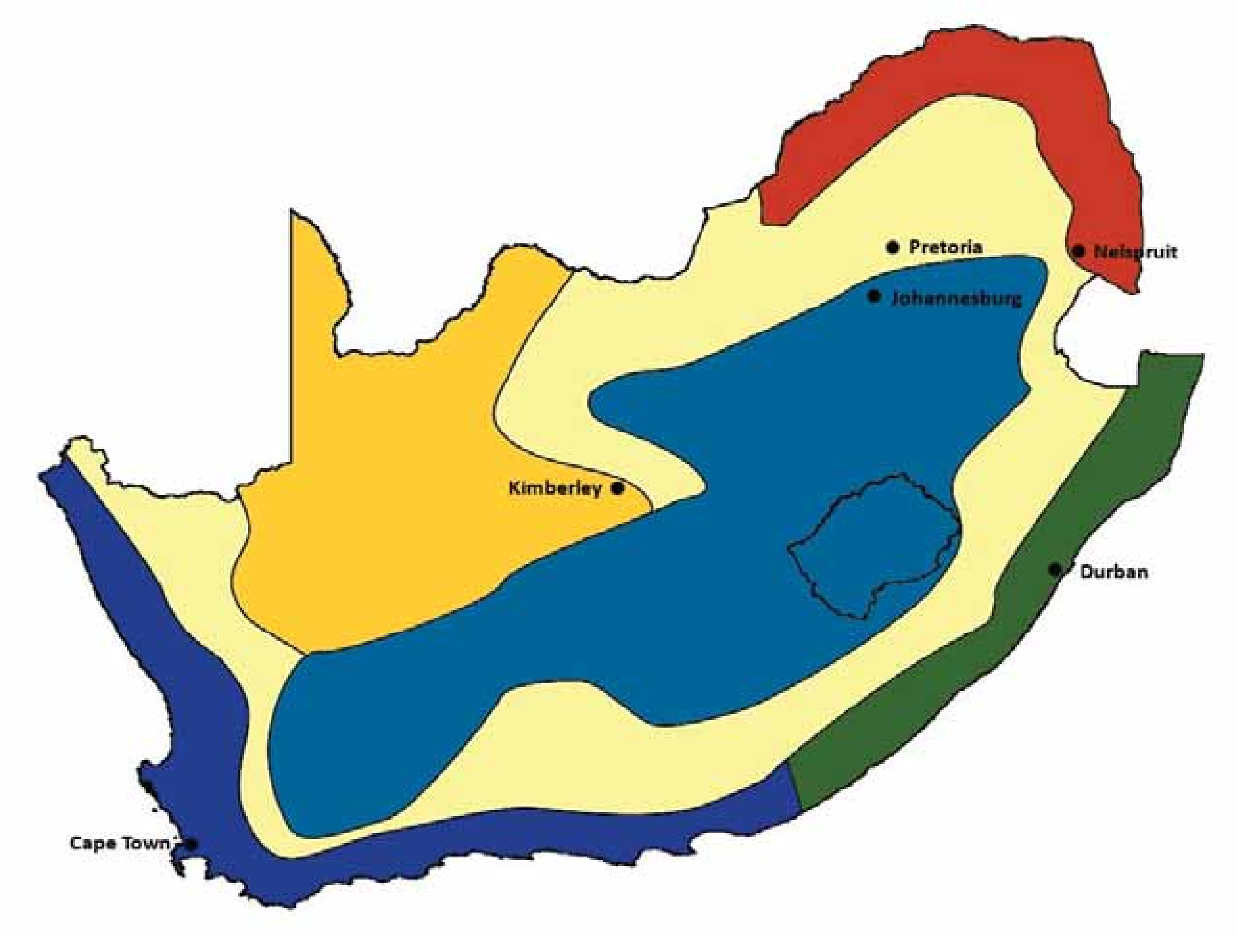

Figure 2: South African climatic zones

2.2 Details and assumptions of model

2.2.1 *Design and dimensions*

The 2007 40m^2 NHBRC RDP house, as referenced in the Department of Minerals and Energy's (DME) energy-usage performance requirements for SANS 204-2 Report OR13554, Dec 2007, is used as a base design, with any variations noted below, where relevant.

Figure 3: Dimensions and layout of NHBRC RDP 40m^2 low cost house

2.2.2 *Construction details*

Roof

The current government specification was used as base case: profiled metal on purlin rafters, with no tile underlay or ceiling.

Ceiling

Simulations were run with two ceiling options:

1. No ceiling.
2. SANS 204 DTS profiled metal on purlin rafters, including air cavity of depth of rafter, with insulation installed over the ceiling to SANS DTS thickness. This option forms the base of the main comparisons in this report.

Air exchange rate

The base infiltration rate was set to 0.8 air changes per hour (ac/h) and used as a base case. The quality of construction is assumed to be poor, as accounted for in the cracks template within DesignBuilder.

The natural ventilation air exchange rate was set to 3 ac/h. This means that if an improvement in internal conditions is to be had by increasing the air exchange rate (simulating the opening of doors or windows), then the increase will be to a maximum of 3 ac/h.

Fenestration

Glazing was represented by clear 3mm glass panes, with a solar heat gain factor (SHGF) = 0.86, and a U-value of 5.78.

Doors

The door was entered into the model as a standard solid timber door.

Electrical loads

The lighting load was set to $3W/m^2$ allowing for compact fluorescent bulbs (CFLs).

The appliance and plug loads were set to $5W/m^2$. This excludes cooking loads which are accounted for separately and run on a different schedule.

The cooking loads were set to $45W/m^2$ for the kitchen zone. Cooking operates on its own schedule.

Occupancy

Occupant density was set to $10m^2$/person (this could possibly be higher in reality).

Schedules

A residential schedule was used and is based on a seven-day occupation, using the residential schedules provided in the energy-modelling software.

Each room has a different schedule applied to it for lighting, appliance use, occupancy, heating and in the case of the kitchen, cooking.

HVAC

Heating: using resistance heating to comfort (with a coefficient of performance (COP) of one). (16°C is used by Agrement, and the DME document (item 1) uses 20°C as the set point)

Cooling: The building was not modelled to have mechanical cooling and was to be naturally ventilated. A comfort band of 18°C - 26°C for the internal acceptable temperature reference was used.

Natural ventilation

EnergyPlus simulates natural ventilation by assuming that the air exchange rate is increased when internal conditions are outside of the comfort band, and doing so will bring them closer to comfort. This is a simulation of how an occupant would react in an attempt to achieve comfort by opening windows and doors to allow fresh air in.

Construction details changed for remodelling

Changes were made as detailed below, to compare the SANS 517 compliant LSFB with the two leaf insulated brick house. See also *2.4.4 SANS 517 Light steel frame building (LSFB)* for wall section details.

SANS 517:2009 *Light Steel Frame Building* distinguishes between *Category 1 buildings* and *All other buildings.*[2] One criterion for Category 1 buildings is a maximum length of 6.0 m between "intersecting walls or members providing lateral support". The living room/kitchen has a wall with exactly 6.0 m between intersecting walls, measured internally (the wall is 6.57 m external dimension as shown in the plan).

Since the design is on the borderline of Category 1, the SANS 517 compliant LSFB house was modelled to meet the stricter insulation requirements for *All other buildings*, which tends to favour the LSFB in comparison to clay brick. The Category 1 case *was* checked for zones 1 and 5 (Johannesburg and Durban respectively), with heating energy consumption higher for Category 1 in both cases i.e. modelling SANS 517 LSFB as Category 1 would not favour LSFB.[3]

Roof

The brick building roof was unaltered.

The LSFB roof/ceiling system was modelled as a SANS 517:2009 *Pitched roof and horizontal ceiling - Ventilated roof space* (predicting some air infiltration associated with low cost building). A steel roof was used (in keeping with existing low cost houses) with the R value of 0.20 m^2K/W stipulated by SANS 517.

Ceiling

The brick building ceiling was kept as SANS 204 DTS profiled metal on purlin rafters, including air cavity of depth of rafter, **with insulation installed over the ceiling** to SANS DTS thickness.

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[2] Category 1 buildings are defined as those which:

a) are designated as class A3, A4, F2, G1, H2, H3, or H4 (Dwelling House - the applicable class in this case) occupancy according to SANS10400
b) do not have a basement
c) have a maximum length of 6.0 m between intersecting walls or members providing lateral support and
d) have a floor area less than or equal to 80 m^2

[3] *For example, increase in heating energy when changing to Category 1 is 12% for Johannesburg, 10 % for Durban, 14 % for Pretoria and 13 % for Nelspruit.*

The LSFB ceiling was modelled according to SANS 517 – 6.4 mm gypsum board with medium weight mineral wool to comply as detailed below.

Table 2: LSFB Roof insulation compliance with SANS 517

Climate zone	Required insulation R value[4] (m²K/W)	Actual insulation thickness (rounded up) (mm)	Actual insulation R value (m²K/W)	Min required roof/ceiling system R value[5] (m²K/W)	Actual roof/ceiling system R value (m²K/W)
1	3.50	140	3.68	3.70	3.88
2	3.00	120	3.16	3.20	3.26
3	2.50[6]	100	2.63	2.70	2.83
4	3.50	140	3.68	3.70	3.88
5	2.50[6]	100	2.63	2.70	2.83
6	3.30	130	3.42	3.50	3.62

Air exchange rate

The base infiltration rate was set to 0.8 air changes per hour (ac/h) and used as a base case. The quality of construction is assumed to be poor, as accounted for in the cracks template within DesignBuilder.

The peak natural ventilation air exchange rate was set to both 3 ac/h and 25 ac/h. This means that if an improvement in internal conditions is to be had by increasing the air exchange rate (simulating the opening of doors or windows), then the increase will be to a maximum of 3 ac/h or 25 ac/h accordingly.

The additional rate of 25 ac/h is based on an approximate calculation of stack-effect ventilation from an open window in a naturally-ventilated room (CIBSE AM10:2005), as well as diverse values quoted in literature. Thus a wide range is covered to expose a possible reversal in the trend previously observed (namely brick constructions having lower heating energy consumption than LSFB, for all climate zones).

[4] *SANS 517:2009 Table 25*

[5] *SANS 517:2009 Table 15*

[6] *SANS 517 allows for this to be reduced to 2.00 if the roof is a light colour, but roof colour was unknown. Therefore the default (higher) insulation value was used.*

Increased natural ventilation means that more heat is lost from the heated house to the colder surroundings, since air is heated in the house, displaced by colder fresh air and the heat of the displaced warmer air lost to the surroundings. This heat loss causes an increase in heating energy use to achieve comfort, as reported in Table 3 below.

Table 3: Effect of peak ventilation rate on annual heating energy consumption

Climate zone		Annual heating energy increase with increased ventilation rate	
		Two leaf insulated brick	LSFB
1	Johannesburg	34 %	30 %
2	Pretoria	38 %	32 %
3	Nelspruit	43 %	35 %
4	Cape Town	46 %	40 %
5	Durban	60 %	51 %
6	Kimberley	31 %	30 %

The increase in annual heating energy with peak ventilation rate increase from 3 ac/h to 25 ac/h, ranges from 30 % to 60 % for the various scenarios. There is always a higher % increase for two leaf insulated brick than for SANS 517 LSFB.

Occupancy

Occupancy was increased from 4 people to 8 people in the house (0.2 people per m², 5 m²/person). All other factors being equal, this increase in occupancy decreases annual heating energy use as shown in Table 4 below.

Table 4: Reduction in annual heating energy consumption with occupancy increase from 4 people to 8 people

Climate region		Two leaf insulated brick	SANS 517 LSFB
1	Johannesburg	15%	13 %
5	Durban	39 %	30 %

Clearly the occupancy can be very significant as less electrical heating is needed when additional bodies heat the space. However the trend remains that for this house, brick construction has lower heating energy use than SANS 517 LSFB.

2.3 Thermal mass and insulation

Thermal mass is the ability of a material to absorb heat energy. Altering the temperature of high density materials such as masonry and ceramics requires a significant amount of heat energy. They are said to have high thermal mass. Low thermal mass materials are lightweight, examples include timber and gypsum plaster.

Thermal mass is an age-old means of stabilising indoor temperatures and using solar energy as needed. Its traditional use has been best suited to climates where days are reliably warm and nights are cold. High thermal mass retards the time from when sunlight reaches the outside of the wall and when an indirect solar gain is realised in the space. Thus, when daytime conditions are very hot, it will delay the uptake of heat into the space. When the cold of night comes around, the heat gained by the thermal mass in the day is radiated into the environment, maintaining the indoor environmental temperature.

Insulation and thermal mass act as dampers on the fluctuations of internal conditions. Broadly speaking, insulation acts to preserve internal conditions and shield from outdoor conditions, whilst thermal mass serves to store energy, delaying the uptake of indirect solar gain, as well as distributing it over a longer period of time.

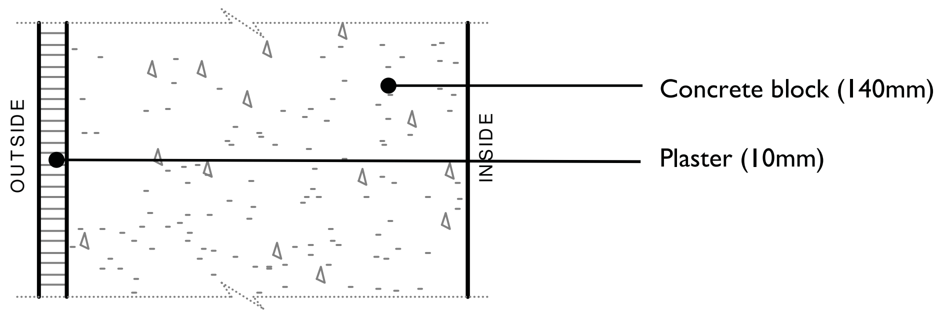
The optimal use of insulation and thermal mass varies widely depending on building type, form, use and the local climate. Broadly speaking, thermal mass is effective where high diurnal swings in temperature are common, whilst insulation is well suited to climates where temperatures remain fairly constant for long periods of time.

Thermal mass and insulation can be combined to gain the benefits of both; however this often comes at an increased construction cost.

2.4 Walling materials used for comparison

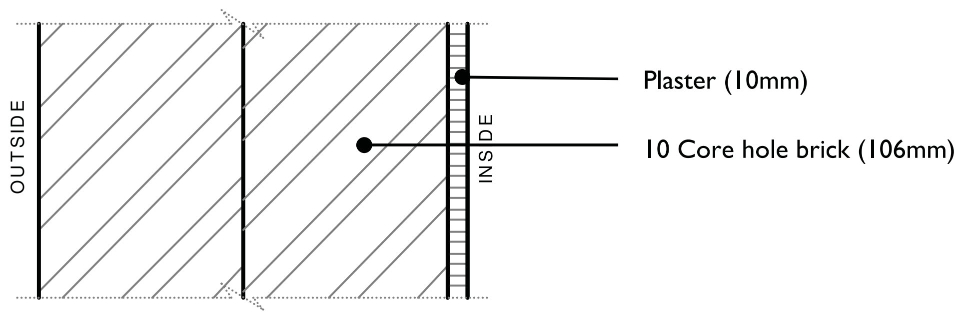
2.4.1 *Concrete block wall*

Note that the minimum specifications for concrete blocks used in low-cost housing are used. Properties are not representative of all concrete blocks, but of those used in low cost housing, the minimum requirements of which are specified by the Concrete Manufacturer's Association. See Appendix C for material properties.

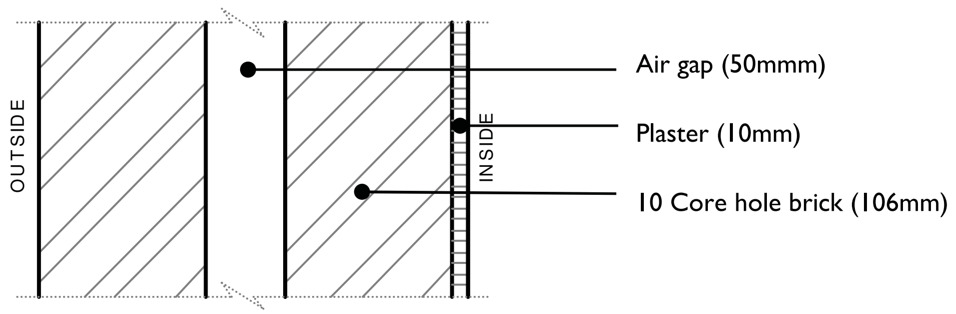


2.4.2 *Clay brick walls*

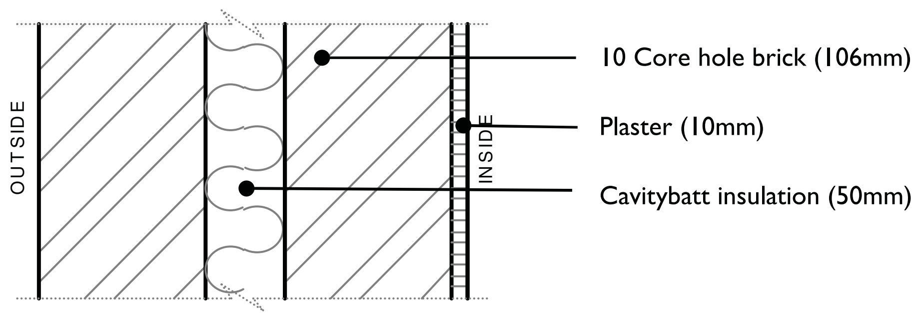
Two leaf clay brick



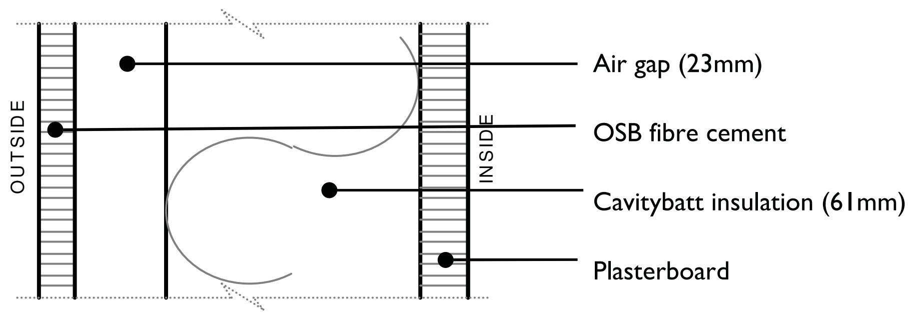
Cavity clay brick



Insulated clay brick



2.4.3 *Light steel frame building (LSFB)*



** Note that the section chosen for the light steel frame walling was based on information received from a number of SASFA member organisations which were contacted by WSP – the section would however not be in strict accordance with SANS:517:2009, which SASFA would require them to build according to.*

Thermal bridging

Thermal bridges exist where a conductive material bridges a less conductive walling layer. In the case of light steel-frame walls, the galvanised steel frame breaches the insulating layer, most commonly by what are called the 'studs'. The thermally-bridged frontal area of the steel frame is approximately 0.185%. Given that the frame is made of steel, a significant amount of heat transfer takes place across the insulation layer via the steel studs. The effective R-value is reduced, as seen in the table below. The R-value is reduced by approximately 36%, which is unsurprising given that the steel frame studs are thousands of times more thermally-conductive than the insulating layer[7]. The ASHRAE (American Society of Heating, Refrigeration and Air-conditioning Engineers) recommends that such a light steel frame be insulated externally[8].

EnergyPlus accounts for the effect of thermal bridging. In the image below, the manner in which the insulation layer is thermally bridged by the studs is clear.

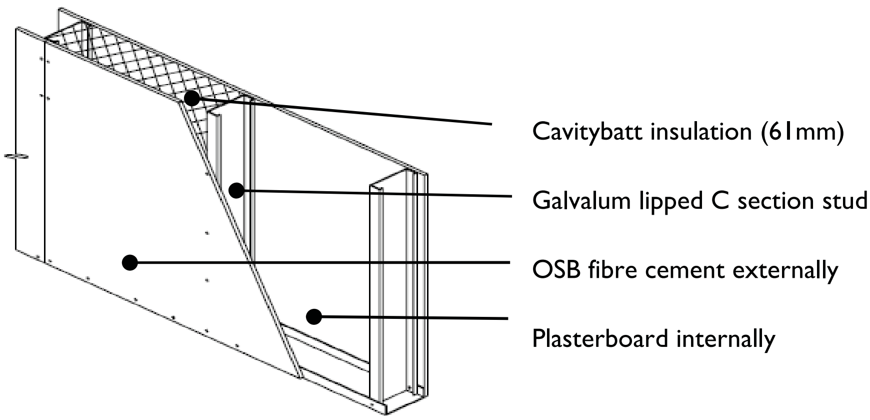


Image source: U.S. Department of Housing and Urban Development

Table 5: Effect of thermal bridging on R-value in light steel frame walling

	Excluding thermal bridging	Including the effect of thermal bridging
R-value of light steel frame wall	2.2	1.4

[7] *Holman, J.P., Heat Transfer 9th ed., 2002*
[8] Joseph W. Lstiburek, Ph.D., P.Eng., Fellow ASHRAE,, A Bridge Too Far, ASHRAE Journal, 2007

2.4.4 *SANS 517 Light steel frame building (LSFB)*

As per SANS 517:2009, external walls have different insulation thickness for zones 2, 3 and 5 vs zones 1, 4 and 6.

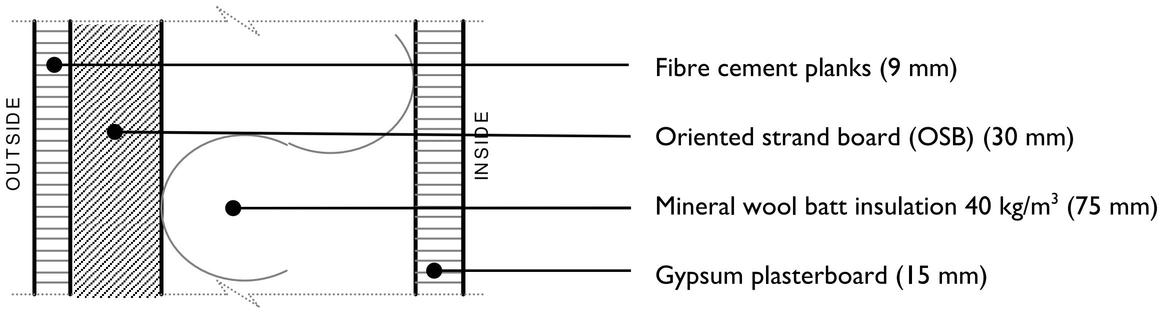


Figure 4: LSFB external wall section for climate zones 1, 4 and 6

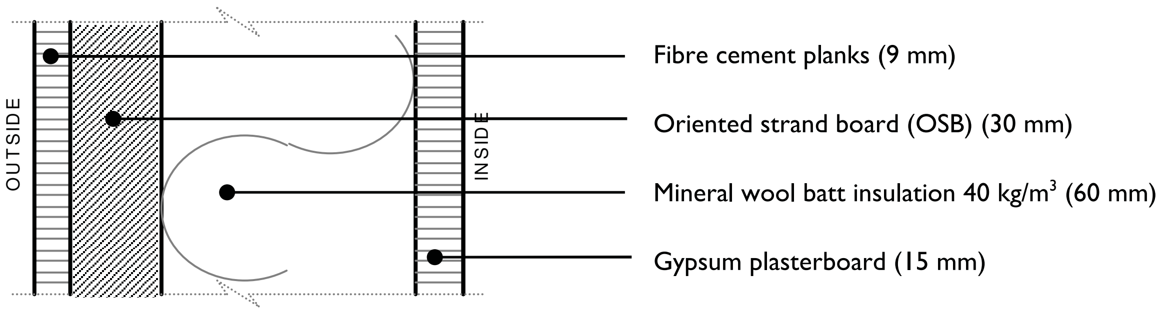


Figure 5: LSFB external wall section for climate zones 2, 3 and 5

For SANS 517 compliance, the OSB serving as a thermal break between outer board layer and steel frame, must have an R value of at least 0.2 m^2K/W. For the 30 mm board, R = 30 mm / 0.13 W/m·K = 0.23 m^2K/W hence it complies. Further requirements are fulfilled in Table 6 below.

Table 6: LSFB external walls SANS 517 compliance

Climate zones	Required insulation R value[9] (m²K/W)	Actual insulation thickness (mm)	Actual insulation R value (m²K/W)	Required wall R value[10] (m²K/W)	Wall R value (hand calc) (m²K/W)	Wall R value (Design builder) (m²K/W)
1, 4, 6	1.73	75	1.97	2.20	2.44	2.46
2, 3, 5	1.43	60	1.58	1.90	2.05	2.07

Internal walls are modelled according to Figure 32 of SANS 517:2009 as shown below. (Although the standard allows for alternative compliance paths, it does not provide clear compliance criteria.)

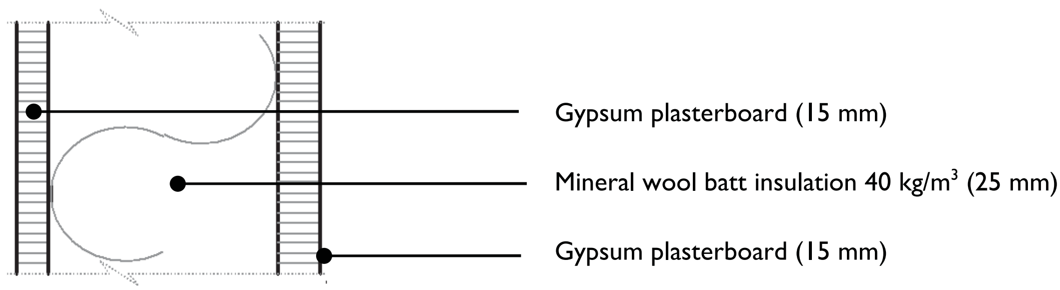


Figure 6: LSFB SANS 517 internal wall.

[9] *SANS 517:2009 Table 19*
[10] *SANS 517:2009 Table 14*

2.4.5 *Imison wall system*

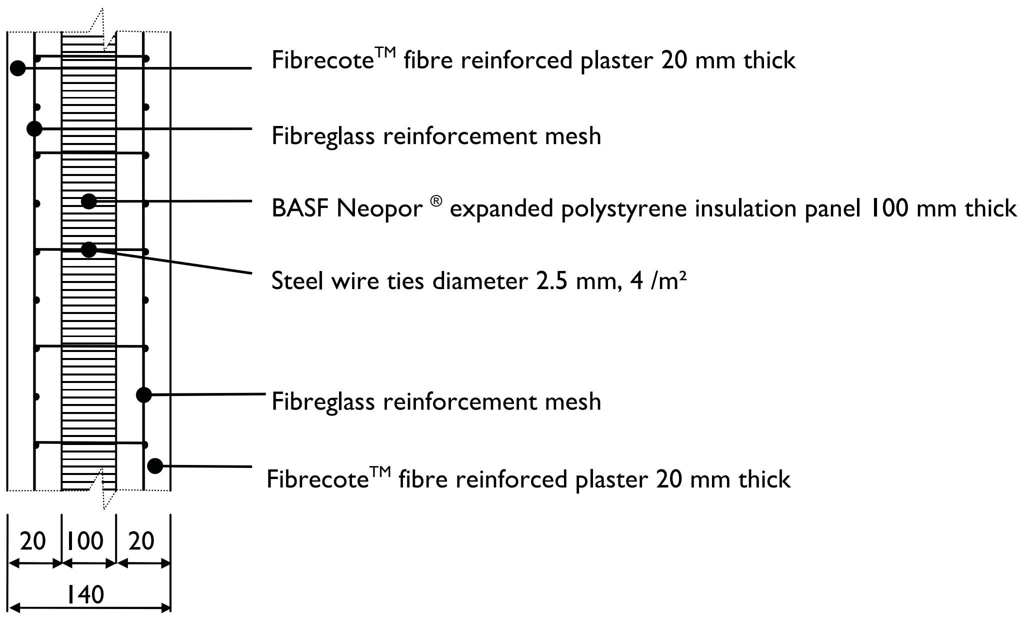


Figure 7: Imison wall system internal and external walls typical section. Additional thermal mass of steel columns and roof ring beam is accounted for: columns are steel lipped channel 55x32x15x0.8 mm spaced at 600 mm intervals and fitted into insulation panels; roof ring beam is steel U channel 90x36x0.8 mm, fitted into top edge of insulation panels.

2.4.6 *Ikhaya Futurehouse system (IFHS)*

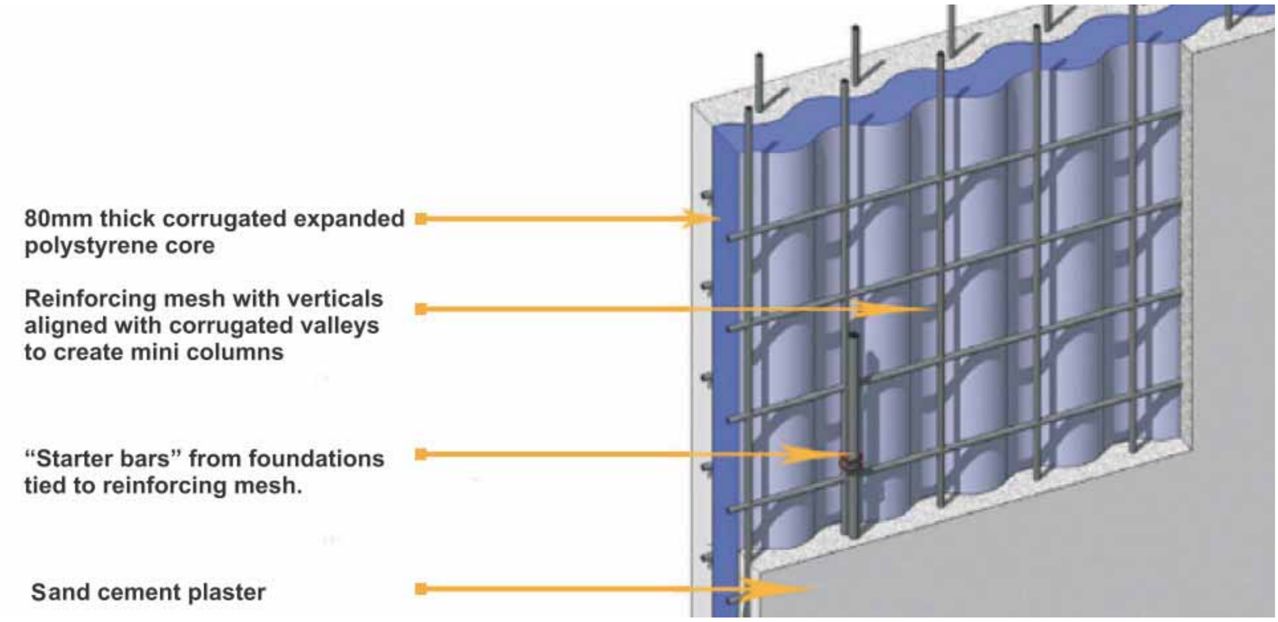


Figure 8: Ikhaya Futurehouse system, image courtesy of Ikhaya Futurehouse Systems, showing general design with corrugated EPS core

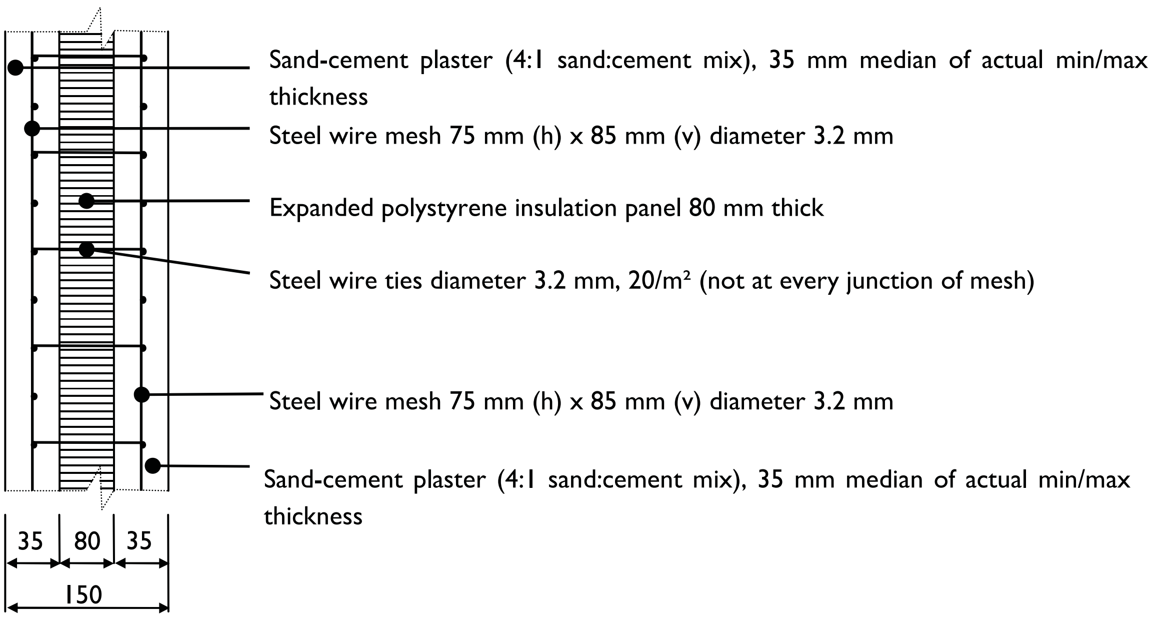


Figure 9: Ikhaya Futurehouse System (IFHS) typical external wall section, as modelled, based on information from the manufacturer

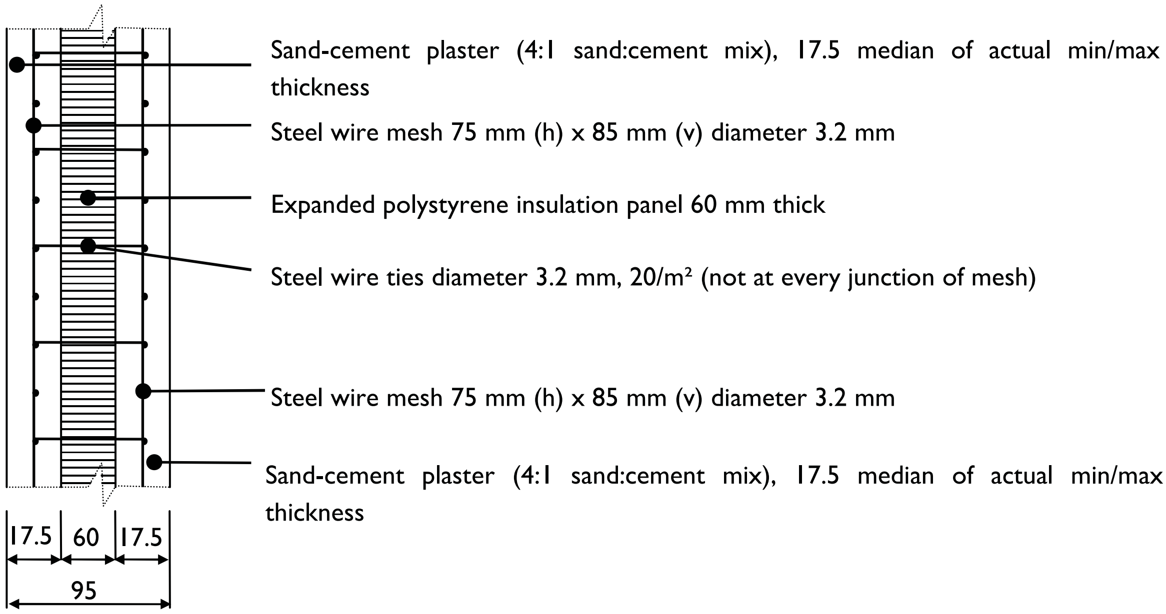


Figure 10: Ikhaya Futurehouse System (IFHS) typical internal wall section, as modelled, based on information from the manufacturer

2.5 Energy consumption comparison

Total heating energy-usage per annum is used as a metric for comparison between different walling materials. In each simulation, only the walls are changed, such that the modelled house is in accordance with the costing comparison of this report.

Simulations were run for a location in each South African climate zone, as per Table 1. The described low-cost house was simulated with each walling type. In each case, this was done for a house with no ceiling, and a house with a ceiling insulated to SANS 204-2 DTS.

Over the course of a simulation year, hourly results were generated. These were then reported on an hourly, monthly or yearly basis for comparison.

2.5.1 *Climate zones and heating energy*

Given that low cost houses rely on natural ventilation for cooling, the use of alternate building materials affects heating energy the most. Figure 11 shows the amount of energy used for heating annually in each climate zone for the most common low cost house construction, namely concrete block walling with no ceiling.

It is clear that certain regions require far more energy for heating, and this correlates to the intensity of the winter months in that region, among other factors.

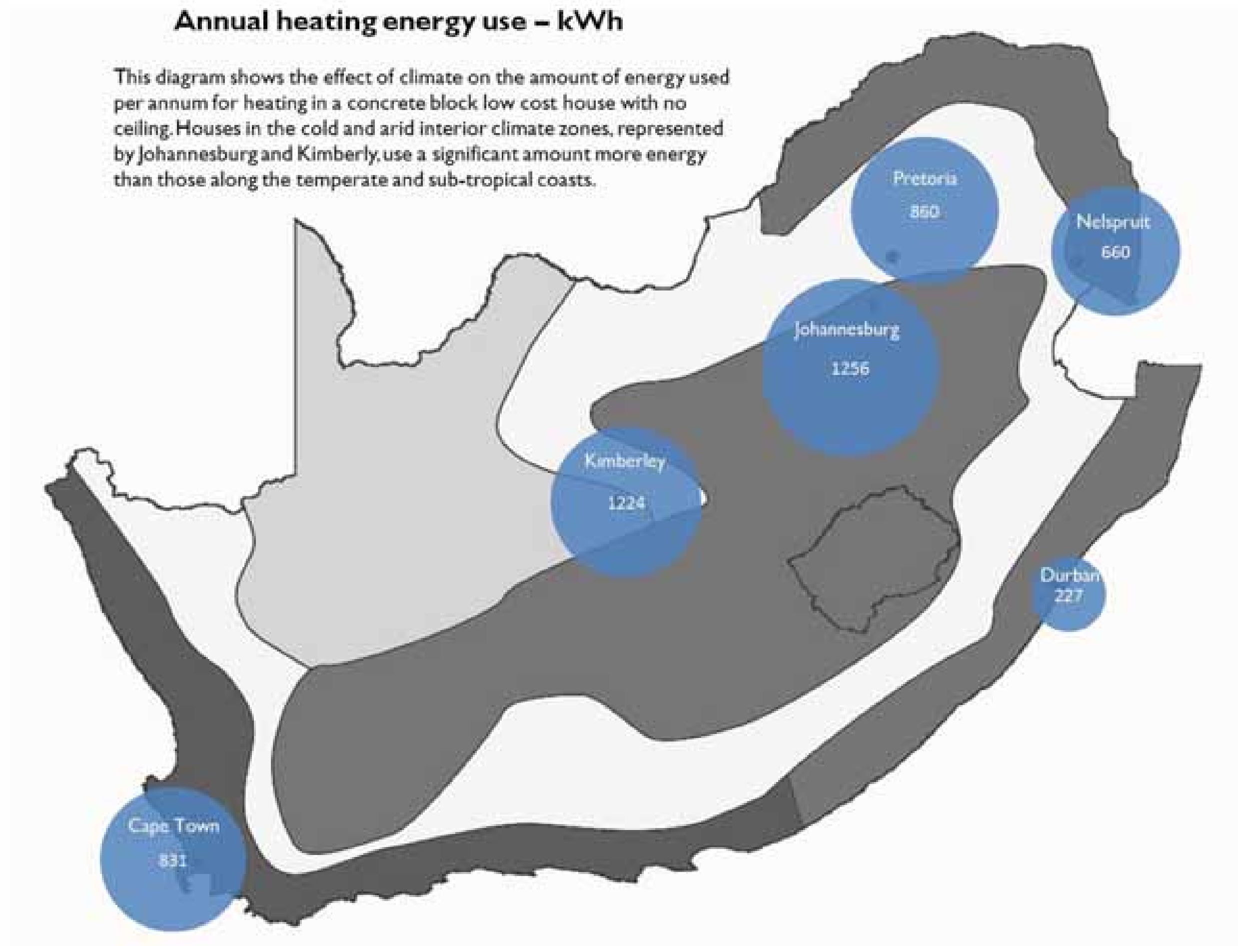


Figure 11: Heating energy in concrete block low cost housing (four occupants, 3 ac/h)

2.5.2 *Annual heating energy use*

The annual heating energy used in a low cost household is presented for three major urban areas in different climate zones. These are Johannesburg, Cape Town and Durban representing climate zones 1, 4 and 5 respectively.

