SUSTAINABLE DESIGN SOLUTIONS

FOR THE MIDDLE CLASS IN THE CENTRE OF PRETORIA, SOUTH AFRICA

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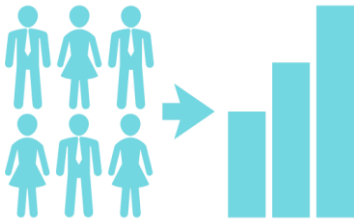
LOCATION: PRETORIA

INTRODUCTION



Population of Pretoria will grow by 27% between 2016 and 2030

Despite rapid developments in the cities, the housing sector is not able to deliver enough housing solutions at the rate and scale needed

It is not able to deliver housing solutions for the varying social classes and the realistic affordability for these classes.

Housing solutions have been provided at the lowest and uppermost ends of the market.

PROBLEM STATEMENT

Government's approach has given a lot of "one-size-fits all" houses, located far from work opportunities and services.

"There has been surprisingly little innovation in the field of housing. It's time for that to change, before it's too late." (Osman, A., 2017)

Climate change results in more extreme weather conditions which is resulting in floods, heat and drought.

There are not enough sustainable design solutions for the middle class and most of the existing solutions are not resisted against the extreme weather conditions and the climate change.

GENERAL OBJECTIVE & RESEARCH QUESTION

The general objective of this research is to provide sustainable design solutions for the middle class of Pretoria, South Africa, which enable climate change adaptation and mitigation.

"What are the sustainable design solutions for the middle class of Pretoria, South Africa, which enable climate change adaptation and mitigation?"

SUB RESEARCH QUESTIONS

SUB RESEARCH QUESTIONS

CONTEXT

What is the definition of the middle class in Pretoria?

What are important, location related, circumstances for middle class homes in Pretoria?

What is the (geographical) history of Pretoria?

What are the climate conditions in Pretoria?

SUB RESEARCH QUESTIONS

TECHNOLOGY

What materials, resources and production techniques are locally available?

What are the current building methods used in middle class homes?

What are the current developments for middle class homes?

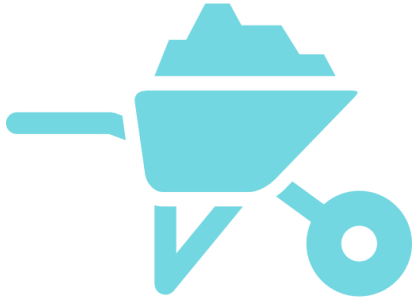
What are the strategies for climate change adaptation and mitigation for this location?

FINAL RESULT

LIST OF SUSTAINABLE DESIGN SOLUTIONS

focused on:

comfort

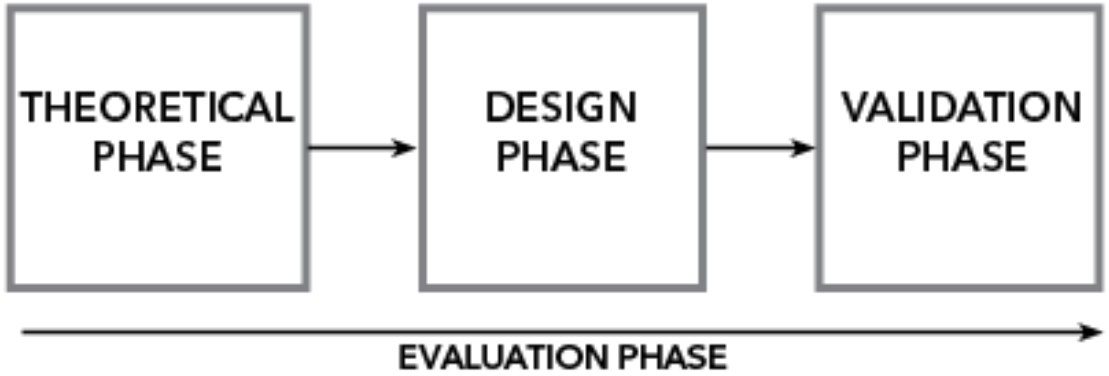


materials

energy use

which are tested on an existing building in Pretoria and a new development in housing for SA (Butterfly Housing)

APPROACH & METHODOLOGY



THEORETICAL PHASE

- Literature study, focused on context and technology
- Visit to Pretoria (two weeks), South Africa
- Analysis on site
- Meetings with professionals, during visit (CSIR, University of Pretoria, etc.)
- A simple analysis of an existing middle class apartment building in the centre of Pretoria (Thembelihle Village) and a new development/concept in housing for SA (Butterfly Housing)

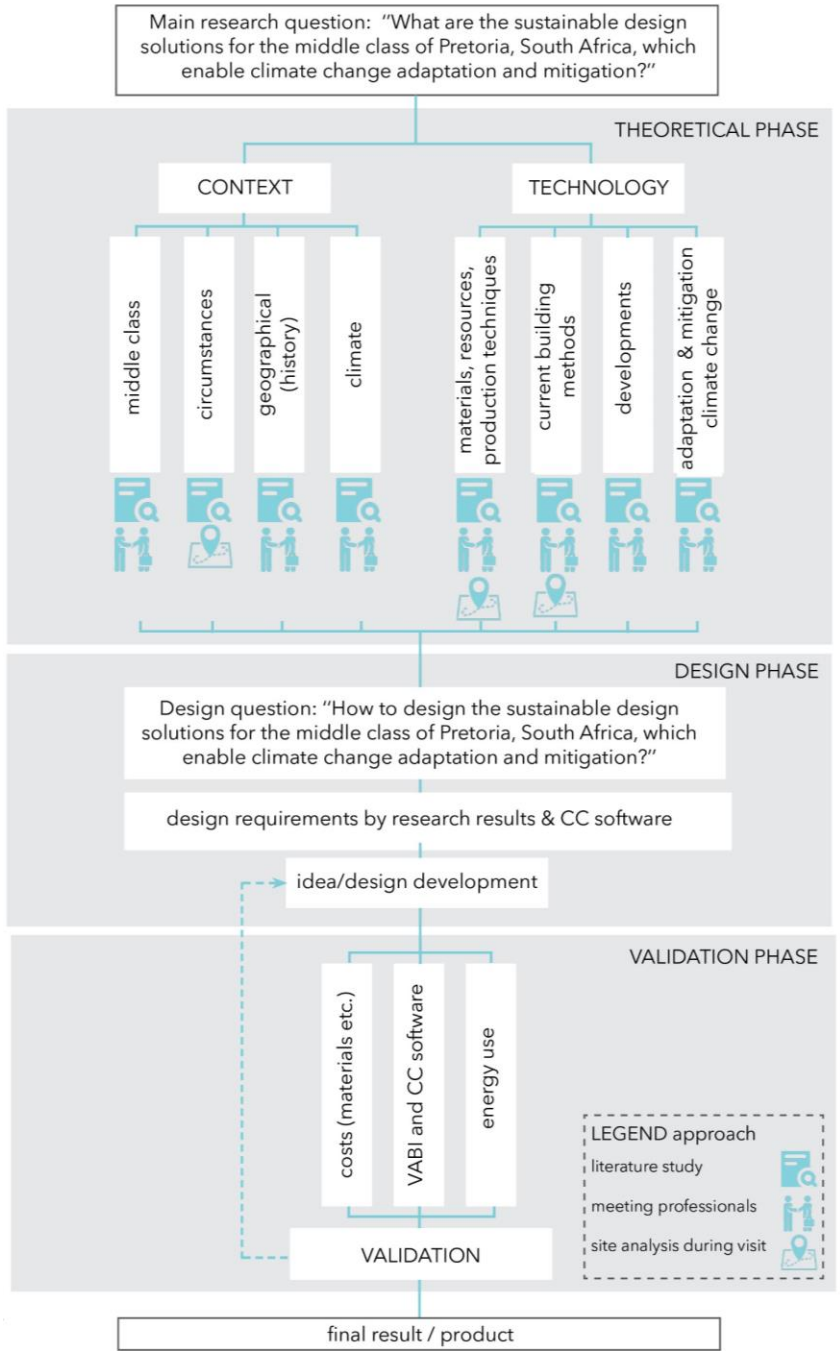
DESIGN PHASE

- the program of requirements was formulated (by using research results)
- Climate Consultant is used to find the passive design strategies for this climate
- design requirements (by using research results and results CC)
- Design development
- VABI elements software to simulate Thembelihle Village and Butterfly Housing (How comfortable are these buildings? What are the material costs? How many energy needed to cool and heat the apartments?)

VALIDATION PHASE

- VABI elements simulations
- Calculate material costs
- Calculate energy use and costs

APPROACH & METHODOLOGY



RESEARCH RESULTS

GEOGRAPHY & HISTORY

THE NETHERLANDS

Population	17.1 million
Area	41.540 km²
Density	411 pers./km²
Female	49,6%
Male	50,4%
Formal housing	99-100%
Access to water	100%
Access to electricity	100%
Access sanitation facilities	100%

SOUTH AFRICA

Population	55.6 million
Area	1.220.000 km²
Density	45 pers./km²
Female	51%
Male	49%
Formal housing	79,2%
Access to water	89,9%
Access to electricity	91,1%
Access sanitation facilities	97,6
Households experienced crime	7,5%
Feelings safety during day	79,4%
Feelings safety during night	34,3%

GAUTENG

Population	12.2 million
Area	18.176 km²
Density	671 pers./km²
Female	50,7%
Male	49,3%
Formal housing	81,4%
Access to water	97,5%
Access to electricity	90,4%
Access sanitation facilities	98,5%
Households experienced crime	9,1%
Feelings safety during day	78,7%
Feelings safety during night	32,8%

CITY OF TSHWANE

Population	2.9 million
Area	6368 km²
Density	455 pers./km²
Female	50.2%
Male	49.8%
Formal housing	75,0%
Access to water	98,7%
Access to electricity	98,9%
Access sanitation facilities	99,0%

GEOGRAPHY & HISTORY

740.000

INHABITANTS,
POPULATION

680

KM² AREA

CENTRE OF GOVERNMENT
UNIVERSITY OF SOUTH AFRICA
UNIVERSITY OF PRETORIA
MULTIPLE EMBASSIES

data: Statistics South Africa

THEMBELIHLE VILLAGE, PRETORIA

Thembelihle Village, Pretoria Centre

Base for the design process

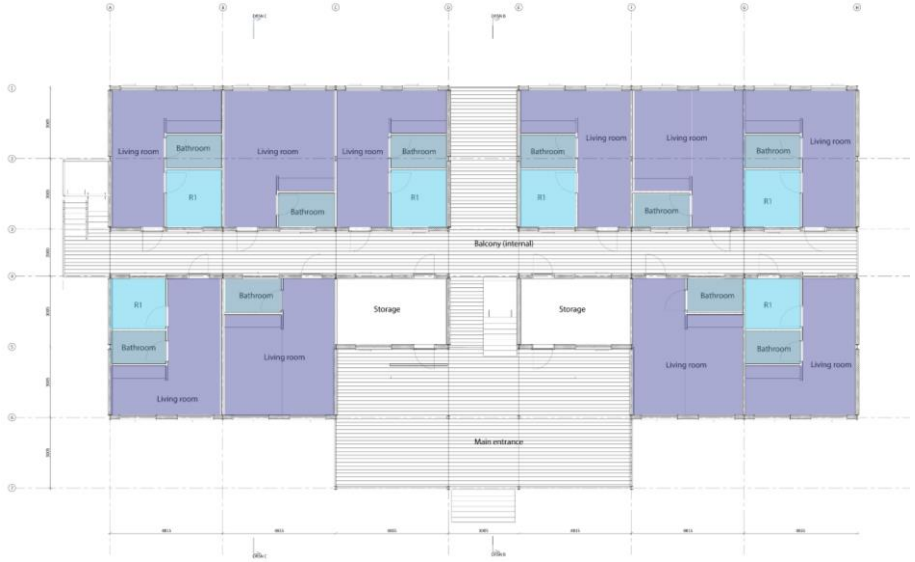
THEMBELIHLE VILLAGE, PRETORIA

- Located in the centre > transport
- One of the newer projects in the area
- Four different apartment types
- The income range of the tenants is R2200 - R7500.
- Rent from R750 - R2250.
- Used to describe the middle class

