Technical analysis

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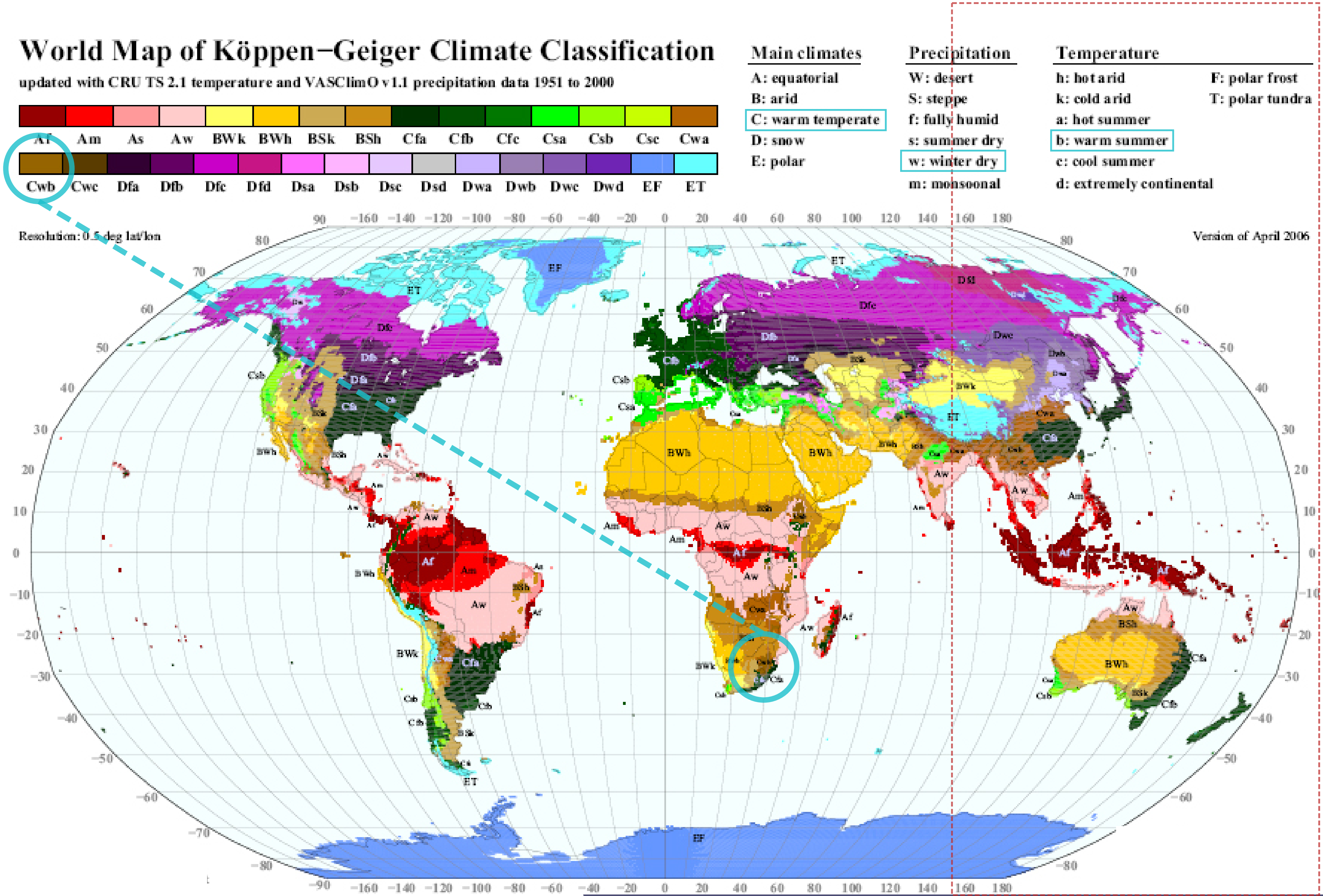


Figure 30 : Koppen-Geiger Climate Classification (http:koeppen-geiger.va)

Climate data

Pretoria

Position: 25° 44' S 28° 11' E
Height: 1330m
Period: 1961-1990
This climatological information is the normal values and, according to World Meteorological Organization (WMO) prescripts, based on monthly averages for the 30-year period 1961 – 1990

Month	Temperature (° C)				Precipitation		
	Highest Recorded	Average Daily Maximum	Average Daily Minimum	Lowest Recorded	Average Monthly (mm)	Average Number of days with >= 1mm	Highest 24 Hour Rainfall (mm)
January	36	29	18	8	136	14	160
February	36	28	17	11	75	11	95
March	35	27	16	6	82	10	84
April	33	24	12	3	51	7	72
May	29	22	8	-1	13	3	40
June	25	19	5	-6	7	1	32
July	26	20	5	-4	3	1	18
August	31	22	8	-1	6	2	15
September	34	26	12	2	22	3	43
October	36	27	14	4	71	9	108
November	36	27	16	7	98	12	67
December	35	28	17	7	110	15	50
Year	**36**	**25**	**12**	**-6**	**674**	**87**	**160**

Table 3 : Climate data - Pretoria (www.weathersa.co.za)

According to the Koppen-Geiger Climate Classification system Pretoria is located within a Cwb climate zone, although it can be seen to share some of the charactersitics of a BSh zone.