Figure 12 shows that in Johannesburg and Cape Town, the concrete block construction shows the worst performance, followed by light steel frame walling, whilst the three clay brick masonry options offer significant energy efficiency improvements against concrete block and LSFB. The Ikhaya Futurehouse (IFHS) and Imison system tend to lie between LSFB and clay brick.

In Durban, the same figure shows light steel frame walls are outperformed by concrete block walls, while the two leaf clay brick wall as the best performing option. The fact that two leaf brick walls offer better energy performance in this region than *insulated* brick walls shows clearly the undesirability of high insulation in this climate.

In Kimberley the clay brick options take 1st, 3rd and 5th place out of the seven walls, outperforming LSFB and concrete block. In all other climate zones, the three high thermal mass clay brick walling options are the top three thermal performers, reducing the energy required for heating in all these cases.

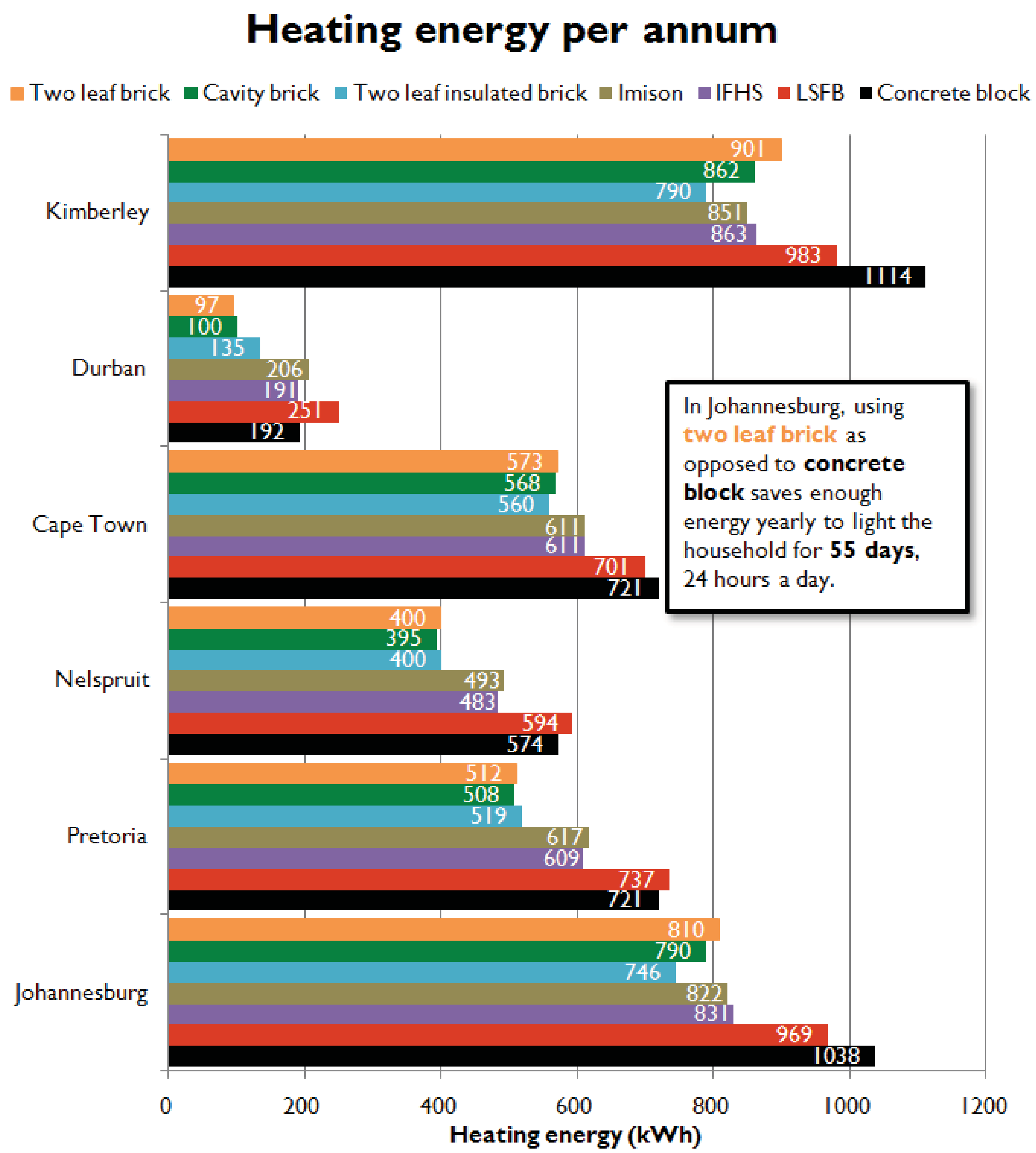


Figure 12: Heating energy per annum in low cost housing comparing different wall types (four occupants, 3 ac/h, LSFB to supplier spec)

The two leaf insulated brick house is compared to the SANS 517 compliant light steel frame house, both with insulated ceilings and eight occupants.

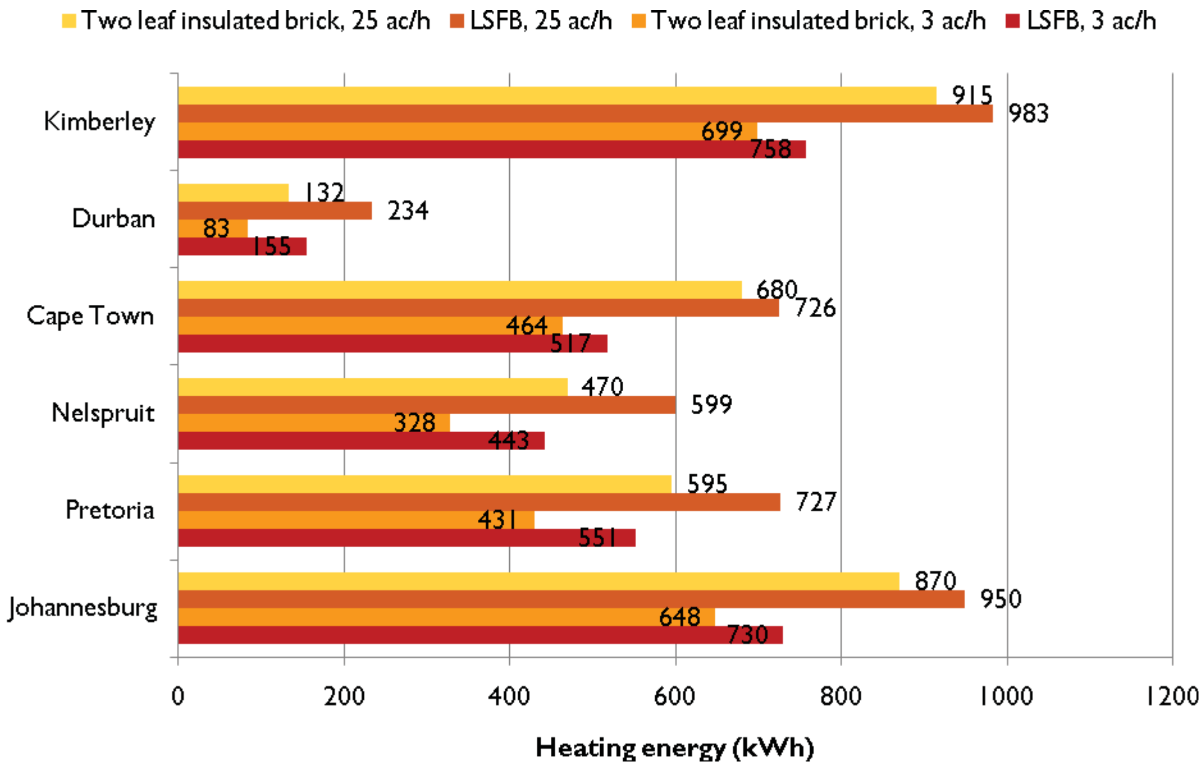


Figure 13: Annual heating energy for SANS 517 compliant LSFB and two leaf insulated brick house, for 8 occupants and insulated ceilings.

For air exchange of both 3 and 25 air changes per hour, the brick construction saves energy in all 6 SA climate zones, although by smaller margins than in the modelling done on the non-SANS-517 compliant simulations and comparisons. As mentioned previously, natural ventilation peaking at 25 ac/h increases heating energy use by 30 % - 60 % relative to the 3 ac/h case, depending on house construction type and climate region.

2.5.3 *Heating energy savings*

Figure 14 shows the amount of energy saved annually on heating in clay brick houses as opposed to light steel frame houses (SANS 517 non-compliant). Using clay brick walling as the base case, the increase in annual heating energy consumption for light steel frame walls is shown as a percentage. Although the greatest percentage saving is to be had in Durban, it is also the region with the lowest heating requirement. Similarly, Figure 15 shows the energy savings when comparing clay brick walling and concrete block walling.

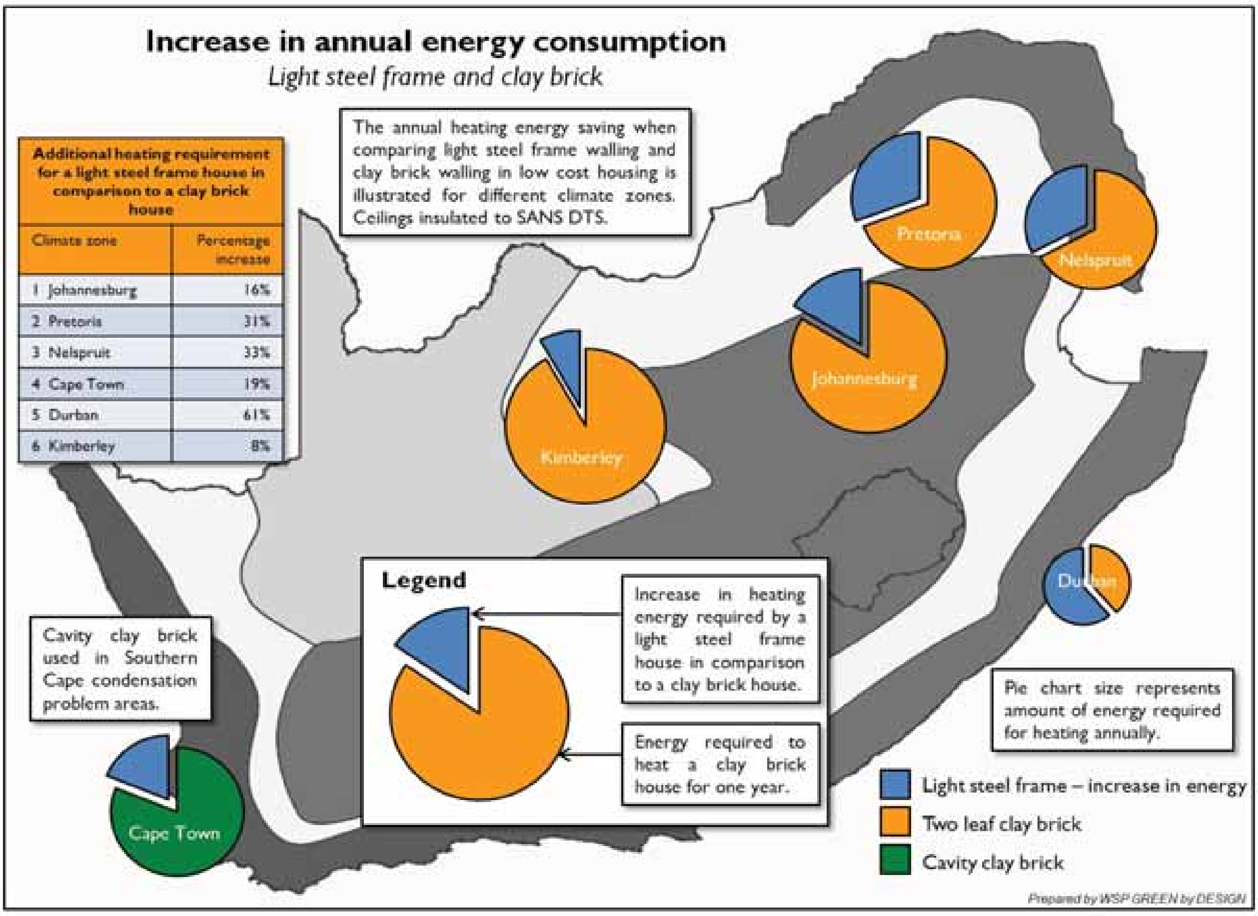


Figure 14: Increase in heating energy required by LSFB in comparison to clay brick walling types (four occupants, 3 ac/h)

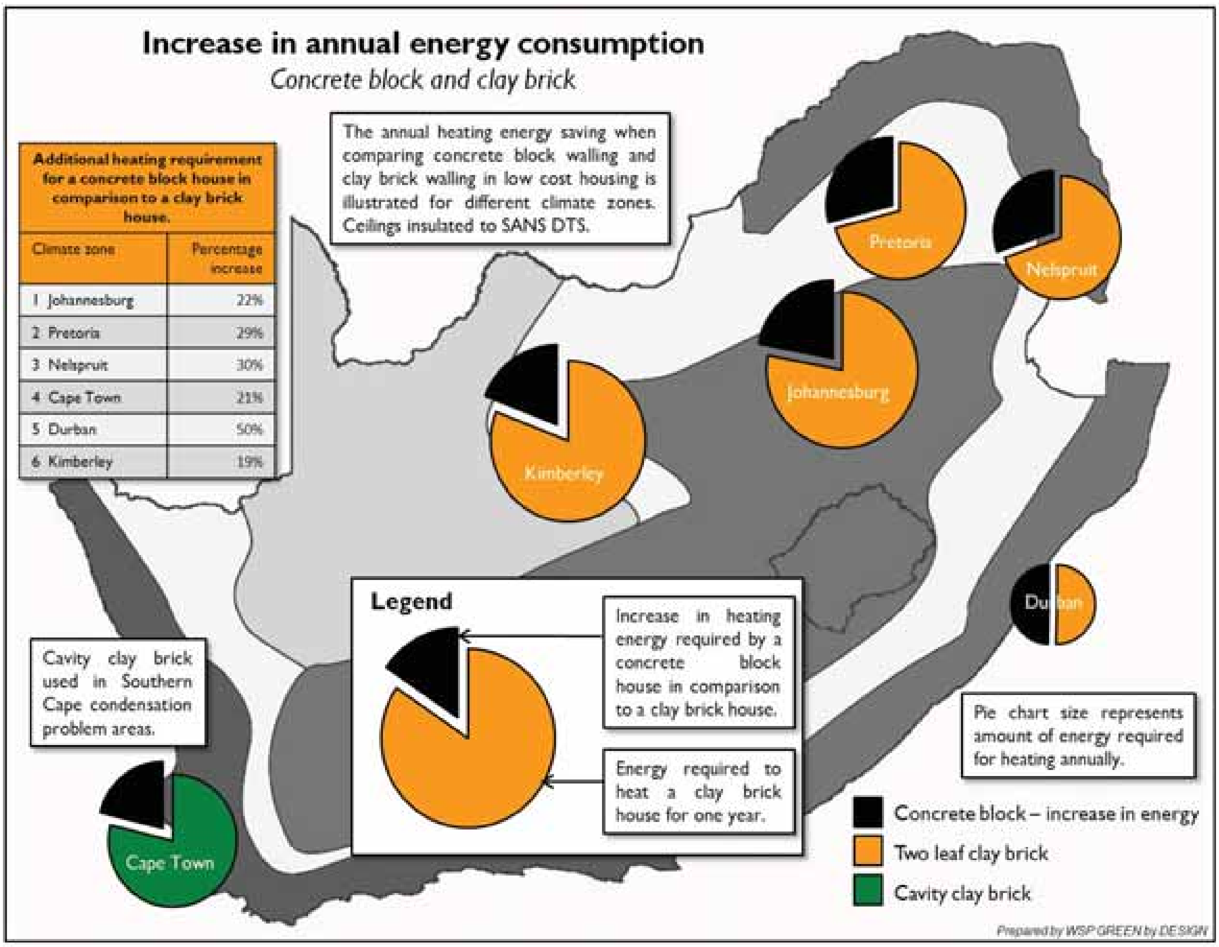


Figure 15: Increase in heating energy required by concrete walling in comparison to clay brick walling types (four occupants, 3 ac/h)

2.5.4 *Monthly energy usage*

Refining the resolution and investigating the monthly heating requirements for low cost houses built with different walling materials allows one to see the high increase in energy use during the winter months. This spike puts strain on an already overloaded national grid, and homeowners incur significantly higher energy bills during winter. Figure 16 shows the average energy used for heating on a monthly basis over the SA climatic regions. Monthly heating energy requirements for each climatic region are presented in Appendix A.

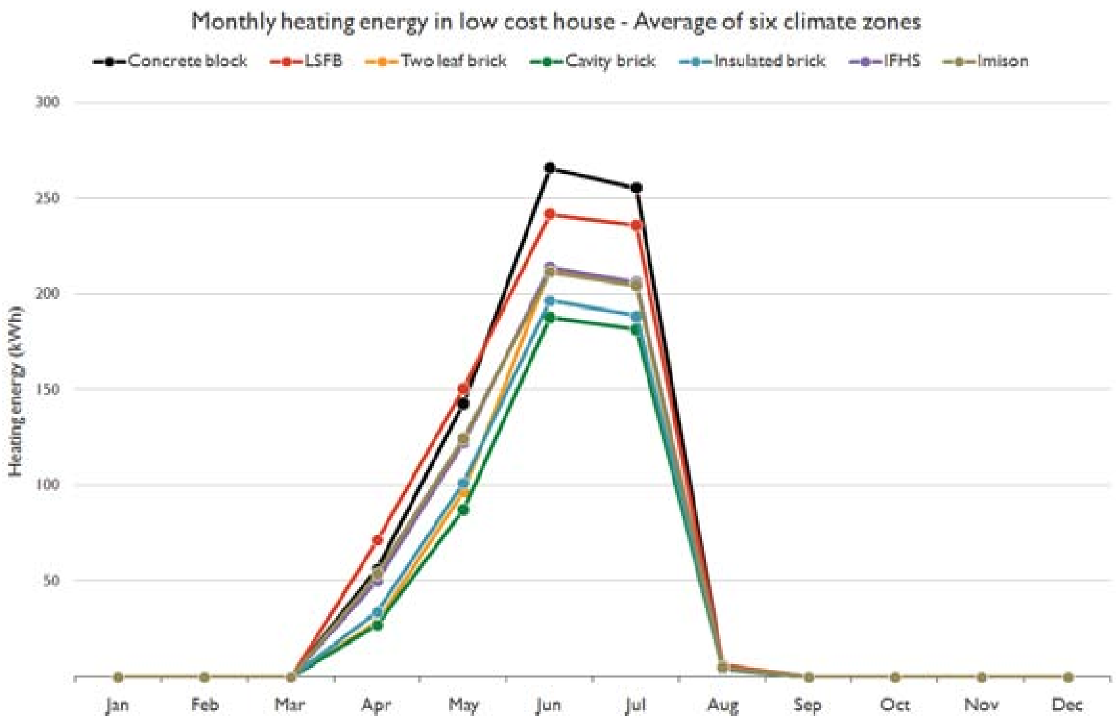


Figure 16: Average monthly heating energy for all climate zones types (four occupants, 3 ac/h)

Remodelling

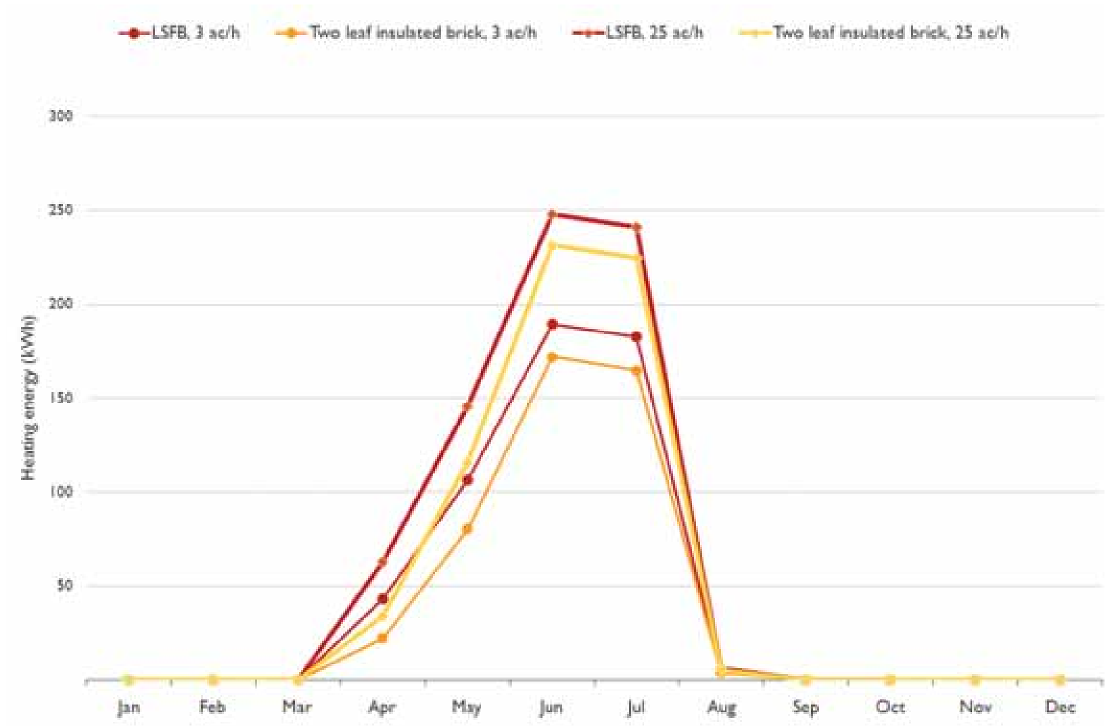


Figure 17: Monthly heating energy use averaged for the six climates, 8 occupants, SANS 517 LSFB

2.5.5 *The effect of insulated ceilings*

Significant energy savings are to be realised by the implementation of a ceiling with insulation. In this study, unless otherwise stated, all results are shown for a low cost house with an insulated ceiling, given that it is the logical first choice for addressing energy efficiency and indoor environmental quality.

The SANS 204 standard (which will include low cost housing) is set to be promulgated in the year 2010 and become part of the national building codes (according to Lisa Reynolds, SANS 204 chairperson), which will most likely require insulated ceilings.

Figure 18 shows that the addition of an insulated ceiling lowers annual heating energy consumption across all wall construction types to a similar scale in each case.

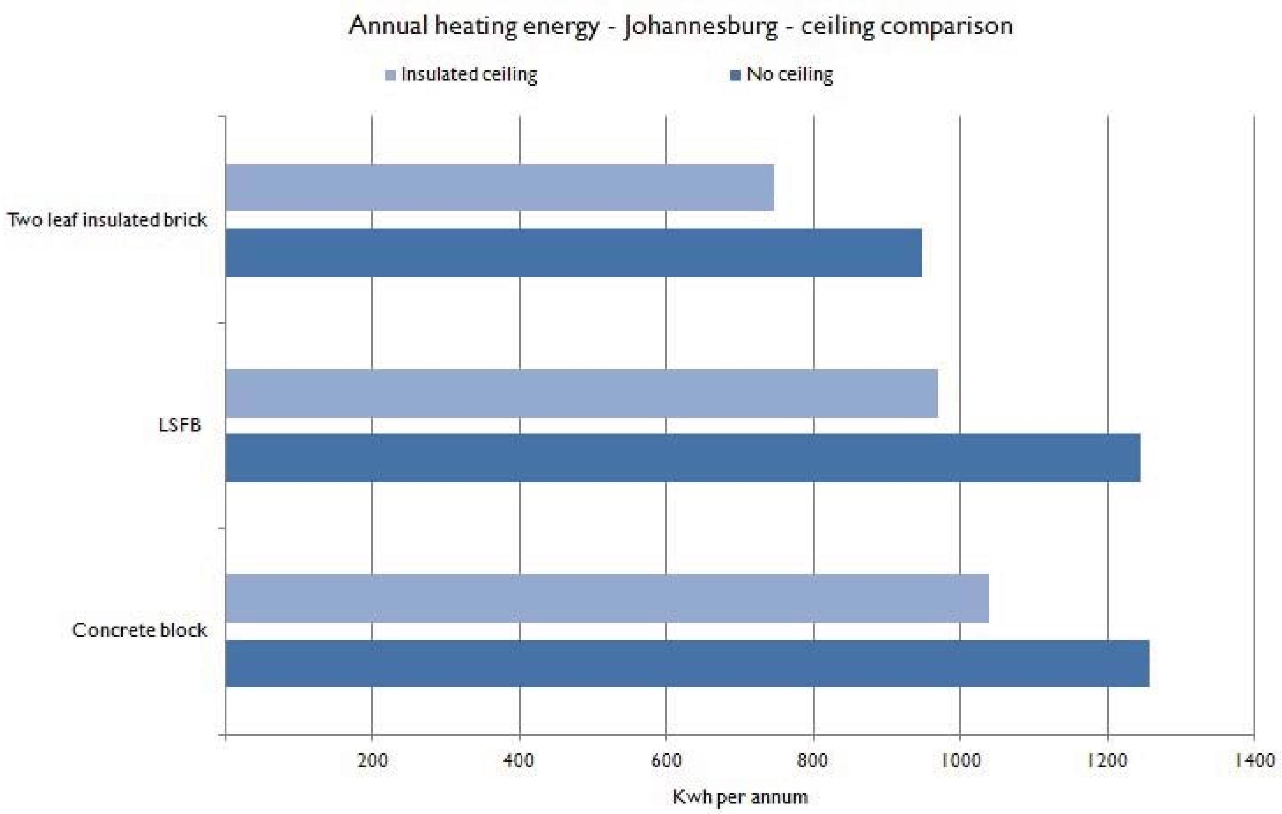


Figure 18: The effect of insulated ceilings on annual energy consumption types (four occupants, 3 ac/h)

2.5.6 *Bridged and unbridged light steel frame walls*

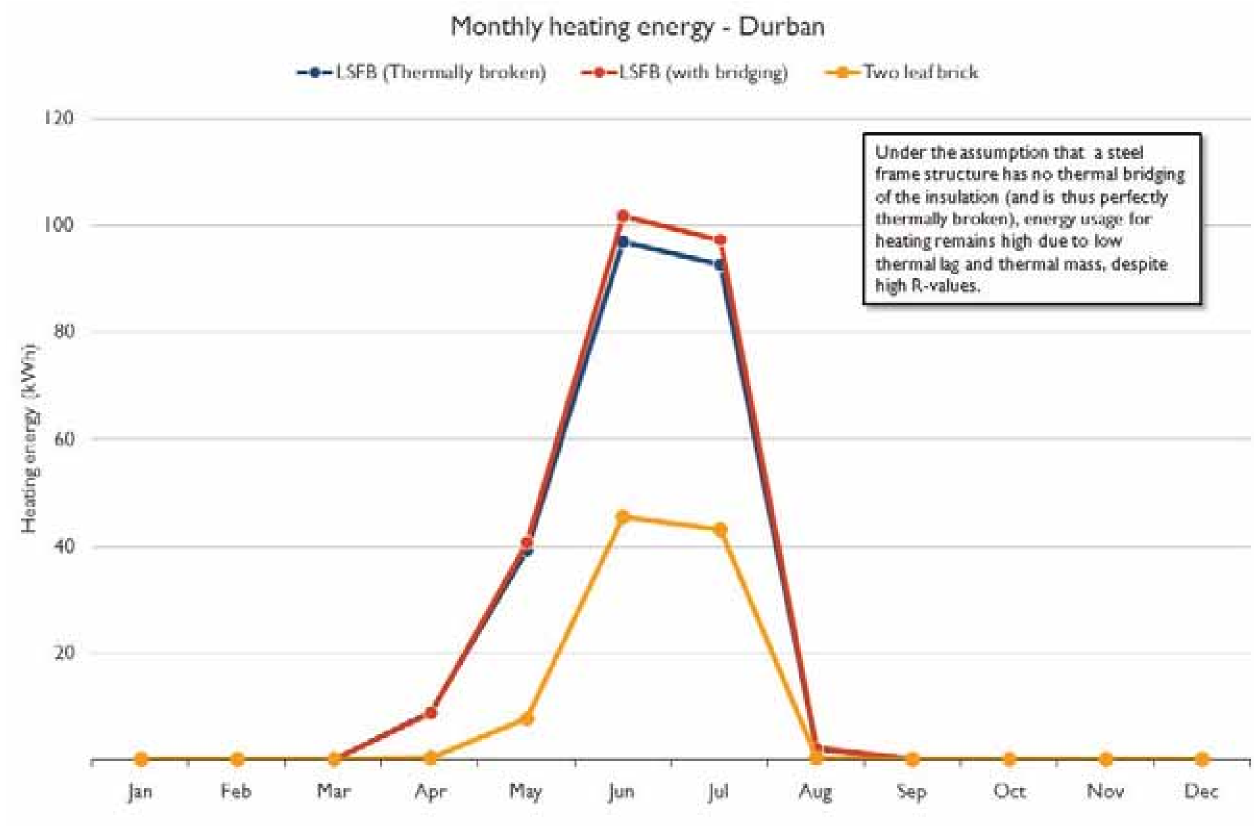


Figure 19: The effect of bridging in LSFB (four occupants, 3 ac/h)

As can be seen in Figure 19, the effect of reduced R-value due to thermal bridging in LSFB walls is far less significant than the characteristic low thermal mass of LSFB in reducing the requirement of heating energy. An un-bridged LSFB wall is akin to a light timber frame construction, where the studs are replaced by less thermally conductive wood members. This is a common light weight construction type for many homes in the USA.

2.5.7 *Cost of energy*

The cost of energy for a low cost house is a significant proportion of the family's income – according to research done by the World Bank it is typically about 15% (transport is the most significant – about 40%). Therefore any improvements of energy efficiency and energy cost savings to the low cost housing family are likely to have a significant impact on their livelihood in the long term. Besides the direct implications on the families living conditions in these homes, there are national implications to providing more or less energy, and associated greenhouse gas emissions – these national aspects are highlighted in later sections of this report.

The graphs below illustrate some of energy cost differences applicable for various constructions of such a house. The cost of energy is taken to be based on pre-paid electricity tariffs for 2009/2010. The price of R0.66/kWh was used, a conservative value for different municipalities in South Africa.

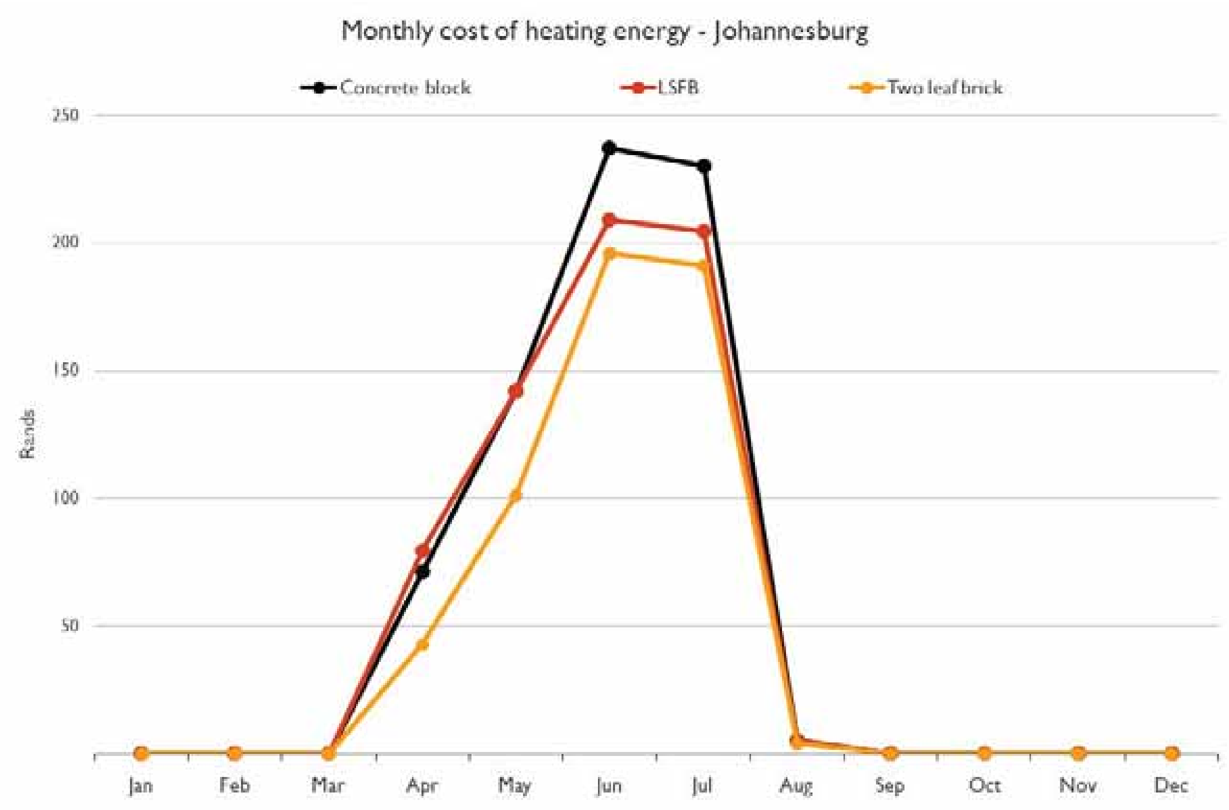


Figure 20: Cost of heating a low cost house in Johannesburg types (four occupants, 3 ac/h)

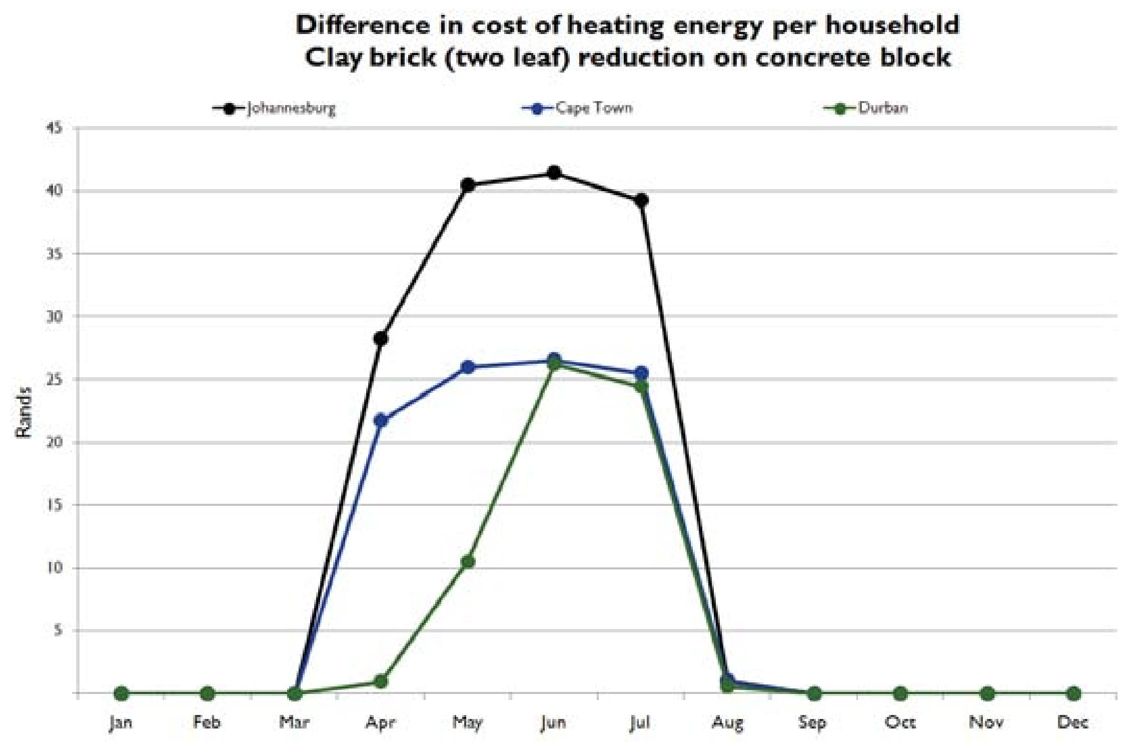


Figure 21: Difference in cost of heating energy – two clay brick and concrete block types (four occupants, 3 ac/h)