Studio apartment
1-Bedroom apartment
2-Bedroom apartment

BUTTERFLY HOUSING

new concept for housing SA



- Designed as a product
- Based on a hybrid construction system
- Steel structure/skeleton (columns and floors) with a finish of different infill materials such as earth blocks or insulated panels

Together with Thembelihle Village,

Base for the design process

THE MIDDLE CLASS

- The income range (monthly) of the tenants is R2200 - R7500
- (150 € - 510 €)
- Rent from R750 - R2250

Thembelihle Village

	POOR	VULNERABLE CLASS	STABLE MIDDLE CLASS	ELITE
Population share (%)	65.02	17.99	13.53	3.46
Income range	R0-R1,283	R1,283 - R3,104	R3,104 - R10,387	>R10,387
Median expenditure	R476	R1,890	R5,031	R14,727
Expenditure share (%)	16.9	16.8	35.2	31.1
African (%)	90.46	79.99	47.62	23.94
White (%)	0.82	5.31	35.31	57.39
Years of education	8.3	10.3	12	13.3
Educated (tertiary qualifications) (%)*	7.63	22.90	42.87	61.93
Employed** (%)	48.47	73.42	82.54	83.68
Unemployed*** (%)	22.98	13.02	6.31	1.29

Fig. XX Aspects of the four social classes data and figure: Zizzamia, et al. *(2016)*
** Employment statistics for individuals between the ages of 15 and 62.*
*** 'Unemployed' includes both the 'strict' and 'discouraged' unemployed.*
**** 'Educated' limited to adults above the age of 23.*

THE MIDDLE CLASS

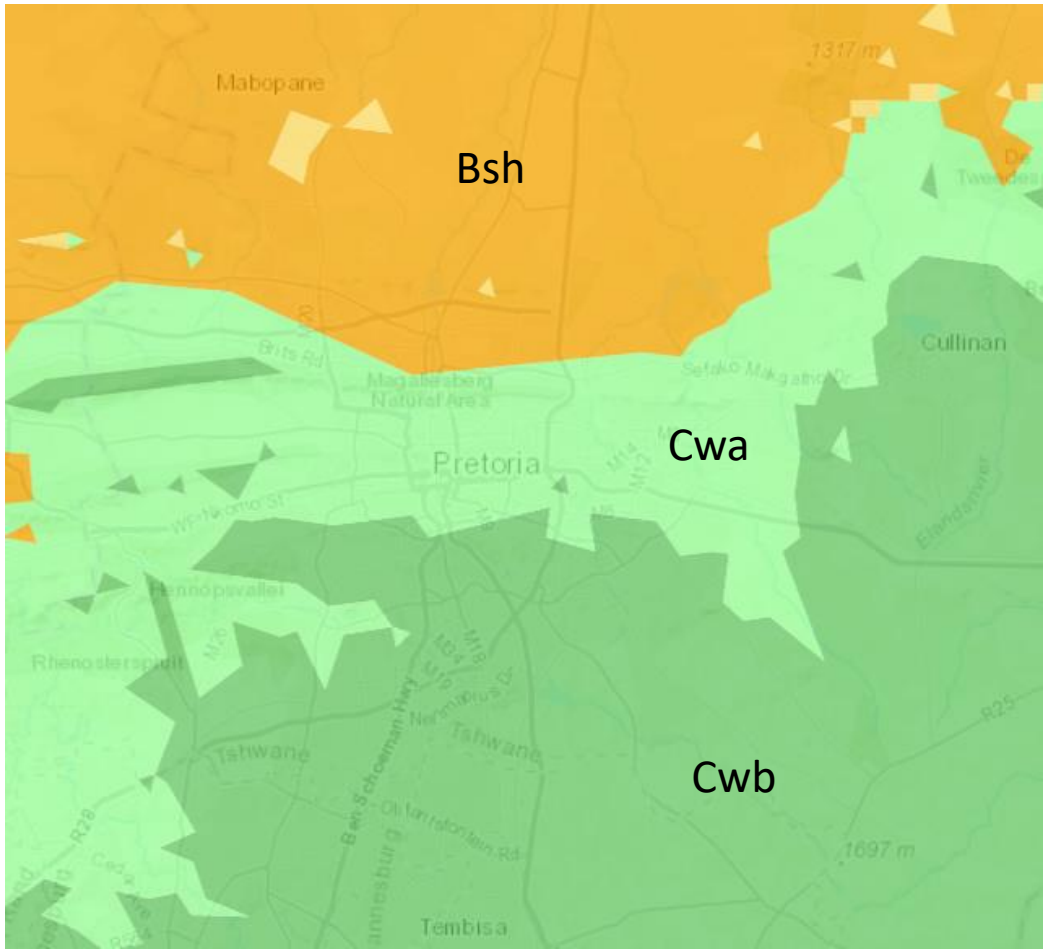
For this research, the middle class in the centre of Pretoria is defined as the people who:

- Live in multilevel apartment buildings
- With an income range of R2000-R8000 ZAR

Apartment buildings in Pretoria




CLIMATE IN PRETORIA

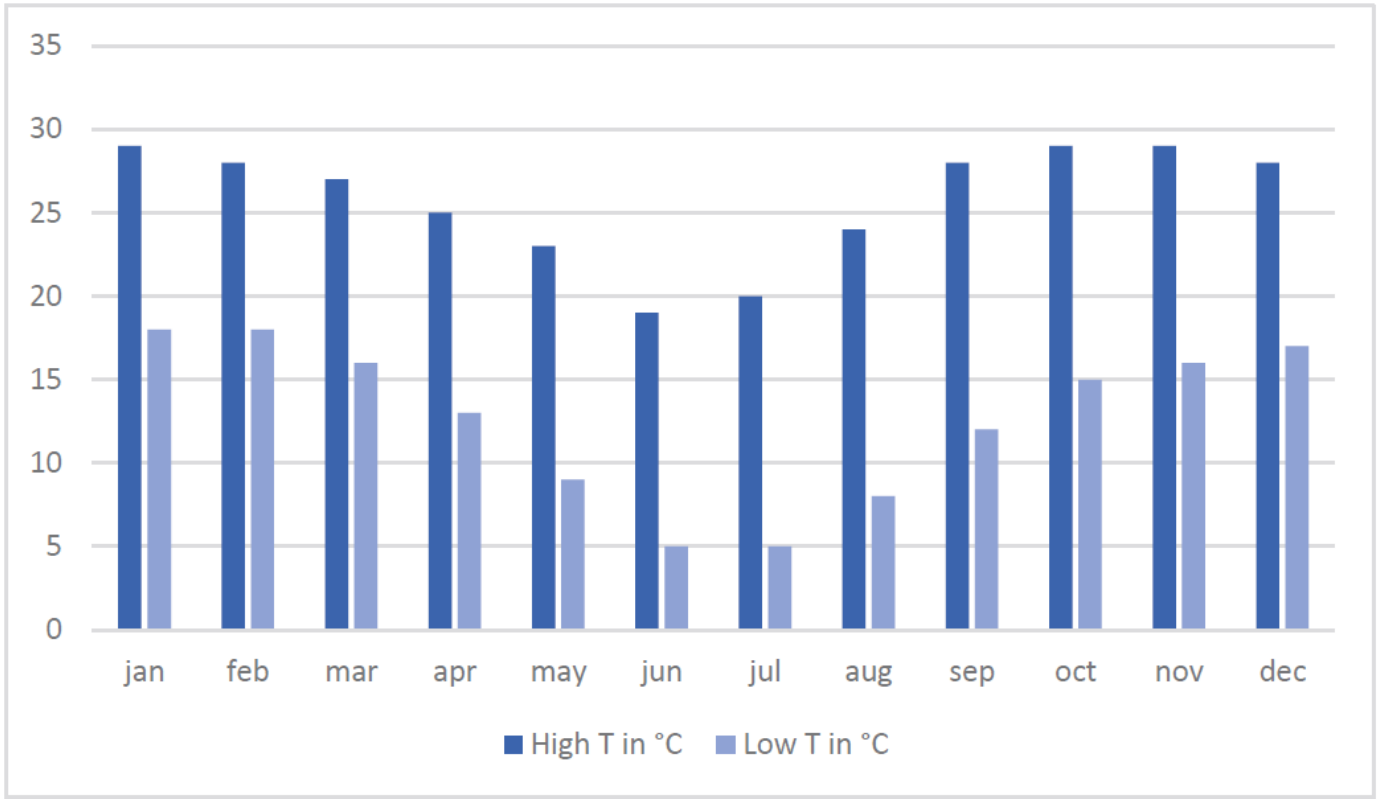


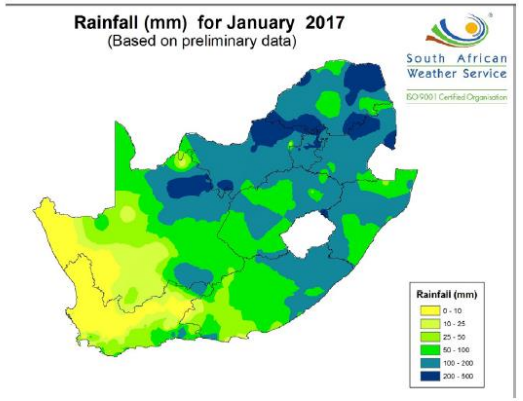
Pretoria is located in multiple climate zones:

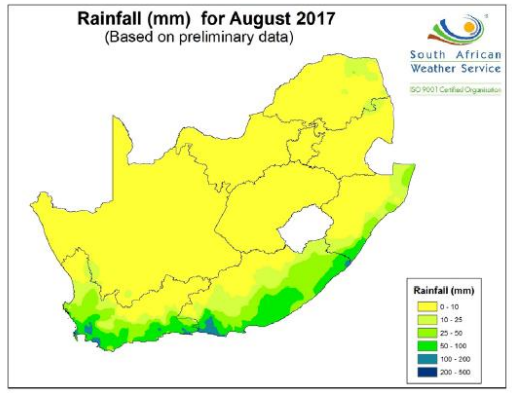
- Bsh (Arid steppe, hot arid)
- Cwa (Warm temperature, dry winter, hot summer)
- Cwb (Warm temperature, Dry winter, Warm summer).

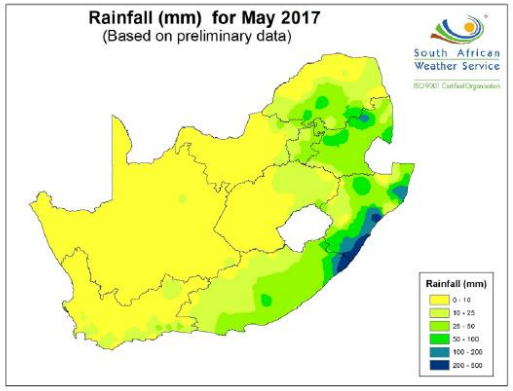
In the future (2030) > Bsh

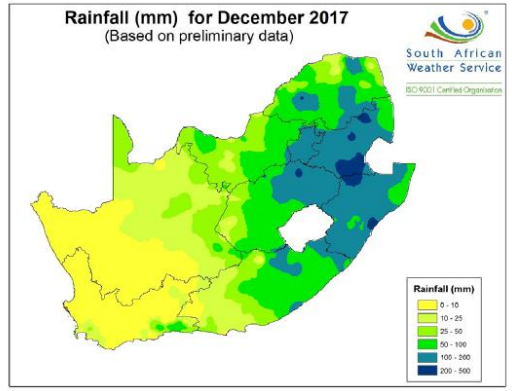
CLIMATE IN PRETORIA











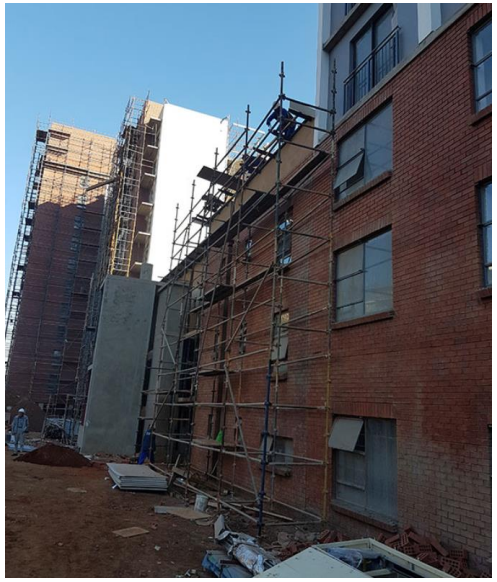
BUILDING METHODS

1

Germiston Fire Station &
Delville ext 9,
Johannesburg

2

Thembelihle Village,
Pretoria



BUILDING METHODS

- Concrete floors
- Concrete structural elements or walls
- Masonry walls, some parts plastered and painted
- Concrete foundation strips
- Some apartments use AC and small radiators

RESEARCH RESULTS CONTEXT

& programme of requirements

Result is for both the vulnerable as the stable middle class, with an income range of R2200 - R7500

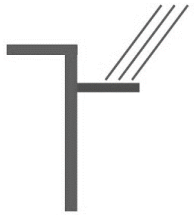
Take into account that building is located in the centre of Pretoria, South Africa

82,2 Of the households use electricity for cooking, 83,2% use electricity for heating water, 86,2% use electricity for lighting and 64,2% use electricity for space heating.
Goal is to use less electricity (and overall less energy) by using passive design strategies

The climate will be drier, with less rain and higher temperatures.
For this reason more shading and catching rain water would be usefull.