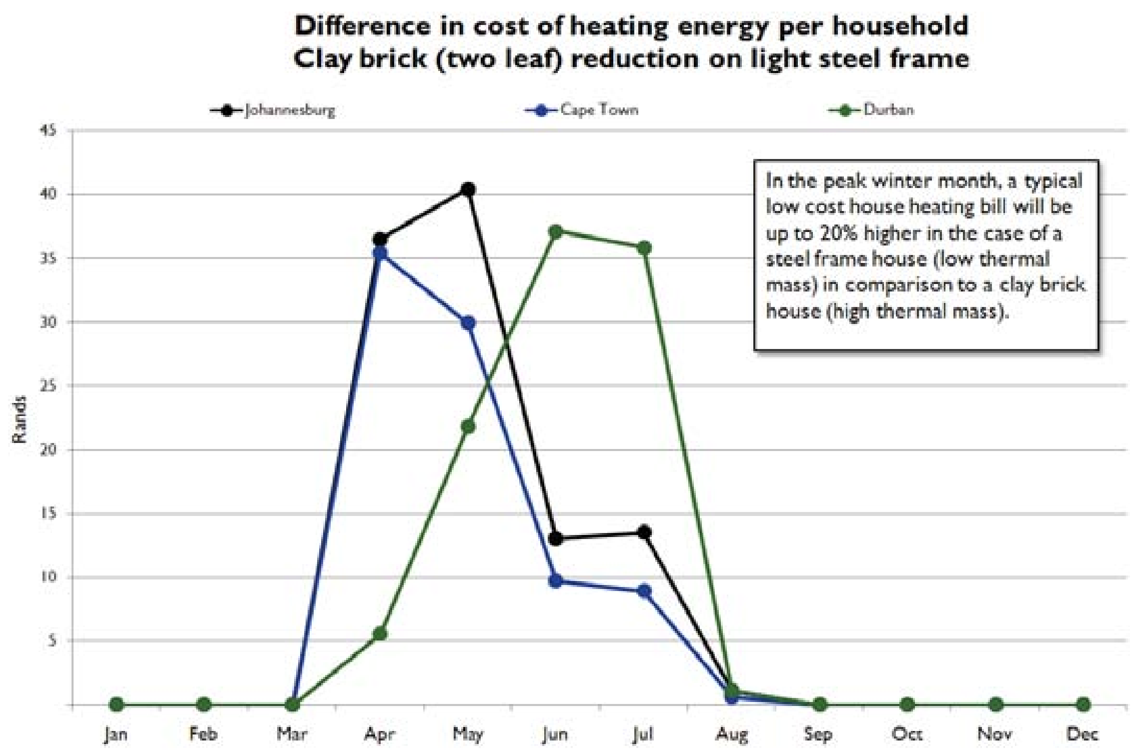


Figure 22: Difference in cost of heating energy – two leaf clay brick and LSFB types (four occupants, 3 ac/h)

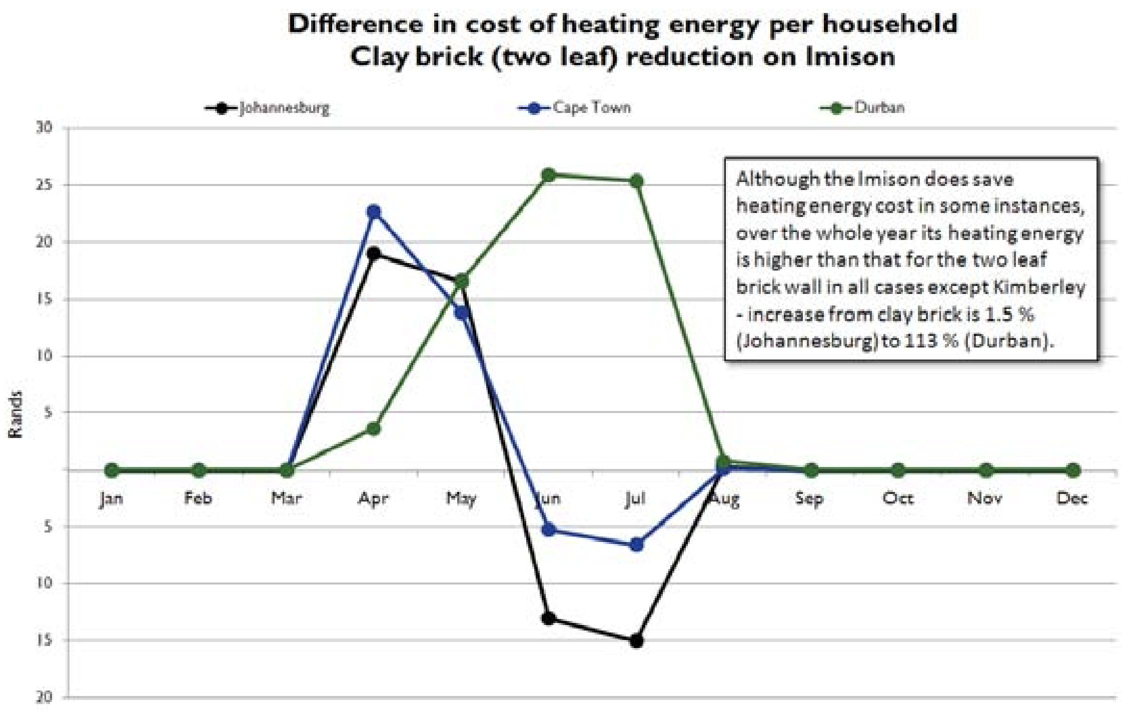


Figure 23: Difference in cost of heating energy – two leaf clay brick and Imison types (four occupants, 3 ac/h)

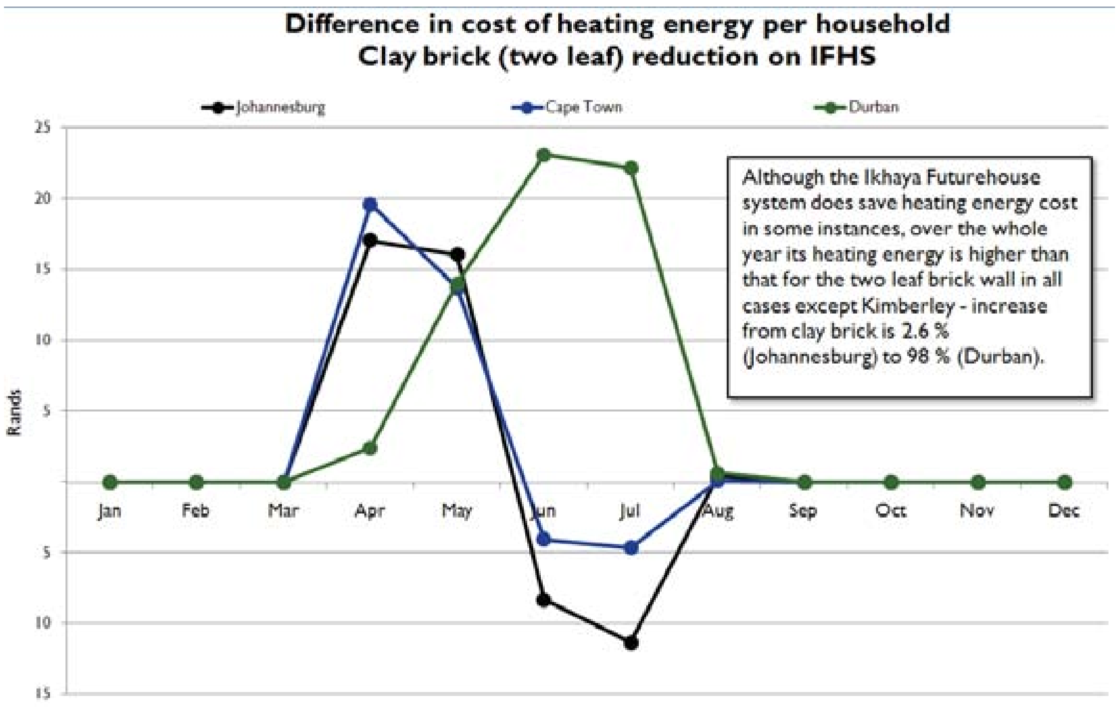


Figure 24: Difference in cost of heating energy – two leaf clay brick and Ikhaya Futurehouse types (four occupants, 3 ac/h)

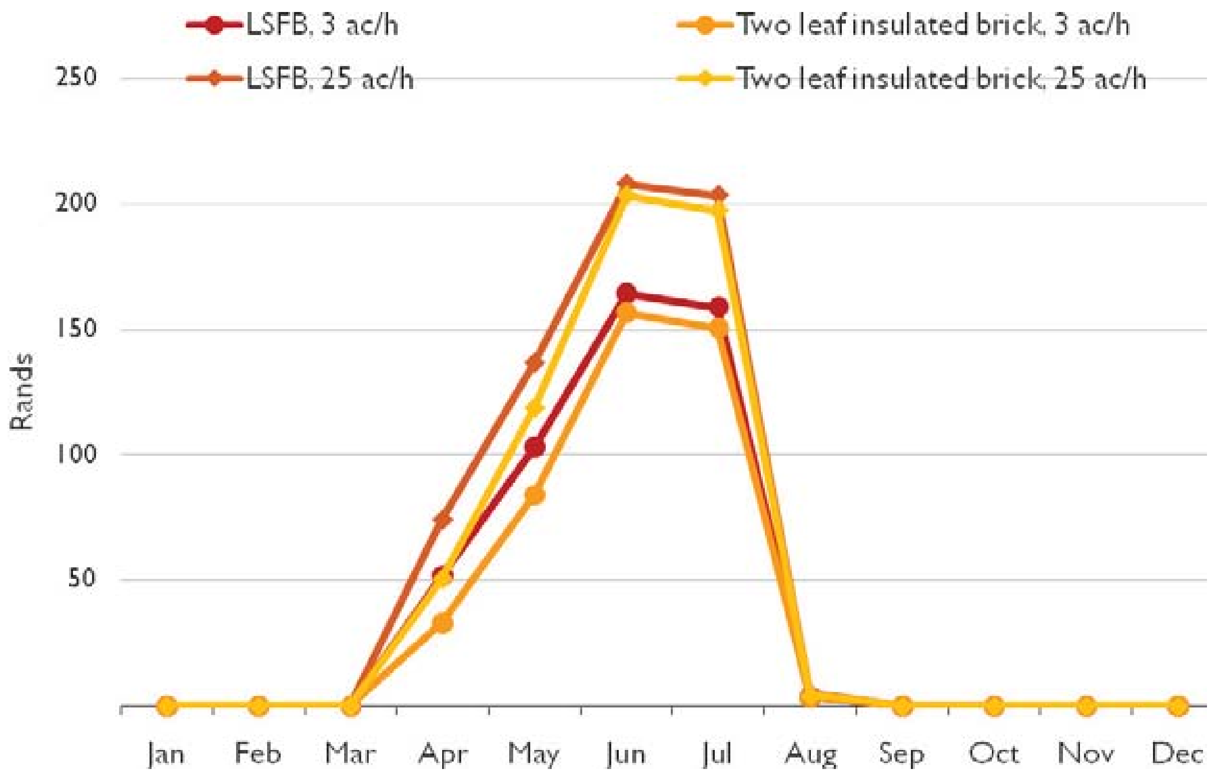


Figure 25: Monthly cost of heating energy – Johannesburg (8 occupants)

Here heating energy costs more in the SANS compliant LSFB than in the SANS compliant two leaf insulated brick house, for both natural ventilation rates. Over the year, the LSFB's heating costs R54 (12%) more than that of the brick house, and monthly the difference ranges between 0% (R0) and 55% R19.

For Durban, the LSFB annual energy use costs 87% (R48) more than that for the brick house.

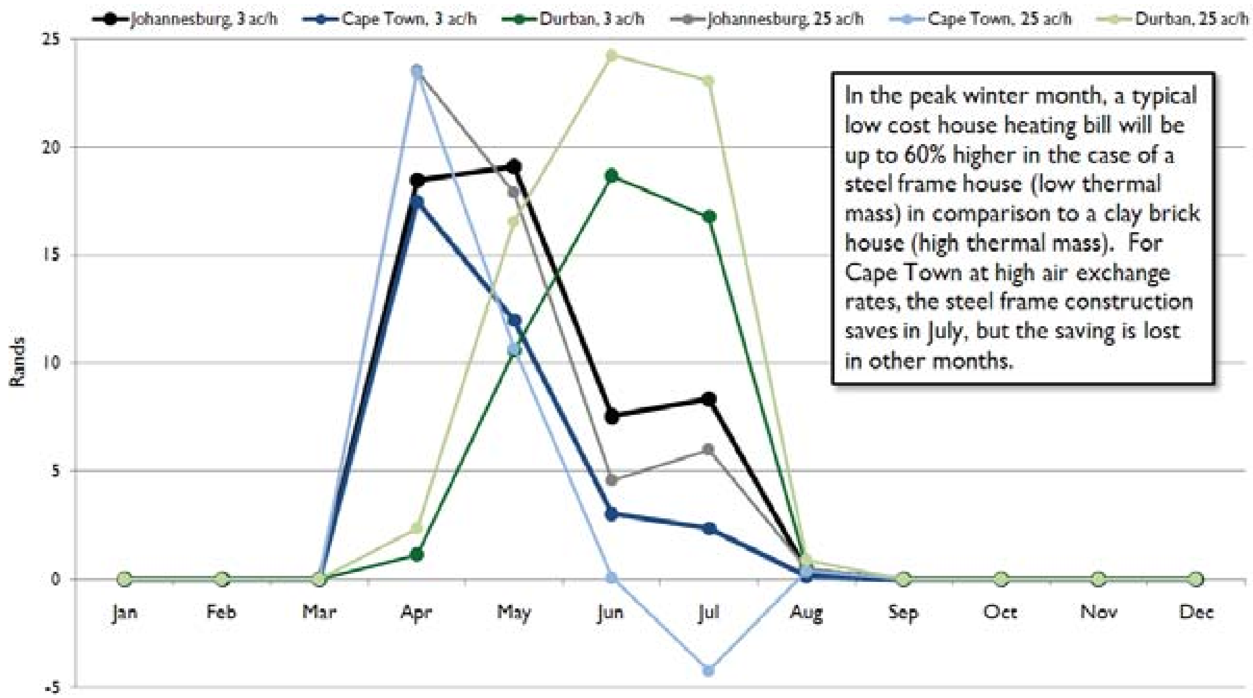


Figure 26: Difference in cost of heating energy - two leaf insulated clay brick reduction on SANS light steel frame

3. COST COMPARISON

The cost estimates for the different wall constructions and the overall low cost house comparison was done by recognised professional quantity surveyors based in Cape Town, namely MFS Quantity Surveyors. Below is a summary of the cost comparison based on Johannesburg rates, where the detailed rates and bills of quantities given in appendix D. The detailed breakdown in the appendix also highlights cost comparisons done for other regions to highlight any regional differences. The cost comparisons do not take account of the impact of the economies of scale where contractors might be able to price thousands of houses at lower costs due to higher volumes of materials being bought. This could have a significant impact on actual prices, depending on the volume of houses per contract.

The Imison and Ikhaya systems were costed in a subsequent exercise, also based on Gauteng rates. It should be noted that the costs quoted for Imison wall construction are estimates from the manufacturer and not a formal quote, as their formal costing can only be done on a per-project basis. Furthermore, they are:

- Based on costing for a structure with > 500 m^2 of wall area.
- Assuming the use of Styropor® panels, which are cheaper and of lesser thermal performance than the Neopor® panels considered in the thermal modelling, and currently being brought into use. This would tend to underestimate the cost.
- Assuming additional 5 mm of plaster finish, tending to overestimate the cost.

Table 7: Construction costs of low cost housing based on Johannesburg rates

Construction costs based on Johannesburg rates							
	Concrete block	Two leaf brick	Ikhaya Futurehouse System (IFHS)	Imison	Cavity brick	Insulated brick	LSFB
Preliminary and General :	R 6 021.00	R 6 174.00	R 6 627.60[11]	R 6 627.60[11]	R 6 764.00	R 6 914.00	R 7 265.00
Foundations: (assumed spec.)	R 6 445.93	R 6 445.93	R 6 445.93	R 6 445.93	R 6 445.93	R 6 445.93	R 5 653.27
Ground Floor Construction: (assumed spec.)	R 4 659.39	R 4 659.39	R 4 659.39	R 4 659.39	R 4 659.39	R 4 659.39	R 4 659.39
Roofs :	R 8 678.72	R 8 678.72	R 8 678.72	R 8 678.72	R 8 678.72	R 8 678.72	R 8 678.72
External Walling :	R 19 839.94	R 21 399.33	R 25 057.00	R 25 657.60	R 27 289.30	R 28 799.14	R 32 577.88
Internal Divisions :	R 1 652.47	R 1 629.67	R 2 968.00	R 3 865.40	R 1 631.09	R 1 631.13	R 4 992.65
Floor Finishes :	R 2 146.00	R 2 146.00	R 2 146.00	R 2 146.00	R 2 146.00	R 2 146.00	R 2 146.00
Internal Wall Finishing :	R 6 175.00	R 6 175.00	R 3 335.00	R 3 335.00	R 6 175.00	R 6 175.00	R 3 335.00
Ceilings :	R -	R -	R -	R -	R -	R -	R -
Electrical Installation :	R 3 659.65	R 3 659.65	R 3 659.65	R 3 659.65	R 3 659.65	R 3 659.65	R 3 659.65
Plumbing Installation :	R 4 800.00	R 4 800.00	R 4 800.00	R 4 800.00	R 4 800.00	R 4 800.00	R 4 800.00
Provisional Sums :	R 2 150.00	R 2 150.00	R 2 150.00	R 2 150.00	R 2 150.00	R 2 150.00	R 2 150.00
Contingency Allowance :	0	0	0	0	0	0	0
Sub-Total	R 66 228.10	R 67 917.70	R 70 527.30	R 72 025.30	R 74 399.09	R 76 058.96	R 79 917.56
VAT	R 9 271.93	R 9 508.48	R 9 873.82	R 10 083.54	R 10 415.87	R 10 648.25	R 11 188.46
TOTAL : Estimate excluding ceiling (i)	R 75 500.04	R 77 426.17	R 80 401.12	R 82 108.84	R 84 814.96	R 86 707.22	R 91 106.02
R/m2	R 1 887.49	R 1 935.66	R 2 010.03	R 2 052.72	R 2 120.36	R 2 167.69	R 2 277.66
% difference on concrete block	0%	3%	6%	9%	12%	15%	21%

[11] Preliminary and general cost for Imison and Ikhaya Futurehouse walls are estimated from the average of corresponding values for the remaining wall types.

	Concrete block	Two leaf brick	Ikhaya Futurehouse System (IFHS)	Imison	Cavity brick	Insulated brick	LSFB
Optional ceiling							
Construction cost brought forward (item i)	R 66 228.10	R 67 917.70	R 70 527.30	R 72 025.30	R 74 399.09	R 76 058.96	R 79 917.56
Ceiling & insulation	R 7 848.00	R 7 848.00	R 7 848.00	R 7 848.00	R 7 848.00	R 7 848.00	R 7 848.00
Sub-Total	R 74 076.10	R 75 765.70	R 78 375.30	R 79 873.30	R 82 247.09	R 83 906.96	R 87 765.56
VAT	R 10 370.65	R 10 607.20	R 10 972.54	R 11 182.26	R 11 514.59	R 11 746.97	R 12 287.18
TOTAL : Estimate including ceiling	R 84 446.76	R 86 372.89	R 89 347.84	R 91 055.56	R 93 761.68	R 95 653.94	R100 052.74
R/m2	R 2 111.17	R 2 159.32	R 2 233.70	R 2 276.39	R 2 344.04	R 2 391.35	R 2 501.32
% difference on concrete block	0%	2%	6%	8%	11%	13%	18%

4. CARBON FOOTPRINT

4.1 Construction Carbon Footprint

A desktop study of the construction embodied energy (carbon footprint) was done to approximate the energy used in manufacturing and construction of the materials and products used to construct the low cost house design referred to in this report. The embodied energy unit that was used was kg CO_2, and was calculated using freely available sources where available for the kg CO_2 / kg of material or product. The specific material embodied energy as they occur and are supplied in South Africa were not measured or quantified (except for the Corobrik products, where these were available), but instead the closest match to the selected materials was selected where kg CO_2 / kg values were found to be available. The plumbing and electrical installations were excluded from these calculations, as kg CO_2 / kg values were not readily available. The method used was not according to any specific standard, but purely based on a simple desktop arithmetical exercise – the details are given in the appendices.

The energy for transport of materials was not accounted for in this desktop study. One might expect that LSFB might have lower transportation energy requirements based on their lighter mass and slightly lower volumes, however this would not necessarily be the case, as it would also depend on the types of transport used (which could include shipping) and distance travelled. Corobrik, as with concrete block manufacturers, have production facilities around the country. LSFBs are composite structures, the components of which could be sourced from a number of locations. Further to this, the location of the construction is different in every case. Such a comparison can only be done for a specific project with a specific location and choice of suppliers and transport modes. It is for these reasons that embodied energy due to transport of the materials is not included in this study.

Table 8 shows a summary of the estimated carbon footprint of the different construction types.

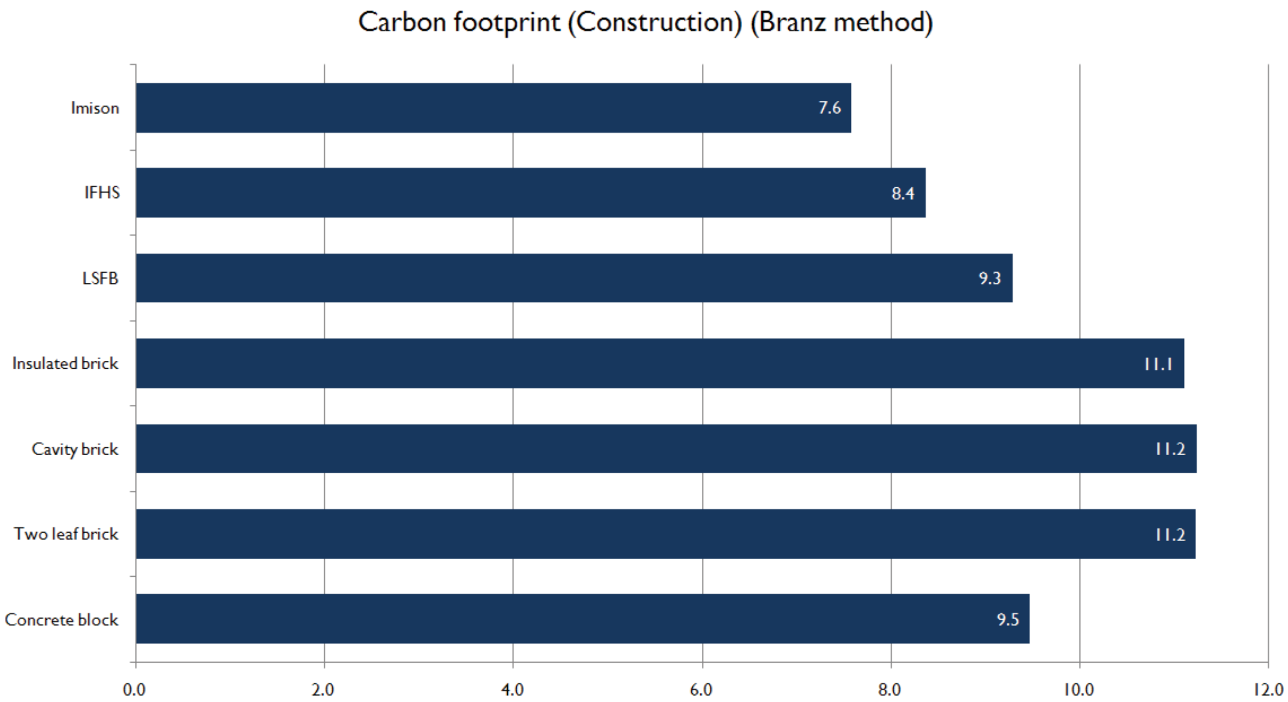
Out of the various references used, the summary below applies the numbers obtained using the Branz method, since it was the most conservative; that is, it had the highest values for embodied energy.

Imison and Ikhaya Futurehouse wall systems were subsequently included in the study.

Table 8: Carbon footprint of the construction of a low cost house

Embodied CO_2 (kg) using the Branz (2006) method							
	Concrete block	**Two leaf brick**	**Cavity brick**	**Insulated brick**	**LSFB**	**Imison**	**Ikhaya Futurehouse System (IFHS)**
Foundations :	2146	2146	2146	2146	1852	2146	2146
Ground Floor Construction :	1480	1480	1480	1480	1442	1480	1480
Roofs :	1291	1291	1291	1291	1291	1291	1291
External Walling :	1714	4739*	4742*	4776*	3380	1524	2339
Internal Divisions :	1845	578*	578*	578*	467	282	252
Floor Finishes :	566	566	566	566	566	566	566
Internal Wall Finishing :	223	223*	223*	67*	86	86	86
TOTAL (kg CO2) (i)	**9266**	**11024**	**11027**	**10904**	**9085**	**7376**	**8160**
% difference on concrete block	0%	19%	19%	18%	-2%	-20%	-12%
Total house including a ceiling							
CO2 brought forward (item i)	9266	11024	11027	10904	9085	7376	8160
Ceiling & insulation	205	205	205	205	205	205	205
TOTAL (kg CO2)	**9470**	**11229**	**11231**	**11109**	**9290**	**7582**	**8366**
% difference	0%	19%	19%	17%	-2%	-20%	-12%
Specific comparison							
External walls (incl. finish)	1595	4620	4623	4657	3261	1405	2220
% difference on concrete block	0%	190%	190%	192%	104%	-12%	39%
Internal walls (incl. internal finishes)	2068	801	801	645	544	369	338
% difference on concrete block	0%	-61%	-61%	-69%	-74%	-82%	-84%
	Concrete block	**Two leaf brick**	**Cavity brick**	**Insulated brick**	**LSFB**	**Imison**	**Ikhaya Futurehouse System (IFHS)**

* The Embodied CO2 and density for all clay bricks were directly provided by Corobrik, based on the average between their production facilities for the given product.



	Concrete block	Two leaf brick	Cavity brick	Insulated brick	LSFB	IFHS	Imison
■ Tons of CO2	9.5	11.2	11.2	11.1	9.3	8.4	7.6

Data sourced from embodied energy study undertaken by Econic Environmental Consultants (amended)

Figure 27: Carbon footprint of the construction of a low cost house

Figure 27 above shows the results of the *embodied* CO_2 study. The embodied CO_2 of the house must however be put into the context of its life cycle energy consumption or carbon emissions, to give a holistic perspective of the actual 'carbon footprint' of that house.

4.2 Overall Carbon Footprint

Figure 28 indicates the life cycle 'carbon footprint' over a period of 40 years of the low cost house. The life of the building is set to 40 years for the purposes of this illustration, but the life of these buildings could be longer (up to 50-70 years, depending on construction quality and maintenance).

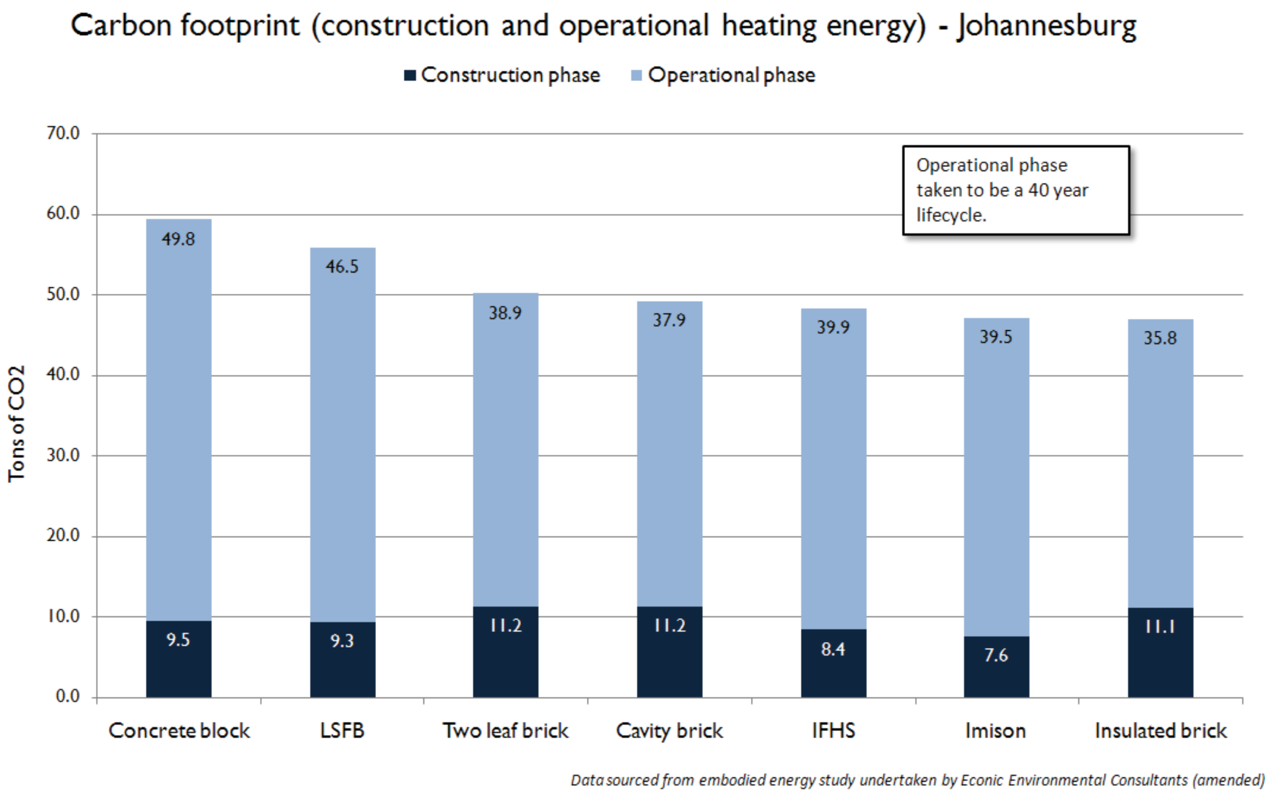


Figure 28: Carbon footprint of the construction and operational heating energy of a low cost house over 40 years (operational energy use based on four occupants, 3 ac/h ventilation)

Figure 28 clearly shows how over the life of a building the operational energy usage and emissions are the more important considerations.

The South African government of 2009 has stated that their aim is to increase the number of low cost houses built per year to 500,000. Given this proposed volume, the energy usage in these houses has substantial carbon emissions implications. Refer to the later section in this report on national implications for further illustration of this.

5. INDOOR ENVIRONMENT QUALITY

5.1 Occupant thermal comfort

Predicted Mean Vote (PMV)

Indoor air temperatures are not sufficient to adequately describe occupant comfort. Comfort is based on a number of factors highlighted below. The internationally-accepted method for measuring comfort is a metric called Predicted Mean Vote (PMV), and is defined by ISO 7730 as the standard means of assessing the comfort of occupants under different indoor environment conditions. The key variables determining human comfort as defined by ISO 7730 are:

- Mean radiant temperature
- Air Temperature
- Metabolic rate
- Clothing
- Air speed
- Humidity

Table 9: Predicted Mean Vote levels

PMV level	interpretation
-3	cold
-2	cool
-1	slightly cool
0	comfortable
1	slightly warm
2	warm
3	hot

PMV levels outside of ±3 represent significant occupant discomfort.

5.1.1 *Comfort by region*

Given that Mean Radiant Temperature is a dominant factor in thermal comfort (accounting for a half to two-thirds of perceived temperature), thermal mass often gives a reprieve from very hot or cold internal temperatures - by the effect of thermal lag. Walling materials with high thermal mass attenuate swings in comfort levels. High insulation, low thermal mass walls do have the advantage of allowing the space to be heated quickly, as can be seen during the evening hours when the house is heated from waste cooking-energy. This mechanism, however, acts to reduce comfort when it exacerbates high late-afternoon temperatures in summer, trapping in heat due to high insulation.

Figure 29 shows how clay brick walling minimises the number of occupied hours where significant thermal discomfort is present. Given that the house is naturally ventilated, and only has heating of limited power, some thermal discomfort is to be expected.

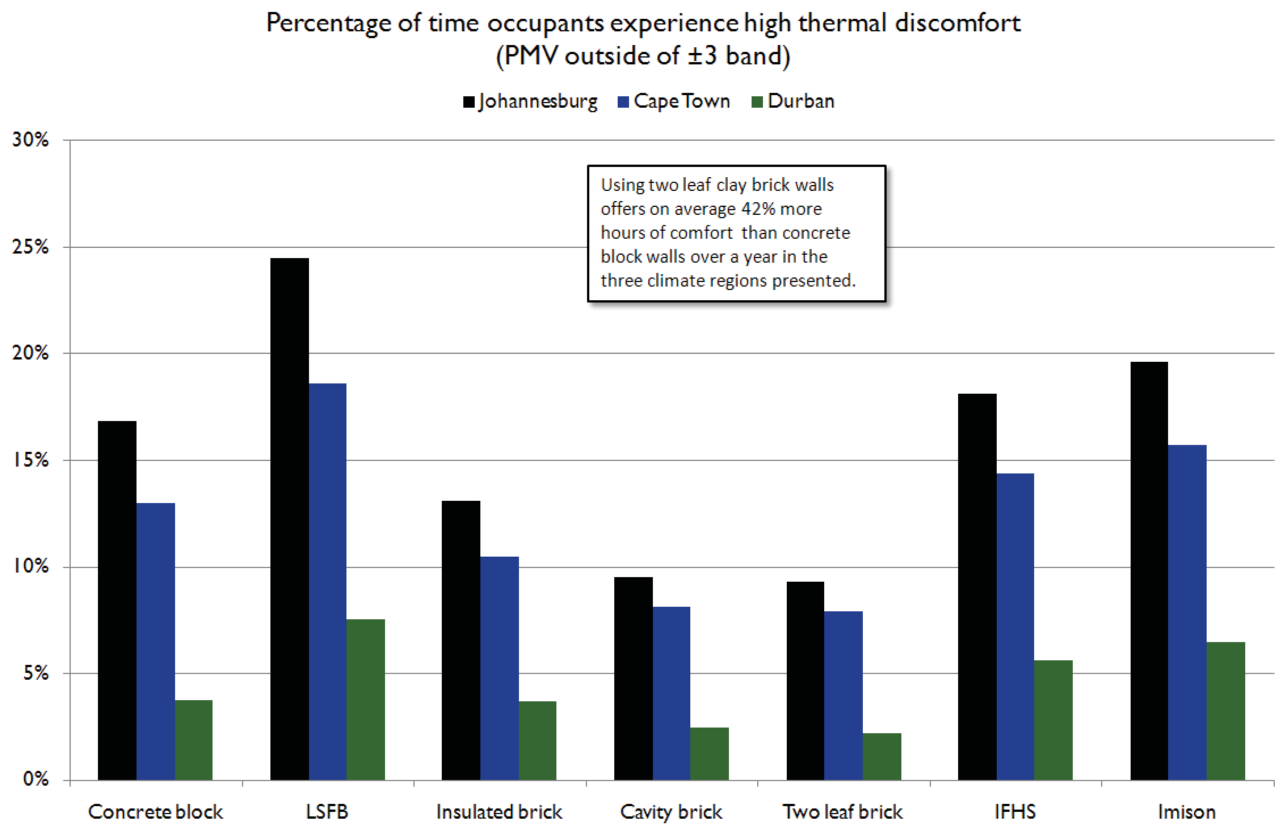


Figure 29: Amount of time of occupant discomfort (four occupants, 3 ac/h natural ventilation)

Figure 30 shows the hourly values for PMV over the year in Johannesburg. The attenuating effect of thermal mass can be seen. This means that comfort can fluctuate more rapidly in light steel frame structures, whilst high thermal mass structures have more consistent comfort conditions. Figure 31shows a similar though less pronounced trend comparing concrete block with the higher thermal mass Imison and Ikhaya Futurehouse (IFHS) walls. Appendix B shows the hourly PMV values for Durban and Cape Town.

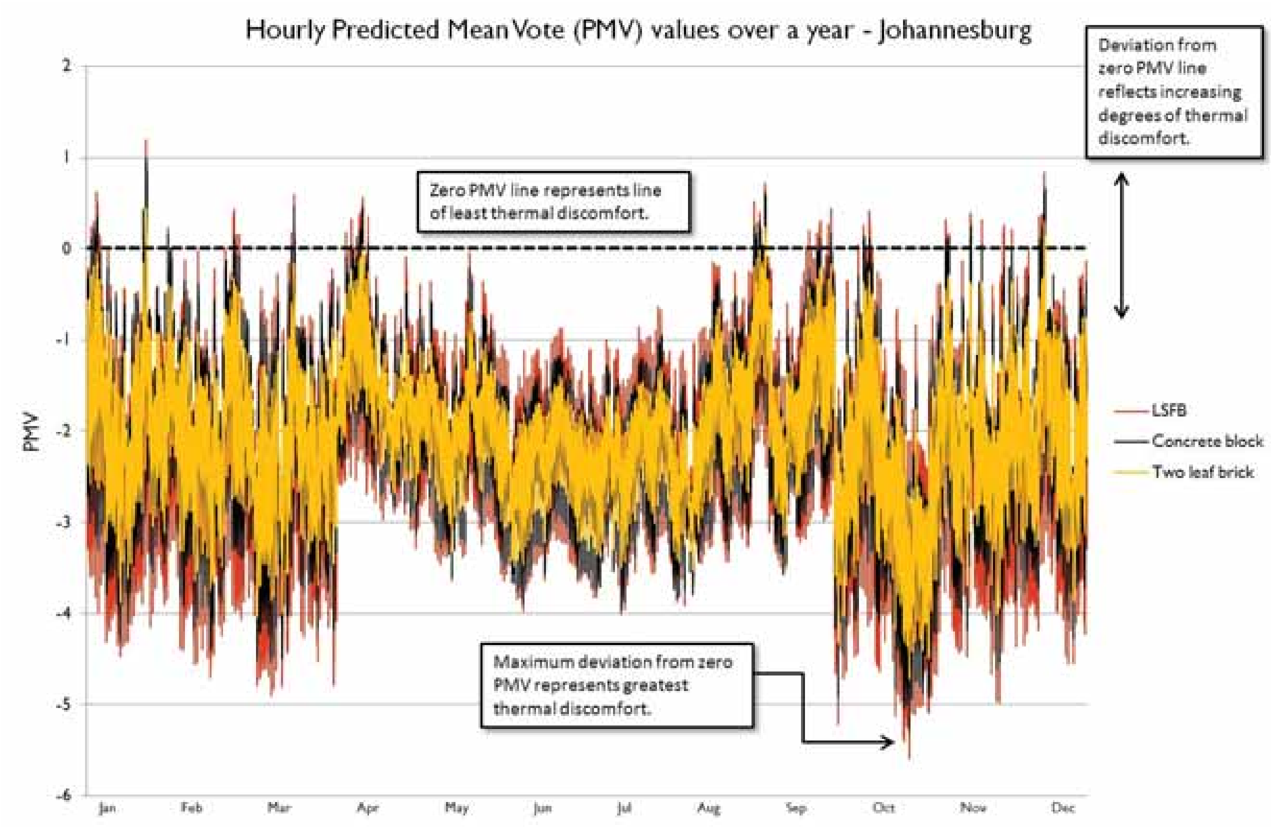


Figure 30: Hourly PMV levels over a year in Johannesburg (four occupants, 3 ac/h natural ventilation)

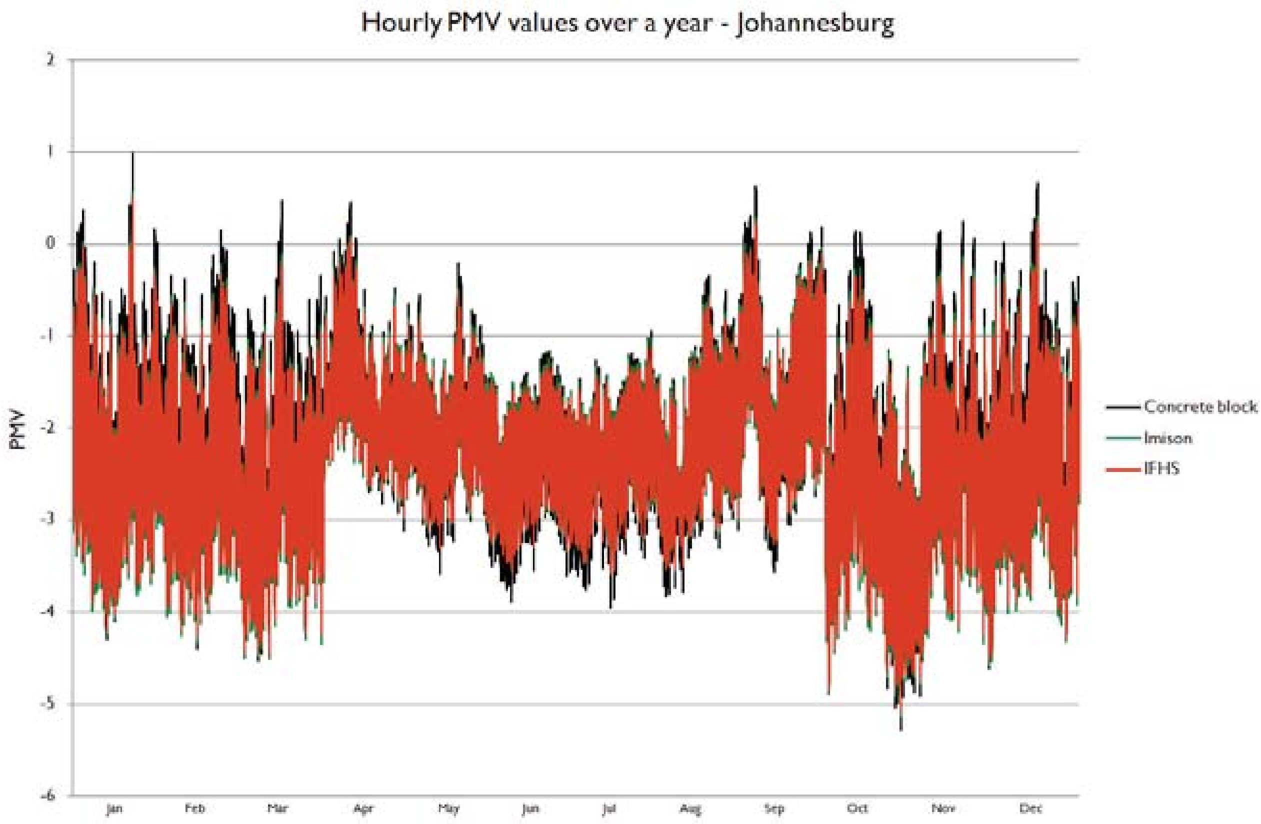


Figure 31: Hourly PMV levels over a year in Johannesburg, comparing Imison and Ikhaya Futurehouse (four occupants, 3 ac/h natural ventilation)

The comfort results accounting for the SANS compliant LSFB and 8 occupants are shown below.

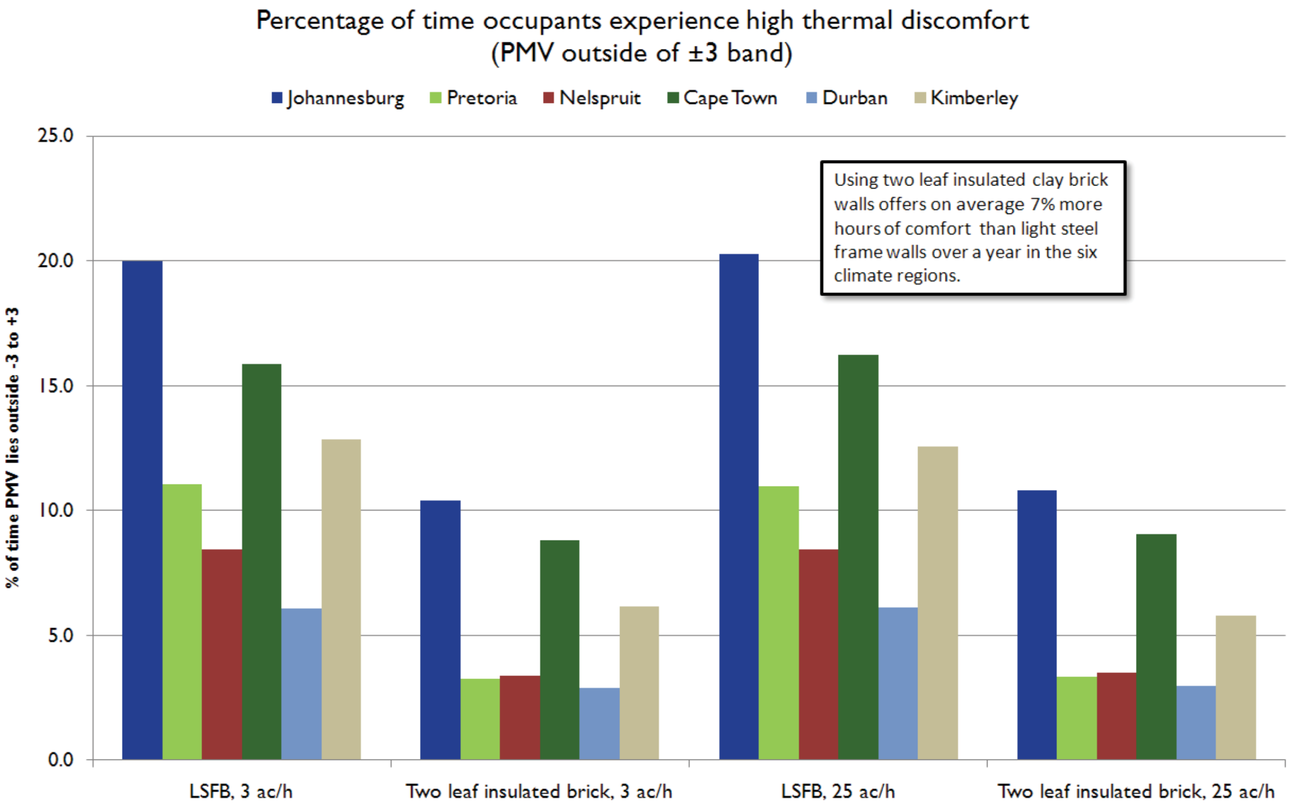


Figure 32: Percentage of time occupants experience high thermal discomfort (PMV outside of -3 to +3 band) with LSFB to SANS 517, 8 occupants

PMV is plotted over the year for the revised case. The Johannesburg case is shown – see Appendix A for further results.

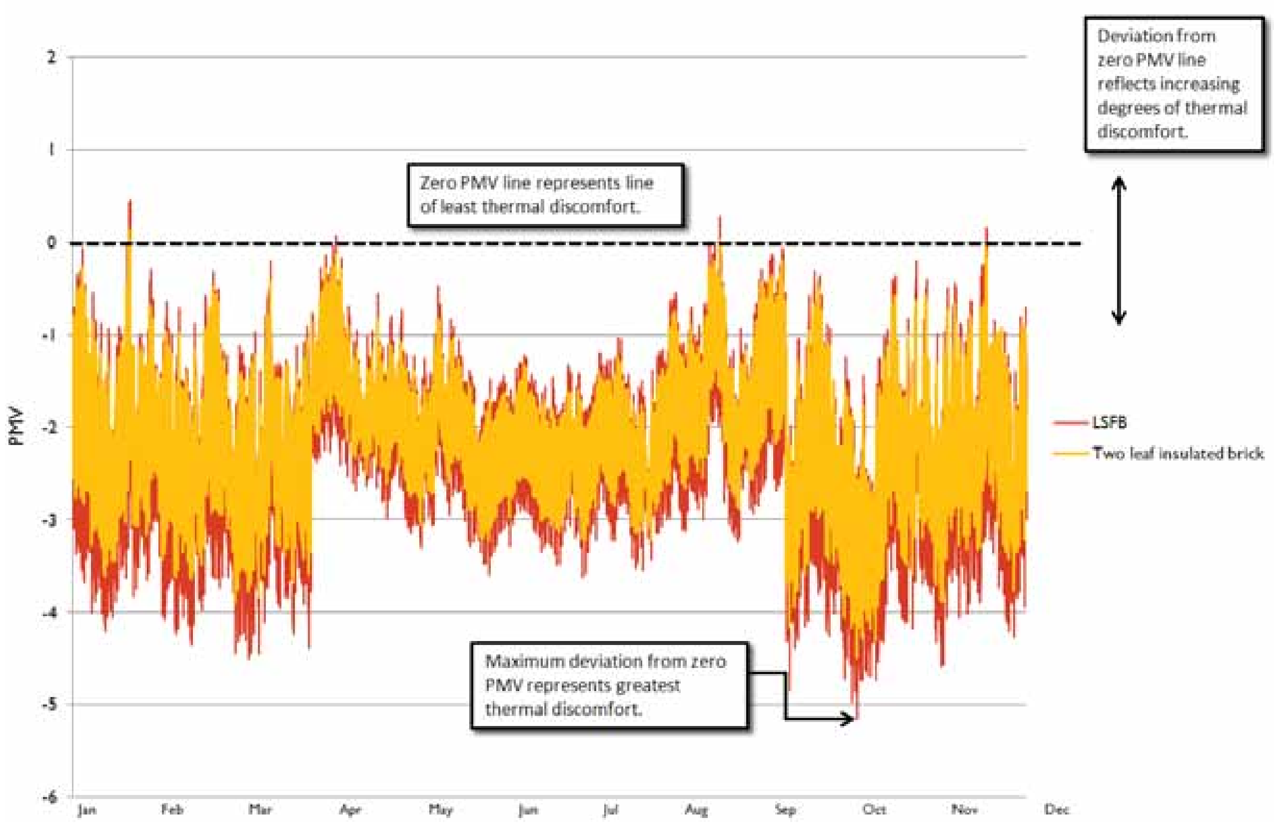


Figure 33: PMV over a year in Johannesburg with SANS 517 LSFB, 8 occupants and 3 ac/h

5.1.2 *Energy and comfort*

Different walling materials affect the amount of energy required to bring a space to comfort. Typically, low thermal mass materials have less thermal inertia than those with high thermal mass. This means that lightweight structures will heat up and cool down faster. This can be advantageous in brining a space to comfort quickly, however it prevents heating energy from the day to be stored in the structure at night.

In Figure 34, the improvement in comfort (PMV values go closer to zero) seen in the evening is due to cooking energy heating up the space. The house with light steel frame walls heats up more quickly, but does not retain that heat which is quickly lost again when it is needed inside.

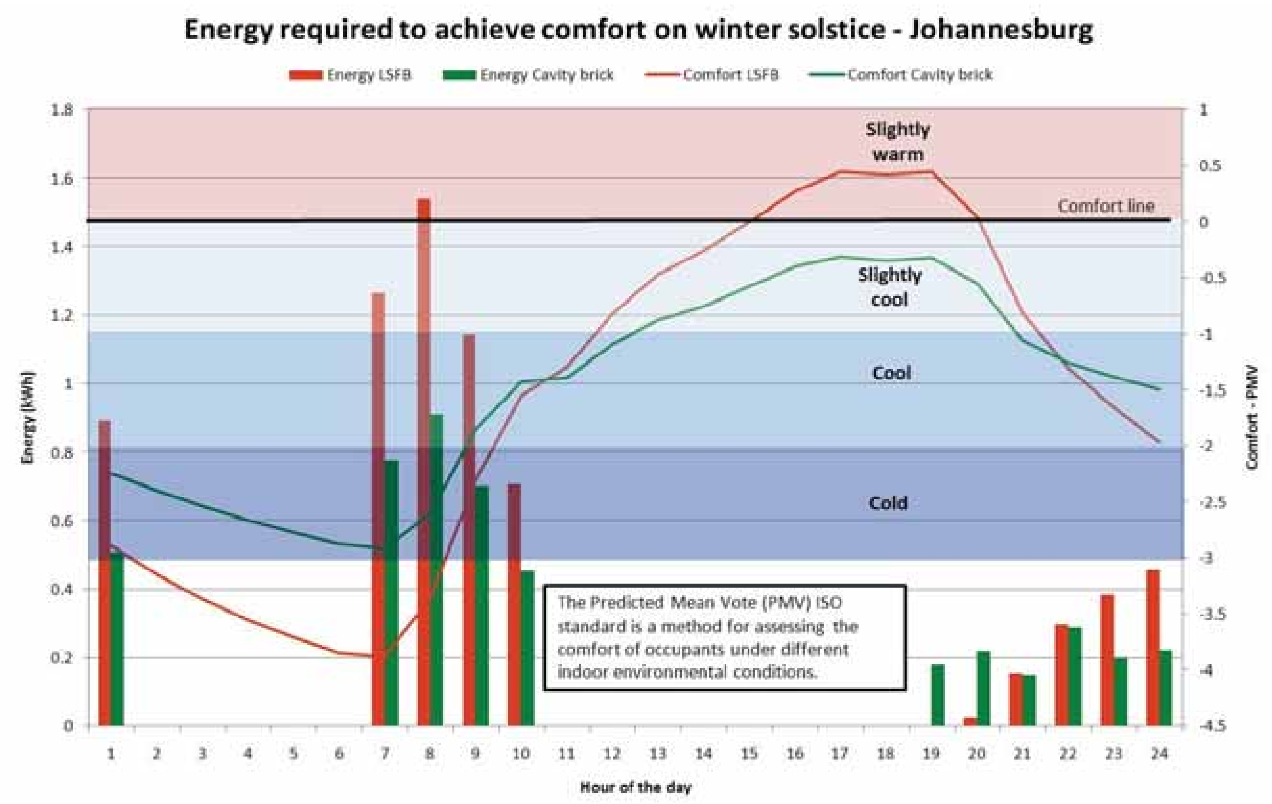


Figure 34: Energy required to achieve thermal comfort during winter in Johannesburg, comparing cavity brick and light steel frame (4 occupants, 3 ac/h)

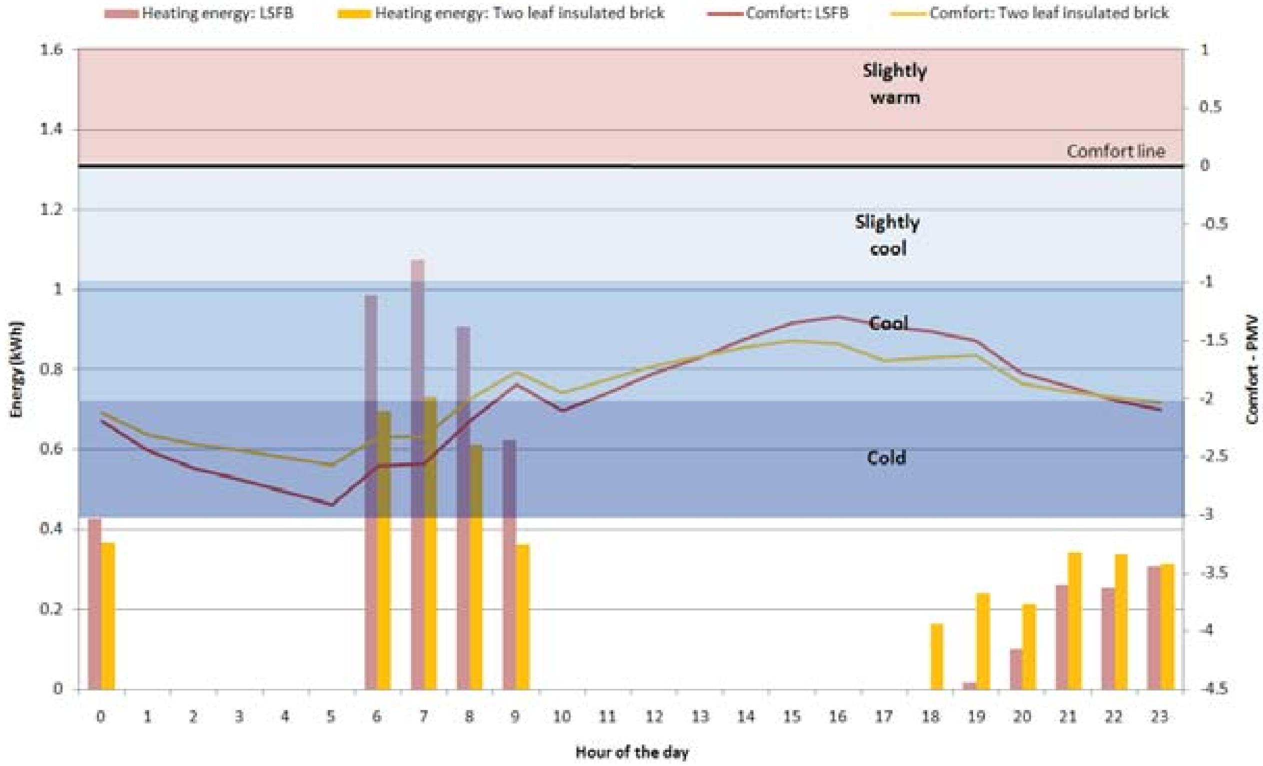


Figure 35: Energy required for comfort on winter solstice - Johannesburg, 3 ac/h, 8 occupants

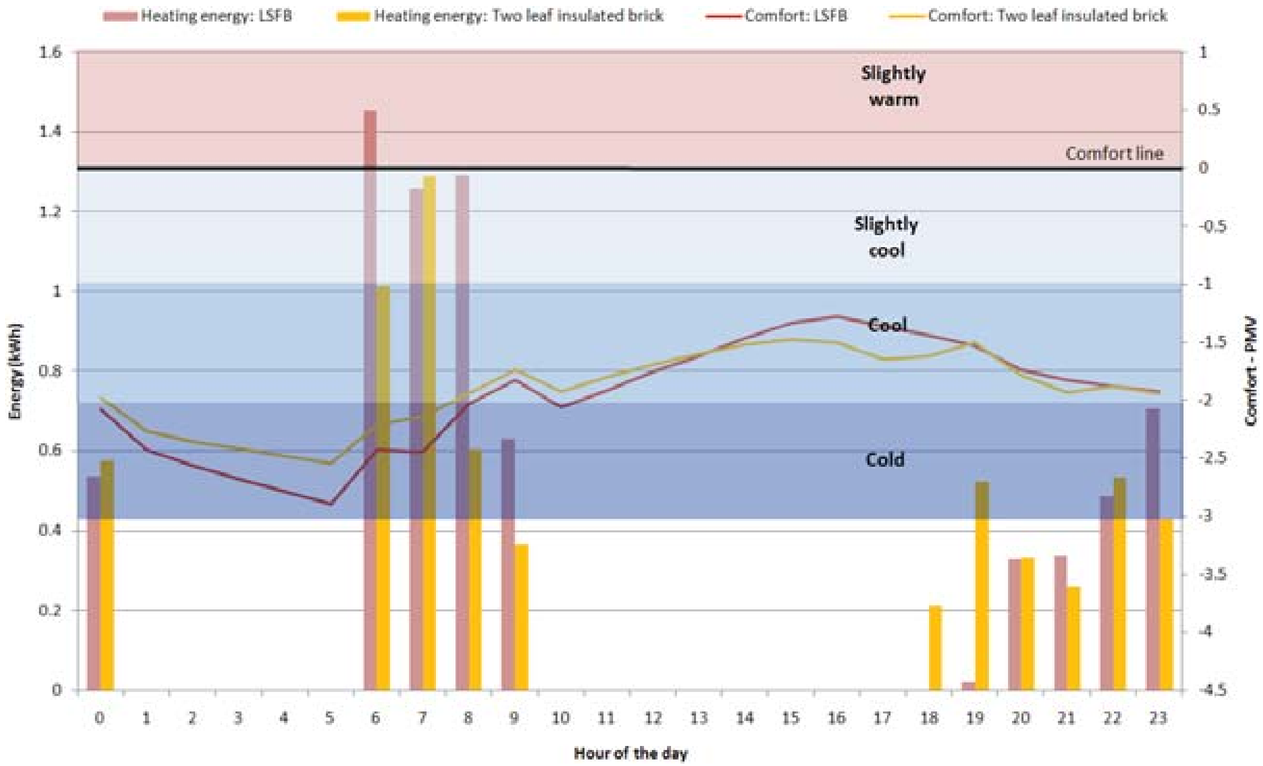


Figure 36: Energy required for comfort on winter solstice - Johannesburg, 25 ac/h, 8 occupants

5.2 Daylight

A daylight study was performed on the existing low cost house design. Maximising natural light can lead to savings on lighting energy, as well as improve indoor environmental quality which can have a significant impact on occupant health and well being. A design sky representing an overcast condition was used, with the sky lux level set to 10,000. The average lux level in the house is 148, which is fairly low. Changing window placement and dimensions, depending on the orientation of the house on the plot would have a beneficial effect on natural light levels and should be considered when planning low cost housing layouts for a particular area. Placing the dominant glazed face on the North facade will offer both natural light and solar heat gain advantages.

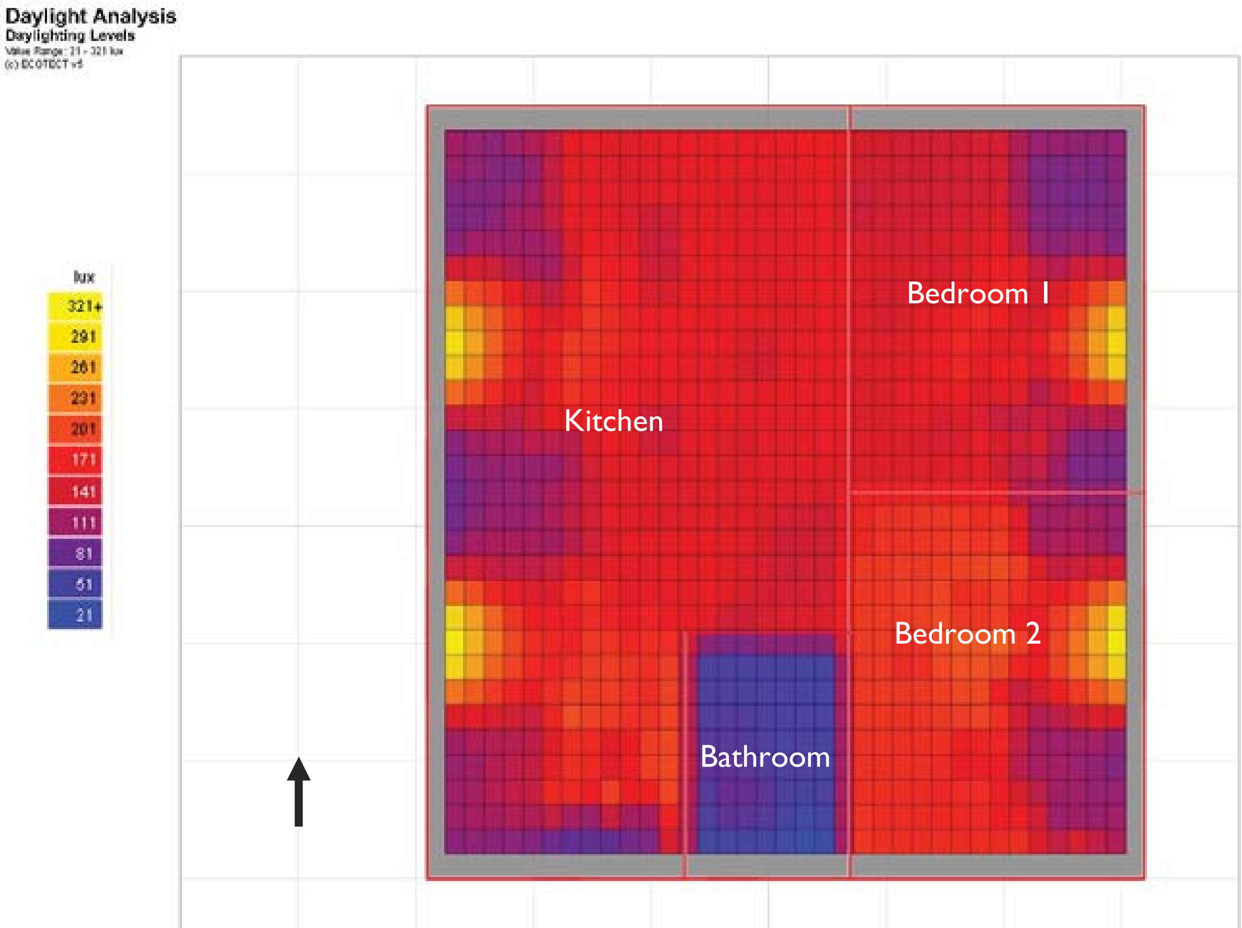


Figure 37: Daylight map of low cost house

5.3 Moisture, damp & mould

Rain and damp have often been found to be problems which concrete block constructed low cost homes experience, especially in areas where wind driven rain occurs. This problem is often exacerbated by poor quality workmanship. Concrete blocks also have the characteristic of retaining moisture absorbed, which can often cause mould growth. Water ingress and mould are both unwanted and unhealthy in a home, and can cause significant long term health problems for the occupants, especially in terms of the human respiratory system.

The clay brick construction allows for a cavity wall (common in the Western Cape coastal region), which very effectively allows water ingress to drain down the cavity without penetrating the home. Similarly mould is less common on clay brick walls, which tend to allow water to be absorbed and released more readily and thus do not retain moisture as the concrete blocks do.

LSFB construction for low cost housing is yet to be rolled out on a large scale and thus the quality of workmanship could be as significant an issue where it comes to potential water ingress.

5.4 Volatile Organic Compounds

Volatile organic compounds (VOC) are found in most paint products used in South Africa, especially in the low cost housing industry where typically cheaper products would be sourced. VOCs in internal spaces over extended periods can cause significant health problems and cause respiratory problems. Both concrete block and LSFB construction typically require painting for aesthetic reasons, whereas a clay brick does not necessarily need to be bagged and painted. This certainly allows the opportunity for no VOCs in these households, and also reduces potential maintenance costs.

6. DESIGN CONSIDERATIONS

6.1 Extensibility

A very simplistic exercise was done to understand the potential of being able to extend the 40m² house, as and when the family was able to do so. Below is an illustration of one such option, where placing the initial house on the plot allows for extensibility, and thus allows the opportunity for the family to improve the quality and value of their house. This goes a long way towards establishing communities that want to remain in their homes on that property, instilling community upliftment.

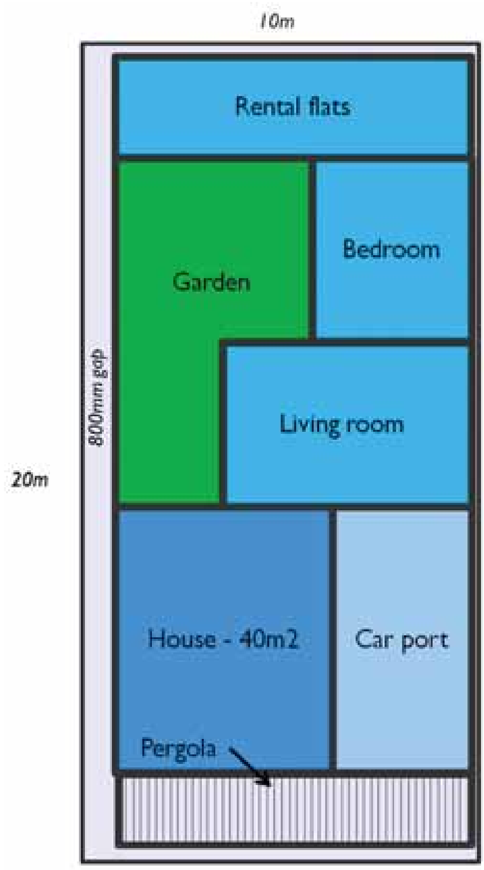


Figure 38: Option for extensibility and development of plot

Any form of brickwork construction verses LSFB construction will allow the family to make their own extensions and renovations in their own time without requiring the more specialised skills which would typically be required for LSFB construction. This is a significant consideration for these families who aim to improve the quality of their homes.

6.2 Aesthetics, Value & Sense of Place

The aesthetic and value of a house are incredibly important to the family that lives in that house, so much so that they use whatever little they have to create a sense of place, identity and value in their home where possible. Building in face brick allows for this and allows for home owners to use some of the inherent beauty of the clay brick to produce design elements that start to create identity and attractive homes that people want to live in – this often is created by adding elements of human scale.

Below are some sketches of a low cost home that simply applies a few basic elements or details to introduce the human scale and add value to the property in creating a home (sketches prepared by Eric Noir).

Figure 39: Sketch of low cost house 1

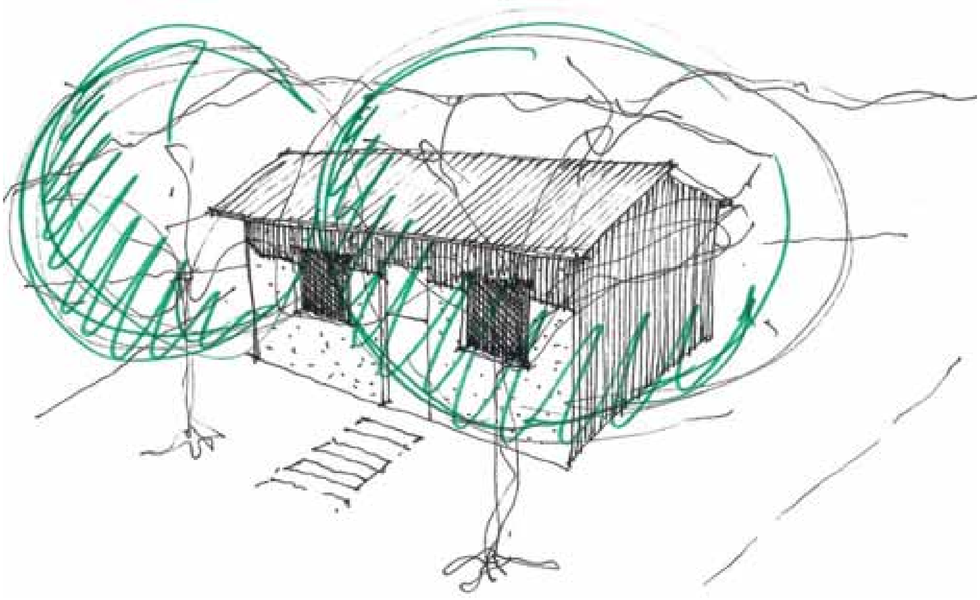


Figure 40: Sketch of low cost house 2

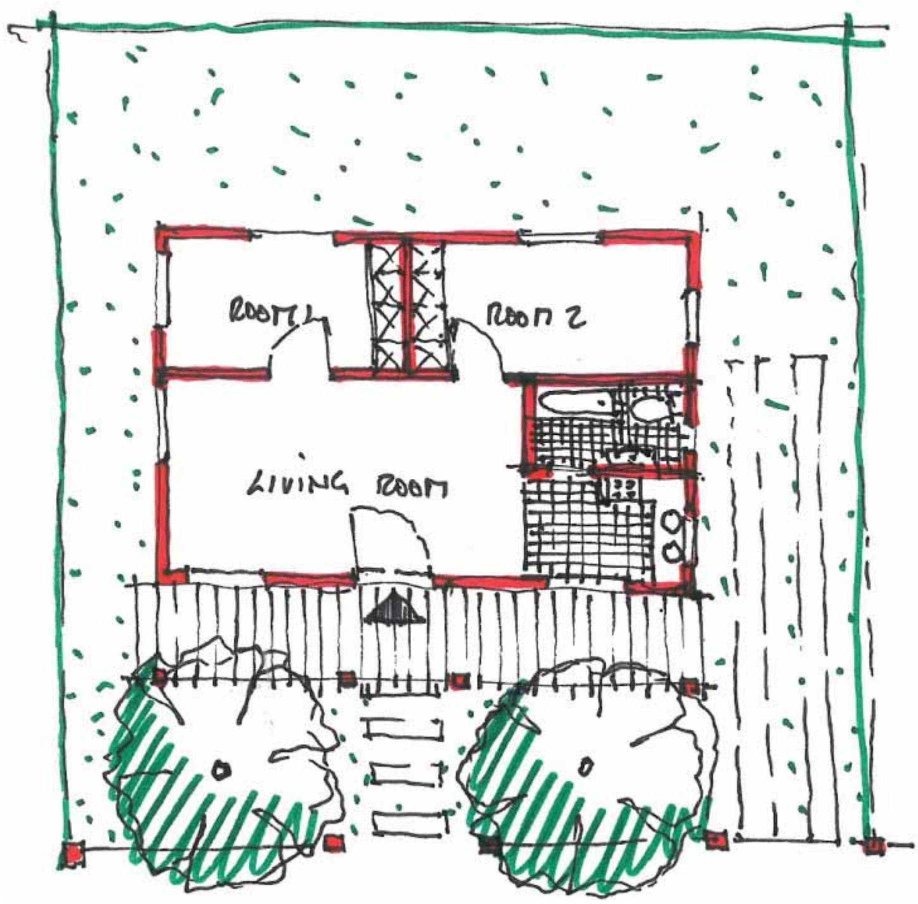
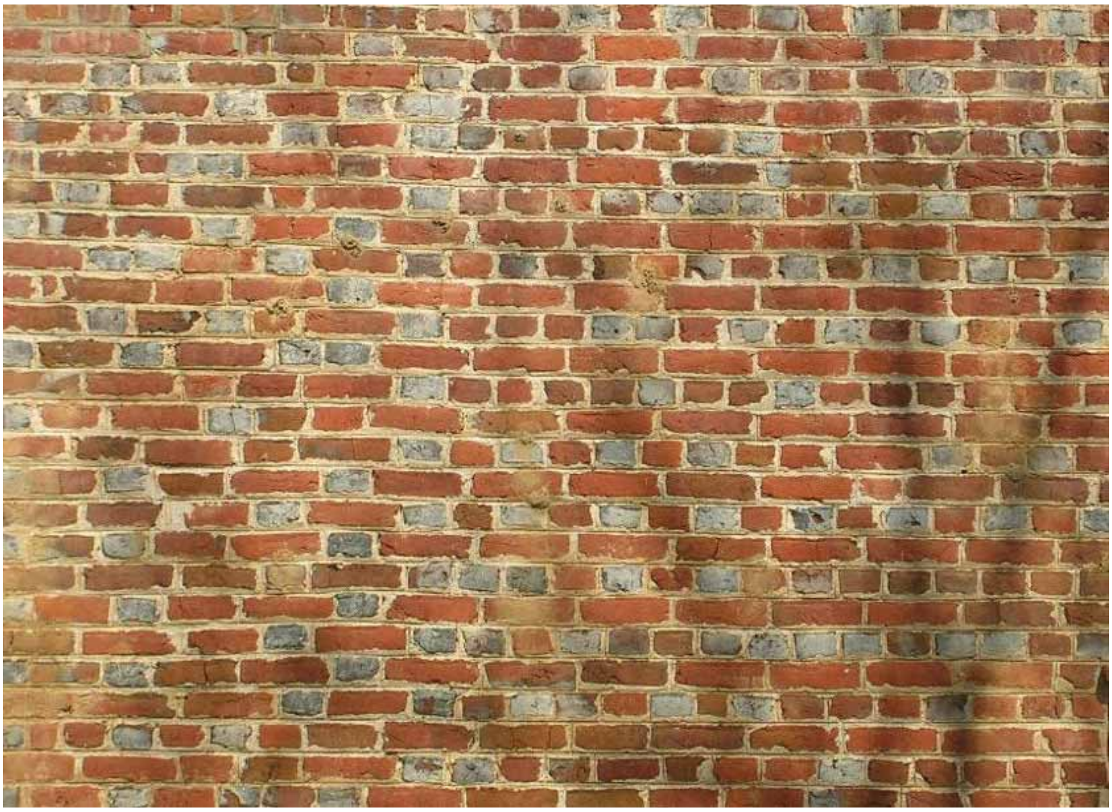
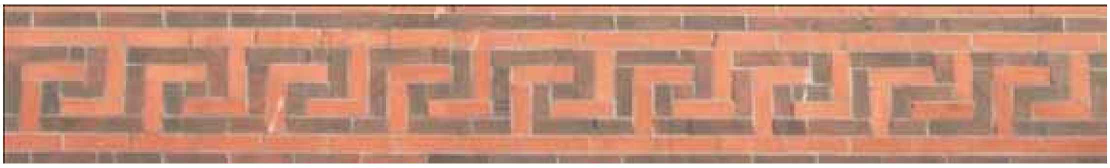


Figure 41: Floor plan of low cost house

The photographs below also illustrate various means by which clay brick can be used to create design elements and human scale detailing on a façade or building, all of which can transform the appearance of a house and transform it into a home worth living in, and one which adds to the values of the community – after all, communities are made up of families and their homes. The pictures are not necessarily representative of what to do for low cost houses, but rather to highlight the aesthetic value of face brick (flat or plastered surfaces can be painted in various ways to achieve aesthetically attractive homes, and face brick can be creatively used to do the same).





6.3 Fire & Maintenance Costs

Two additional issues worth raising in the context of clay brick and face brick homes are the following:

Fire proofing: clay brick has inherent fire proofing qualities where additional materials and monies do not necessarily need to be spent on improving the fire proofing of walls in a low cost housing situation, especially compared to a LSFB construction where fire proof insulation would need to be considered to improve the fire proofing properties.

Maintenance costs: a face brick wall will not require painting, which a bagged brick wall or a LSFB wall will require. Seldom do families in these environments spend money on re-painting their homes, but if they did want to, this would cost them probably about three quarters of a monthly income. Therefore maintenance is typically neglected, and a house that requires less maintenance in a low cost environment is far more suitable in establishing long term value not just for the family, but also for the community and the nation.

7. NATIONAL IMPLICATIONS

7.1 Cost, energy & emissions

The choice of materials in low cost housing has an obvious upfront capital cost implication, especially considering the large volumes of homes that plan to be rolled out across South Africa. However, the choice of materials also has a long term impact on the nation by introducing indirect costs (monetary, environmental, health) to the nation during the lifetime in which these houses are occupied. The other consideration is the cost that is being transferred to occupants of these homes by providing homes that will need additional energy to heat, for example.