RESEARCH RESULTS - TECHNOLOGY

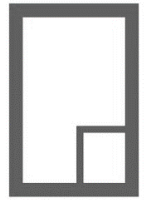
& programme of requirements



Current housing has not a lot of shading, more shading would probably improve the comfort and less energy would be needed to cool the apartments.

Current housing has single glass windows, insulated glass (in combination with insulated walls) will keep the high temperatures outside

Current housing has masonry walls (one layer walls) with no insulation, insulation or high mass walls will keep the high temperatures outside



Take into account that the apartment types are studio's, 1-bedroom, 2-bedroom and 3-bedroom apartments

The construction costs should be the same or lower than current housing (also include possible improvements in energy use)

DESIGN PROCESS

climate consultant

CLIMATE CONSULTANT SOFTWARE

Use Climate Consultant to find out which passive design strategies would work in this area

Use climate file with climate data from nearest weather station

WEATHER DATA SUMMARY

LOCATION: **Pretoria Forum, -, -**
Latitude/Longitude: 25.733° South, 28.183° East, **Time Zone from Greenwich** 2
Data Source: MN7 689950 WMO Station Number, **Elevation** 4366 ft

MONTHLY MEANS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	
Global Horiz Radiation (Avg Hourly)	158	152	146	129	125	119	126	144	161	162	161	166	Btu/sq.ft
Direct Normal Radiation (Avg Hourly)	135	138	139	136	173	189	199	203	188	167	148	150	Btu/sq.ft
Diffuse Radiation (Avg Hourly)	63	55	54	47	36	29	28	30	40	51	58	60	Btu/sq.ft
Global Horiz Radiation (Max Hourly)	386	359	333	298	270	236	250	295	331	363	385	395	Btu/sq.ft
Direct Normal Radiation (Max Hourly)	345	329	330	319	316	306	307	318	327	335	339	345	Btu/sq.ft
Diffuse Radiation (Max Hourly)	168	161	163	133	116	101	101	119	139	148	170	174	Btu/sq.ft
Global Horiz Radiation (Avg Daily Total)	2133	1971	1775	1479	1348	1245	1342	1615	1913	2050	2147	2257	Btu/sq.ft
Direct Normal Radiation (Avg Daily Total)	1822	1790	1693	1555	1865	1971	2114	2261	2227	2116	1967	2040	Btu/sq.ft
Diffuse Radiation (Avg Daily Total)	856	717	665	540	386	312	302	334	476	657	777	815	Btu/sq.ft
Global Horiz Illumination (Avg Hourly)	5166	4947	4743	4188	3989	3779	3979	4555	5075	5168	5208	5370	footcandles
Direct Normal Illumination (Avg Hourly)	3827	3966	3905	3894	4877	5305	5610	5780	5372	4695	4192	4317	footcandles
Dry Bulb Temperature (Avg Monthly)	72	72	70	65	58	53	52	60	66	71	70	72	degrees F
Dew Point Temperature (Avg Monthly)	59	59	57	51	41	39	32	37	39	49	54	58	degrees F
Relative Humidity (Avg Monthly)	66	66	65	65	58	61	49	45	40	50	59	62	percent
Wind Direction (Monthly Mode)	80	70	80	300	290	290	290	310	50	90	70	70	degrees
Wind Speed (Avg Monthly)	2	2	2	1	1	2	1	2	3	3	3	3	mph
Ground Temperature (Avg Monthly of 1 Depths)	67	69	69	69	67	65	63	62	61	62	63	65	degrees F

Back Next

PSYCHROMETRIC CHART
Adaptive Comfort

LOCATION: **Pretoria Forum, -, -**
Latitude/Longitude: 25.733° South, 28.183° East, **Time Zone from Greenwich** 2
Data Source: MN7 689950 WMO Station Number, **Elevation** 4366 ft

LEGEND

COMFORT INDOORS
100% COMFORTABLE
0% NOT COMFORTABLE

M... PLUS ASHRAE Standard 55

PLOT: COMFORT INDOORS

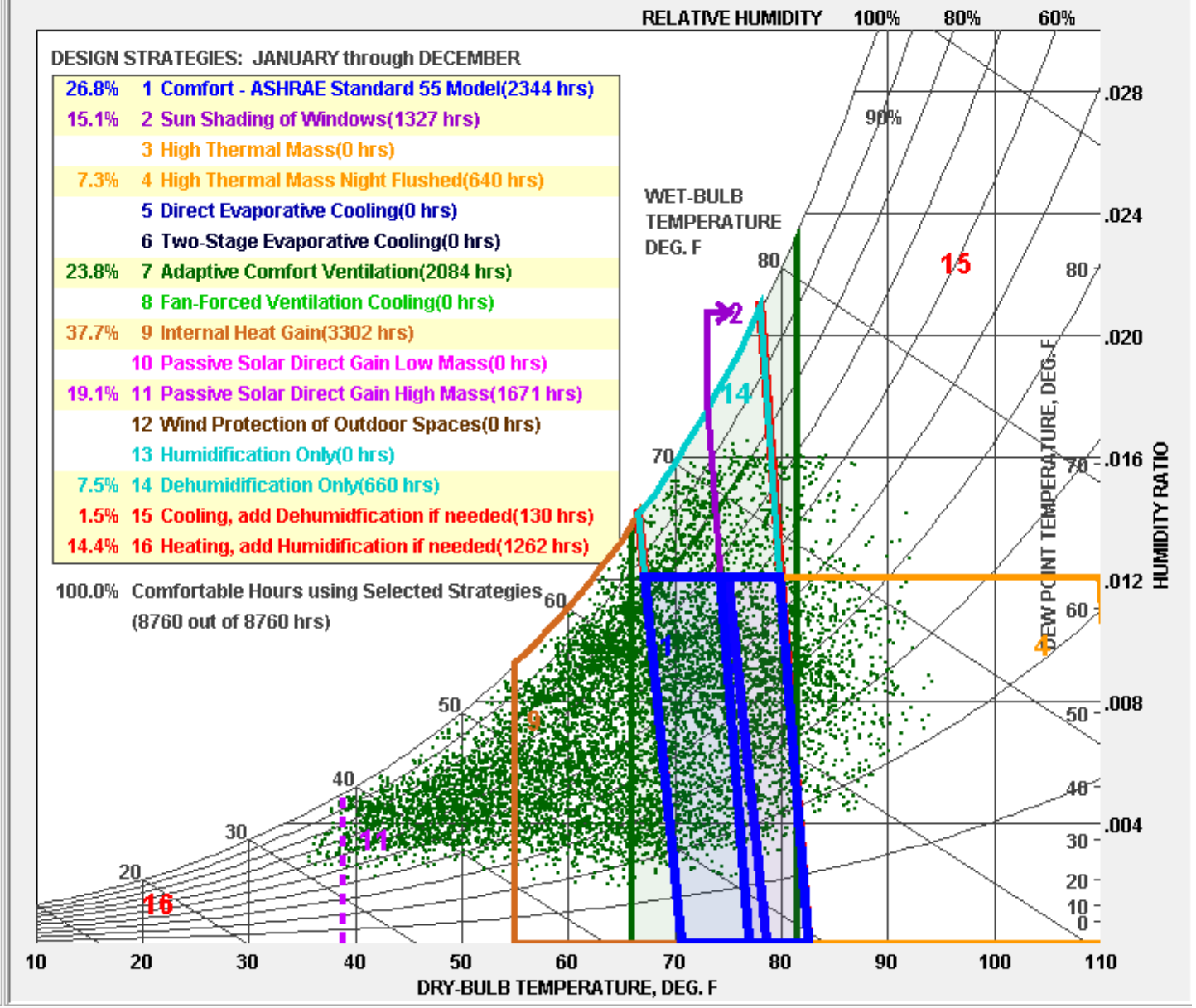
◉ Hourly ○ Daily Min/Max

◉ All Hours ○ Select Hours
1 a.m. through 12 a.m.

◉ All Months ○ Select Months
JAN through DEC
○ 1 Month JAN Next
○ 1 Day 1 Next
○ 1 Hour 1 a.m. Next

TEMPERATURE RANGE:
◉ 10 to 110 °F ○ Fit to Data

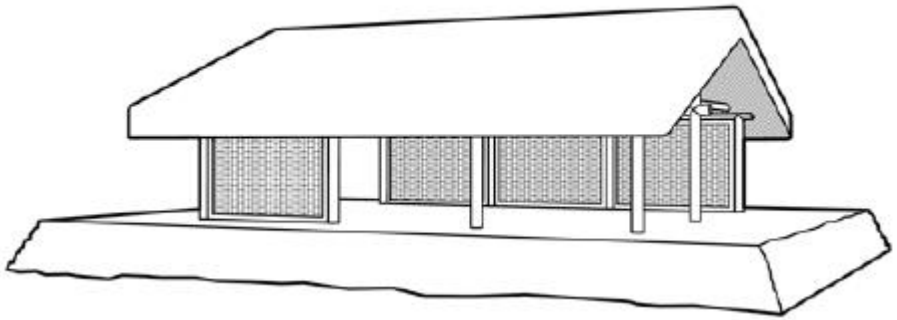
☑ Display Design Strategies
☑ Show Best set of Design Strategies



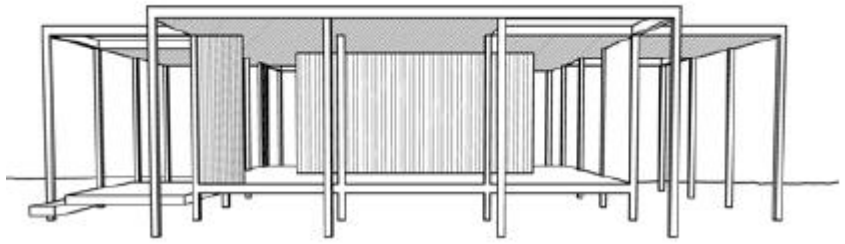
RESULTS CC

DESIGN STRATEGY	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
relative humidity (avg monthly)	66	66	65	65	58	61	49	45	40	50	59	62
1 Comfort– ASHRAE standard 55 model	30.8%	30.8%	39,7%	32.1%	14.1%	3.3%	6.2%	19.8%	32.5%	37.1%	36.3%	38.8%
2 Sun shading of windows	27.3%	22.0%	20.4%	12.2%	3.2%			5.0%	16.0%	23.7%	24.2%	28.2%
3 High thermal mass					0.4%			1.1%	7.5%			
4 High thermal mass night	12.1%	13.4%	9.3%	3.5%							11.4%	12.5%
5 Direct evaporative cooling												
6 Two-stage evaporative cooling										17.2%		
7 Adaptive comfort ventilation	32.9%	33.6%	31.7%	21.8%	14.7%	9.9%	10.5%	19.0%	22.5%	25.9%	28.9%	34.7%
8 Fan-forced ventilation												
9 Internal heat gain	28.4%	29.8%	34.5%	54.2%	44.4%	40.7%	34.9%	43.7%	44.2%	37.1%	34.9%	25.8%
10 Passive solar direct gain low mass												
11 Passive solar direct gain high mass	14.5%	15.9%	19.6%	20.3%	19.9%	13.5%	15.2%	27.3%	25.6%	20.3%	18.9%	17.7%
12 Wind protection of outdoor spaces												
13 Humidification only												
14 Dehumidification only	21.0%	22.5%	14.0%							6.0%	11.0%	16.8%
15 Cooling, add dehumidification if needed	6.2%	3.4%	1.1%							0.3%	2.9%	3.8%
16 Heating, add humidification if needed			0.7%	9.0%	30.9%	45.7%	47.8%	24.1%	10.7%	0.9%	1.9%	