The illustrations below describe a possible scenario where over a 10 year period 500,000 low cost house are rolled out per annum (using the Johannesburg modelled case as an example[12]) – various other scenarios could and should be tested, but in this case is limited to a 10 year scenario:

- Based on the cost comparisons presented in part 3 of this report, if 500,000 homes were to be rolled out every year over 10 years (assuming no inflation) it could cost South Africa anything from about R 9.6 billion more to build these homes using clay brick (two leaf) compared to concrete block, and anything from R 68.4 billion more to build these homes using LSFB compared to clay brick (two leaf). (These costs are based on a house with an insulated ceiling in both cases.)

- The average peak difference in power over 8 randomly selected winter days between the concrete block house and the two leaf brick house is 0.63kW. At 500,000 units per annum (a total of 315MW per annum), this results in the equivalent need for a new Atlantis peaking power station every 2 years (588MW), or a new Koeberg power station every 5.7 years (1800MW) or a new Kendall power station every 12 years (3840MW). The estimated cost of a new coal fired power station the size of Atlantis (588MW) at today's costs is approximately R 9 billion (equivalent to the additional capex required for 5,000,000 two leaf clay bricks homes (over 10 years), as noted in the first point above). Therefore over 10 years, the impact of building 500,000 such homes could cost the country anything from R 45 billion in additional power plant capacity if the houses were built in concrete block rather than two leaf clay brick.

- The above scenario would also pass on anything from R 2.6 billion in costs (in the case of concrete block compared to two leaf clay brick) to the home owners in terms of energy costs during that 10 year period.

- Further to this, the CO_2 emissions over a ten year period of the concrete block homes would be approximately 11.7 million tons more than if these homes were to be built using two leaf clay brick over the same 10 year period.

- The energy savings produced by choosing clay brick over concrete block in this example over the 10 year period would be the equivalent of providing enough energy to another 13.6 million clay brick low cost houses for one year.

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[12] *Regarding the LSFB remodelling, this here is the original modelled case of four occupants, natural ventilation of three air changes per hour and light steel frame building being as described by suppliers and not SANS 517:2009 compliant.*

- The standard concrete block low cost house energy model with an insulated ceiling in Johannesburg showed that it would use 1038 kWh of energy per year, whilst the same house with two leaf clay brick walls uses 810 kWh to heat. The resulting higher heating requirement amounts to an additional 274 kg of CO_2 being emitted annually per house. If 500,000 units are built per year, this produces an additional 136,946 metric tons of CO_2 emitted into the atmosphere annually. This is equivalent to an additional 26,366 passenger cars on the road annually[13]. The value of this carbon on the market at the time of this report is R20,541[14] (in terms of the Clean Development Mechanism).

- In a separate study commissioned by the City of Johannesburg in 2009, WSP evaluated the potential climate change that might be experienced in Johannesburg over the next century, and WSP recommended potential adaptations that would need to be considered by the city. The climate modelling undertaken showed projections of an approximate average temperature increase of 2.3 degrees Celsius by 2060 (near future) and 4.4 degrees Celsius by 2090 (far future); the modelling also showed increased average rainfall, and expected greater storm intensities. A rise in average rainfall and temperature over the decades to come will mean that careful selection of materials and walling construction types will become all the more critical to ensure optimum occupant health and comfort, and to ensure energy efficiency.

7.2 Property values

The value of property in the low cost housing market appears to have a lot to do with quality of construction and maintenance of the property. The fact that a face brick exterior wall requires minimal maintenance whilst keeping a good appearance throughout its life means that the property value of such a house is more likely to be higher than one that was painted and has not been maintained. This together with the aesthetic and design considerations highlighted in this report available through clay brick construction can maximise the long term value of properties in the low cost housing market, which over time will hopefully also be extended, and grow even more so in value.

The property value per capita in South Africa is an important indication of the level of empowerment and upliftment that has taken place, and can act as an economic indicator and an attraction to international investment.

Unrealistic minimum standards contribute to premature obsolescence and deterioration, and inhibit development.

7.3 Social – Personal wealth & well being

Besides the financial value of the property that can be added to through clay brick homes, they are able to enhance the sense of place, individuality and human scale of the home, which significantly add to the sense of pride and well being of the community. This is an important consideration when realising that the country is made up of a group of individuals that need to be treated and respected as first class citizens, who deserve the right to a better future.

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[13] US environmental protection agency, CO2 emissions for road transport fleet, standard mid-sized sedan

[14] www.pointcarbon.com, excluding project registration fees

8. CONCLUSIONS OF SANS-517 REMODELLING

Some comments are presented following the remodelling of the light steel frame house to comply with SANS 517:2009. These conclusions are limited by the time that could be spent on remodelling and re-reporting.

8.1 Key conclusions

For the low cost house modelled, for ventilation of 3 or 25 air changes per hour:

- Two leaf insulated brick construction as detailed herein outperforms light steel frame construction to SANS 517:2009 as detailed herein, in terms of annual heating energy use. This applies to all six SA climate zones. (See Figure 13 on page 29.)

- The two leaf insulated brick construction modelled therefore has a lower operational energy cost than the SANS 517 modelled light steel frame construction. This is again applicable to all six SA climate zones.

- The modelled two leaf insulated brick construction provides 7 % more hours of comfort (PMV between -3 and +3) during the year, as an average across all six climate zones. The brick house also outperforms LSFB in each of the six zones individually. (See Figure 32 on page 52.)

Some parameters were investigated individually to determine their influence on the results. Although all climate zones were re-modelled for final conclusions above, the single-parameter studies below are for a couple of zones only.

8.2 Increased occupancy

Occupancy was increased from 4 people to 8 people in the house). All other factors held equal, this increase in occupancy decreases annual heating energy use as shown in Table 10 below, also shown earlier.

Table 10: Reduction in annual heating energy use with occupancy increase from 4 people to 8 people

Climate region		Two leaf insulated brick	SANS 517 LSFB
1	Johannesburg	15%	13 %
5	Durban	39 %	30 %

Clearly the occupancy can be very significant as less electrical heating is needed when additional bodies heat the space. However the trend remains that for this house, brick construction has lower heating energy use than SANS 517 LSFB.

8.3 Natural ventilation rate

Peak ventilation rate was increased from 3 ac/h to 25 ac/h to see if much greater ventilation would alter the previously observed trend. All else being equal, the increase in annual heating energy with, ranges from 30 % to 60 % for the various scenarios (see Table 3, p16). There is always a higher % increase for two leaf insulated brick than for SANS 517 LSFB. Even so, at 25 ac/h the two leaf insulated brick low cost house still has lower annual heating energy consumption than the SANS 517 LSFB low cost house (evident on Figure 13, page 29).

8.4 SANS 517 compliant LSFB construction

Comparing the original non-compliant LSFB house (4 person occupancy and 3 ac/h ventilation), with the SANS 517 house with the same occupancy and ventilation, SANS 517 compliance reduces annual heating energy consumption by 14 % in Johannesburg and 11 % in Durban.

8.5 Comparing influences on energy use

To give a sense of the relative influence of the factors discussed above, one can consider the LSFB Johannesburg and Durban cases, changing from non-compliant with 4 occupants and 3 ac/h, to SANS 517 compliant with 8 occupants and 25 ac/h., as shown in Table 11 below.

Table 11: Comparison of influence of parameters on energy use for Johannesburg and Durban

	Incremental change due to given parameter [kWh]	
	Zone 1 (Johannesburg)	Zone 5 (Durban)
SANS 517 compliance	-133	-29
Occupancy 4 to 8 people	-107	-67
Ventilation rate 3 ac/h to 25 ac/h	220	79
Total	-19	-17

Ventilation rate is clearly most significant, with SANS 517 compliance and occupancy having smaller but significant effects, with a noticeable different between climates. In Durban the occupancy becomes more significant than construction, whereas for Johannesburg the construction dominates slightly.

Appendix A
Energy simulation data

Table 12: Table of results - heating energy per annum - insulated ceiling

	Concrete block	LSFB	Two leaf brick	Cavity brick	Insulated brick	IFHS	Imison
Johannesburg	1038	969	810	790	746	831	822
Pretoria	721	739	512	508	519	609	617
Nelspruit	574	594	400	100	400	483	493
Cape Town	721	701	573	568	560	611	611
Durban	192	251	97	100	135	191	206
Kimberley	1114	983	901	862	790	863	851

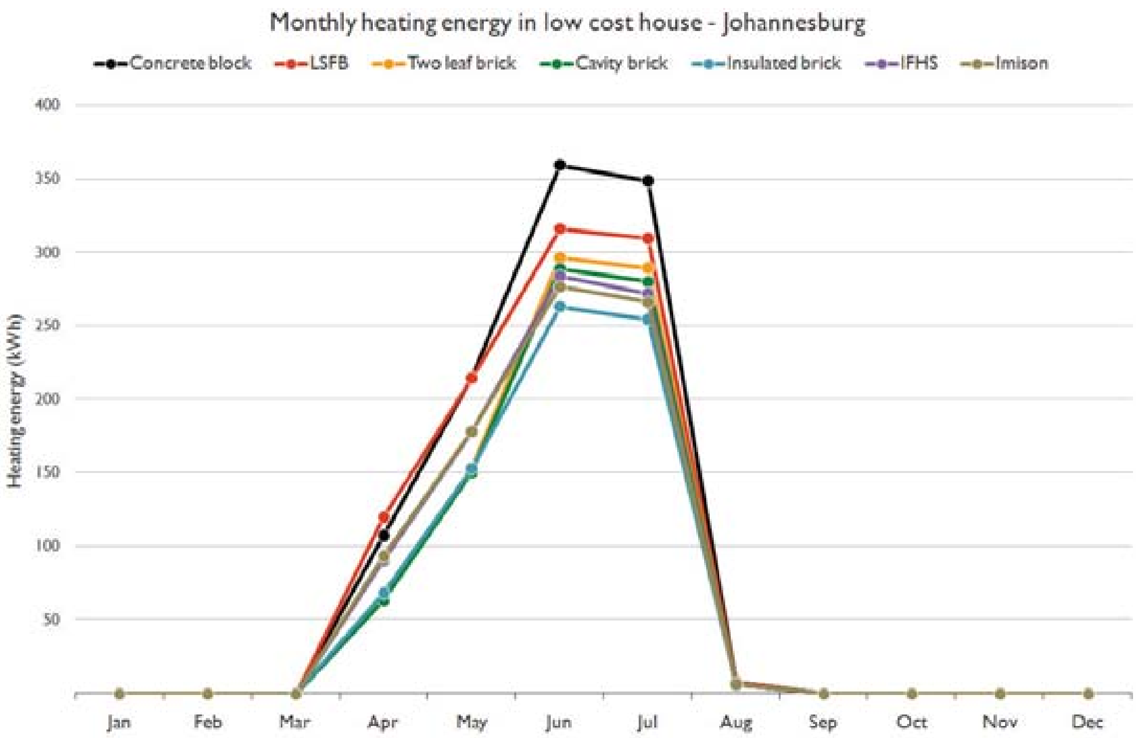


Figure 42: Monthly heating energy - Johannesburg

Figure 43: Monthly heating energy - Pretoria

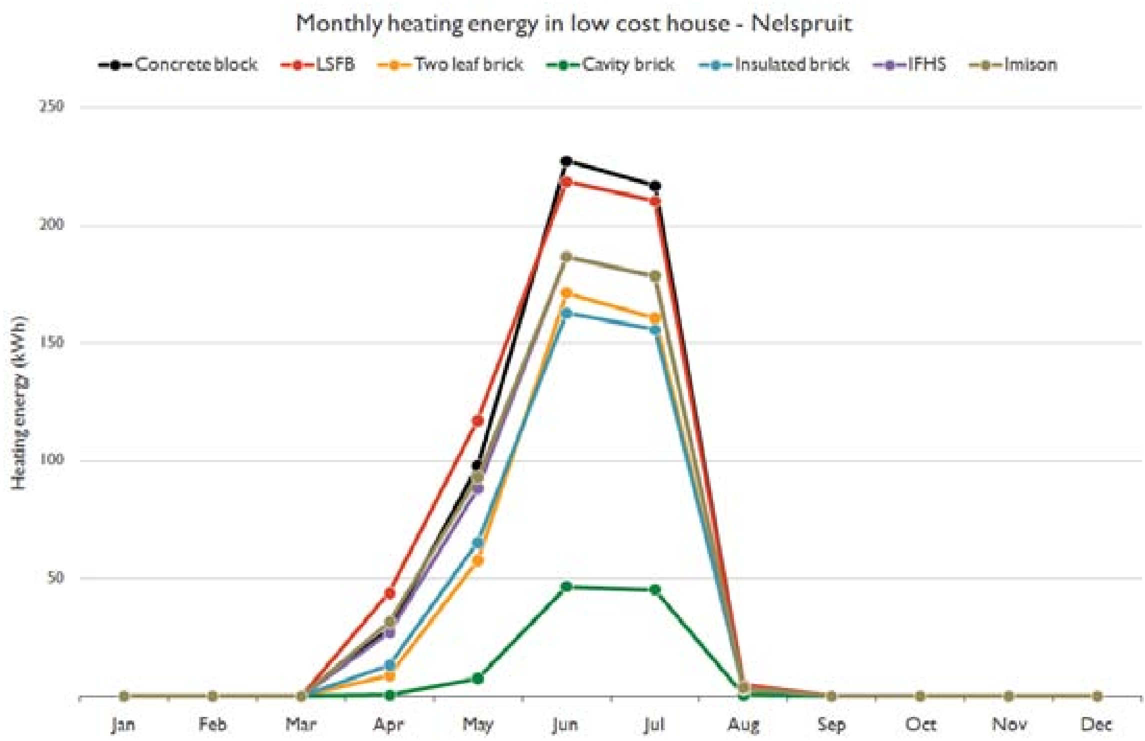


Figure 44: Monthly heating energy - Nelspruit

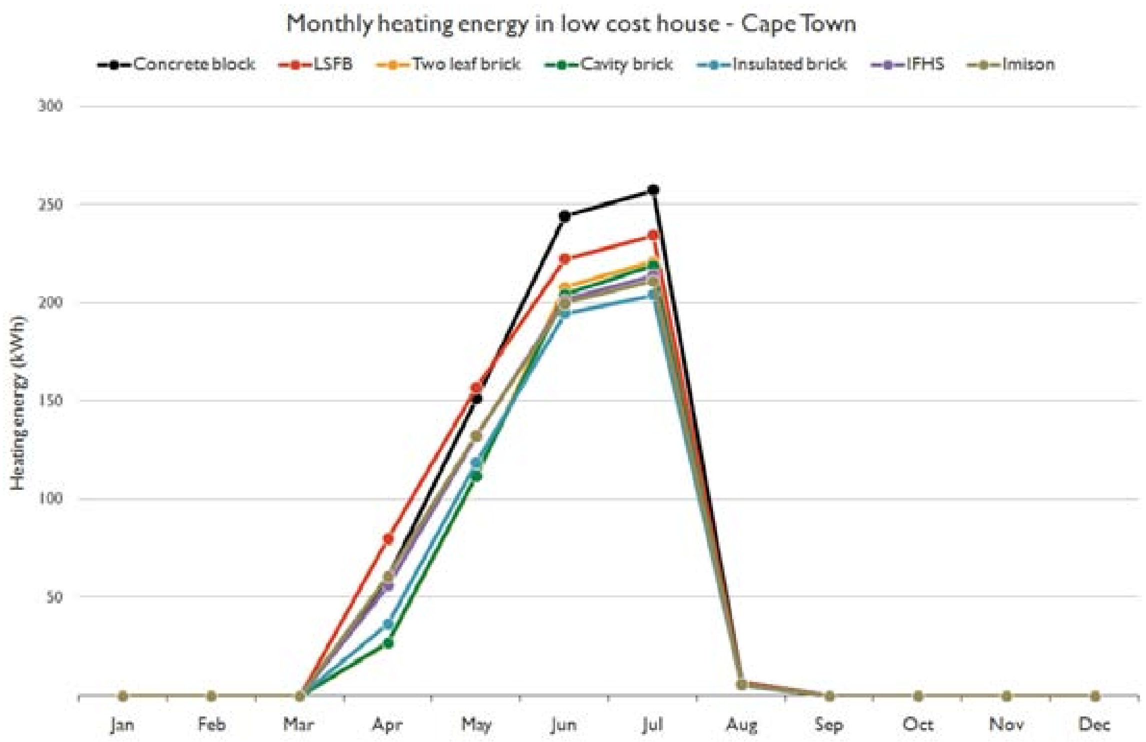


Figure 45: Monthly heating energy - Cape Town

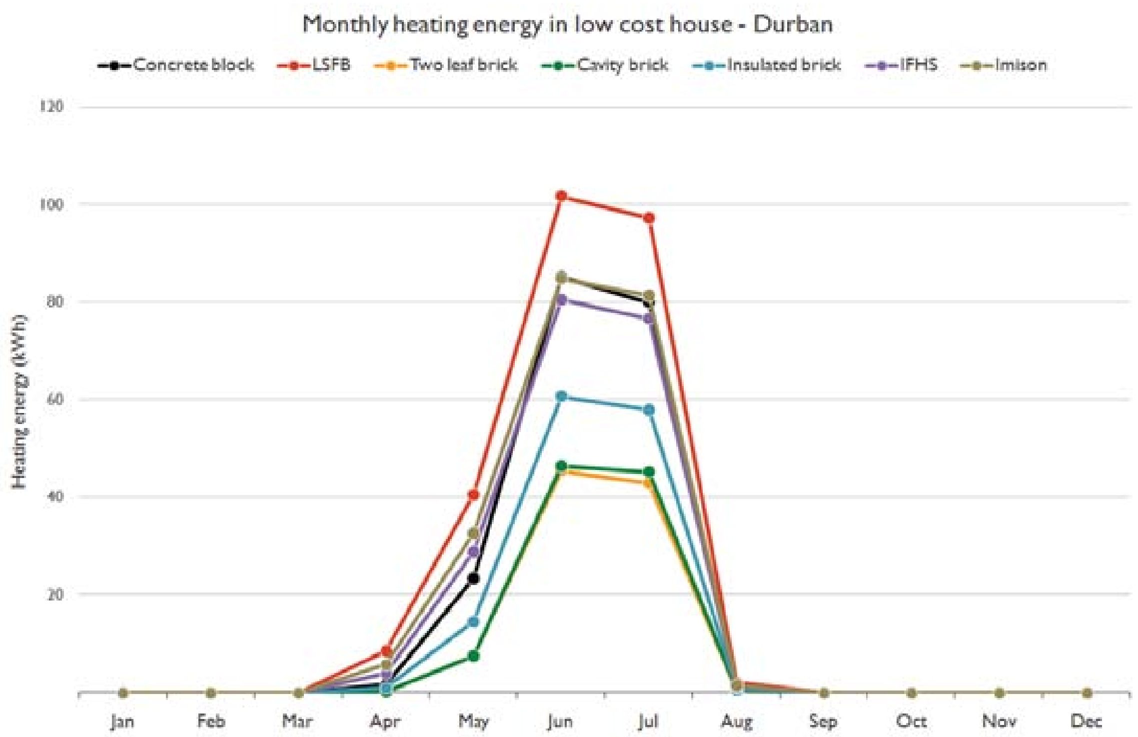


Figure 46: Monthly heating energy - Durban

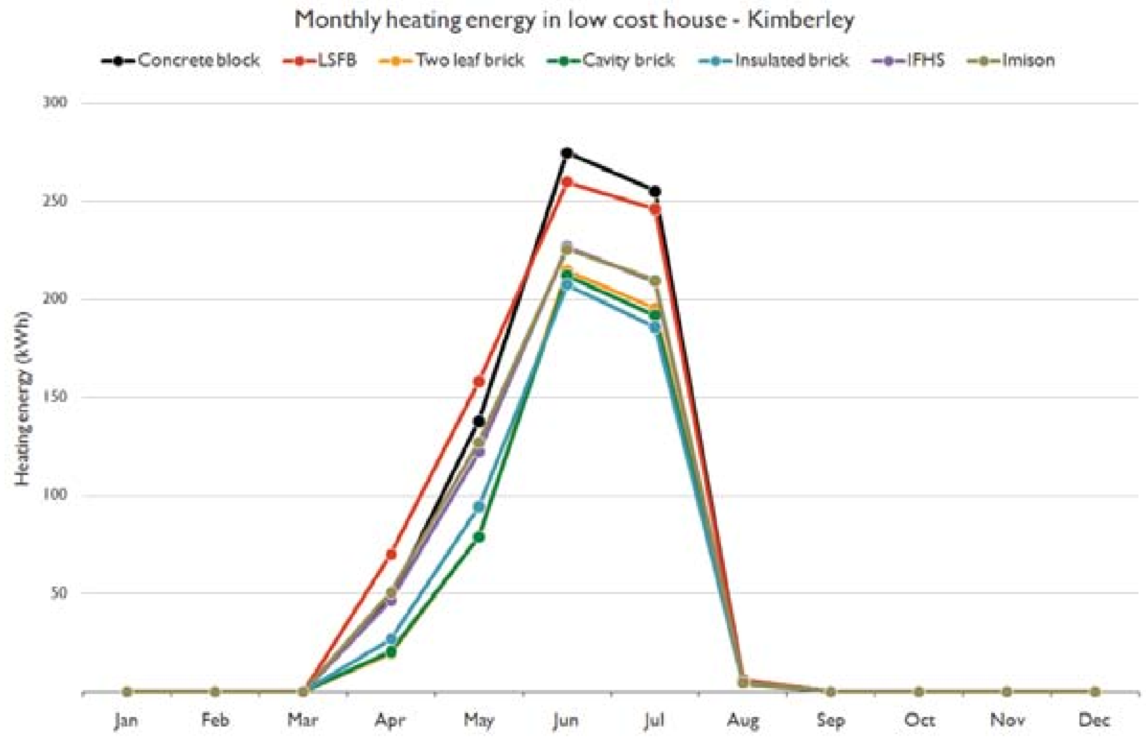


Figure 47: Monthly heating energy – Kimberley

The table and graphs below are for the remodelled case of SANS 517 compliant LSFB construction and 8 occupants with 3 ac/h and 25 ac/h natural ventilation.

Table 13: Table of results - heating energy per annum (kWh) - insulated ceilings, 8 occupants, SANS 517 compliant LSFB

	LSFB, 3 ac/h	LSFB, 25 ac/h	Ins. brick, 3 ac/h	Ins. brick, 25 ac/h
Johannesburg	730	950	648	870
Pretoria	551	727	431	595
Nelspruit	443	599	328	470
Cape Town	517	726	464	680
Durban	155	234	83	132
Kimberley	758	983	699	915

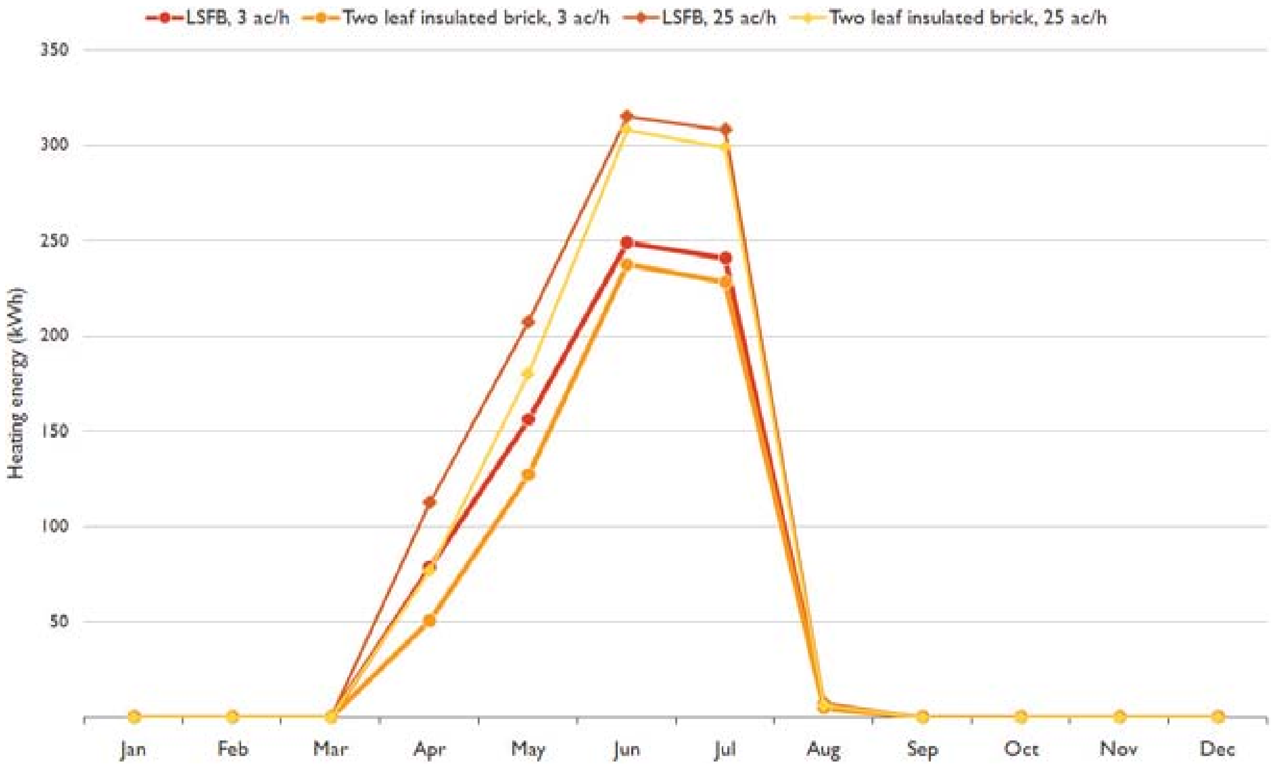


Figure 48: Monthly heating energy in low cost house - 8 occupants, LSFB to SANS 517, Johannesburg

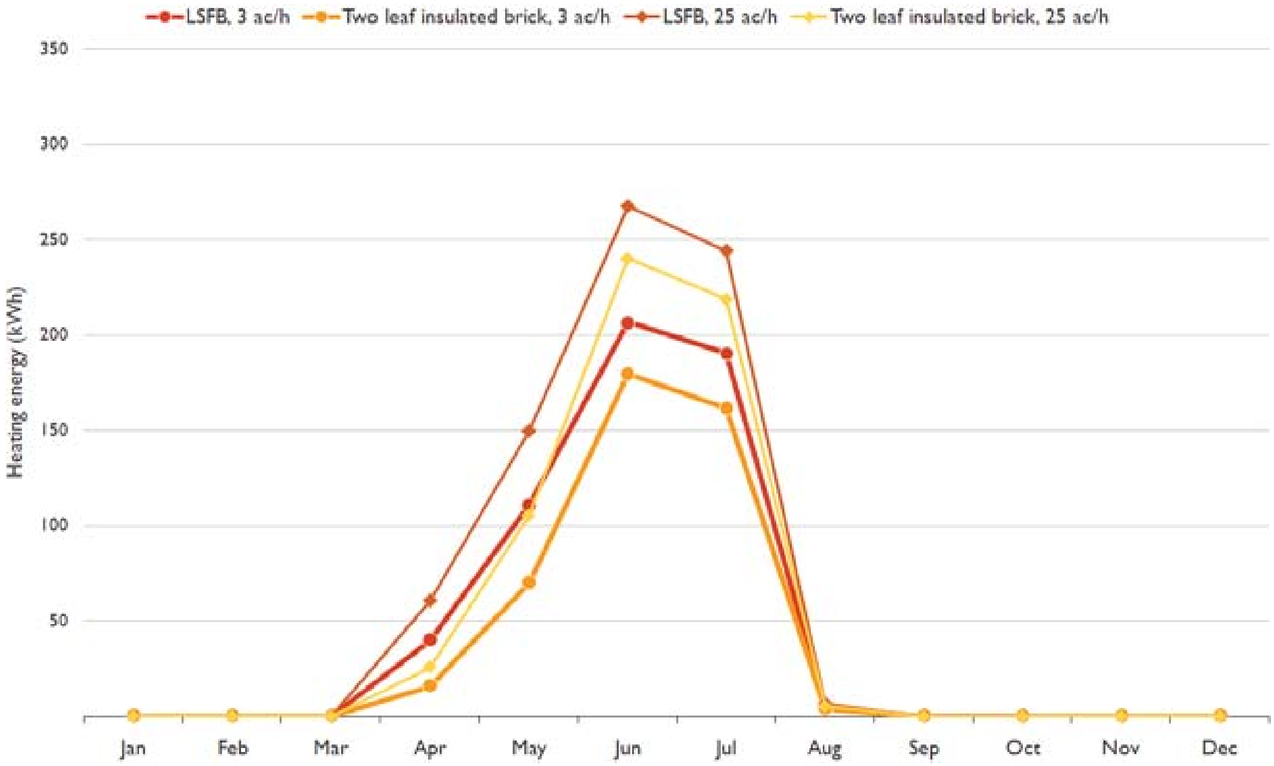


Figure 49: Monthly heating energy in low cost house - 8 occupants, LSFB to SANS 517, Pretoria

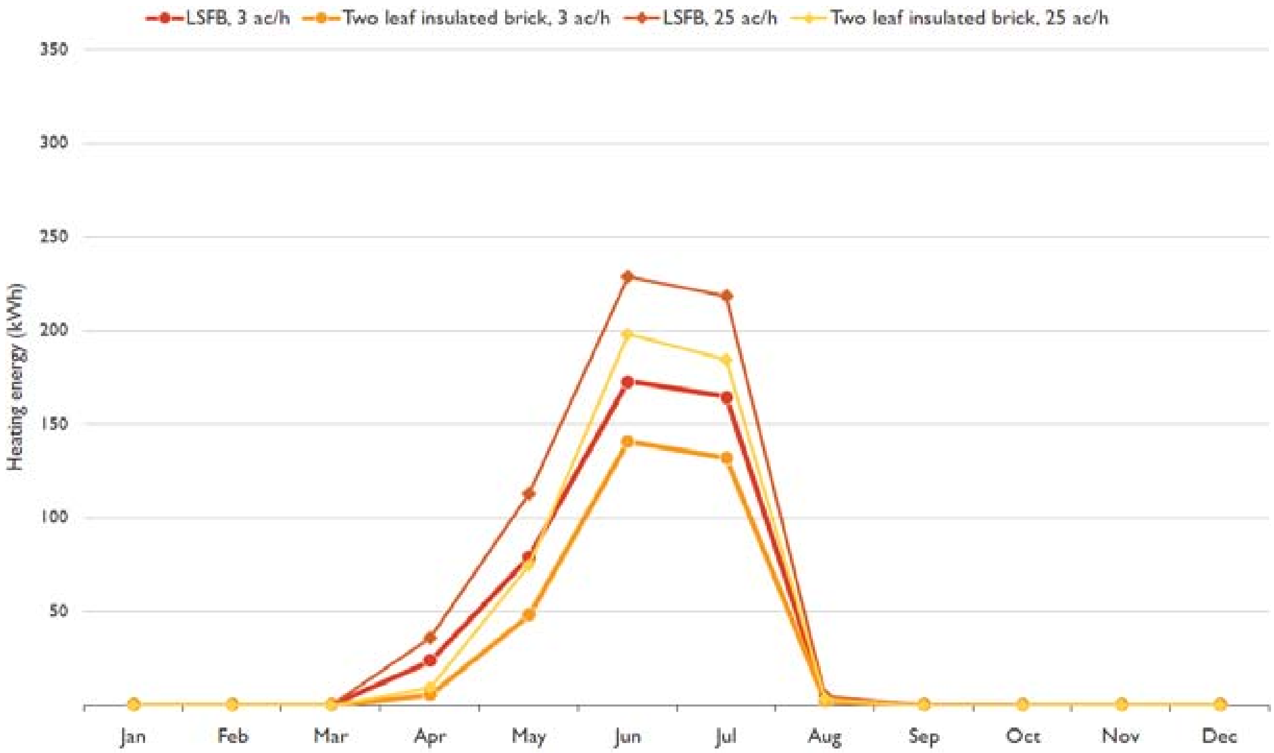


Figure 50: Monthly heating energy in low cost house - 8 occupants, LSFB to SANS 517, Nelspruit

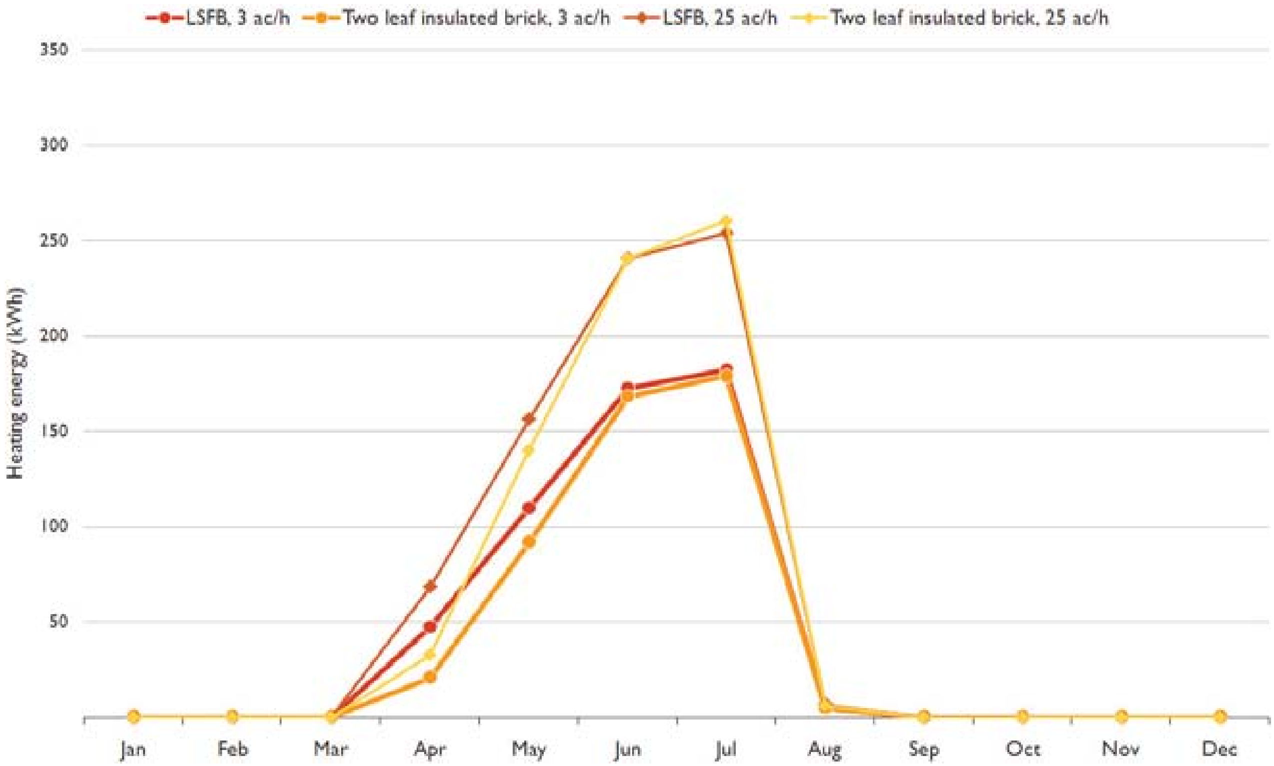


Figure 51: Monthly heating energy in low cost house - 8 occupants, LSFB to SANS 517, Cape Town

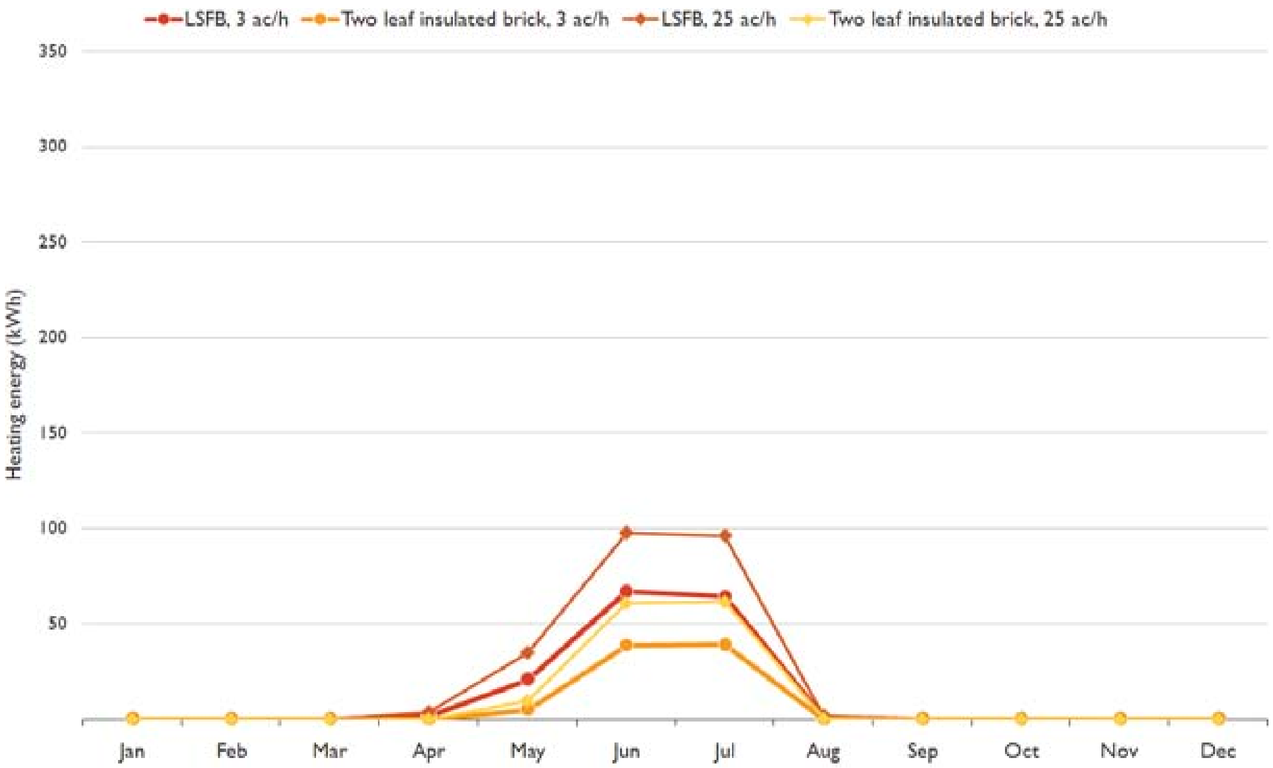


Figure 52: : Monthly heating energy in low cost house - 8 occupants, LSFB to SANS 517, Durban

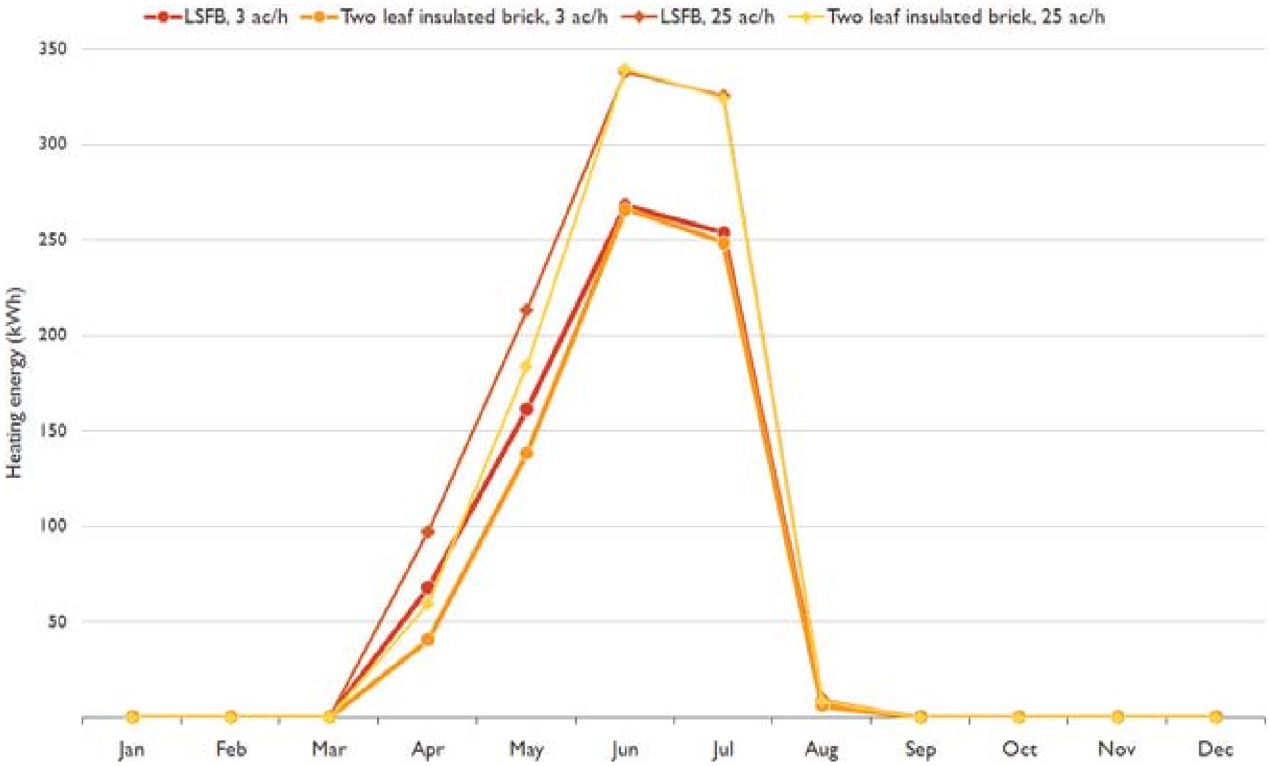
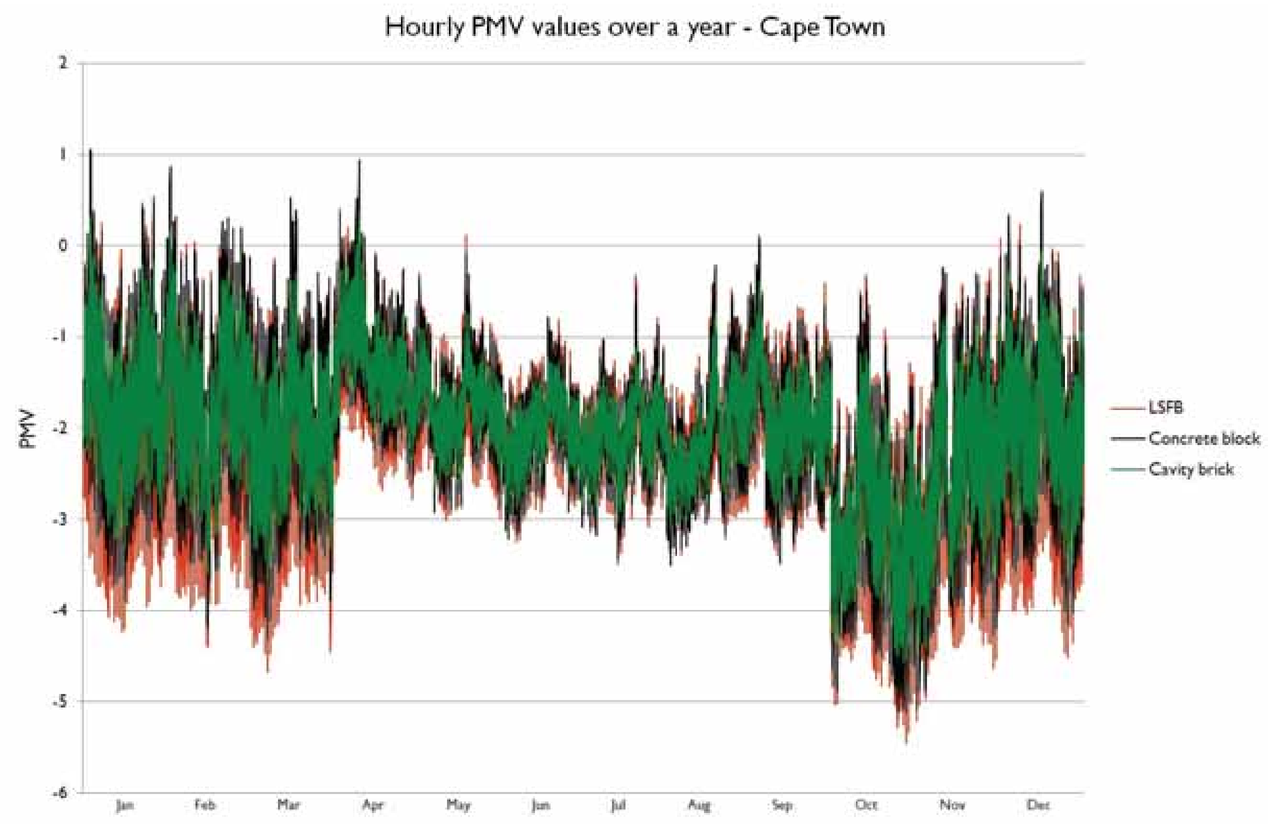
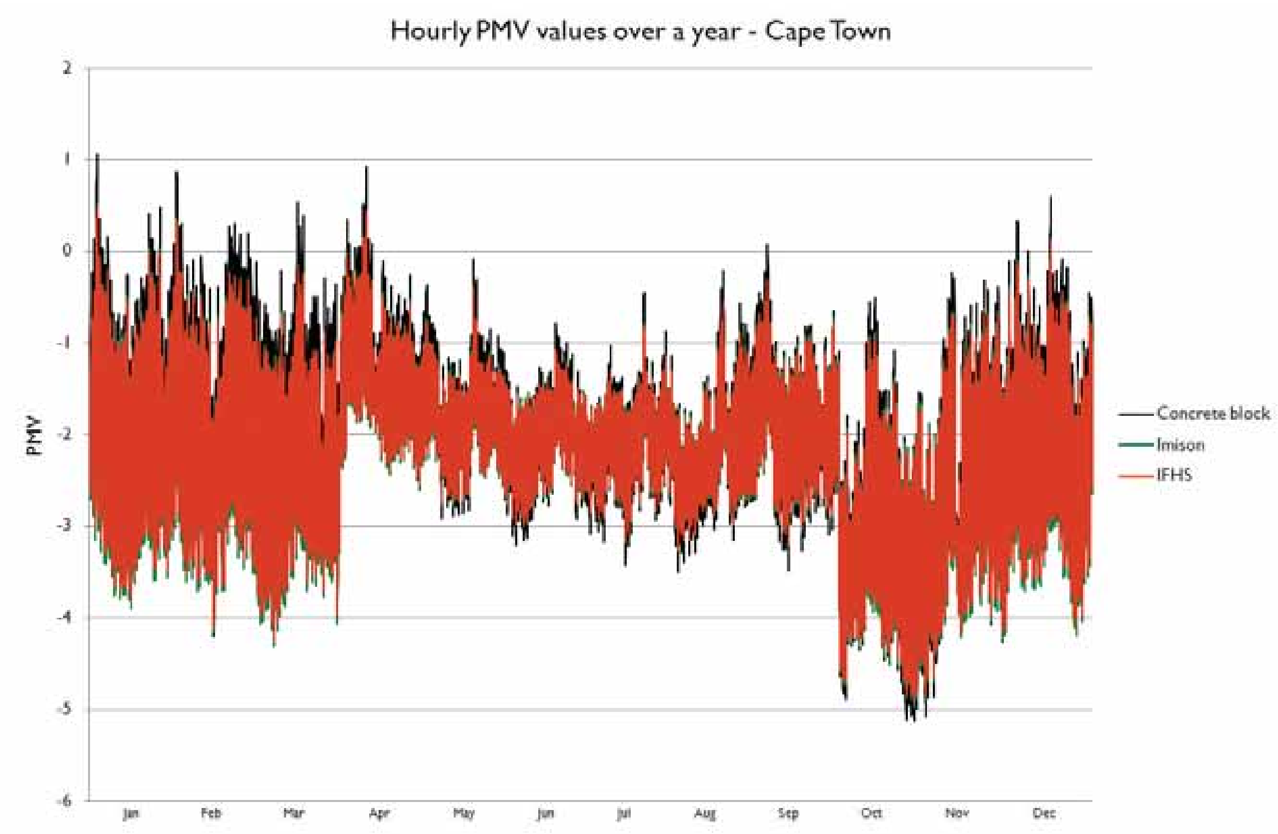
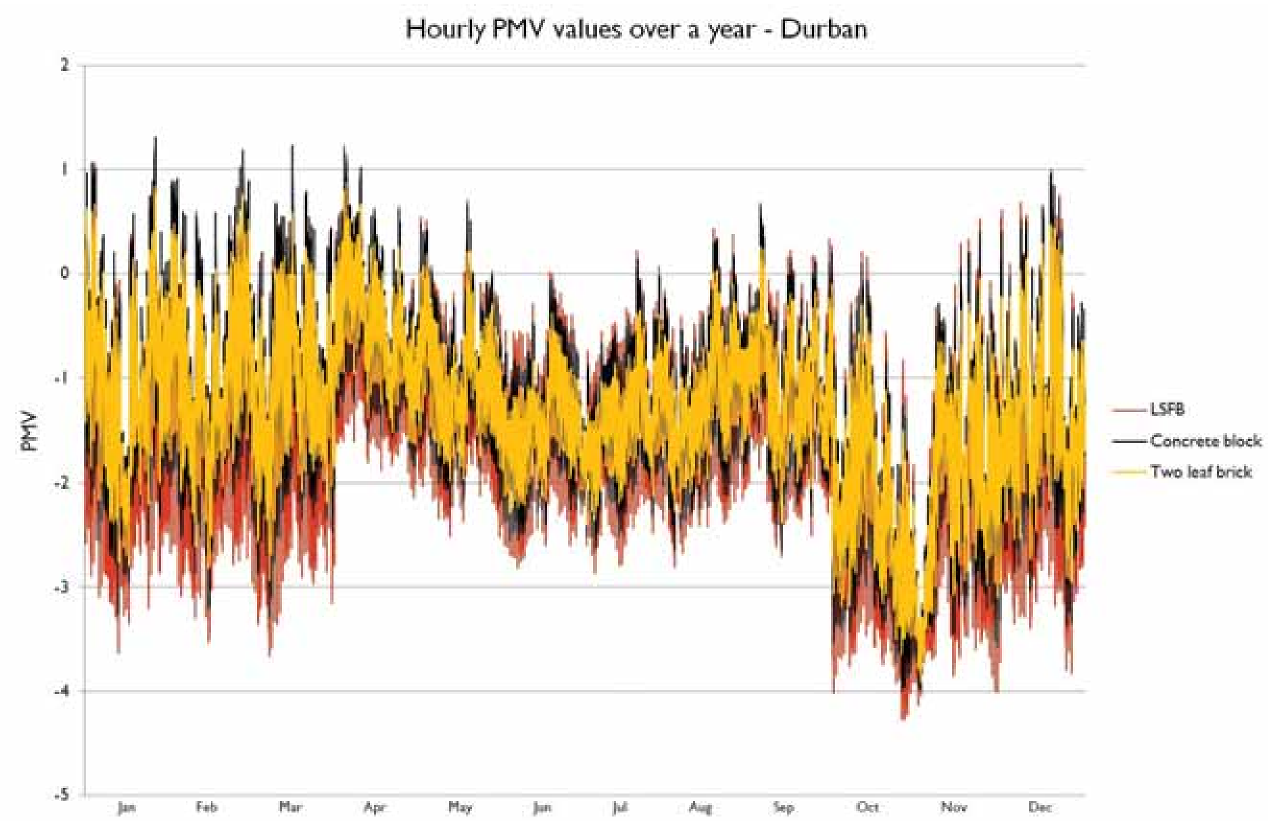


Figure 53: Monthly heating energy in low cost house - 8 occupants, LSFB to SANS 517, Kimberley

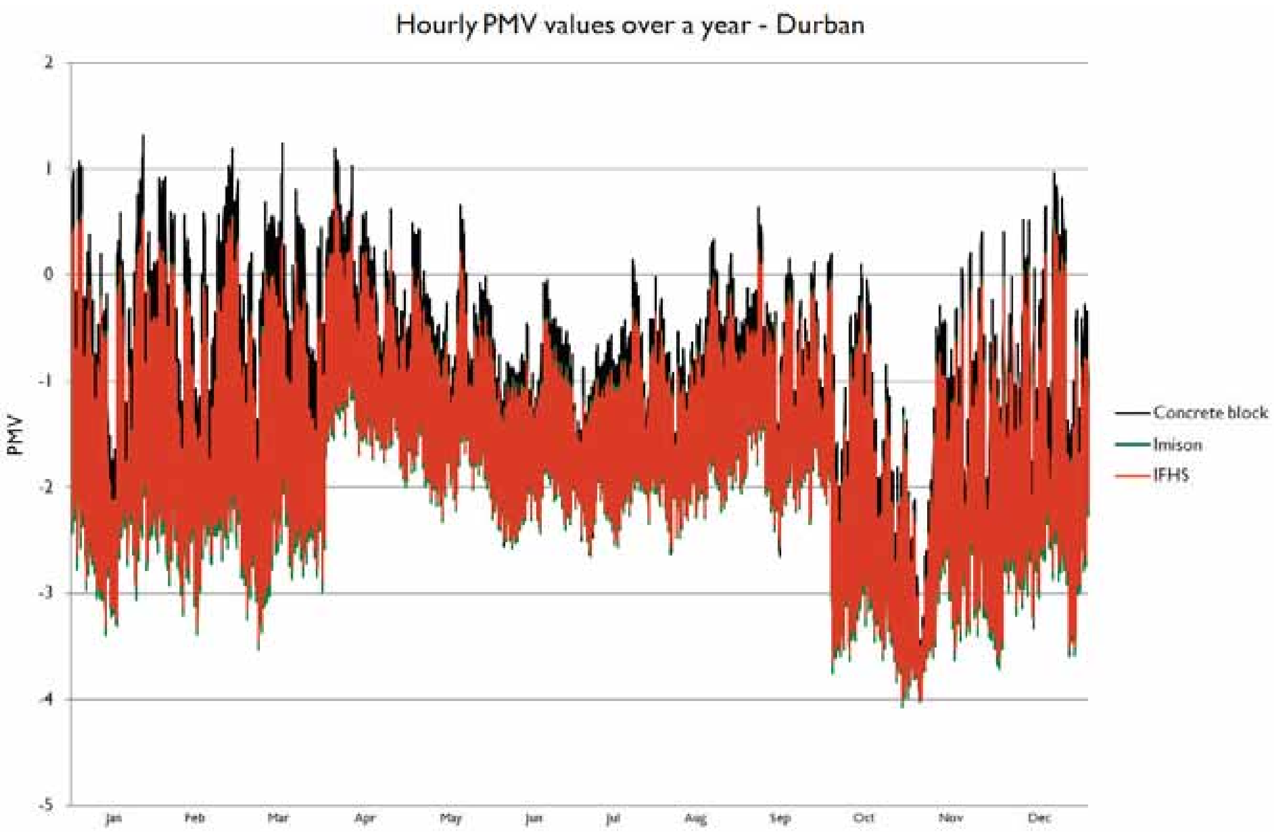
Appendix B
Comfort simulation data


Hourly PMV values over a year - Cape Town
PMV
2
1
0
-1
-2
-3
-4
-5
-6
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
LSFB
Concrete block
Cavity brick


Hourly PMV values over a year - Cape Town
PMV
2
1
0
-1
-2
-3
-4
-5
-6
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Concrete block
Imison
IFHS



Hourly PMV values over a year - Durban
2
1
0
-1
-2
-3
-4
-5
PMV
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
LSFB
Concrete block
Two leaf brick



Hourly PMV values over a year - Durban
2
1
0
-1
-2
-3
-4
-5
PMV
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Concrete block
Imison
IFHS

The graphs below are for the remodelled case of SANS 517 compliant LSFB construction and 8 occupants with 3 ac/h and 25 ac/h natural ventilation.

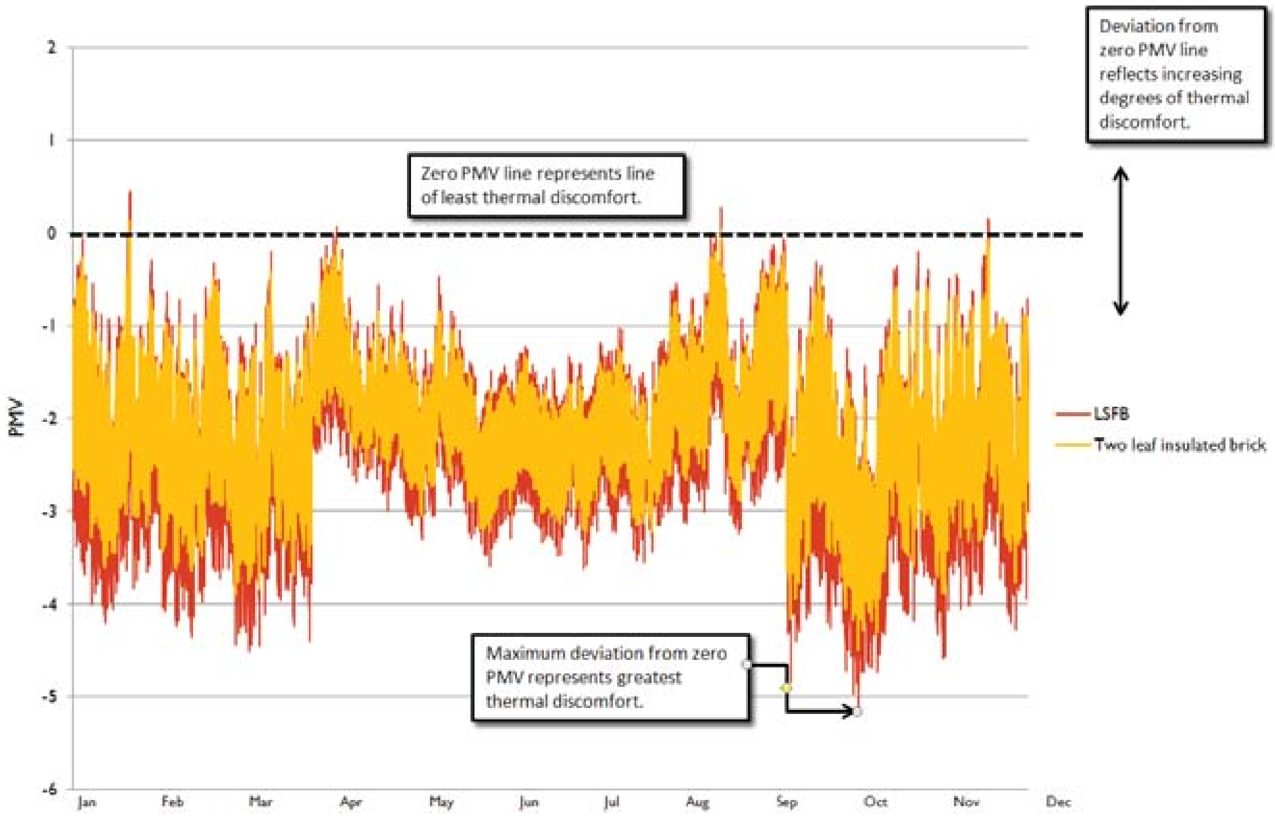


Figure 54: PMV for a year - SANS 517 LSFB construction, 8 occupants, Johannesburg, 3 ac/h

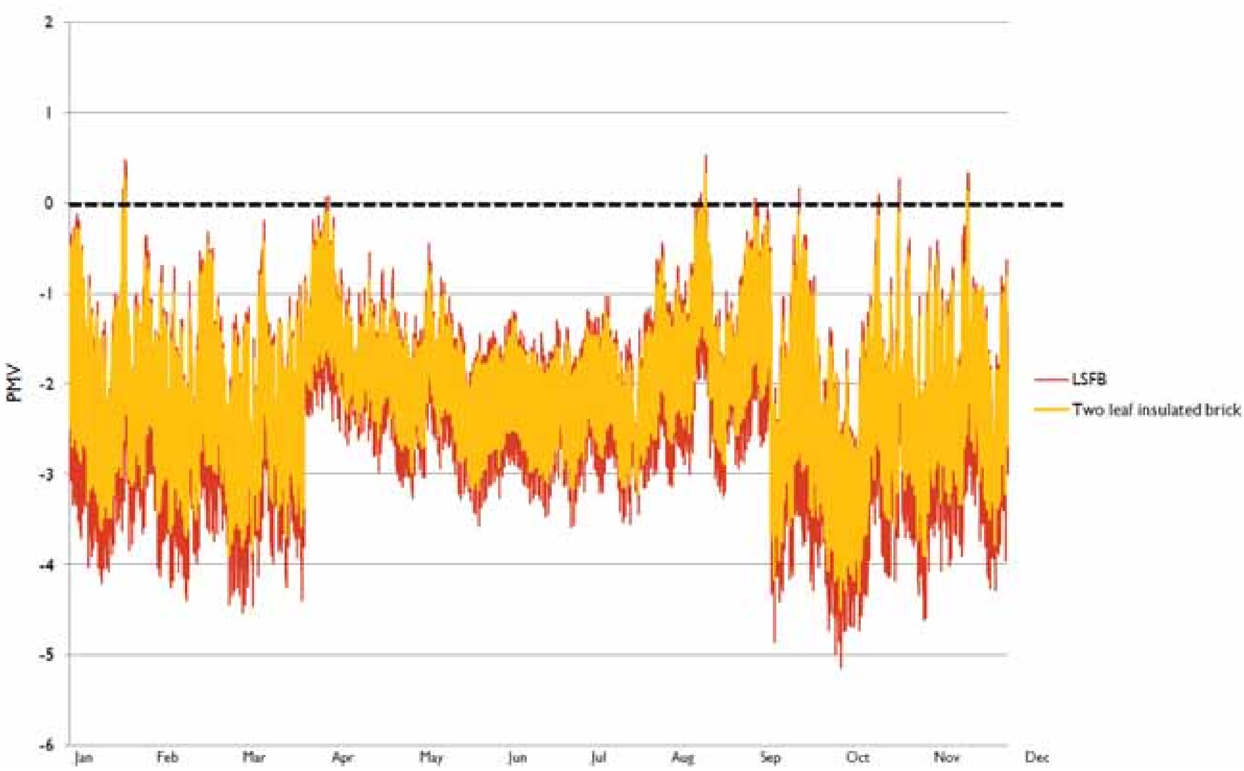


Figure 55: PMV for a year - SANS 517 LSFB construction, 8 occupants, Johannesburg, 25 ac/h

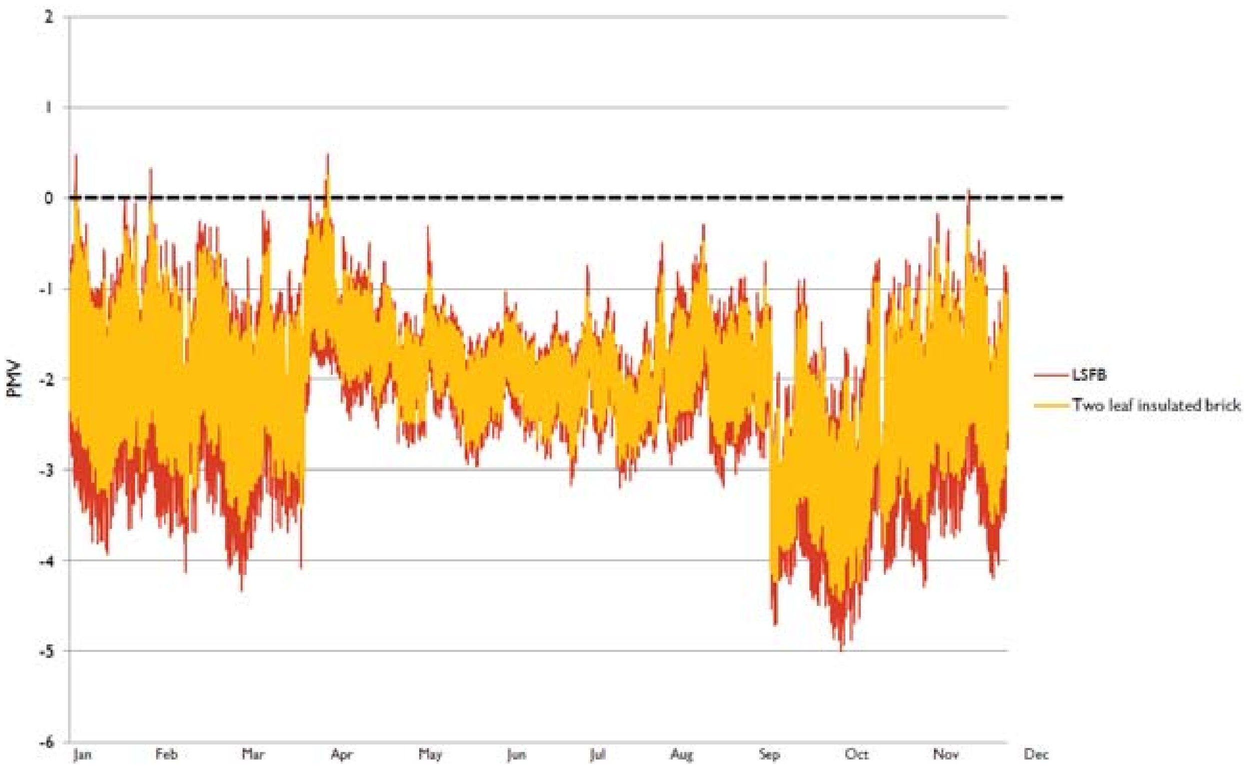


Figure 56: PMV for a year - SANS 517 LSFB construction, 8 occupants, Cape Town, 3 ac/h

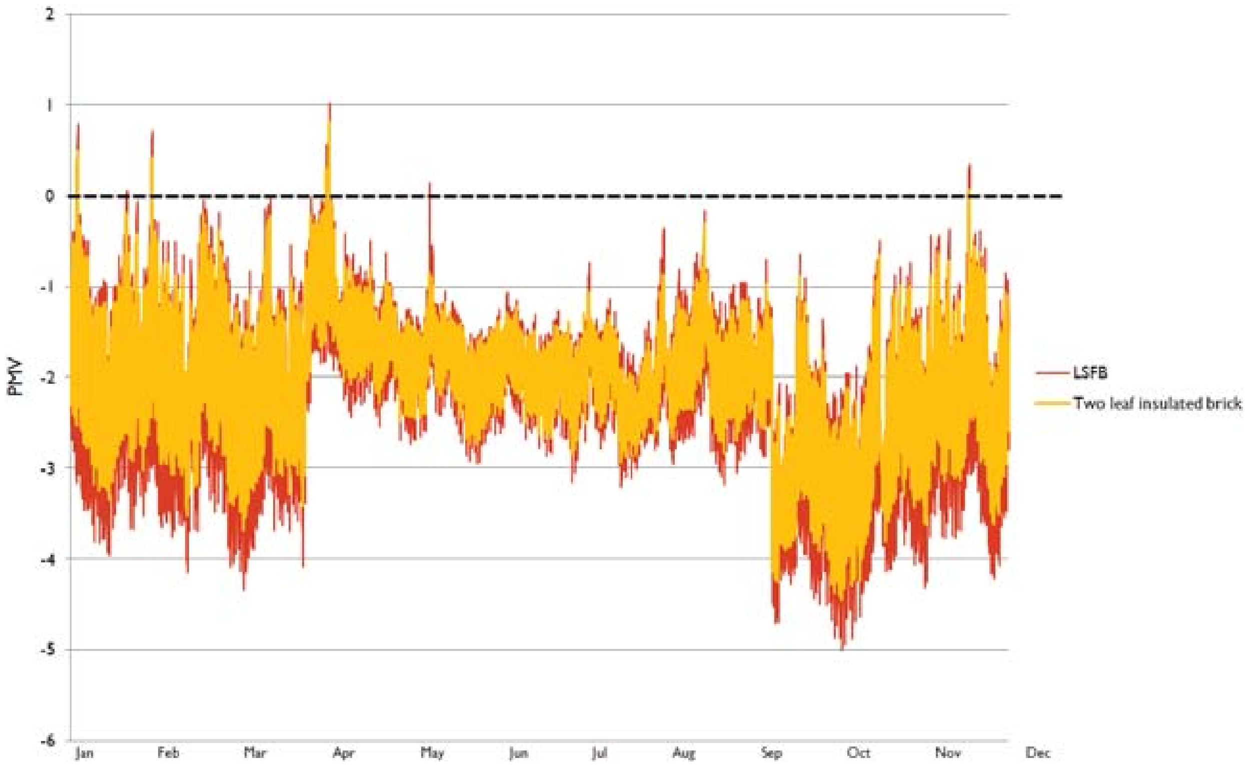


Figure 57: PMV for a year - SANS 517 LSFB construction, 8 occupants, Cape Town, 25 ac/h

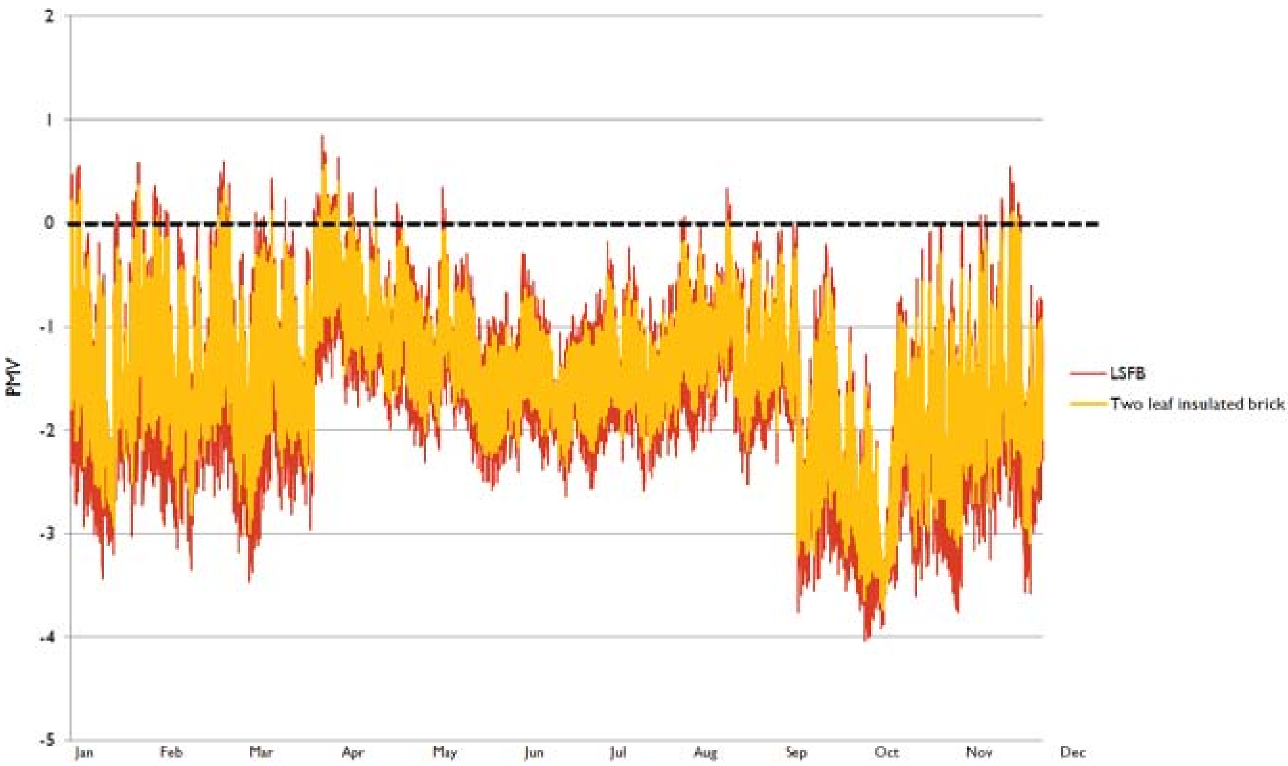


Figure 58: PMV for a year - SANS 517 LSFB construction, 8 occupants, Durban, 3 ac/h

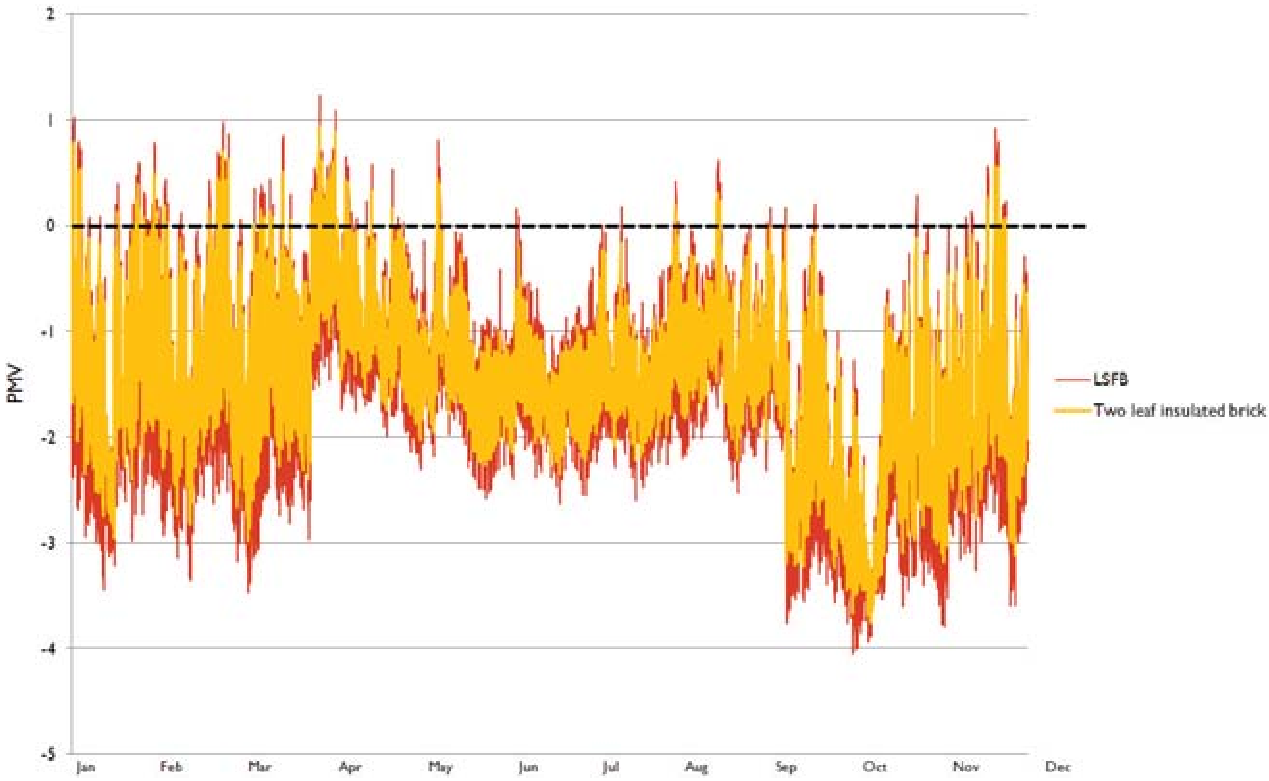


Figure 59: PMV for a year - SANS 517 LSFB construction, 8 occupants, Durban, 25 ac/h

Appendix C
Material properties

Common materials

Air gaps

Thermal resistance: 0.18 $m^2 \cdot K/W$

Gypsum plaster

Conductivity: 0.4 $W/m \cdot K$

Specific heat: 1000 $J/kg \cdot K$

Density: 1000 kg/m^3

Mineral wool stone wool rigid insulation

Conductivity: 0.038 $W/m \cdot K$

Specific heat: 840 $J/kg \cdot K$

Density: 40 kg/m^3

Concrete block

Conductivity: 0.603 $W/m \cdot K$

Specific heat: 880 $J/kg \cdot K$

Density: 1330 kg/m^3

Clay brick[15]

Conductivity: 0.62 $W/m \cdot K$

Specific heat: 800 $J/kg \cdot K$

Density: 1900 kg/m^3

[15] *Clay brick represented by Corobrik's 10 core hole brick, density provided by Corobrik. Dimensions:222mm x 90mm x 114mm*

Light steel frame

Note: the configuration and dimensions of the light steel frame construction used represented the most common design as presented by LSFB suppliers. Reference was also made to the South African Steel Frame Association (SASFA) Building Code for low rise Light Steel Frame Building, but this was not strictly complied with.

The thermal bridging percentage was derived from common designs as presented by suppliers, as well as the SASFA Building Code.