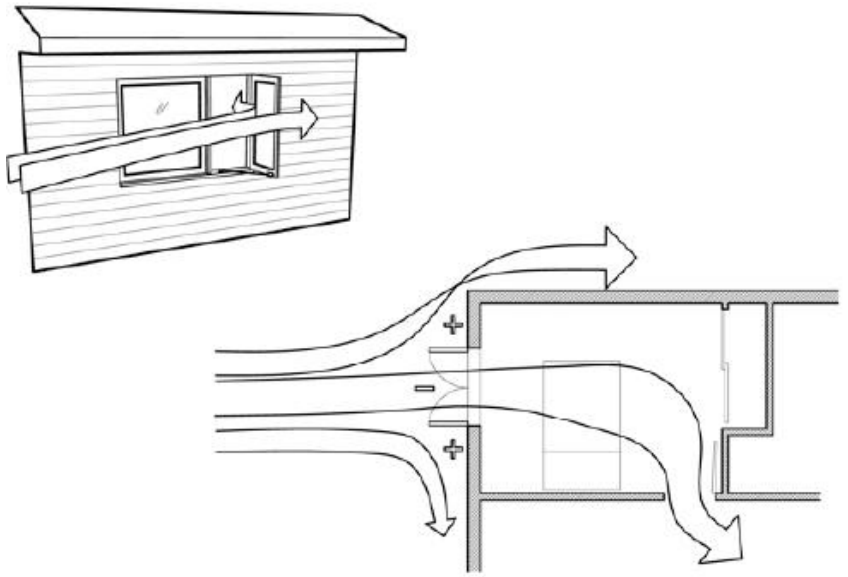
RESULTS CC



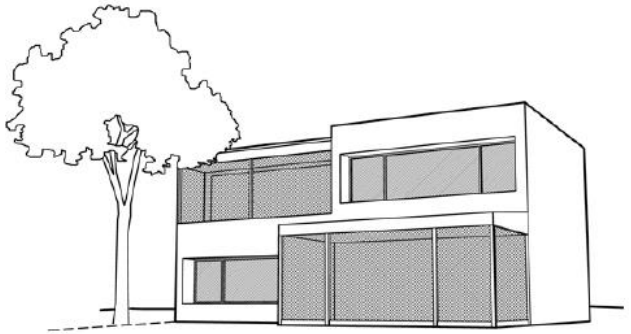
#62: Traditional passive homes in temperate climates used light weight construction with slab on grade and operable walls and shaded outdoor spaces



#58: This is one of the more comfortable climates, so shade to prevent overheating, open to breezes in summer, and use passive solar gain in winter



#35: Good natural ventilation can reduce or eliminate air conditioning in warm weather, if windows are well shaded and oriented to prevailing breezes

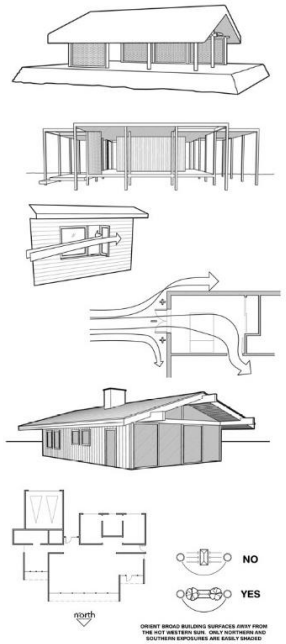


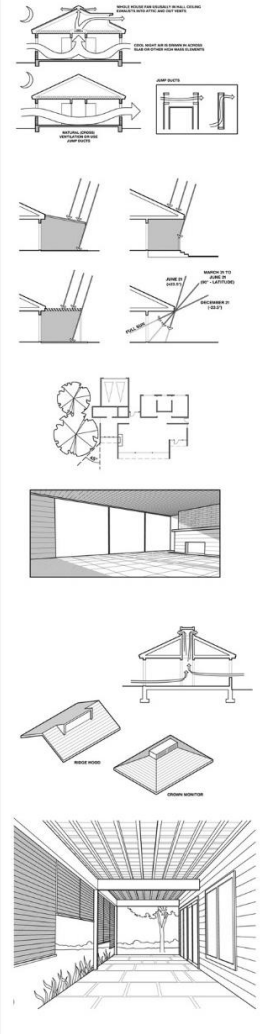
#56: Screened porches and patios can provide passive comfort cooling by ventilation in warm weather and can prevent insect problems

RESULTS CC

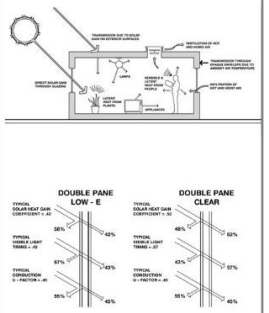
Four different categories

DESIGN

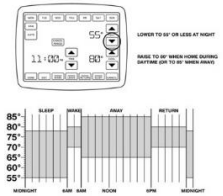




MATERIALS

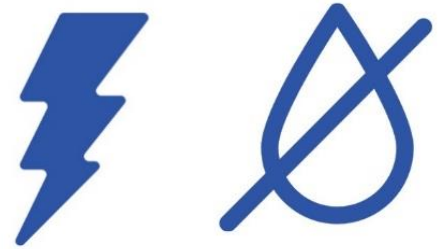


BEHAVIOUR



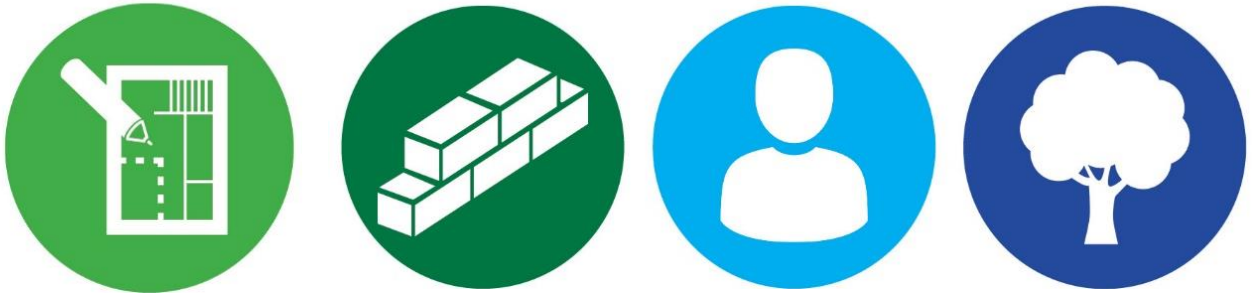
PLOT

DESIGN REQUIREMENTS



CONTEXT RESEARCH RESULTS & PROGRAMME OF REQUIREMENTS

TECHNOLOGY RESEARCH RESULTS & PROGRAMME OF REQUIREMENTS



RESULTS PASSIVE DESIGN STRATEGIES IN CC FOR SA

DESIGN PROCESS

vabi elements

VABI ELEMENTS

a software which simulates the comfort in a room or building

VABI elements software combines: the climate data, materials and building design with comfort temperature.

simulate current situation in: vabi elements

results: what could be improved?

choose design strategies based on what could be improved

simulate new design in: vabi elements

is the result an improvement and it is expected that it cannot be further improved

yes / no

extra validation on: expected energy use, costs & climate consultant result (progr. req.)

outcome is an improvement according to programme of requirements

yes / no

final design Thembelihle Village

simulate current situation in: vabi elements

results: what could be improved?

choose design strategies based on what could be improved

simulate new design in: vabi elements

is the result an improvement and it is expected that it cannot be further improved

yes / no

extra validation on: expected energy use, costs & climate consultant result (progr. req.)

outcome is an improvement according to programme of requirements

yes / no

final design Butterfly Housing

FIRST SIMULATIONS

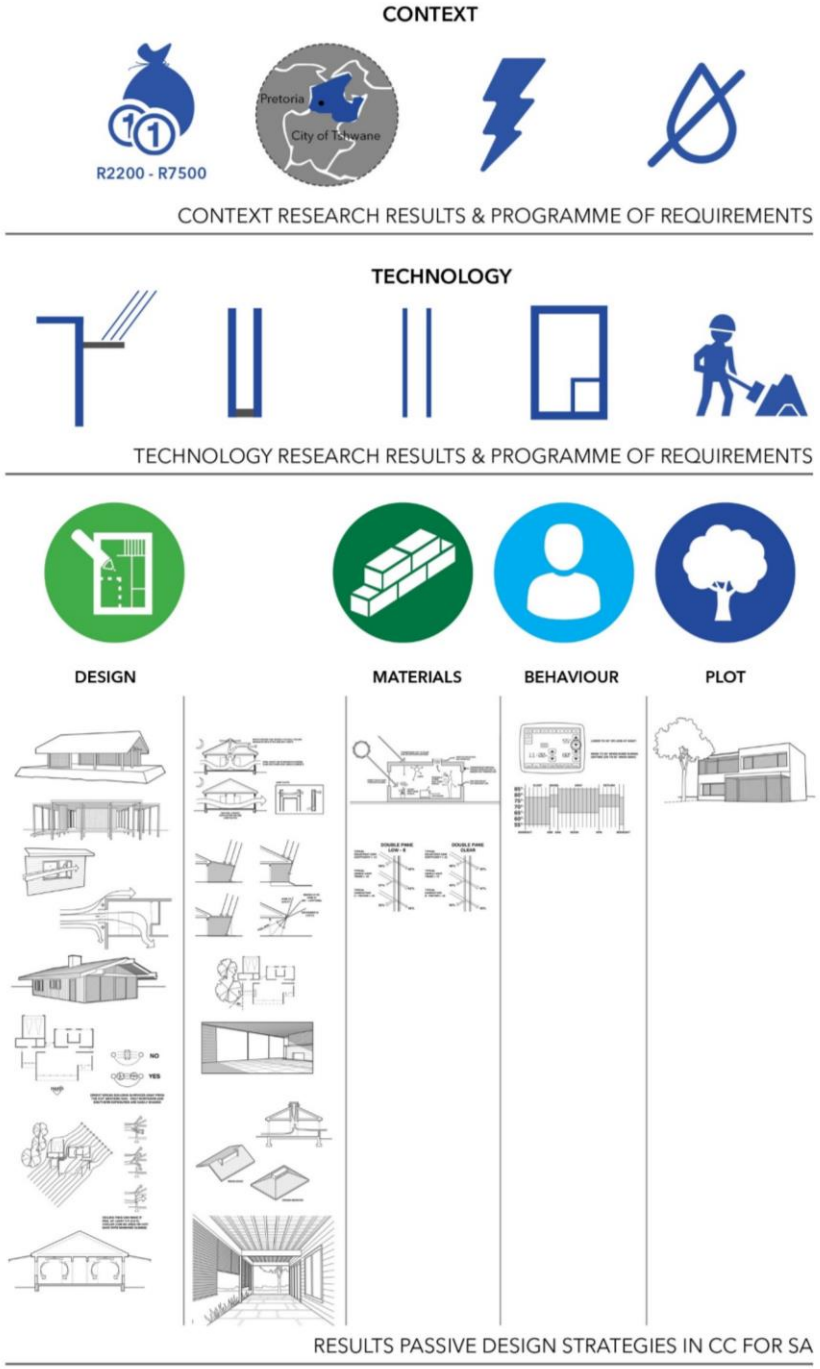
The first simulation will be a basic simulation of Butterfly Housing and Thembelihle with the current situation.