OSB fibre cement

Conductivity: 0.06 W/m·K

Specific heat: 1000 J/kg·K

Density: 300 kg/m^3

Galvalum[16]

Conductivity: 158 W/m·K

Specific heat: 880 J/kg·K

Density: 4900 kg/m^3

[16] *Holman, J.P., Heat Transfer 9th ed., 2002*

EPS insulation

Conductivity: 0.037 W/m ·K[17]

Specific heat: 1500 J/kg ·K[18]

Density: 16 kg/m^3 [19]

Steel (wire mesh and ties, starter bars) [20]

Conductivity: 50 W/m ·K

Specific heat: 450 J/kg ·K

Density: 7800 kg/m^3

Plaster (4:1 mix sand:cement) [21]

Conductivity: 0.64 W/m ·K

Specific heat: 850 J/kg ·K

Density: 1630 kg/m

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[17] *http://www.epsasa.co.za/Images/Publications/EPS_Application_Guide.pdf*

[18] *http://www.epsasa.co.za/Images/Publications/Selection_Guide_Introducing_EPS.pdf*

[19] *Ikhaya Futurehouse Systems*

[20] *DesignBuilder material library*

[21] *Values averaged from several sources: J.P. Holman, Heat Transfer; Corobrik/CBA, Agrement/CBA, www.ybsinsulation.com, http://en.wikipedia.org/wiki/Thermal_Transmittance, http://www.mortar.cn/en/News.aspx?NewID=19288, www.engineeringtoolbox.com/thermal-conductivity-d_429.htm, www.bath.ac.uk/~absmaw/BEnv1/properties.pdf, http://www.engineering.com/Library/ArticlesPage/tabid/85/articleType/ArticleView/articleId/152/Thermal-Conductivity.aspx*

EPS insulation

Conductivity: 0.032 W/m ·K[22]

Specific heat: 1500 J/kg ·K[23]

Density: 16 kg/m^3 [24]

Steel (columns, ring beam, wire ties) [25]

Conductivity: 50 W/m ·K

Specific heat: 450 J/kg ·K

Density: 7800 kg/m^3

Fibrecote™ Plaster

Conductivity: 0.7 W/m ·K[26]

Specific heat: 850 J/kg ·K[27]

Density: 2025 kg/m^3 (median in range 1850 kg/m^3 to 2200 kg/m^3)[28]

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[22] *Imison, BASF info for BASF Neopor®*

[23] *http://www.epsasa.co.za/Images/Publications/Selection_Guide_Introducing_EPS.pdf, http://www.isowall.co.za*

[24] *Imison, Agrement*

[25] *DesignBuilder material library*

[26] *Imison*

[27] *Fibrecote™ specific heat value not found. Cement-sand plaster values were used, with the values averaged from several sources: J.P. Holman, Heat Transfer; Corobrik/CBA, Agrement/CBA, www.ybsinsulation.com, http://www.mortar.cn/en/News.aspx?NewID=19288, www.bath.ac.uk/~absmaw/BEnv1/properties.pdf, http://www.engineering.com/Library/ArticlesPage/tabid/85/articleType/ArticleView/articleId/152/Thermal-Conductivity.aspx*

[28] *Agrement*

LSFB material properties changed or added in remodelling

Fibre cement board/planks[29]

Conductivity: 0.3 W/m·K

Specific heat: 900 J/kg·K

Density: 1453 kg/m^3

Oriented Strand Board (OSB)

Conductivity: 0.13 W/m·K

Specific heat: 1700 J/kg·K

Density: 650 kg/m^3

Gypsum plasterboard

Conductivity: 0.25 W/m·K

Specific heat: 1000 J/kg·K

Density: 900 kg/m^3

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[29] *Data for fibre cement board averaged from data available at:*

http://www.rcmltd.biz/cem+.cfm

http://www.ecplaza.net/tradeleads/seller/5811151/sell_fibre_cement_board.html

http://www.alibaba.com/product-gs/226771748/Fibre_Cement_Board.html

http://www.engineeringtoolbox.com/specific-heat-solids-d_154.html

http://www.tastimber.tas.gov.au/species/pdfs/Rvalue-Edition-2-Intro-V2.pdf

http://www.panelsystemsgroup.co.uk/download/literature/Pelicolor%20Brochure.pdf

http://www.tpl.fpv.ukf.sk/engl_vers/thermophys/proceedings/03/toman.pdf

Appendix D *MFS Quantity Surveyors: Cost report*

Appendix E *Econic: Construction carbon footprinting report*

PRELIMINARY COST COMPARISONS
COROBRIK - LOW COST HOUSING MODELLING PROJECT

Revision 3 - Cape Town Rates

Summary

Note: No allowance has been made for bringing services to the site.

		Option A: 140mm Concrete blocks	Option B (1): 230mm brick walls using maxi bricks	Option B (2): 280mm un-insulated cavity walls using maxi bricks
1.00	Preliminary and General :	6,021	6,380	6,963
2.00	Foundations : (assumed spec.)	6,446	6,446	6,446
3.00	Ground Floor Construction : (assumed spec.)	4,659	4,659	4,659
4.00	Roofs :	8,679	8,679	8,679
5.00	External Walling :	19,840	23,402	29,233
6.00	Internal Divisions :	1,652	1,682	1,682
7.00	Floor Finishes :	2,146	2,146	2,146
8.00	Internal Wall Finishing :	6,175	6,175	6,175
9.00	Ceilings :	0	0	0
10.00	Electrical Installation :	3,660	3,660	3,660
11.00	Plumbing Installation :	4,800	4,800	4,800
12.00	Provisional Sums :	2,150	2,150	2,150
13.00	Contingency Allowance :	0	0	0
	Sub-Total	66,228	70,179	76,592
	VAT	9,272	9,825	10,723
	TOTAL : Estimate for Feasibility	**R 75,500**	**R 80,004**	**R 87,315**
	R/m2	**R 1,887**	R 2,000	R 2,183
	% cost difference	0%	6%	16%

prepared by mfs Q.S.

PRELIMINARY COST COMPARISONS

COROBRIK - LOW COST HOUSING MODELLING PROJECT

Revision 3 - Cape Town Rates

Summary

Note: No allowance has been made for bringing services to the site.

	Option A: 140mm Concrete blocks	Option B (1): 230mm brick walls using maxi bricks	Option B (2): 280mm un-insulated cavity walls using maxi bricks
Optional ceiling			
Construction cost brought forward (page 1)	66,228	70,179	76,592
Ceiling & insulation	7,848	7,848	7,848
Sub-Total	74,076	78,027	84,440
VAT	10,371	10,924	11,822
TOTAL : Estimate for Feasibility	**R 84,447**	**R 88,951**	**R 96,262**

Specific cost comparison (excl P&G & VAT)			
External walls (incl finish)	R 14,742	R 18,304	R 24,135
	0%	24%	64%
Internal walls (incl internal finishes)	R 7,827	R 7,857	R 7,857
	0%	0.4%	0.4%

prepared by mfs Q.S.

Preliminary Cost Comparisons
Corobrik - Low cost housing Modelling project

Revision 3 - Johannesburg Rates

Summary

Note: No allowance has been made for bringing services to the site.

		Option A: 140mm Concrete blocks	Option B (1): 230mm brick walls using maxi bricks	Option B (2): 280mm un-insulated cavity walls using maxi bricks
1.00	Preliminary and General :	6,021	6,174	6,764
2.00	Foundations : (assumed spec.)	6,446	6,446	6,446
3.00	Ground Floor Construction : (assumed spec.)	4,659	4,659	4,659
4.00	Roofs :	8,679	8,679	8,679
5.00	External Walling :	19,840	21,399	27,289
6.00	Internal Divisions :	1,652	1,630	1,631
7.00	Floor Finishes :	2,146	2,146	2,146
8.00	Internal Wall Finishing :	6,175	6,175	6,175
9.00	Ceilings :	0	0	0
10.00	Electrical Installation :	3,660	3,660	3,660
11.00	Plumbing Installation :	4,800	4,800	4,800
12.00	Provisional Sums :	2,150	2,150	2,150
13.00	Contingency Allowance :	0	0	0
	Sub-Total	66,228	67,918	74,399
	VAT	9,272	9,508	10,416
	TOTAL : Estimate for Feasibility	**R 75,500**	**R 77,426**	**R 84,815**
	R/m2	**R 1,887**	R 1,936	R 2,120
	% cost difference	0%	3%	12%

prepared by mfs Q.S.

Preliminary Cost Comparisons
Corobrik - Low cost housing Modelling project

Revision 3 - Johannesburg Rates

Summary

Note: No allowance has been made for bringing services to the site.

	Option A: 140mm Concrete blocks	Option B (1): 230mm brick walls using maxi bricks	Option B (2): 280mm un-insulated cavity walls using maxi bricks
Optional ceiling			
Construction cost brought forward (page 1)	66,228	67,918	74,399
Ceiling & insulation	7,848	7,848	7,848
Sub-Total	74,076	75,766	82,247
VAT	10,371	10,607	11,515
TOTAL : Estimate for Feasibility	**R 84,447**	**R 86,373**	**R 93,762**
Specific cost comparison (excl P&G & VAT)			
External walls (incl finish)	R 14,742	R 16,301	R 22,191
	0%	11%	51%
Internal walls (incl internal finishes)	R 7,827	R 7,805	R 7,806
	0%	-0.3%	-0.3%

prepared by mfs Q.S.

Preliminary Cost Comparisons

Corobrik - Low cost housing Modelling project

28-Jul-09

been es to	Option A: 140mm Concrete blocks	Option B (1): 230mm brick walls using maxi bricks	Option B (2): 280mm un-insulated cavity walls using maxi bricks	Option B (3): 280mm insulated cavity walls using maxi bricks	Option C: Steel framed structure
:	6,021	6,543	7,384	7,535	7,265
pec.)	6,446	6,446	6,446	6,446	5,653
on : (assumed spec.)	4,659	4,659	4,659	4,659	4,659
	8,679	8,679	8,679	8,679	8,679
	19,840	24,595	33,013	34,523	32,578
	1,652	2,115	2,115	2,115	4,993
	2,146	2,146	2,146	2,146	2,146
	6,175	6,175	6,175	6,175	3,335
	0	0	0	0	0
	3,660	3,660	3,660	3,660	3,660
	4,800	4,800	4,800	4,800	4,800
	2,150	2,150	2,150	2,150	2,150
	0	0	0	0	0
	66,228	71,968	81,227	82,888	79,918
	9,272	10,076	11,372	11,604	11,188
Feasibility	**R 75,500**	**R 82,044**	**R 92,599**	**R 94,492**	**R 91,106**
	R 1,887	R 2,051	R 2,315	R 2,362	R 2,278
	0%	9%	23%	25%	21%

Preliminary Cost Comparisons

Corobrik - Low cost housing Modelling project

28-Jul-09

been
es to

	Option A: 140mm Concrete blocks	Option B (1): 230mm brick walls using maxi bricks	Option B (2): 280mm un-insulated cavity walls using maxi bricks	Option B (3): 280mm insulated cavity walls using maxi bricks	Option C: Steel framed structure
t forward (page 1)	66,228	71,968	81,227	82,888	79,918
	7,848	7,848	7,848	7,848	7,848
	74,076	79,816	89,075	90,736	87,766
	10,371	11,174	12,471	12,703	12,287
Feasibility	**R 84,447**	**R 90,991**	**R 101,546**	**R 103,439**	**R 100,053**

n (excl P&G & VAT)

)	R 14,742	R 19,497	R 27,915	R 29,425	R 27,480
	0%	32%	89%	100%	86%
al finishes)	R 7,827	R 8,290	R 8,290	R 8,290	R 8,328
	0%	5.9%	5.9%	5.9%	6%

Preliminary Cost Comparisons
Corobrik - Low cost housing Modelling project

Revision 2 27-Jul-09

mfs Developers & Quantity Surveyors CC
CK No. 2005/111319/23; VAT No. 4800 205 132
PO Box 480 Greenpoint 8051 Cape Town South Africa
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Preliminary Cost Comparisons

Corobrik - Low cost housing Modelling project

27-Jul-09

	Option A: 140mm Concrete blocks	Option B (1): 230mm brick walls using core hole bricks	Option B (2): 280mm un-insulated cavity walls using core hole bricks	Option B (3): 280mm insulated cavity walls using core hole bricks	Option C (1): 230mm brick walls using maxi bricks	Option C (2): 280mm un-insulated cavity walls using maxi bricks	Option C (3): 280mm insulated cavity walls using maxi bricks	Option D: Steel framed structure
	6,021	6,545	6,962	7,112	6,687	7,112	7,263	7,265
	6,446	6,446	6,446	6,446	6,446	6,446	6,446	5,653
d spec.	4,659	4,659	4,659	4,659	4,659	4,659	4,659	4,659
	8,679	8,679	8,679	8,679	8,679	8,679	8,679	8,679
	19,840	24,549	28,719	30,229	25,533	29,776	31,286	32,578
	1,652	2,181	2,181	2,181	2,626	2,626	2,626	4,993
	2,146	2,146	2,146	2,146	2,146	2,146	2,146	2,146
	6,175	6,175	6,175	6,175	6,175	6,175	6,175	3,335
	0	0	0	0	0	0	0	0
	3,660	3,660	3,660	3,660	3,660	3,660	3,660	3,660
	4,800	4,800	4,800	4,800	4,800	4,800	4,800	4,800
	2,150	2,150	2,150	2,150	2,150	2,150	2,150	2,150
	0	0	0	0	0	0	0	0
	66,228	71,990	76,577	78,237	73,560	78,228	79,889	79,918
	9,272	10,079	10,721	10,953	10,298	10,952	11,184	11,188
	R 75,500	**R 82,069**	**R 87,298**	**R 89,190**	**R 83,859**	**R 89,180**	**R 91,073**	**R 91,106**
	R 1,887	R 2,052	R 2,182	R 2,230	R 2,096	R 2,229	R 2,277	R 2,278
	0%	9%	16%	18%	11%	18%	21%	21%

Preliminary Cost Comparisons

Corobrik - Low cost housing Modelling project

27-Jul-09

	Option A: 140mm Concrete blocks	Option B (1): 230mm brick walls using core hole bricks	Option B (2): 280mm un-insulated cavity walls using core hole bricks	Option B (3): 280mm insulated cavity walls using core hole bricks	Option C (1): 230mm brick walls using maxi bricks	Option C (2): 280mm un-insulated cavity walls using maxi bricks	Option C (3): 280mm insulated cavity walls using maxi bricks	Option D: Steel framed structure
ge 1)	66,228	71,990	76,577	78,237	73,560	78,228	79,889	79,918
	7,848	7,848	7,848	7,848	7,848	7,848	7,848	7,848
	74,076	79,838	84,425	86,085	81,408	86,076	87,737	87,766
	10,371	11,177	11,820	12,052	11,397	12,051	12,283	12,287
	R 84,447	**R 91,015**	**R 96,245**	**R 98,137**	**R 92,805**	**R 98,127**	**R 100,020**	**R 100,053**
G & VAT)								
	R 14,742	R 19,451	R 23,621	R 25,131	R 20,435	R 24,678	R 26,188	R 27,480
	0%	32%	60%	70%	39%	67%	78%	86%
	R 7,827	R 8,356	R 8,356	R 8,356	R 8,801	R 8,801	R 8,801	R 8,328
	0%	7%	7%	7%	12%	12%	12%	6%

Option A: 140mm Concrete blocks 27-Jul-09

		Quantity	Unit	Unit Rate	Total cost
1.00	**Preliminary and General :**				
1.01	Allowance for preliminary & general	10.00%	Item	60,207	6,021
		40	m2	150.53	6,021
2.00	**Foundations : (assumed spec.)**				
2.01	Foundations comprising of RC 700 x 200mm strip footings incl excav min 600mm below top of s.b., incl. DPM, ROC & backfill and reinforcement (100kg/m3	32	m	176	5,653
2.02	Ditto, but 600 x 185mm to 90mm walls	6	m	124	793
		40	m2	161.15	6,446
3.00	**Ground Floor Construction : (assumed spec.)**				
3.01	80mm Reinforced concrete surface bed incl. damp proof course, etc. and reinforcement (100kg/m3)	39	m2	119	4,659
		40	m2	116.48	4,659
4.00	**Roofs :**				
4.01	New Corrugated profiled roof on PAR rafters/purlins incl. wall plates, straps, flashings, fixings, copings etc. as per manufacturers specs	41	m2	212.09	8,679
		40	m2	216.97	8,679
5.00	**External Walling :**				
5.01	140mm concrete blockwork to external walls	66	m2	157	10,415

		Quan-tity	Unit	Unit Rate	Total cost
5.02	Bagging to new concrete blocks	66	m2	30	1,990
5.03	1 Undercoat & 1 ct paint to new brickwork	66	m2	35	2,337
5.04	External & internal timber doors incl. hinges, locks, frames and painting		Item		2,185
5.05	Timber windows incl glazing & painting		Item		2,450
5.06	Builders work to build in doors & windows	10.00%	Item	4,635	463
		40	m2	496.00	19,840

6.00 Internal Divisions :

		Quan-tity	Unit	Unit Rate	Total cost
6.01	90mm half brick walls	14	m2	117	1,652
		40	m2	41.31	1,652

7.00 Floor Finishes :

		Quan-tity	Unit	Unit Rate	Total cost
7.01	25mm Screeds to floors	39	m2	55	2,146
		40	m2	53.65	2,146

8.00 Internal Wall Finishing :

		Quan-tity	Unit	Unit Rate	Total cost
8.01	Bagging to new brick/block work	95	m2	30	2,840
8.02	1 Ct undercoat & 1ct paint to new walls	95	m2	35	3,335
		40	m2	154.38	6,175

		Quan-tity	Unit	Unit Rate	Total cost
9.00	**Ceilings :**				
9.01	Insulation to ceiling				optional - refer to summary
9.02	6mm Gypsum rhinoboard fixed to underside of rafters				optional - refer to summary
10.00	**Electrical Installation :**				
10.01	Allowance for new electrical DB board		Item		494
10.02	Light points, switches and fittings		Item		958
10.03	Plug points		Item		1,041
10.04	Labour to electrical connections		Item		1,166
		40	m2	91.49	3,660
11.00	**Plumbing Installation :**				
11.01	All plumbing including taking possession of, fitting and connecting fittings incl dishwasher and washing machine points and connecting to supply and waste points	4	No	1200	4,800
		40	m2	120.00	4,800
12.00	**Provisional Sums :**				
12.01	New mirrors		Item		not included
12.02	New WC's, incl taps etc.	1	No	300	300
12.03	New basins incl taps, traps etc.	1	No	300	300

		Quan-tity	Unit	Unit Rate	Total cost
12.04	New bath incl. taps etc.	1	No	800	800
12.05	New sinks incl taps etc.	1	No	600	600
12.06	Provision for kitchen cupboards		Item		not included
12.07	Provision for built in cupboards		Item		not included
12.08	Contractors mark-up on Provisional Sums	7.5	%	2,000	150
		40	m2	53.75	2,150

13.00 Contingency Allowance :

		Quan-tity	Unit	Unit Rate	Total cost
13.01	Detail design contingency				not included
	TOTAL : Estimate for Feasibility	**40**	**m2**	**R**	**66,228**
					Excl VAT
	VAT				**9,272**
	TOTAL (incl VAT)			**R**	**75,500**
				R/m2	1,887

Option B (1): 230mm brick walls using core hole bricks 17-Jul-09

		Quan-tity	Unit	Unit Rate	Total cost
1.00	**Preliminary and General :**				
1.01	Allowance for preliminary & general	10.00%	Item	65,445	6,545
		40	m2	163.63	6,545
2.00	**Foundations : (assumed spec.)**				
2.01	Foundations comprising of RC 700 x 200mm strip footings incl excav min 600mm below top of s.b., incl. DPM, ROC and backfill	32	m	176	5,653
2.02	Ditto, but 600 x 185mm to 90mm walls	6	m	124	793
		40	m2	161.15	6,446
3.00	**Ground Floor Construction : (assumed spec.)**				
3.01	80mm Reinforced concrete surface bed incl. damp proof course, etc. and reinforcement (100kg/m3)	39	m2	119	4,659
		40	m2	116.48	4,659
4.00	**Roofs :**				
4.01	New Corrugated profiled roof on PAR rafters/purlins incl. wall plates, straps, flashings, fixings, copings etc. as per manufacturers specs	41	m2	212.09	8,679
		40	m2	216.97	8,679
5.00	**External Walling :**				
5.01	230mm brickwork from 222 x 106 x 73mm				

		Quan-tity	Unit	Unit Rate	Total cost
	core hole bricks to external walls	66	m2	235	15,558
5.02	Extra over for 115mm face brickwork to external walls	66	m2	59	3,893
5.03	External & internal timber doors incl. hinges, locks, frames and painting		Item		2,185
5.04	Timber windows incl glazing & painting		Item		2,450
5.05	Builders work to build in doors & windows	10.00%	Item	4,635	463
		40	m2	613.72	24,549
6.00	**Internal Divisions :**				
6.01	106mm core hole bricks from 222 x 90 x 114mm bricks to internal walls	14	m2	154	2,181
		40	m2	54.54	2,181
7.00	**Floor Finishes :**				
7.01	25mm Screeds to floors	39	m2	55	2,146
		40	m2	53.65	2,146
8.00	**Internal Wall Finishing :**				
8.01	Bagging to new brick/block work	95	m2	30	2,840
8.02	1 Ct undercoat & 2cts paint to new brickwork	95	m2	35	3,335
		40	m2	154.38	6,175

		Quan-tity	Unit	Unit Rate	Total cost
9.00	**Ceilings :**				
9.01	50mm Insulation to ceiling				optional - refer to summary
9.02	6mm Gypsum rhinoboard fixed to underside of rafters				optional - refer to summary
10.00	**Electrical Installation :**				
10.01	Allowance for new electrical DB board		Item		494
10.02	Light points, switches and fittings		Item		958
10.03	Plug points		Item		1,041
10.04	Labour to electrical connections		Item		1,166
		40	m2	91.49	3,660
11.00	**Plumbing Installation :**				
11.01	All plumbing including taking possession of, fitting and connecting fittings incl dishwasher and washing machine points and connecting to supply and waste points	4	No	1200	4,800
		40	m2	120.00	4,800
12.00	**Provisional Sums :**				
12.01	New mirrors		Item		not included
12.02	New WC's, incl taps etc.	1	No	300	300
12.03	New basins incl taps, traps etc.	1	No	300	300

		Quan-tity	Unit	Unit Rate	Total cost
12.04	New bath incl. taps etc.	1	No	800	800
12.05	New sinks incl taps etc.	1	No	600	600
12.06	Provision for kitchen cupboards		Item		not included
12.07	Provision for built in cupboards		Item		not included
12.08	Contractors mark-up on Provisional Sums	7.5	%	2,000	150
		40	m2	53.75	2,150

13.00 Contingency Allowance :

13.01	Detail design contingency				not included

TOTAL : Estimate for Feasibility	**40**	**m2**	**R**	**71,990**
				Excl VAT
VAT				**10,079**
TOTAL (incl VAT)			**R**	**82,068**
			R/m2	2,052

Option B (2): 280mm un-insulated cavity walls using core hole bricks 17-Jul-09

		Quan-tity	Unit	Unit Rate	Total cost
1.00	**Preliminary and General :**				
1.01	Allowance for preliminary & general	10.00%	Item	69,615	6,962
		40	m2	174.05	6,962
2.00	**Foundations : (assumed spec.)**				
2.01	Foundations comprising of RC 700 x 200mm strip footings incl excav min 600mm below top of s.b., incl. DPM, ROC & backfill	32	m	176	5,653
2.02	Ditto, but 600 x185mm to 90mm walls	6	m	124	793
		40	m2	161.15	6,446
3.00	**Ground Floor Construction : (assumed spec.)**				
3.01	80mm Reinforced concrete surface bed incl. damp proof course, etc. and reinforcement (100kg/m3)	39	m2	119	4,659
		40	m2	116.48	4,659
4.00	**Roofs :**				
4.01	New Corrugated profiled roof on PAR rafters/purlins incl. wall plates, straps, flashings, fixings, copings etc. as per manufacturers specs	41	m2	212.09	8,679
		40	m2	216.97	8,679
5.00	**External Walling :**				
5.01	280mm brickwork from 222 x 106 x 73mm				

		Quan-tity	Unit	Unit Rate	Total cost
	core hole bricks to external walls	66	m2	297	19,728
5.02	Extra over for 115mm face brickwork to external walls	66	m2	59	3,893
5.03	External & internal timber doors incl. hinges, locks, frames and painting		Item		2,185
5.04	Timber windows incl glazing & painting		Item		2,450
5.05	Builders work to build in doors & windows	10.00%	Item	4,635	463
		40	m2	717.97	28,719

6.00 Internal Divisions :

		Quan-tity	Unit	Unit Rate	Total cost
6.01	106mm core hole bricks from 222 x 90 x 114mm bricks to internal walls	14	m2	154	2,181
		40	m2	54.54	2,181

7.00 Floor Finishes :

		Quan-tity	Unit	Unit Rate	Total cost
7.01	25mm Screeds to floors	39	m2	55	2,146
		40	m2	53.65	2,146

8.00 Internal Wall Finishing :

		Quan-tity	Unit	Unit Rate	Total cost
8.01	Bagging to new brick/block work	95	m2	30	2,840
8.02	1 Ct undercoat & 2cts paint to new brickwork	95	m2	35	3,335
		40	m2	154.38	6,175

Option B (2): 280mm un-insulated cavity walls using core hole bricks 17-Jul-09

		Quantity	Unit	Unit Rate	Total cost
9.00	**Ceilings :**				
9.01	50mm Insulation to ceiling				optional - refer to summary
9.02	6mm Gypsum rhinoboard fixed to underside of rafters				optional - refer to summary
10.00	**Electrical Installation :**				
10.01	Allowance for new electrical DB board		Item		494
10.02	Light points, switches and fittings		Item		958
10.03	Plug points		Item		1,041
10.04	Labour to electrical connections		Item		1,166
		40	m2	91.49	3,660
11.00	**Plumbing Installation :**				
11.01	All plumbing including taking possession of, fitting and connecting fittings incl dishwasher and washing machine points and connecting to supply and waste points	4	No	1200	4,800
		40	m2	120.00	4,800
12.00	**Provisional Sums :**				
12.01	New mirrors		Item		not included
12.02	New WC's, incl taps etc.	1	No	300	300
12.03	New basins incl taps, traps etc.	1	No	300	300

Option B (2): 280mm un-insulated cavity walls using core hole bricks 17-Jul-09

		Quan-tity	Unit	Unit Rate	Total cost
12.04	New bath incl. taps etc.	1	No	800	800
12.05	New sinks incl taps etc.	1	No	600	600
12.06	Provision for kitchen cupboards		Item		not included
12.07	Provision for built in cupboards		Item		not included
12.08	Contractors mark-up on Provisional Sums	7.5	%	2,000	150
		40	m2	53.75	2,150

13.00 Contingency Allowance :

13.01	Detail design contingency				not included
	TOTAL : Estimate for Feasibility	**40**	**m2**	**R**	**76,577**
					Excl VAT
	VAT				**10,721**
	TOTAL (incl VAT)			**R**	**87,297**
				R/m2	2,182

Option B (3): 280mm insulated cavity walls using core hole bricks — 17-Jul-09

		Quan-tity	Unit	Unit Rate	Total cost
1.00	**Preliminary and General :**				
1.01	Allowance for preliminary & general	10.00%	Item	71,125	7,112
		40	m2	177.80	7,112
2.00	**Foundations : (assumed spec.)**				
2.01	Foundations comprising of RC 700 x 200mm strip footings incl excav min 600mm below top of s.b., incl. DPM, ROC & backfill	32	m	176	5,653
2.02	Ditto, but 600 x 185mm to 90mm walls	6	m	124	793
		40	m2	161.15	6,446
3.00	**Ground Floor Construction : (assumed spec.)**				
3.01	80mm Reinforced concrete surface bed incl. damp proof course, etc. and reinforcement (100kg/m3)	39	m2	119	4,659
		40	m2	116.48	4,659
4.00	**Roofs :**				
4.01	New Corrugated profiled roof on PAR rafters/purlins incl. wall plates, straps, flashings, fixings, copings etc. as per manufacturers specs	41	m2	212.09	8,679
		40	m2	216.97	8,679
5.00	**External Walling :**				
5.01	280mm brickwork from 222 x 106 x 73mm				

		Quan-tity	Unit	Unit Rate	Total cost
	core hole bricks to external walls	66	m2	297	19,728
5.02	Extra over for 115mm face brickwork to external walls	66	m2	59	3,893
5.03	51mm Cavitybatt insulation to cavity of 280mm brickwork	66	m2	23	1,510
5.04	External & internal timber doors incl. hinges, locks, frames and painting		Item		2,185
5.05	Timber windows incl glazing & painting		Item		2,450
5.06	Builders work to build in doors & windows	10.00%	Item	4,635	463
	Note: Alternative insulation option is 50mm Isoboard @ R116.15/m2				
		40	m2	755.72	30,229

6.00 Internal Divisions :

		Quan-tity	Unit	Unit Rate	Total cost
6.01	106mm core hole bricks from 222 x 90 x 114mm bricks to internal walls	14	m2	154	2,181
		40	m2	54.54	2,181

7.00 Floor Finishes :

		Quan-tity	Unit	Unit Rate	Total cost
7.01	25mm Screeds to floors	39	m2	55	2,146
		40	m2	53.65	2,146

8.00 Internal Wall Finishing :

		Quan-tity	Unit	Unit Rate	Total cost
8.01	Bagging to new brick/block work	95	m2	30	2,840
8.02	1 Ct undercoat & 2cts paint to new				

		Quan-tity	Unit	Unit Rate	Total cost
	brickwork	95	m2	35	3,335
		40	m2	154.38	6,175

9.00 Ceilings :

9.01	50mm Insulation to ceiling				optional - refer to summary
9.02	6mm Gypsum rhinoboard fixed to underside of rafters				optional - refer to summary

10.00 Electrical Installation :

10.01	Allowance for new electrical DB board		Item		494
10.02	Light points, switches and fittings		Item		958
10.03	Plug points		Item		1,041
10.04	Labour to electrical connections		Item		1,166
		40	m2	91.49	3,660

11.00 Plumbing Installation :

11.01	All plumbing including taking possession of, fitting and connecting fittings incl dishwasher and washing machine points and connecting to supply and waste points	4	No	1200	4,800
		40	m2	120.00	4,800

12.00 Provisional Sums :

		Quan-tity	Unit	Unit Rate	Total cost
12.01	New mirrors		Item		not included
12.02	New WC's, incl taps etc.	1	No	300	300
12.03	New basins incl taps, traps etc.	1	No	300	300
12.04	New bath incl. taps etc.	1	No	800	800
12.05	New sinks incl taps etc.	1	No	600	600
12.06	Provision for kitchen cupboards		Item		not included
12.07	Provision for built in cupboards		Item		not included
12.08	Contractors mark-up on Provisional Sums	7.5	%	2,000	150
		40	m2	53.75	2,150

13.00 Contingency Allowance :

		Quan-tity	Unit	Unit Rate	Total cost
13.01	Detail design contingency				not included
	TOTAL : Estimate for Feasibility	**40**	**m2**	**R**	**78,237**
					Excl VAT
	VAT				**10,953**
	TOTAL (incl VAT)			**R**	**89,191**
				R/m2	2,230

Option C (1): 230mm brick walls using maxi bricks 17-Jul-09

		Quan-tity	Unit	Unit Rate	Total cost
1.00	**Preliminary and General :**				
1.01	Allowance for preliminary & general	10.00%	Item	66,873	6,687
		40	m2	167.18	6,687
2.00	**Foundations : (assumed spec.)**				
2.01	Foundations comprising of RC 700 x 200mm strip footings incl excav min 600mm below top of s.b., incl. DPM, ROC & backfill	32	m	176	5,653
2.02	Ditto, but 600 x 185mm to 90mm walls	6	m	124	793
		40	m2	161.15	6,446
3.00	**Ground Floor Construction : (assumed spec.)**				
3.01	80mm Reinforced concrete surface bed incl. damp proof course, etc. and reinforcement (100kg/m3)	39	m2	119	4,659
		40	m2	116.48	4,659
4.00	**Roofs :**				
4.01	New Corrugated profiled roof on PAR rafters/purlins incl. wall plates, straps, flashings, fixings, copings etc. as per manufacturers specs	41	m2	212.09	8,679
		40	m2	216.97	8,679
5.00	**External Walling :**				

Option C (1): 230mm brick walls using maxi bricks | 17-Jul-09

		Quan-tity	Unit	Unit Rate	Total cost
5.01	230mm brickwork from 222 x 90 x 114mm maxi bricks to external walls	66	m2	249	16,542
5.02	Extra over for 115mm face brickwork to external walls	66	m2	59	3,893
5.03	External & internal timber doors incl. hinges, locks, frames and painting		Item		2,185
5.04	Timber windows incl glazing & painting		Item		2,450
5.05	Builders work to build in doors & windows	10.00%	Item	4,635	463
		40	m2	638.32	25,533

6.00 Internal Divisions :

		Quan-tity	Unit	Unit Rate	Total cost
6.01	90mm brickwalls from 222 x 90 x 114mm maxi bricks to internal walls	14	m2	185	2,626
		40	m2	65.64	2,626

7.00 Floor Finishes :

		Quan-tity	Unit	Unit Rate	Total cost
7.01	25mm Screeds to floors	39	m2	55	2,146
		40	m2	53.65	2,146

8.00 Internal Wall Finishing :

		Quan-tity	Unit	Unit Rate	Total cost
8.01	Bagging to new brick/block work	95	m2	30	2,840
8.02	1 Ct undercoat & 2cts paint to new brickwork	95	m2	35	3,335
		40	m2	154.38	6,175

		Quan-tity	Unit	Unit Rate	Total cost
9.00	**Ceilings :**				
9.01	50mm Insulation to ceiling				optional - refer to summary
9.02	6mm Gypsum rhinoboard fixed to underside of rafters				optional - refer to summary
10.00	**Electrical Installation :**				
10.01	Allowance for new electrical DB board		Item		494
10.02	Light points, switches and fittings		Item		958
10.03	Plug points		Item		1,041
10.04	Labour to electrical connections		Item		1,166
		40	m2	91.49	3,660
11.00	**Plumbing Installation :**				
11.01	All plumbing including taking possession of, fitting and connecting fittings incl dishwasher and washing machine points and connecting to supply and waste points	4	No	1200	4,800
		40	m2	120.00	4,800
12.00	**Provisional Sums :**				
12.01	New mirrors		Item		not included
12.02	New WC's, incl taps etc.	1	No	300	300
12.03	New basins incl taps, traps etc.	1	No	300	300

Option C (1): 230mm brick walls using maxi bricks 17-Jul-09

		Quantity	Unit	Unit Rate	Total cost
12.04	New bath incl. taps etc.	1	No	800	800
12.05	New sinks incl taps etc.	1	No	600	600
12.06	Provision for kitchen cupboards		Item		not included
12.07	Provision for built in cupboards		Item		not included
12.08	Contractors mark-up on Provisional Sums	7.5	%	2,000	150
		40	m2	53.75	2,150

13.00 Contingency Allowance :

		Quantity	Unit	Unit Rate	Total cost
13.01	Detail design contingency				not included
	TOTAL : Estimate for Feasibility	**40**	**m2**	**R**	**73,560**
					Excl VAT
	VAT				**10,298**
	TOTAL (incl VAT)			**R**	**83,859**
				R/m2	2,096

Option C (2): 280mm un-insulated cavity walls using maxi bricks 17-Jul-09

		Quan-tity	Unit	Unit Rate	Total cost
1.00	**Preliminary and General :**				
1.01	Allowance for preliminary & general	10.00%	Item	71,116	7,112
		40	m2	177.80	7,112
2.00	**Foundations : (assumed spec.)**				
2.01	Foundations comprising of RC 700 x 200mm strip footings incl excav min 600mm below top of s.b., incl. DPM, ROC & backfill	32	m	176	5,653
2.02	Ditto, but 600 x 185mm to 90mm walls	6	m	124	793
		40	m2	161.15	6,446
3.00	**Ground Floor Construction : (assumed spec.)**				
3.01	80mm Reinforced concrete surface bed incl. damp proof course, etc. and reinforcement (100kg/m3)	39	m2	119	4,659
		40	m2	116.48	4,659
4.00	**Roofs :**				
4.01	New Corrugated profiled roof on PAR rafters/purlins incl. wall plates, straps, flashings, fixings, copings etc. as per manufacturers specs	41	m2	212.09	8,679
		40	m2	216.97	8,679
5.00	**External Walling :**				

Option C (2): 280mm un-insulated cavity walls using maxi bricks 17-Jul-09

		Quan-tity	Unit	Unit Rate	Total cost
5.01	280mm brickwork from 222 x 90 x 114mm maxi bricks to external walls	66	m2	313	20,785
5.02	Extra over for 115mm face brickwork to external walls	66	m2	59	3,893
5.03	External & internal timber doors incl. hinges, locks, frames and painting		Item		2,185
5.04	Timber windows incl glazing & painting		Item		2,450
5.05	Builders work to build in doors & windows	10.00%	Item	4,635	463
		40	m2	744.40	29,776

6.00 Internal Divisions :

		Quan-tity	Unit	Unit Rate	Total cost
6.01	90mm brickwalls from 222 x 90 x 114mm maxi bricks to internal walls	14	m2	185	2,626
		40	m2	65.64	2,626

7.00 Floor Finishes :

		Quan-tity	Unit	Unit Rate	Total cost
7.01	25mm Screeds to floors	39	m2	55	2,146
		40	m2	53.65	2,146

8.00 Internal Wall Finishing :

		Quan-tity	Unit	Unit Rate	Total cost
8.01	Bagging to new brick/block work	95	m2	30	2,840
8.02	1 Ct undercoat & 2cts paint to new brickwork	95	m2	35	3,335
		40	m2	154.38	6,175

		Quan-tity	Unit	Unit Rate	Total cost
9.00	**Ceilings :**				
9.01	50mm Insulation to ceiling				optional - refer to summary
9.02	6mm Gypsum rhinoboard fixed to underside of rafters				optional - refer to summary
10.00	**Electrical Installation :**				
10.01	Allowance for new electrical DB board		Item		494
10.02	Light points, switches and fittings		Item		958
10.03	Plug points		Item		1,041
10.04	Labour to electrical connections		Item		1,166
		40	m2	91.49	3,660
11.00	**Plumbing Installation :**				
11.01	All plumbing including taking possession of, fitting and connecting fittings incl dishwasher and washing machine points and connecting to supply and waste points	4	No	1200	4,800
		40	m2	120.00	4,800
12.00	**Provisional Sums :**				
12.01	New mirrors		Item		not included
12.02	New WC's, incl taps etc.	1	No	300	300
12.03	New basins incl taps, traps etc.	1	No	300	300

	Quan-tity	Unit	Unit Rate	Total cost
12.04 New bath incl. taps etc.	1	No	800	800
12.05 New sinks incl taps etc.	1	No	600	600
12.06 Provision for kitchen cupboards		Item		not included
12.07 Provision for built in cupboards		Item		not included
12.08 Contractors mark-up on Provisional Sums	7.5	%	2,000	150
	40	m2	53.75	2,150

13.00 Contingency Allowance :

	Quan-tity	Unit	Unit Rate	Total cost
13.01 Detail design contingency				not included
TOTAL : Estimate for Feasibility	**40**	**m2**	**R**	**78,228**
				Excl VAT
VAT				**10,952**
TOTAL (incl VAT)			**R**	**89,180**
			R/m2	2,229