The second simulation includes:
- a lightweight construction
- overhang by the roof
- operable walls

The third simulation includes:
- shading above the windows
- open windows to breeze
- use of passive solar gain in winter
(glass on north facade)

The fourth simulation includes:
- insulated walls and roofs

The fifth simulation includes:
- singe glass windows and doors which are changed to e glass



COMFORT GRAPH IN VABI ELEMENTS

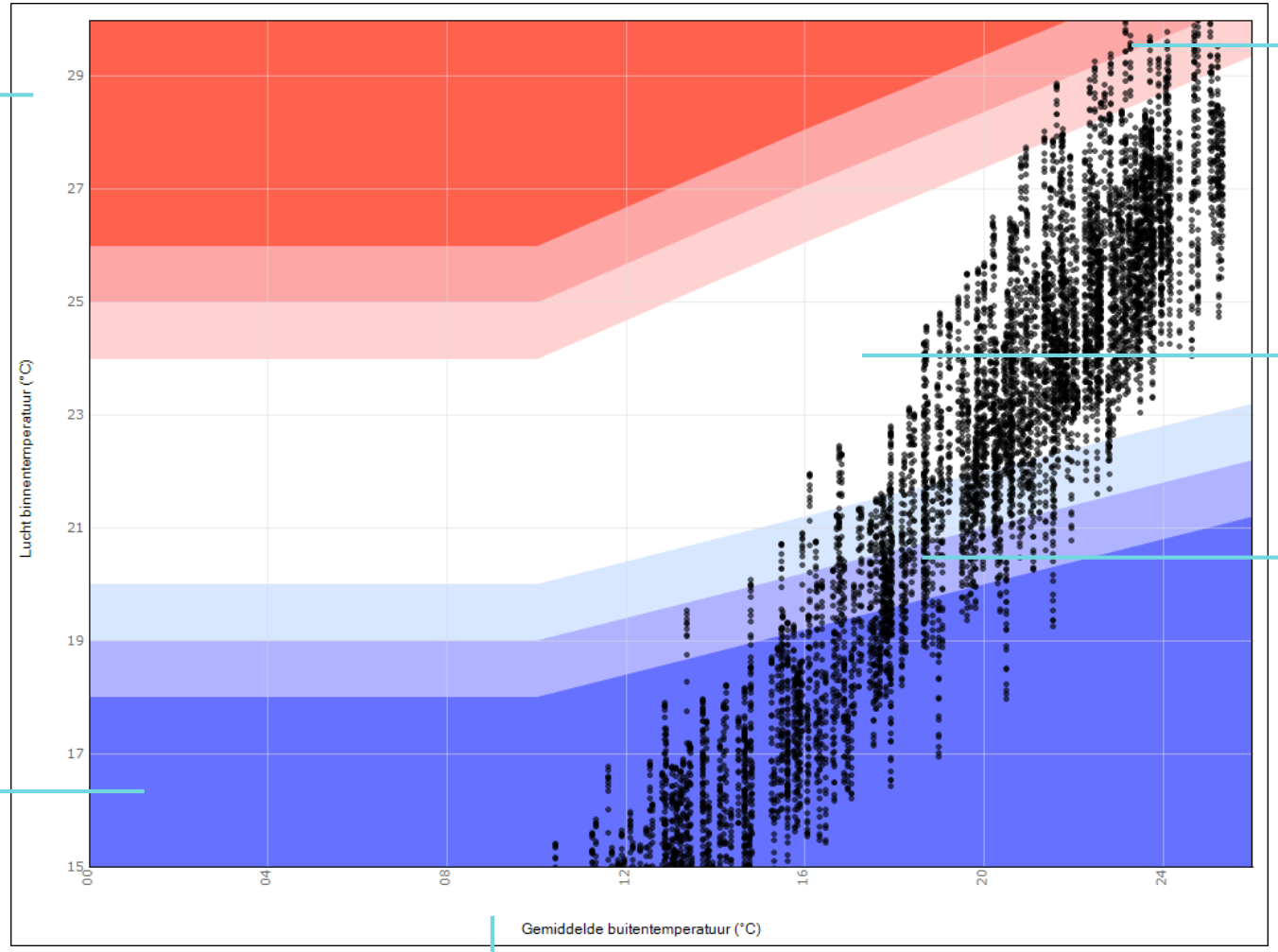
Inside air temperature

Too warm

Comfort "area"

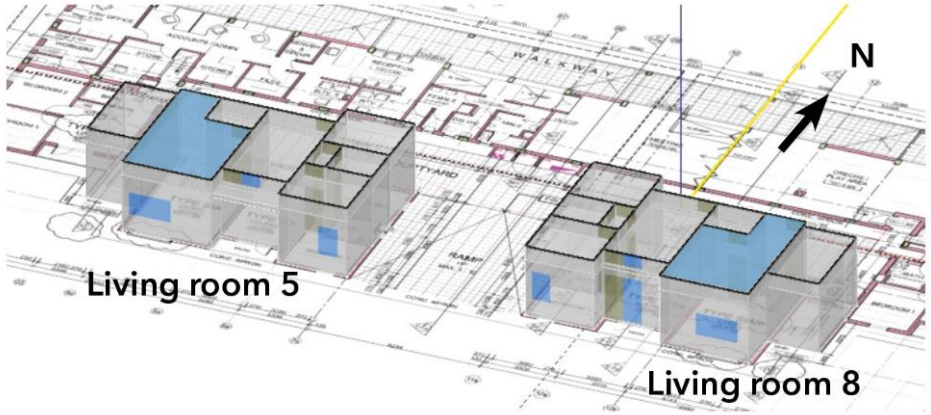
Every point in the graph is one moment/hour (year)

Too cold



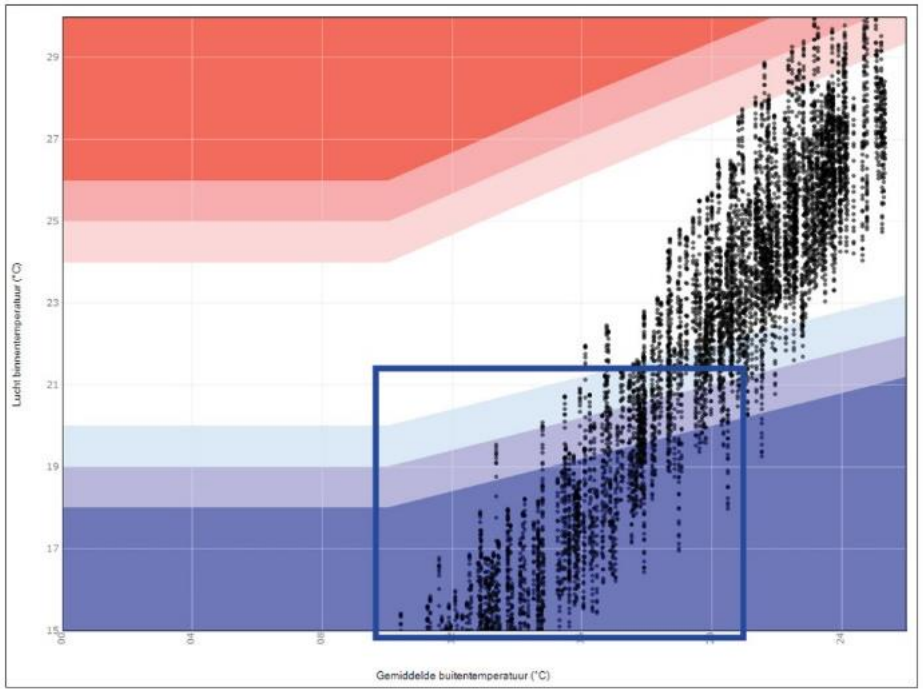
Average outside temperature

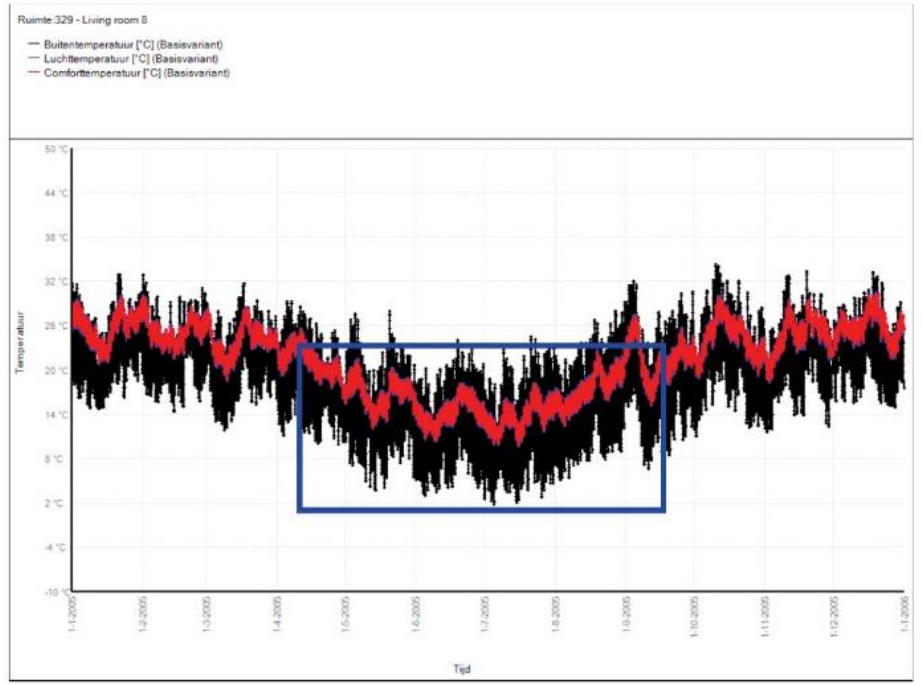
1 THEMBELIHLE BASIC



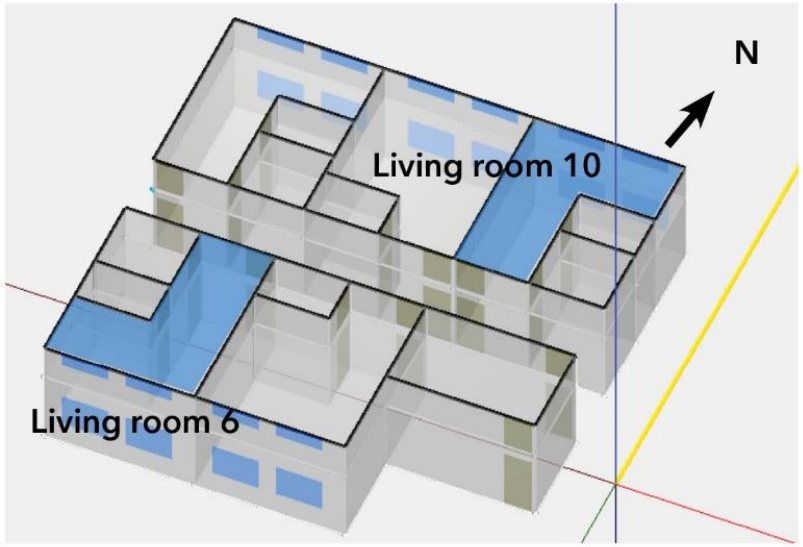
Class	Too cold [h]	Too warm [h]	Total	% hours
Klasse A	4212	173	4385	51,04
Klasse C	3575	23	3598	41,88
Klasse D	3060	0	3060	35,62

The goal is to get the numbers of Class C get as low as possible, which means an dissatisfaction of 15%, and to get most of the points in the graph in the ''white area''.

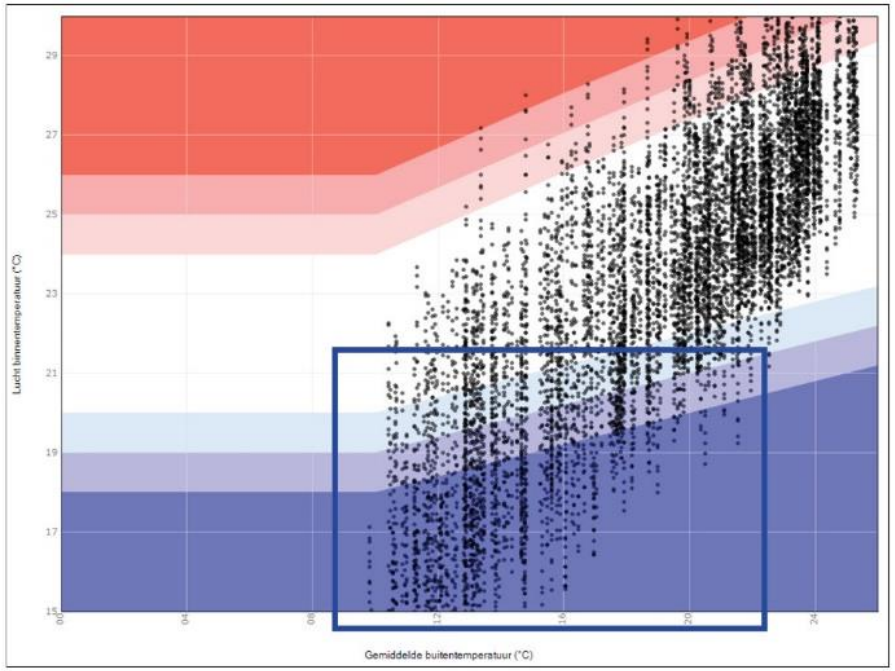


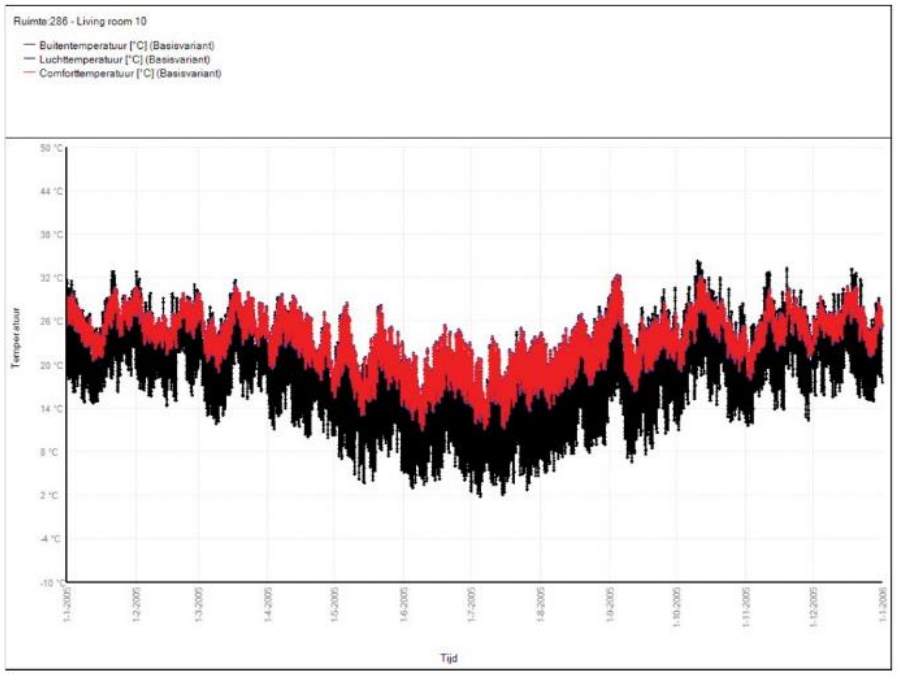


1 BUTTERFLY BASIC

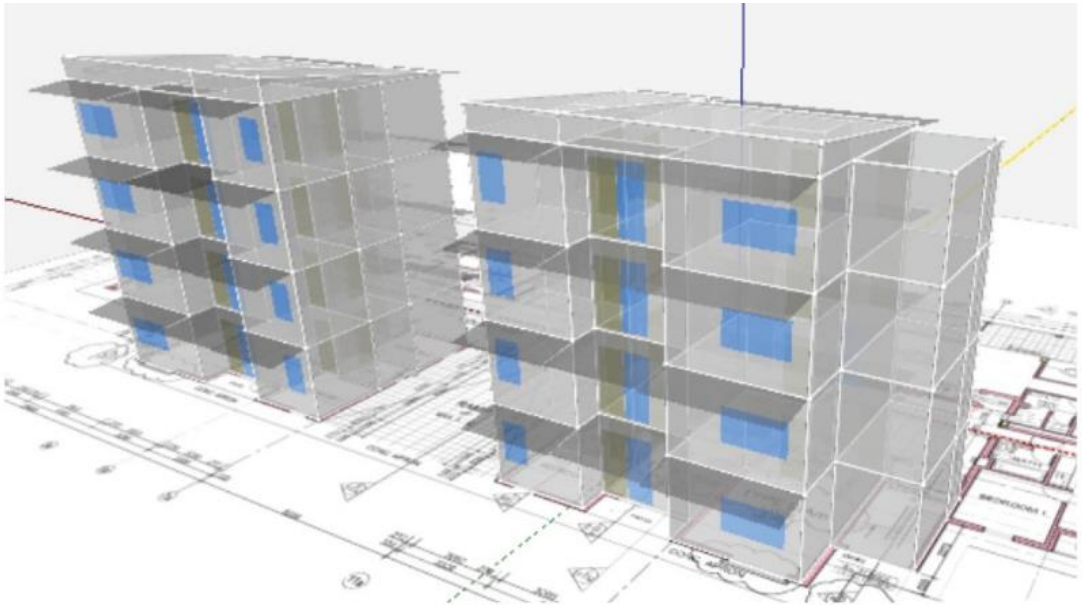


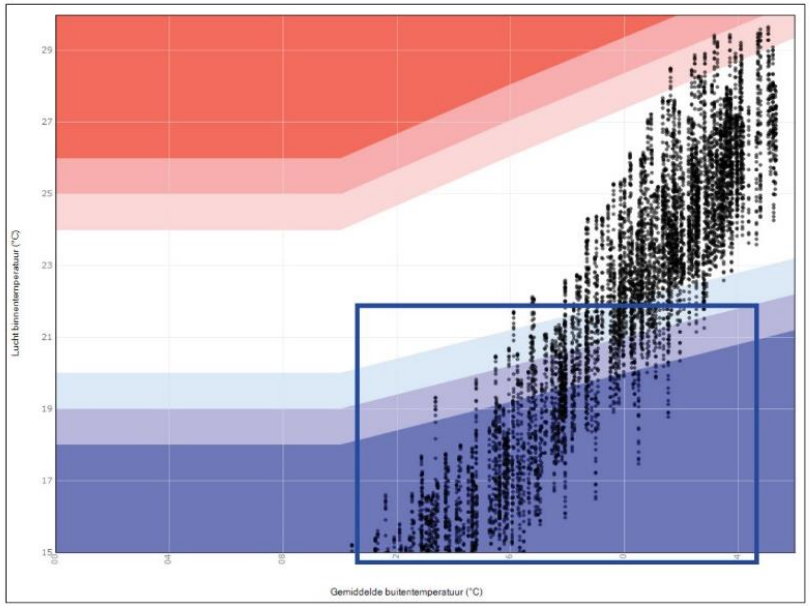
Class	Too cold [h]	Too warm [h]	Total	% hours
Klasse A	2688	664	3352	39,02
Klasse C	1991	274	2265	26,36
Klasse D	1433	76	1509	17,56





3 THEMBELIHLE SIMULATION

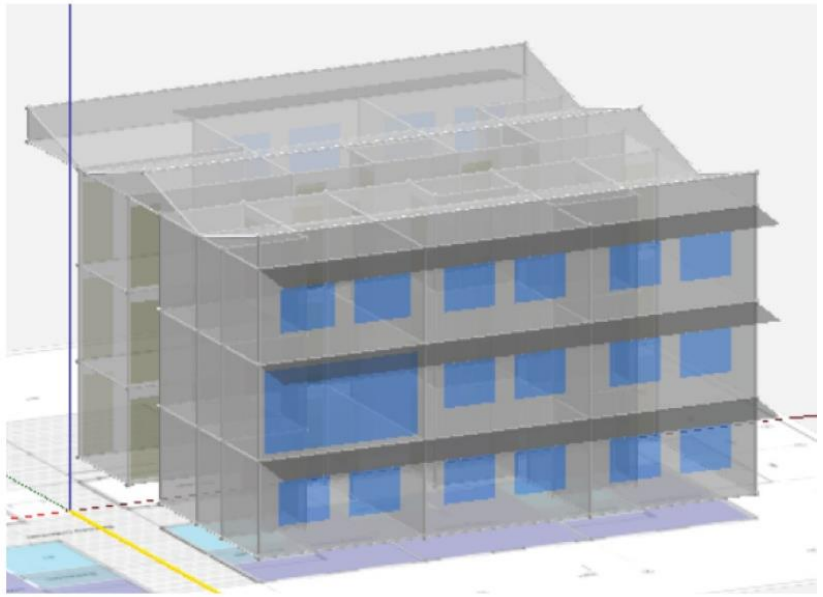


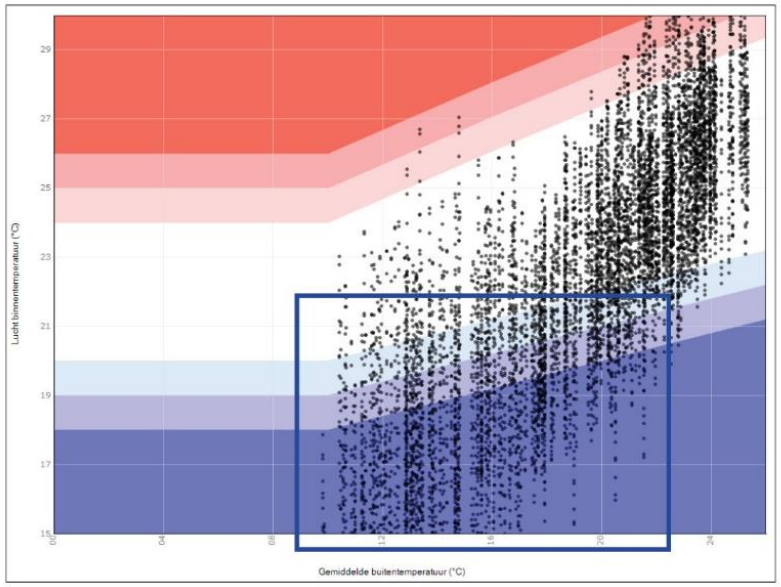


Class	Too cold [h]	Too warm [h]	Total	% hours
Klasse A	4472	100	4572	53,22
Klasse C	3773	0	3773	43,92
Klasse D	3230	0	3230	37,60

The third simulation includes:
- shading above the windows
- open windows to breeze
- use of passive solar gain in winter (glass on north facade)

3 BUTTERFLY SIMULATION



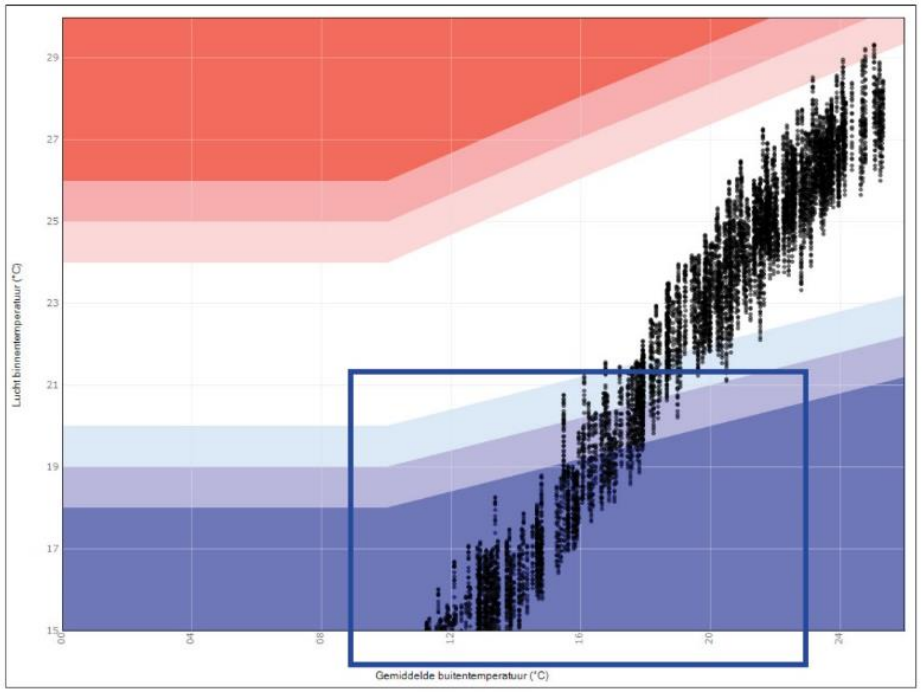


Class	Too cold [h]	Too warm [h]	Total	% hours
Klasse A	3798	386	4184	48,70
Klasse C	2947	153	3100	36,08
Klasse D	2258	23	2281	26,55

The third simulation includes:
- shading above the windows
- open windows to breeze
- use of passive solar gain in winter (glass on north facade)