Preliminary Estimate

Corobrik - Low cost housing Modelling project

Option C (3): 280mm insulated cavity walls using maxi bricks 17-Jul-09

		Quan-tity	Unit	Unit Rate	Total cost
1.00	**Preliminary and General :**				
1.01	Allowance for preliminary & general	10.00%	Item	72,626	7,263
		40	m2	181.58	7,263
2.00	**Foundations : (assumed spec.)**				
2.01	Foundations comprising of RC 700 x 200mm strip footings incl excav min 600mm below top of s.b., incl. DPM, ROC & backfill	32	m	176	5,653
2.02	Ditto, but 600 x 185mm to 90mm walls	6	m	124	793
		40	m2	161.15	6,446
3.00	**Ground Floor Construction : (assumed spec.)**				
3.01	80mm Reinforced concrete surface bed incl. damp proof course, etc. and reinforcement (100kg/m3)	39	m2	119	4,659
		40	m2	116.48	4,659
4.00	**Roofs :**				
4.01	New Corrugated profiled roof on PAR rafters/purlins incl. wall plates, straps, flashings, fixings, copings etc. as per manufacturers specs	41	m2	212.09	8,679
		40	m2	216.97	8,679
5.00	**External Walling :**				

		Quan-tity	Unit	Unit Rate	Total cost
5.01	280mm brickwork from 222 x 90 x 114mm maxi bricks to external walls	66	m2	313	20,785
5.02	Extra over for 115mm face brickwork to external walls	66	m2	59	3,893
5.03	51mm Cavitybatt insulation to cavity of 280mm brickwork	66	m2	23	1,510
5.04	External & internal timber doors incl. hinges, locks, frames and painting		Item		2,185
5.05	Timber windows incl glazing & painting		Item		2,450
5.06	Builders work to build in doors & windows	10.00%	Item	4,635	463
	Note: Alternative insulation option is 50mm Isoboard @ R116.15/m2				
		40	m2	782.14	31,286

6.00 Internal Divisions :

6.01	90mm brickwalls from 222 x 90 x 114mm maxi bricks to internal walls	14	m2	185	2,626
		40	m2	65.64	2,626

7.00 Floor Finishes :

7.01	25mm Screeds to floors	39	m2	55	2,146
		40	m2	53.65	2,146

8.00 Internal Wall Finishing :

8.01	Bagging to new brick/block work	95	m2	30	2,840

		Quan-tity	Unit	Unit Rate	Total cost
8.02	1 Ct undercoat & 2cts paint to new brickwork	95	m2	35	3,335
		40	m2	154.38	6,175

9.00 Ceilings :

9.01	50mm Insulation to ceiling				optional - refer to summary
9.02	6mm Gypsum rhinoboard fixed to underside of rafters				optional - refer to summary

10.00 Electrical Installation :

10.01	Allowance for new electrical DB board		Item		494
10.02	Light points, switches and fittings		Item		958
10.03	Plug points		Item		1,041
10.04	Labour to electrical connections		Item		1,166
		40	m2	91.49	3,660

11.00 Plumbing Installation :

11.01	All plumbing including taking possession of, fitting and connecting fittings incl dishwasher and washing machine points and connecting to supply and waste points	4	No	1200	4,800
		40	m2	120.00	4,800

		Quan-tity	Unit	Unit Rate	Total cost
12.00	**Provisional Sums :**				
12.01	New mirrors		Item		not included
12.02	New WC's, incl taps etc.	1	No	300	300
12.03	New basins incl taps, traps etc.	1	No	300	300
12.04	New bath incl. taps etc.	1	No	800	800
12.05	New sinks incl taps etc.	1	No	600	600
12.06	Provision for kitchen cupboards		Item		not included
12.07	Provision for built in cupboards		Item		not included
12.08	Contractors mark-up on Provisional Sums	7.5	%	2,000	150
		40	m2	53.75	2,150
13.00	**Contingency Allowance :**				
13.01	Detail design contingency				not included
	TOTAL : Estimate for Feasibility	**40**	**m2**	**R**	**79,889**
					Excl VAT
	VAT				**11,184**
	TOTAL (incl VAT)			**R**	**91,073**
				R/m2	2,277

Option D: Steel framed structure 17-Jul-09

		Quan-tity	Unit	Unit Rate	Total cost
1.00	**Preliminary and General :**				
1.01	Allowance for preliminary & general	10.00%	Item	72,653	7,265
		40	m2	181.63	7,265
2.00	**Foundations : (assumed spec.)**				
2.01	Foundations comprising of RC 700 x 200mm strip footings incl excav min 600mm below top of s.b., incl. DPM, ROC & backfill	32	m	176	5,653
		40	m2	141.33	5,653
3.00	**Ground Floor Construction : (assumed spec.)**				
3.01	80mm Reinforced concrete surface bed incl. damp proof course, etc. and reinforcement (100kg/m3)	39	m2	119	4,659
		40	m2	116.48	4,659
4.00	**Roofs :**				
4.01	New Corrugated profiled roof on PAR rafters/purlins incl. wall plates, straps, flashings, fixings, copings etc. as per manufacturers specs	41	m2	212.09	8,679
		40	m2	216.97	8,679
5.00	**External Walling :**				
5.01	Steel frame structure with Nutech fibre cement board externally & 12mm Gypsum board internally	66	m2	287	19,016

		Quan- tity	Unit	Unit Rate	Total cost
5.02	63mm Cavitybatt insulation	66	m2	26	1,703
5.03	1200 x 400 x 100 Steel frame structures to fibre cement board and Gypsum boards incl fixing (	66	m2	59	3,918
5.04	1 Undercoat & 2 cts paint to new fibre cement boards externally	66	m2	43	2,843
5.05	External & internal timber doors incl. hinges, locks, frames and painting		Item		2,185
5.06	Timber windows incl glazing & painting		Item		2,450
5.07	Builders work to build in doors & windows	10.00%	Item	4,635	463
	Note: No allowance has been made for skimming plasterboard walls internally				
		40	m2	814.45	32,578

6.00 Internal Divisions :

		Quan- tity	Unit	Unit Rate	Total cost
6.01	12mm Gypsum board fixed on both sides of steel frame structure	14	m2	278	3,934
6.02	63mm Cavitybatt insulation	14	m2	16	222
6.03	1200 x 400 x 100 Steel frame structures to fibre cement board and Gypsum boards incl fixing (	14	m2	59	836
		40	m2	124.82	4,993

7.00 Floor Finishes :

		Quan- tity	Unit	Unit Rate	Total cost
7.01	25mm Screeds to floors	39	m2	55	2,146
		40	m2	53.65	2,146

		Quan-tity	Unit	Unit Rate	Total cost
8.00	**Internal Wall Finishing :**				
8.01	1 Undercoat & 2 cts paint to new fibre cement boards internally	95	m2	35	3,335
	Note: No allowance has been made for skimming plasterboard walls internally				
		40	m2	83.38	3,335
9.00	**Ceilings :**				
9.01	50mm Insulation laid on top on brandering to ceiling				optional - refer to summary
9.02	6.4mm "Rhino" Gypsum plasterboard fixed to underside of rafters				optional - refer to summary
10.00	**Electrical Installation :**				
10.01	Allowance for new electrical DB board		Item		494
10.02	Light points, switches and fittings		Item		958
10.03	Plug points		Item		1,041
10.04	Labour to electrical connections		Item		1,166
		40	m2	91.49	3,660
11.00	**Plumbing Installation :**				
11.01	All plumbing including taking possession of, fitting and connecting fittings incl dishwasher and washing machine points				

		Quan-tity	Unit	Unit Rate	Total cost
	and connecting to supply and waste points	4	No	1200	4,800
		40	m2	120.00	4,800

12.00 Provisional Sums :

		Quan-tity	Unit	Unit Rate	Total cost
12.01	New mirrors		Item		not included
12.02	New WC's, incl taps etc.	1	No	300	300
12.03	New basins incl taps, traps etc.	1	No	300	300
12.04	New bath incl. taps etc.	1	No	800	800
12.05	New sinks incl taps etc.	1	No	600	600
12.06	Provision for kitchen cupboards		Item		not included
12.07	Provision for built in cupboards		Item		not included
12.08	Contractors mark-up on Provisional Sums	7.5	%	2,000	150
		40	m2	53.75	2,150

13.00 Contingency Allowance :

		Quan-tity	Unit	Unit Rate	Total cost
13.01	Detail design contingency				not included
	TOTAL : Estimate for Feasibility	**40**	**m2**	**R**	**79,918**
					Excl VAT
	VAT				**11,188**
	TOTAL (incl VAT)			**R**	**91,106**

Option D: Steel framed structure 17-Jul-09

	Quantity	Unit	Unit Rate	Total cost
			R/m2	2,278

Optional ceiling with insulation 17-Jul-09

		Quan-tity	Unit	Unit Rate	Total cost
1.00	**Ceilings and insulation :**				
1.01	6.4mm "Rhino" Gypsum plasterboard fixed to underside of rafters	39	m2	97	3,764
1.02	115mm Aerolite Insulation laid on top on brandering to ceiling	39	m2	23	910
1.03	Skimming to plasterboard ceiling	39	m2	45	1,767
1.04	2 cts paint on skimmed plasterboard ceiling	39	m2	36	1,407
					7,848
	TOTAL : Estimate for Feasibility	**40**	**m2**	**R**	**7,848**
					Excl VAT
	VAT				**1,099**
	TOTAL (incl VAT)			**R**	**8,947**
				R/m2	224

IFHS wall cost estimate
Derived from info from Ikhaya futurehouse systems, by email
Excludes VAT

	cost/m² of wall	cost for building
External walls		
Details as per manufacturer		
80 mm Eps core futurehouse panel	R 175.00	R 11 550.00
Plaster both sides at average thickness of 35mm using 4:1 sand to cement mix	R 70.00	R 4 620.00
Ancillaries inclusive of mesh at corners, starter bars, wire ties = R10	R 10.00	R 660.00
Subtotal for walling itself	R 255.00	R 16 830.00
Additional items as per MFS study		
Ext wall paint 1 under coat, 1 top coat	R 35.41	R 2 337.00
External & internal timber doors incl. hinges, locks, frames and painting		R 2 185.00
Timber windows incl glazing & painting		R 2 450.00
Builders work to build in doors & windows		R 463.00
Labour **	R 12.00	R 792.00
Labour % of total	5%	
		R 25 057.00
Internal divisions		
Details as per manufacturer		
60 mm EPS core Futurehouse panel	R 155.00	R 10 230.00
Plaster both sides at average thickness of 17.5mm using 4:1 sand to cement mix	R 35.00	R 2 310.00
Ancillaries inclusive of mesh at corners, starter bars, wire ties = R10	R 10.00	R 660.00
Labour **	R 12.00	R 792.00
Labour % of total	R 0.06	
	R 212.00	R 2 968.00

** Notes
Labour differs from area to area but assume a labour rate of R100/person/day.
Typically can construct and plaster the Futurehouse system with 3 people considering the lightweight nature of the panels.
Would also assume that plastering is done by spray machine for the bulk of the plaster and finished by hand.
On a simple house should be able to erect 35 panels in a day (100m²) and plaster with same crew over 3 days. i.e. 4 days to complete 100m² of wall.
Labour cost = R1200 so cost of labour = R12/m²

Imison wall cost estimate

Derived from info from Imison, by email

Excludes VAT

Excludes preliminaries, as in the other wall type cost calcs

	cost/m² of wall	cost for building
External walls		
Details as per manufacturer		
NLB walls (used for external walls in this scenario), at R276.10 / m² **incl. labour**	R 276.10	R 18 222.60
Additional items as per MFS study		
Ext wall paint 1 under coat, 1 top coat	R 35.41	R 2 337.00
External & internal timber doors incl. hinges, locks, frames and painting	-	R 2 185.00
Timber windows incl glazing & painting	-	R 2 450.00
Builders work to build in doors & windows	-	R 463.00
		R 25 657.60
Internal divisions (details as per manufacturer)		
NLB walls, at R276.10 / m² **incl. labour**	R 276.10	R 3 865.40

Notes

For non load bearing walling less than 2.7m high the cost of walling per m2 would be:

R 115.50 excl VAT for steel and Styropor® including a 23% labour rate for installation excl. VAT and prelims.

R 160.60 excl VAT for Fibrecote™ both sides to 20mm and a 5mm coat to finish the walls including a 24% labour charge for application excl. VAT and preliminaries.

These prices are by no means firm, are an indication only, include just walls with a plaster finish, exclude VAT, prelims, any additional fixings for infill walling, plumbing, electrical and openings for doors and windows, wall height of less than 2.7m high, Styropor® 100mm thick, no transport, single storey unit, Gauteng prices have been assumed for input costs of raw materials, a structure of more than 500 m2 of wall area.

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This Co2 analysis is based on the following:

Disclaimer

The best efforts of econic have been applied to the preparation of this report, however, we do not make any warranty of any kind, expressed or implied, with regard to the information contained in this report. No warranty is made as to the accuracy, completeness or usefulness for any particular purpose of the information. No liability is accepted for any loss or damage, however caused, arising from reliance on or use of any information or arising from the absence of information or any particular information in this report.

The following sources are have been used for the embodied CO2 data

- A ICE 1.6a (2008) - Inventory of Carbon and Energy (ICE) version 1.6a (2008); University of Bath Dept of Mechanical Engineering; Hammond & Jones
- B Branz (2006) - Study Report No.150 (2006): Towards Carbon Neutral & Climate Adapted Domestic Buildings - Background Document; Jacques & Sheridan
- C Alcorn (2003) - Embodied Energy & CO2 Coefficients for NZ Building Materials ; Centre for Building Performance Research; Alcorn

Where Branz & Alcorn do not have data available, data from ICE has been used for all three samples.

Further:

1) Embodied CO2 & material densities for bricks supplied directly by Corobrick
2) No allowance has been made for the electrical installation due to lack of information available
3) No allowance has been made for the plumbing installation due to lack of information available
4) No allowance has been made for all fixtures & fittings due to lack of information available

Please refer to annexure A at the end of this document for the densities used for the various building materials in this analysis.

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cost housing Modelling project

09-Sep-09

	Option A: 140mm Concrete blocks			Option B (1): 230mm brick walls; maxi bricks			Option B (2): 280mm un-insulated cavity walls, maxi bricks			Option B (3): 280mm insulated cavity walls; maxi bricks			Option C: Steel framed structure		
	ICE 1.6a (2008)	Branz (2006)	Alcorn (2003)	ICE 1.6a (2008)	Branz (2006)	Alcorn (2003)	ICE 1.6a (2008)	Branz (2006)	Alcorn (2003)	ICE 1.6a (2008)	Branz (2006)	Alcorn (2003)	ICE 1.6a (2008)	Branz (2006)	Alcorn (2003)
	1 634	2 146	2 013	1 634	2 146	2 013	1 634	2 146	2 013	1 634	2 146	2 013	1 412	1 852	1 739
	1 126	1 480	1 328	1 126	1 480	1 328	1 126	1 480	1 328	1 126	1 480	1 328	1 088	1 442	1 290
	2 032	1 291	63	2 032	1 291	63	2 032	1 291	63	2 032	1 291	63	2 032	1 291	63
	2 079	1 714	1 483	4 786	4 739	4 339	4 800	4 742	4 342	4 860	4 776	4 376	6 896	3 380	5 513
	830	1 845	1 810	566	578	529	566	578	529	566	578	529	1 222	467	890
	382	566	447	382	566	447	382	566	447	382	566	447	382	566	447
	140	223	149	140	223	149	140	223	149	42	67	45	86	86	86
	8 222	**9 266**	**7 292**	**10 666**	**11 024**	**8 867**	**10 680**	**11 027**	**8 869**	**10 642**	**10 904**	**8 799**	**13 118**	**9 085**	**10 027**
	0%	0%	0%	30%	19%	22%	30%	19%	22%	29%	18%	21%	60%	-2%	38%
	8 222	9 266	7 292	10 666	11 024	8 867	10 680	11 027	8 869	10 642	10 904	8 799	13 118	9 085	10 027
	206	205	205	206	205	205	206	205	205	206	205	205	206	205	205
	8 428	**9 470**	**7 497**	**10 872**	**11 229**	**9 072**	**10 886**	**11 231**	**9 074**	**10 848**	**11 109**	**9 004**	**13 324**	**9 290**	**10 232**
	0%	0%	0%	29%	19%	21%	29%	19%	21%	29%	17%	20%	58%	-2%	36%
	1 873	1 595	1 535	4 580	4 620	4 391	4 595	4 623	4 394	4 654	4 657	4 427	6 691	3 261	5 564
	0%	0%	0%	145%	190%	186%	145%	190%	186%	149%	192%	188%	257%	104%	262%
he:	970	2 068	1 959	706	801	678	706	801	678	608	645	574	1 292	544	968
	0%	0%	0%	-27%	-61%	-65%	-27%	-61%	-65%	-37%	-69%	-71%	33%	-74%	-51%

embodied energy analysis
Corobrick - Low cost housing Modelling project

Option A: 140mm Concrete blocks 09-Sep-09

		Quantity	Unit	Embodied CO2 ICE 1.6a (2008)		Branz (2006)		Alcorn (2003)
				KgCO2	2/Kg	KgCO2	O2/K	KgCO2
1.00	**Foundations : (assumed spec.)**							
1.01	Foundations comprising of RC 700 x 200mm strip footings incl excav min 600mm below top of s.b., incl. DPM, ROC & backfill (assume from excavations)	32	m	1 411.52		1 852.49		1 738.92
1.02	Ditto, but 600 x 185mm to 90mm walls	6	m	222.07		293.07		273.72
				1 633.59		2 145.56		2 012.64
2.00	**Ground Floor Construction : (assumed spec.)**							
2.01	80mm Reinforced concrete surface bed incl. damp proof course, etc. and reinforcement (100kg/m3)	39	m2	1 126.48		1 480.28		1 327.84
	Note: No allowance has been made for the embodied energy of any formwork							
				1 126.48		1 480.28		1 327.84
3.00	**Roofs :**							
3.01	New Corrugated profiled roof on PAR rafters/purlins incl. wall plates, straps, flashings, fixings, copings etc. as per manufacturers specs	41	m2	2 031.89		1 291.28		62.58
				2 031.89		1 291.28		62.58
4.00	**External Walling :**							
4.01	140mm concrete block work to external wa	66	m2	1 774.88		1 484.81		1 430.93
4.02	Bagging to new concrete blocks	66	m2	37.37		49.80		43.64
		1						
4.03	1 Undercoat & 1 ct paint to new brickwork	66	m2	60.61		60.61		60.61
	17.03							
4.04	External & internal timber doors incl. hinges, locks, frames and painting	4	No	103.50		38.67		-92.04
4.05	Timber windows incl glazing & painting	7	No	102.20		80.33		40.20
				2 078.56		1 714.22		1 483.34

		Quantity	Unit	Embodied CO2 ICE 1.6a (2008)	Branz (2006)	Alcorn (2003)
5.00	**Internal Divisions :**					
5.01	90mm half brick walls	14	m2	830.30	1 844.98	1 809.92
				830.30	1 844.98	1 809.92
6.00	**Floor Finishes :**					
6.01	25mm Screeds to floors	39	m2	381.62	566.09	446.62
				381.62	566.09	446.62
7.00	**Internal Wall Finishing :**					
7.01	Bagging to new brick/block work	95	m2	53.32	136.65	62.27
7.02	1 Ct undercoat & 1ct paint to walls	95	m2	86.49	86.49	86.49
				139.81	223.15	148.76
8.00	**Ceilings :**					
8.01	Insulation to ceiling			refer to optional ceilings		
8.02	6mm Gypsum rhinoboard fixed to underside of rafters			refer to optional ceilings		
9.00	**Electrical Installation :**					
	No allowance has been made for the electrical installation due to lack of information available					
10.00	**Plumbing Installation :**					
	No allowance has been made for the plumbing installation due to lack of information available					
11.00	**Provisional Sums :**					
	No allowance has been made for all fixtures & fittings due to lack of information available					
	TOTAL (kg CO2)			**8 222**	**9 266**	**7 292**

		Quantity	Unit	Embodied CO2 ICE 1.6a (2008) KgCO2	O2/K	Branz (2006) KgCO2	O2/K	Alcorn (2003) KgCO2
1.00	**Foundations : (assumed spec.)**							
1.01	Foundations comprising of RC 700 x 200mm strip footings incl excav min 600mm below top of s.b., incl. DPM, ROC & backfill	32	m	1 412		1 852.49		1 738.92
1.02	Ditto, but 600 x 185mm to 90mm walls	6	m	222.07		293.07		273.72
				1 633.59		2 145.56		2 012.64
2.00	**Ground Floor Construction : (assumed spec.)**							
2.01	80mm Reinforced concrete surface bed incl. damp proof course, etc. and reinforcement (100kg/m3)	39	m2	1 126.48		1 480.28		1 327.84
	Note: No allowance has been made for the embodied energy of any formwork							
				1 126.48		1 480.28		1 327.84
3.00	**Roofs :**							
3.01	New Corrugated profiled roof on PAR rafters/purlins incl. wall plates, straps, flashings, fixings, copings etc. as per manufacturers specs	41	m2	2 031.89		1 291.28		62.58
				2 031.89		1 291.28		62.58
4.00	**External Walling :**							
4.01	230mm brickwork from 222 x 90 x 114mm maxi bricks and Montana/Nevada Travertine facings to external walls	66	m2	4 580.35		4 620.36		4 390.83
4.02	External & internal timber doors incl. hinges, locks, frames and painting	4	No	103.50		38.67		-92.04
4.03	Timber windows incl glazing & painting	7	No	102.20		80.33		40.20
				4 786.05		4 739.36		4 339.00
5.00	**Internal Divisions :**							

		Quantity	Unit	Embodied CO2 ICE 1.6a (2008)	Branz (2006)	Alcorn (2003)
5.01	90mm brickwalls from 222 x 90 x 114mm maxi bricks to internal walls	14	m2	566.43	578.26	529.27
				566.43	578.26	529.27
6.00	**Floor Finishes :**					
6.01	25mm Screeds to floors	39	m2	381.62	566.09	446.62
				381.62	566.09	446.62
7.00	**Internal Wall Finishing :**					
7.01	Bagging to new brick/block work	95	m2	53.32	136.65	62.27
7.02	1 Ct undercoat & 1ct paint to walls	95	m2	86.49	86.49	86.49
				139.81	223.15	148.76
8.00	**Ceilings :**					
8.01	Insulation to ceiling			refer to optional ceilings		
8.02	6mm Gypsum rhinoboard fixed to underside of rafters			refer to optional ceilings		
9.00	**Electrical Installation :**					
	No allowance has been made for the electrical installation due to lack of information available					
10.00	**Plumbing Installation :**					
	No allowance has been made for the plumbing installation due to lack of information available					
11.00	**Provisional Sums :**					
	No allowance has been made for all fixtures & fittings due to lack of information available					
	TOTAL (kg CO2)			**10 772**	**11 024**	**8 867**

embodied energy analysis
Corobrick - Low cost housing Modelling project

Option B (2): 280mm un-insulated cavity walls, maxi brick 09-Sep-09

				Embodied CO2		
		Quantity	Unit	ICE 1.6a (2008)	Branz (2006)	Alcorn (2003)
				KgCO2	KgCO2	KgCO2
1.00	**Foundations : (assumed spec.)**					
1.01	Foundations comprising of RC 700 x 200mm strip footings incl excav min 600mm below top of s.b., incl. DPM, ROC & backfill	32	m	1 412	1 852.49	1 738.92
1.02	Ditto, but 600 x 185mm to 90mm walls	6	m	222.07	293.07	273.72
				1 633.59	2 145.56	2 012.64
2.00	**Ground Floor Construction : (assumed spec.)**					
2.01	80mm Reinforced concrete surface bed incl. damp proof course, etc. and reinforcement (100kg/m3)	39	m2	1 126.48	1 480.28	1 327.84
	Note: No allowance has been made for the embodied energy of any formwork					
				1 126.48	1 480.28	1 327.84
3.00	**Roofs :**					
3.01	New Corrugated profiled roof on PAR rafters/purlins incl. wall plates, straps, flashings, fixings, copings etc. as per manufacturers specs	41	m2	2 031.89	1 291.28	62.58
				2 031.89	1 291.28	62.58
4.00	**External Walling :**					
4.01	230mm brickwork from 222 x 90 x 114mm maxi bricks and Montana/Nevada Travertine facings to external walls	66	m2	4 594.79	4 623.06	4 393.52
4.02	External & internal timber doors incl. hinges, locks, frames and painting	4	No	103.50	38.67	-92.04
4.03	Timber windows incl glazing & painting	7	No	102.20	80.33	40.20

		Quantity	Unit	Embodied CO2 ICE 1.6a (2008)	Branz (2006)	Alcorn (2003)
				4 800.49	4 742.06	4 341.68
5.00	**Internal Divisions :**					
5.01	90mm brickwalls from 222 x 90 x 114mm maxi bricks to internal walls	14	m2	566.43	578.26	529.27
				566.43	578.26	529.27
6.00	**Floor Finishes :**					
6.01	25mm Screeds to floors	39	m2	381.62	566.09	446.62
				381.62	566.09	446.62
7.00	**Internal Wall Finishing :**					
7.01	Bagging to new brick/block work	95	m2	53.32	136.65	62.27
7.02	1 Ct undercoat & 1ct paint to walls	95	m2	86.49	86.49	86.49
				139.81	223.15	148.76
8.00	**Ceilings :**					
8.01	Insulation to ceiling			refer to optional ceilings		
8.02	6mm Gypsum rhinoboard fixed to underside of rafters			refer to optional ceilings		
9.00	**Electrical Installation :**					
	No allowance has been made for the electrical installation due to lack of information availat					
10.00	**Plumbing Installation :**					
	No allowance has been made for the plumbing installation due to lack of information availal					

	Quantity	Unit	Embodied CO2 ICE 1.6a (2008)	Branz (2006)	Alcorn (2003)
11.00 Provisional Sums :					
No allowance has been made for all fixtures & fittings due to lack of information available					
TOTAL (kg CO2)			**10 680**	**11 027**	**8 869**

embodied energy analysis
Corobrick - Low cost housing Modelling project

Option B (3): 280mm insulated cavity walls; maxi bricks 09-Sep-09

			Embodied CO2		
	Quantity	Unit	ICE 1.6a (2008)	Branz (2006)	Alcorn (2003)
			KgCO2	KgCO2	KgCO2
1.00 Foundations : (assumed spec.)					
1.01 Foundations comprising of RC 700 x 200mm strip footings incl excav min 600mm below top of s.b., incl. DPM, ROC & backfill	32	m	1 412	1 852.49	1 738.92
1.02 Ditto, but 600 x 185mm to 90mm walls	6	m	222.07	293.07	273.72
			1 633.59	2 145.56	2 012.64
2.00 Ground Floor Construction : (assumed spec.)					
2.01 80mm Reinforced concrete surface bed incl. damp proof course, etc. and reinforcement (100kg/m3)	39	m2	1 126.48	1 480.28	1 327.84
Note: No allowance has been made for the embodied energy of any formwork					
			1 126.48	1 480.28	1 327.84
3.00 Roofs :					
3.01 New Corrugated profiled roof on PAR rafters/purlins incl. wall plates, straps, flashings, fixings, copings etc. as per manufacturers specs	41	m2	2 031.89	1 291.28	62.58
			2 031.89	1 291.28	62.58
4.00 External Walling :					
4.01 230mm brickwork from 222 x 90 x 114mm maxi bricks and Montana/Nevada Travertine facings to external walls	66	m2	4 594.79	4 623.06	4 393.52
4.02 51mm Cavitybatt (glass fibre) insulation to cavity of 280mm brickwork	66	m2	59.37	33.87	33.87
4.03 External & internal timber doors incl.					

		Quantity	Unit	Embodied CO2 ICE 1.6a (2008)	Branz (2006)	Alcorn (2003)
	hinges, locks, frames and painting	4	No	103.50	38.67	-92.04
4.04	Timber windows incl glazing & painting	7	No	102.20	80.33	40.20
				4 859.86	4 775.93	4 375.55
5.00	**Internal Divisions :**					
5.01	90mm brickwalls from 222 x 90 x 114mm maxi bricks to internal walls	14	m2	566.43	578.26	529.27
				566.43	578.26	529.27
6.00	**Floor Finishes :**					
6.01	25mm Screeds to floors	39	m2	381.62	566.09	446.62
				381.62	566.09	446.62
7.00	**Internal Wall Finishing :**					
7.01	Bagging to new brick/block work	28	m2	15.95	40.89	18.63
7.02	1 Ct undercoat & 1ct paint to walls	28	m2	25.88	25.88	25.88
				41.83	66.76	44.51
8.00	**Ceilings :**					
8.01	Insulation to ceiling			refer to optional ceilings		
8.02	6mm Gypsum rhinoboard fixed to underside of rafters			refer to optional ceilings		
9.00	**Electrical Installation :**					

No allowance has been made for the electrical installation due to lack of information availab

	Quantity	Unit	Embodied CO2 ICE 1.6a (2008)	Branz (2006)	Alcorn (2003)
10.00 Plumbing Installation :					
No allowance has been made for the plumbing installation due to lack of information availal					
11.00 Provisional Sums :					
No allowance has been made for all fixtures & fittings due to lack of information available					
TOTAL (kg CO2)			**10 642**	**10 904**	**8 799**

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Option C: Steel framed structure 09-Sep-09

		Quantity	Unit	Embodied CO2 ICE 1.6a (2008)	Branz (2006)	Alcorn (2003)
				KgCO2	KgCO2	KgCO2
1.00	**Foundations : (assumed spec.)**					
1.01	Foundations comprising of RC 700 x 200mm strip footings incl excav min 600mm below top of s.b., incl. DPM, ROC & backfill	32	m	1 411.52	1 852.49	1 738.92
				1 411.52	1 852.49	1 738.92
2.00	**Ground Floor Construction : (assumed spec.)**					
2.01	80mm Reinforced concrete surface bed incl. damp proof course, etc. and reinforcement (100kg/m3)	39	m2	1 088.26	1 442.06	1 289.62
	Note: No allowance has been made for the embodied energy of any formwork					
				1 088.26	1 442.06	1 289.62
3.00	**Roofs :**					
3.01	New Corrugated profiled roof on PAR rafters/purlins incl. wall plates, straps, flashings, fixings, copings etc. as per manufacturers specs	41	m2	2 031.89	1 291.28	62.58
				2 031.89	1 291.28	62.58
4.00	**External Walling :**					
4.01	Steel frame structure with Nutech fibre cement board externally & 12mm Gypsum board internal	66	m2	6 556.65	3 158.92	5 462.04
4.02	63mm Cavitybatt insulation	66	m2	73.34	41.83	41.83
4.03	1 Undercoat & 2 cts paint to new fibre cement boards externally	66	m2	60.61	60.61	60.61
4.04	External & internal timber doors incl. hinges, locks, frames and painting	4	No	103.50	38.67	-92.04

		Quantity	Unit	Embodied CO2 ICE 1.6a (2008)	Branz (2006)	Alcorn (2003)
4.05	Timber windows incl glazing & painting	7	No	102.20	80.33	40.20
				6 896.30	3 380.36	5 512.65
5.00	**Internal Divisions :**					
5.01	12mm Gypsum board fixed on both sides of steel frame structure	14	m2	1 205.87	457.65	881.12
5.02	63mm Cavitybatt insulation	14	m2	15.66	8.93	8.93
				1 221.52	466.58	890.05
6.00	**Floor Finishes :**					
6.01	25mm Screeds to floors	39	m2	381.62	566.09	446.62
				381.62	566.09	446.62
7.00	**Internal Wall Finishing :**					
7.01	1 Undercoat & 2 cts paint to new fibre cement boards internally	95	m2	86.49	86.49	86.49
	Note: No allowance has been made for skimming plasterboard walls internally					
				86.49	86.49	86.49
8.00	**Ceilings :**					
8.01	Insulation to ceiling			refer to optional ceilings		
8.02	6mm Gypsum rhinoboard fixed to underside of rafters			refer to optional ceilings		
9.00	**Electrical Installation :**					

	Quantity	Unit	Embodied CO2 ICE 1.6a (2008)	Branz (2006)	Alcorn (2003)
No allowance has been made for the electrical installation due to lack of information availab					
10.00 Plumbing Installation :					
No allowance has been made for the plumbing installation due to lack of information availal					
11.00 Provisional Sums :					
No allowance has been made for all fixtures & fittings due to lack of information available					
TOTAL (kg CO2)			**13 118**	**9 085**	**10 027**

embodied energy analysis
Corobrick - Low cost housing Modelling project

Optional ceiling with insulation 09-Sep-09

		Quantity	Unit	Embodied CO2 ICE 1.6a (2008)	Branz (2006)	Alcorn (2003)
				KgCO2	KgCO2	KgCO2
1.00	**Ceilings and insulation :**					
1.01	6.4mm "Rhino" Gypsum plasterboard fixed to underside of rafters	39	m2	133.38	147.42	147.77
1.02	115mm Aerolite Insulation laid on top on brandering to ceiling	39	m2	36.49	20.81	20.81
1.03	Skimming to plasterboard ceiling	39	m2	0.48	0.88	0.87
1.04	2 cts paint on skimmed plasterboard ceiling	39	m2	35.64	35.64	35.64
				205.98	204.74	205.08

embodied energy analysis
Corobrick - Low cost housing Modelling project

Ikhaya Futurehouse System (added subsequent to Econic study) 2010-06-21

				Embodied CO2			
		Quantity	Unit	ICE 1.6a (2008)	Branz (2006)	Alcorn (2003)	
				KgCO2	KgCO2	KgCO2	
1.00	**Foundations : (assumed spec.)**						
1.01	Foundations comprising of RC 700 x 200mm strip footings incl excav min 600mm below top of s.b., incl. DPM, ROC & backfill (assume from excavations)	32	m		1 852.49		
1.02	Ditto, but 600 x 185mm to 90mm walls	6	m		293.07		
					2 145.56		
2.00	**Ground Floor Construction : (assumed spec.)**						
2.01	80mm Reinforced concrete surface bed incl. damp proof course, etc. and reinforcement (100kg/m3)	39	m2		1 480.28		
	Note: No allowance has been made for the embodied energy of any formwork						
					1 480.28		
3.00	**Roofs :**						
3.01	New Corrugated profiled roof on PAR rafters/purlins incl. wall plates, straps, flashings, fixings, copings etc. as per manufacturers specs	41	m2		1 291.28		
					1 291.28		
4.00	**External Walling :**						
4.01	IFHS panel: EPS 80 mm + mesh + ties + sta	66	m2		342.79		
4.02	Plaster sand-cement 4:1 mix by volume (4.2	66 1	m2		1 816.67		
4.03	1 Undercoat & 1 ct paint to new brickwork	66	m2		60.61		
	17.03						
4.04	External & internal timber doors incl. hinges, locks, frames and painting	4	No		38.67		
4.05	Timber windows incl glazing & painting	7	No		80.33		

embodied energy analysis
Corobrick - Low cost housing Modelling project

Ikhaya Futurehouse System (added subsequent to Econic study) 2010-06-21

				Embodied CO2			
		Quantity	Unit	ICE 1.6a (2008)	Branz (2006)	Alcorn (2003)	
					2 339.06		
5.00	**Internal Divisions :**						
5.01	IFHS int wall	14	m2		251.53		
					251.53		
6.00	**Floor Finishes :**						
6.01	25mm Screeds to floors	39	m2		566.09		
					566.09		
7.00	**Internal Wall Finishing :**						
7.01	Bagging to new brick/block work	94	m2		0.00		
7.02	1 Ct undercoat & 1ct paint to walls	94	m2		86.20		
					86.20		
8.00	**Ceilings :**						
8.01	Insulation to ceiling			refer to optional ceilings			
8.02	6mm Gypsum rhinoboard fixed to underside of rafters			refer to optional ceilings			
9.00	**Electrical Installation :**						
	No allowance has been made for the electrical installation due to lack of information available						
10.00	**Plumbing Installation :**						
	No allowance has been made for the plumbing installation due to lack of information available						
11.00	**Provisional Sums :**						
	No allowance has been made for all fixtures & fittings due to lack of information available						
	TOTAL (kg CO2)				**8 160**		

embodied energy analysis
Corobrick - Low cost housing Modelling project

Imison wall system (added subsequent to Econic study) 2010-06-21

				Embodied CO2		
			ICE 1.6a (2008)	Branz (2006)	Alcorn (2003)	
	Quantity	Unit	KgCO2	KgCO2	KgCO2	
1.00 Foundations : (assumed spec.)						
1.01 Foundations comprising of RC 700 x 200mm strip footings incl excav min 600mm below top of s.b., incl. DPM, ROC & backfill (assume from excavations)	32	m		1 852.49		
1.02 Ditto, but 600 x 185mm to 90mm walls	6	m		293.07		
				2 145.56		
2.00 Ground Floor Construction : (assumed spec.)						
2.01 80mm Reinforced concrete surface bed incl. damp proof course, etc. and reinforcement (100kg/m3)	39	m2		1 480.28		
Note: No allowance has been made for the embodied energy of any formwork						
				1 480.28		
3.00 Roofs :						
3.01 New Corrugated profiled roof on PAR rafters/purlins incl. wall plates, straps, flashings, fixings, copings etc. as per manufacturers specs	41	m2		1 291.28		
				1 291.28		
4.00 External Walling :						
4.01 Neopor panels with steel columns and roof	66	m2		305.34		
4.02 Plaster sand-cement avg 6:1 mix by volume	66	m2		1 039.21		
4.03 1 Undercoat & 1 ct paint to new brickwork	66	m2		60.61		
4.04 External & internal timber doors incl. hinges, locks, frames and painting	4	No		38.67		
4.05 Timber windows incl glazing & painting	7	No		80.33		
				1 524.17		

embodied energy analysis
Corobrick - Low cost housing Modelling project

Imison wall system (added subsequent to Econic study) 2010-06-21

		Quantity	Unit	Embodied CO2 ICE 1.6a (2008)	Branz (2006)	Alcorn (2003)	
5.00	**Internal Divisions :**						
5.01	Plaster sand-cement avg 6:1 mix by volume	14	m2		219.32		
5.02	Neopor panels with steel columns and roof ring beam				63.15		
					282.48		
6.00	**Floor Finishes :**						
6.01	25mm Screeds to floors	39	m2		566.09		
					566.09		
7.00	**Internal Wall Finishing :**						
~~7.01~~	~~Bagging to new brick/block work~~	~~94~~	~~m2~~		~~0.00~~		
7.02	1 Ct undercoat & 1ct paint to walls	94	m2		86.20		
					86.20		
8.00	**Ceilings :**						
8.01	Insulation to ceiling			refer to optional ceilings			
8.02	6mm Gypsum rhinoboard fixed to underside of rafters			refer to optional ceilings			
9.00	**Electrical Installation :**						
	No allowance has been made for the electrical installation due to lack of information availab						
10.00	**Plumbing Installation :**						
	No allowance has been made for the plumbing installation due to lack of information availat						
11.00	**Provisional Sums :**						
	No allowance has been made for all fixtures & fittings due to lack of information available						
	TOTAL (kg CO2)				**7 376**		