4 THEMBELIHLE SIMULATION

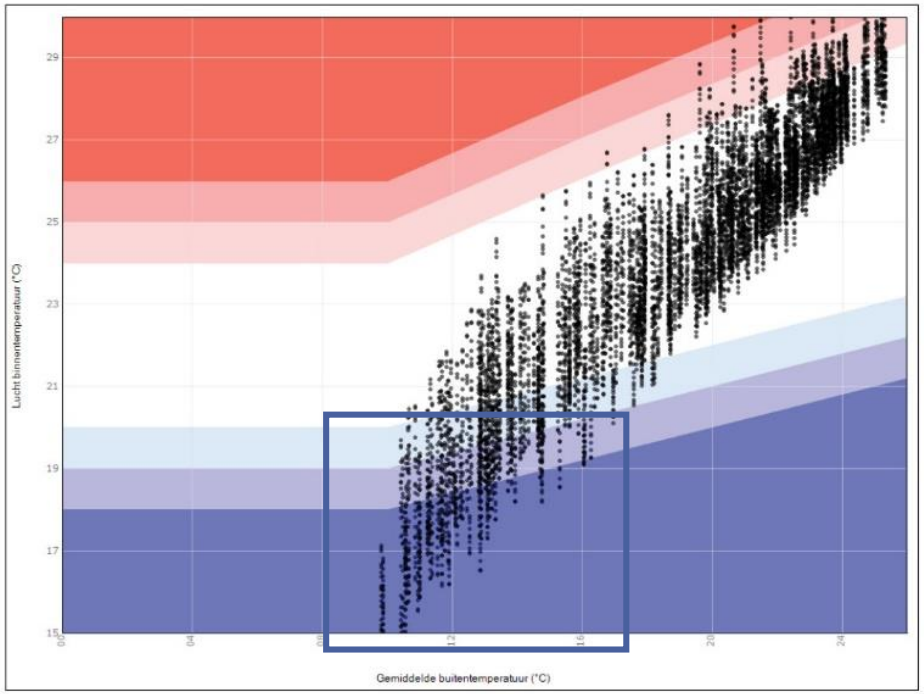
The fourth simulation includes:
- insulated walls and roofs



Class	Too cold [h]	Too warm [h]	Total	% hours
Klasse A	3672	15	3687	42,92
Klasse C	3158	0	3158	36,76
Klasse D	2709	0	2709	31,53

4 BUTTERFLY SIMULATION

The fourth simulation includes:
- insulated walls and roofs



Class	Too cold [h]	Too warm [h]	Total	% hours
Klasse A	1662	458	2120	24,68
Klasse C	1054	71	1125	13,10
Klasse D	572	14	586	6,82

RESULTS FIRST SIMULATIONS

Most positive results were found by applying:

- Glass on north facade improves comfort (less cold)
- Insulation keeps temperature stable

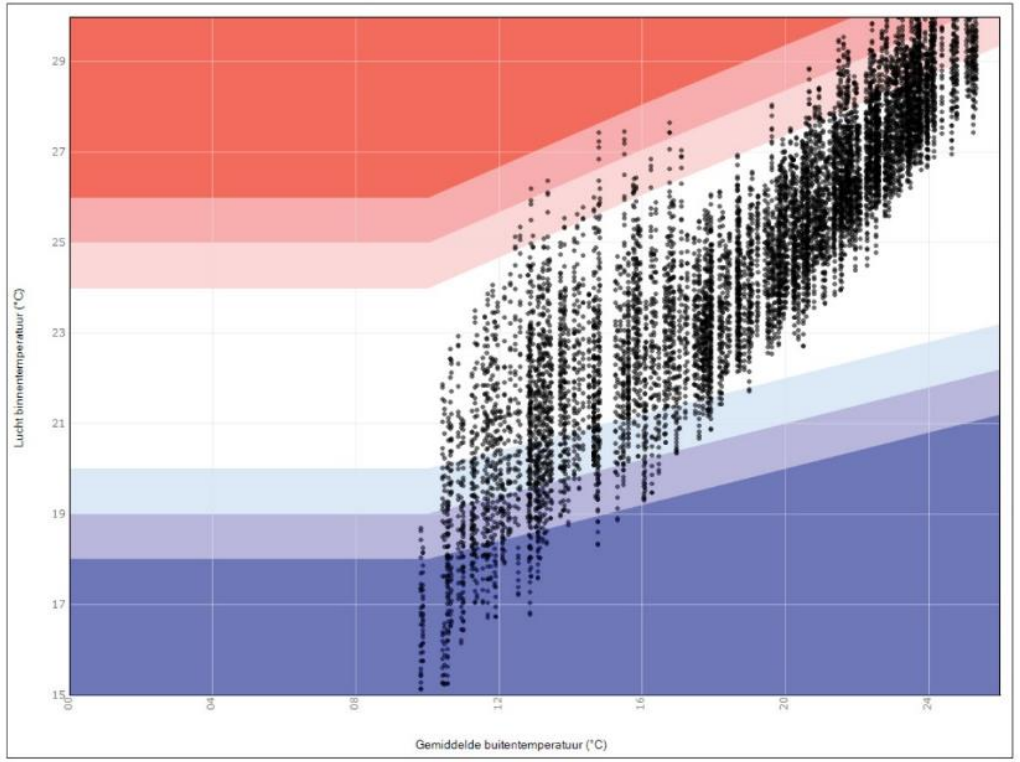
New simulations needed with new combinations of passive design strategies.

In the following slides the final simulations will be presented.

final BUTTERFLY SIMULATION

Final simulation butterfly:
- 145 mm insulation added to the walls and roof
- a lot of glass in the north facade (80%)
- HR++ glass
- overhang above the windows on the north facade for summer, 1 m

Climate change, higher temperatures which means that graph will move a bit higher.

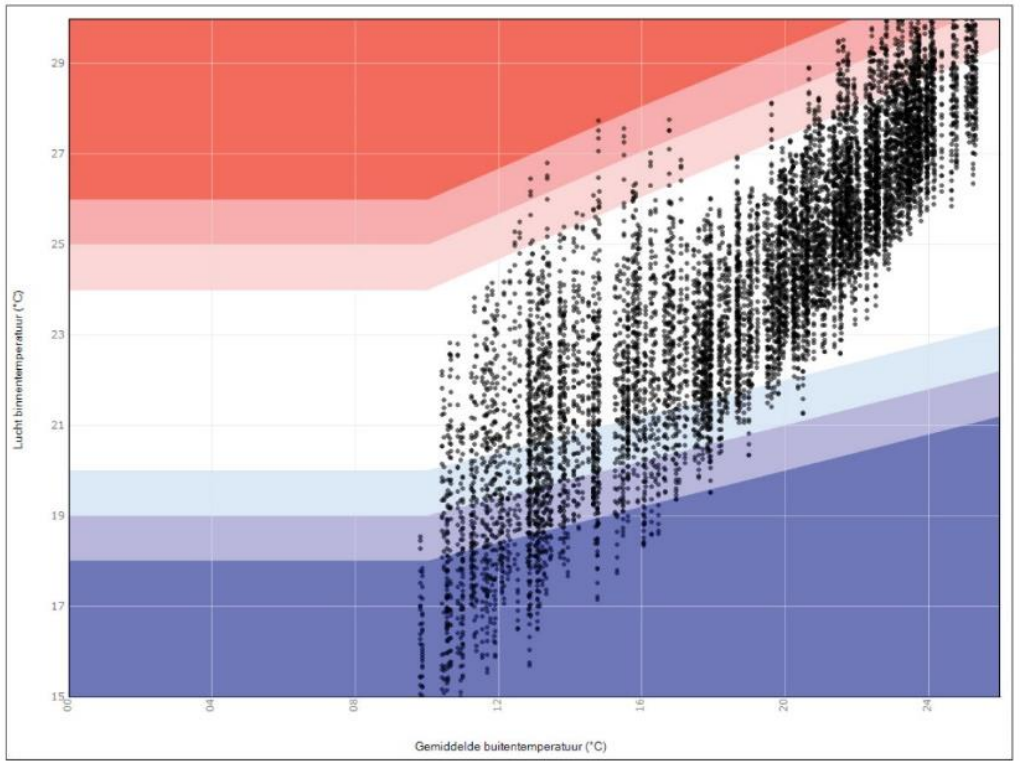


Class	Too cold [h]	Too warm [h]	Total	% hours
Klasse A	1207	970	2177	25,34
Klasse C	650	242	892	10,38
Klasse D	304	8	312	3,63

final THEMBELIHLE SIMULATION

Final simulation thembelihle:
- 145 mm insulation added to the walls and roof
- glass on north facade were possible
- HR ++ glass
- overhang above the windows on the north facade for summer, 1 m
- moving the bathroom to the south facade

Climate change, higher temperatures which means that graph will move a bit higher.



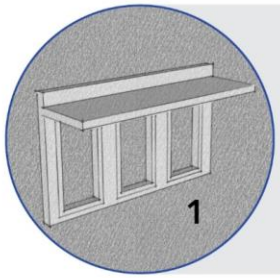
Class	Too cold [h]	Too warm [h]	Total	% hours
Klasse A	1568	910	2478	28,84
Klasse C	982	206	1188	13,83
Klasse D	550	13	563	6,55

OPTIONS
design solutions

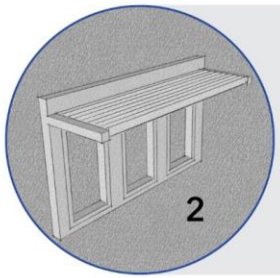
1 INSULATED WALLS & ROOFS

2 HR++ GLASS

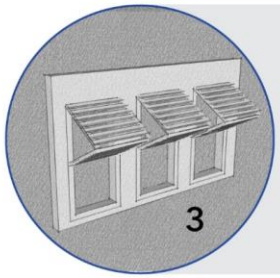
3 OVERHANG / SHADING



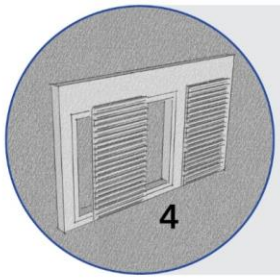
Simple overhang as simulated in VABI elements



Overhang with an integration of rotating lamellas

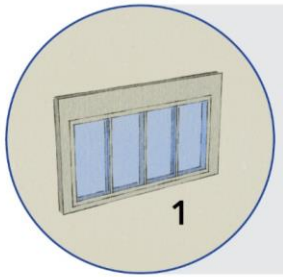


Foldable facade elements with an integration of rotating lamellas

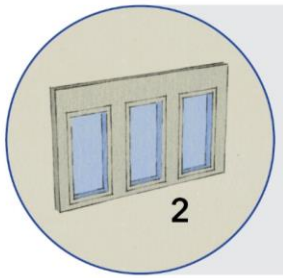


Sliding facade elements with an integration of rotating lamellas

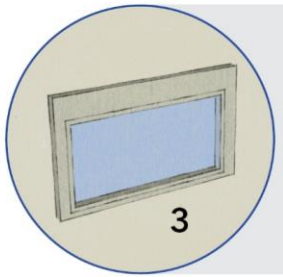
4 GLASS IN NORTH FACADE



One large window with a couple vertical mullions



Multiple windows divided over the wall



One large window with no vertical or horizontal mullions

COST & ENERGY USE

MATERIAL COST current

Materials used Thembelihle, 16 apartments

Material	M2/number	Price	Price total	
Concrete walls (m2)	209,83	970,00	203530,25	
Masonry walls (per 1000), per 1,4 m3	53,42	1270,00	67838,32	
Concrete floors (m3)	125,66	1470,00	184720,20	
Tiling (m2)	557,40	400,00	222959,60	
Windows single glass normal size	32,00	3445,20	110246,40	
Windows single glass small size	18,00	1615,90	29086,20	
Doors single glass	24,00	4840,00	116160,00	
Roof, steel, chromadeck (m2)	176,43	420,00	74101,10	
Timber roof structure 100mm x 50 mm (m)	249,92	135,00	33739,20	
		TOTAL	**1042381,27**	**ZAR**
		1 AP.	**65148,83**	**ZAR**

Materials used Butterfly, 15 apartments

Materials	M2/number	Price/m2	Price total	
Steel columns, IPE 180, per m.	220,71	616,00	135956,13	
Steel beams, IPE 180, per m.	224,06	616,00	138023,42	
Masonry walls (per 1000), per 1,4 m3	43,93	1270,00	55784,75	
Concrete floors (m3)	118,39	1270,00	150354,03	
Tiling (m2)	607,12	400,00	242849,20	
Windows single glass	45,00	3445,20	155034,00	
Doors single glass	18,00	4840,00	87120,00	
Roof, steel, chromadeck (m2)	249,38	420,00	104739,60	
Steel roof structure, beams IPE 180, per m.	61,27	616,00	37741,09	
		TOTAL	**1107602,22**	**ZAR**
		1 AP.	**73840,15**	**ZAR**

MATERIAL COST new

Compared to the current situation, Thembelihle (the building) has increased with an price of **295.005 ZAR (28 %)**. Per apartment:18437,82 ZAR.

Compared to the current situation, Butterfly Housing (the building) has increased with an price of **277.462 ZAR (25%)**. Per apartment: 18497,48 ZAR.

Materials used in NEW Thembelihle, 16 apartments

Material	M2/number	Price	Price total	
Concrete walls (m2)	138,81	873,00	121181,13	
Masonry walls (per 1000), per 1,4 m3	40,28	1143,00	46040,04	
Insulated walls (m2), per 6 m2	23,14	450,00	10410,75	
Concrete floors (m3)	125,66	1323,00	166248,18	
Tiling (m2)	557,40	360,00	200663,64	
Windows double layered glass normal size	24,00	6264,00	150336,00	
Windows double layered glass small size	8,00	2938,00	23504,00	
Large windows (double layered) on north facade	16,00	16000,00	256000,00	
Doors double layered glass	24,00	8800,00	211200,00	
Roof, steel, chromadeck insulated (m2)	176,43	504,00	88921,32	
Timber roof structure 100mm x 50 mm (m)	249,92	121,50	30365,28	
Overhang on north facade concrete (m3)	28,45	1143,00	32516,06	
		TOTAL	**1337386,41**	**ZAR**
		1 AP.	**83586,65**	**ZAR**

Materials used in NEW Butterfly, 15 apartments

Materials	M2/number	Price/m2	Price total	
Steel columns, IPE 180, per m.	220,71	554,40	122360,52	
Steel beams, IPE 180, per m.	224,06	554,40	124221,08	
Masonry walls (per 1000), per 1,4 m3	33,74	1143,00	38564,36	
Insulated walls (m2), per 6 m2	77,18	450,00	34731,00	
Concrete floors (m3)	118,39	1323,00	156628,65	
Tiling (m2)	607,12	360,00	218564,28	
Windows double layered glass	15,00	6577,20	98658,00	
Large windows (double layered) on north facade	15,00	16000,00	240000,00	
Doors double layered glass	18,00	8800,00	158400,00	
Roof, steel, chromadeck insulated (m2)	249,38	560,00	139652,80	
Steel roof structure, beams IPE 180, per m.	61,27	554,40	33966,98	
Overhang on north facade concrete (m3)	16,90	1143,00	19316,70	
		TOTAL	**1385064,37**	**ZAR**
		1 AP.	**92337,62**	**ZAR**

ENERGY SAVINGS, basic & new

by simulating both buildings in vabi elements

Thembelihle Village:

current total	68637 kWh
new total	12092 kWh
difference	56545 kWh

Butterfly Housing:

current total	58763 kWh
new total	40651 kWh
difference	18112 kWh

ENERGY SAVINGS, basic & new

by simulating both buildings in vabi elements

Thembelihle Village:

current total	68637 kWh
new total	12092 kWh
difference	56545 kWh

TOTAL SAVINGS FOR LIVING ROOM 8:

50,31	ZAR	**377,36** only 1 living room
3,35	EURO	**25,16** only 1 living room

48628,70 ZAR
3241,91 EURO

6,1 years payback time

Butterfly Housing:

current total	58763 kWh
new total	40651 kWh
difference	18112 kWh

TOTAL SAVINGS FOR LIVING ROOM 10:

76,46	ZAR	**573,472** only 1 living room
5,10	EURO	**360** only 1 living room

15576,32 ZAR
1038,42 EURO

17,8 years payback time

OTHER IMPROVEMENTS

OTHER improvements
from research results & CC

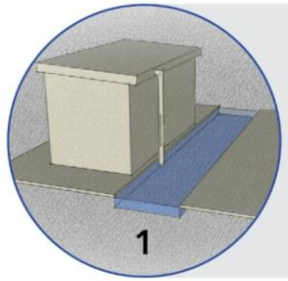
As written before, the climate will change and it will be a lot drier. For this reason it is important to integrate a water catching system in the roof.

There are a lot of sun hours within this climate, for this reason it is important to consider the use of solar panels on the roof (with the right orientation).

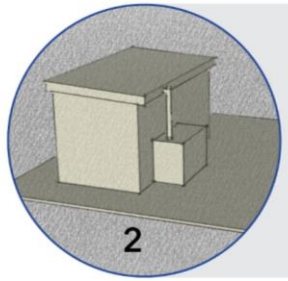
To keep the plot and the air cool around the building (also important for natural ventilation), it is suggested to use a lot of green. Especially when the climate is changing green would be a better choice compared to concrete and stones.

OTHER improvements
from research results & CC

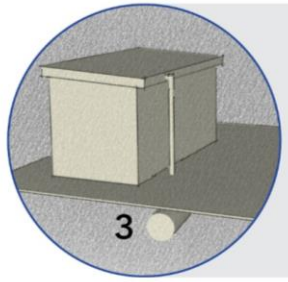
EXTRA RAINWATER HARVESTING



A pond next to the building where the rainwater is stored

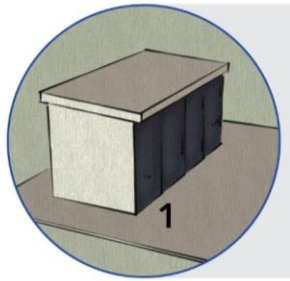


A tank above ground where the rainwater is stored

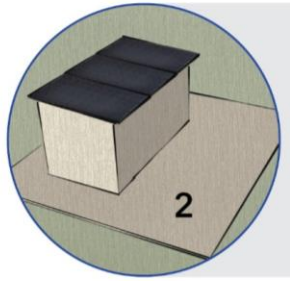


A tank below ground where the rainwater is stored

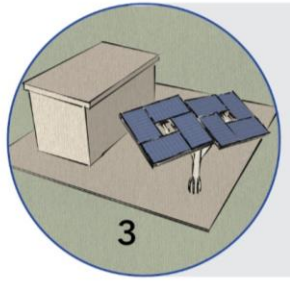
EXTRA USE OF SOLAR ENERGY



Solar panels integrated in the facade

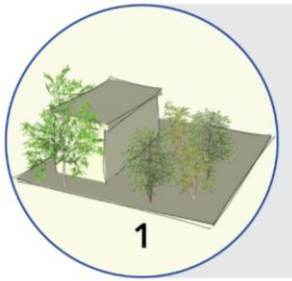


Solar panels integrated in the roof/solar panels which function as the roof

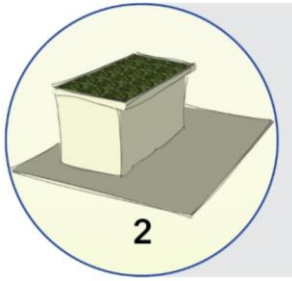


Solar trees on site, around the building

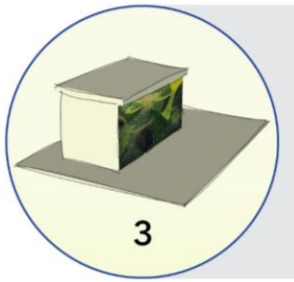
EXTRA USE OF GREEN



Green around the building



Green roof on the building



Green integrated in the facade of the building

SUMMARY DESIGN SOLUTIONS

SUMMARY design solutions

For Butterfly Housing the improvements include:
- 145 mm insulation added to the walls and roof
- a lot of glass in the north facade (80%)
- HR ++ glass in windows and doors
- overhang above the windows on the north facade for summer, 1 m

For Thembelihle Village the improvements include:
- 145 mm insulation added to the walls and roof
- a lot of glass in the north facade after moving the bathroom to the south facade
- HR ++ glass in windows and doors
- overhang above the windows on the north facade for summer, 1 m

Which means that, on the outside, only the overhangs will be a visible change.
All the other things are ''small'' changes.

Extra improvements (which are not validated but are advised):
- Water catching system in the roof
- Use of solar panels which could be very valuable in this climate
- Use a lot of green around the building

DIFFERENT WAYS TO IMPLEMENT

design solutions

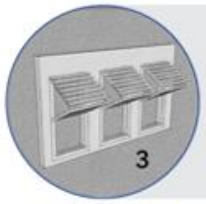
1 INSULATED WALLS & ROOFS

2 HR++ GLASS

3 OVERHANG / SHADING

Simple overhang as simulated in VABI elements

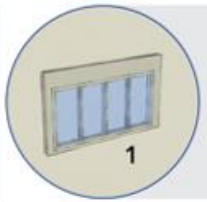
Overhang with an integration of rotating lamellas



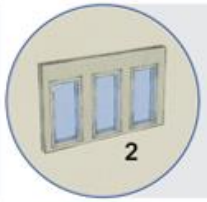
Foldable facade elements with an integration of rotating lamellas

Sliding facade elements with an integration of rotating lamellas

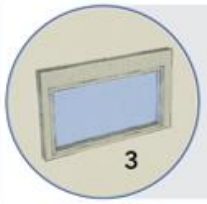
4 GLASS IN NORTH FACADE



One large window with a couple vertical mullions

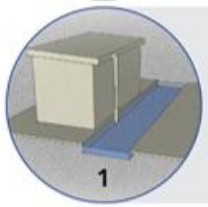


Multiple windows divided over the wall

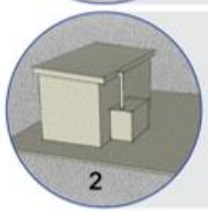


One large window with no vertical or horizontal mullions

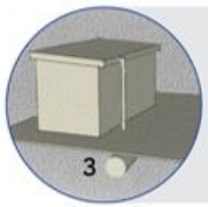
EXTRA RAINWATER HARVESTING



A pond next to the building where the rainwater is stored

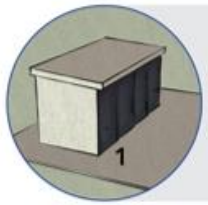


A tank above ground where the rainwater is stored

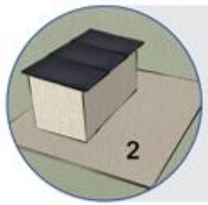


A tank below ground where the rainwater is stored

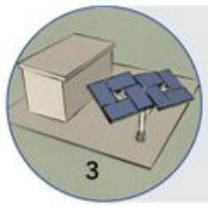
EXTRA USE OF SOLAR ENERGY



Solar panels integrated in the facade

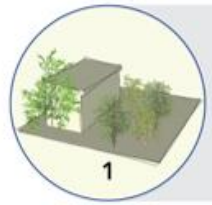


Solar panels integrated in the roof/solar panels which function as the roof

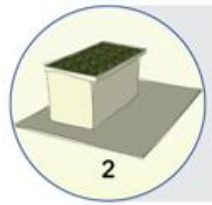


Solar trees on site, around the building

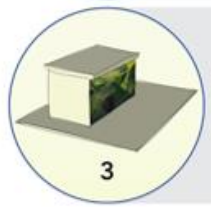
EXTRA USE OF GREEN



Green around the building



Green roof on the building



Green integrated in the facade of the building

CONCLUSION

CONCLUSION research question

''What are the sustainable design solutions for the middle class of Pretoria, South Africa, which enable climate change adaptation and mitigation?''

1

insulation added to the walls and roof

2

a lot of glass in the north facade (80%) & keep north façade connected to living room

3

HR ++ glass in windows and doors

4

overhang above the windows on the north facade for summer

Furthermore it is advised to:
- Integrate a water catching system in the roof
- Use solar panels which could be very valuable in this climate
- Use a lot of green around the building

thembelihle village, Pretoria

Solar panels integrated in the roof/solar panels which function as the roof

Sliding facade elements with an integration of rotating lamellas

One large window with no vertical or horizontal mullions

A pond next to the building where the rainwater is stored

Solar trees on site, around the building

Green around the building

RECOMMENDATIONS

for future research

RECOMMENDATIONS for future research

- The design solutions and simulations were **focused on comfort** and for a smaller part on energy use and material cost. For this reason it would be interesting to further investigate the energy use and material costs to be able to further define the economic value.

- There were two buildings used as an base for this research. It would be valuable to analyse **multiple buildings** at the same location to find some differences which could be used as input in the design process.

Thankyou!