KOPPEN CLIMATE TYPE C - MILD MID-LATITUDE

Definition: Coldest month above 0°C, but below 18°C, warmest month above 10°C.

w - denotes dry winters

b - denotes warm summers

KOPPEN CLIMATE TYPE B - HOT DRY

Definition: Receive less than 86cm of precipitation per year.

S - denotes Steppe precipitation pattern (dry & barren most of the year, but revitalised by spring rains)

h - denotes hot arid conditions

South African Renewable Energy Resource Database - Annual Solar Radiation

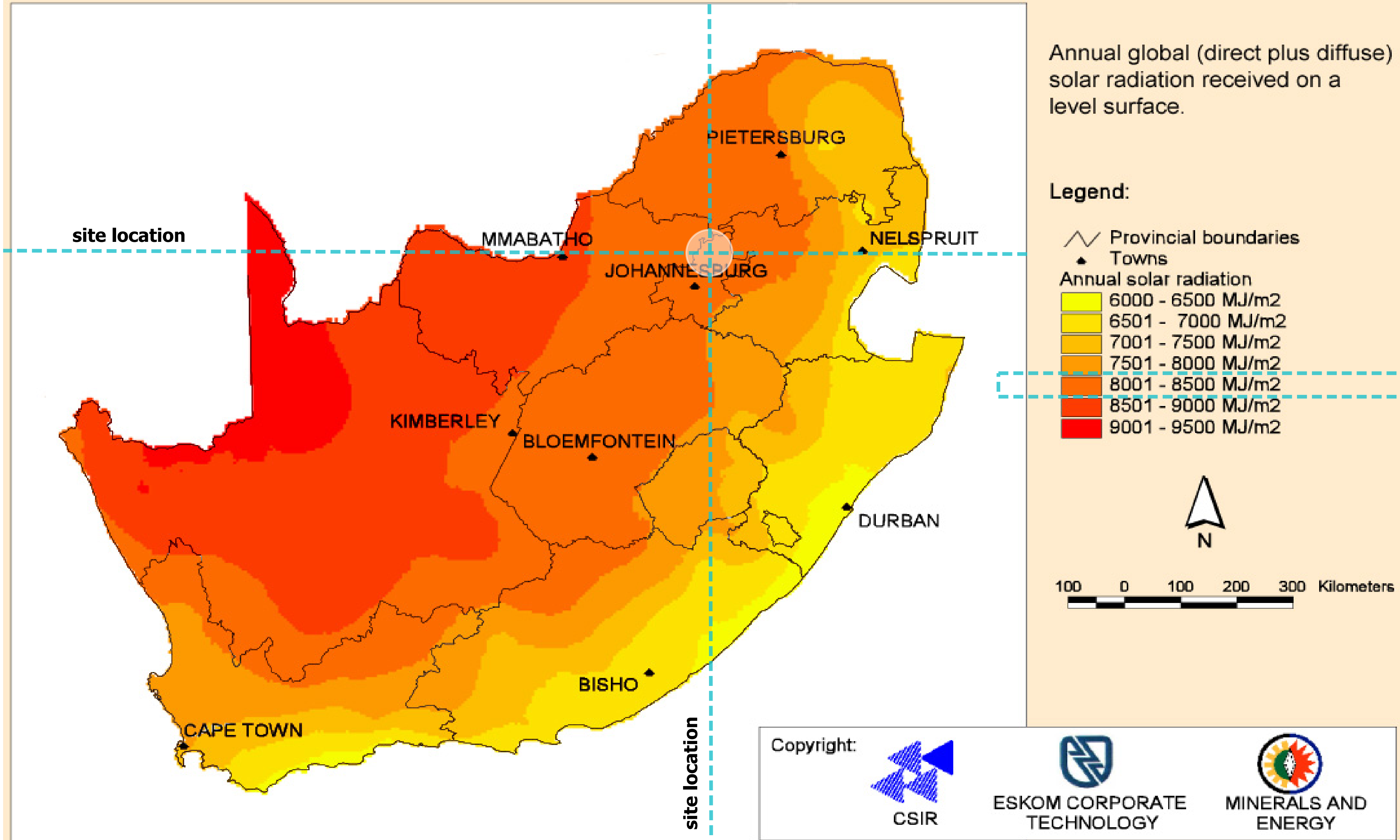


Figure 31 : Annual Solar Radiation (www.eskom.co.za)

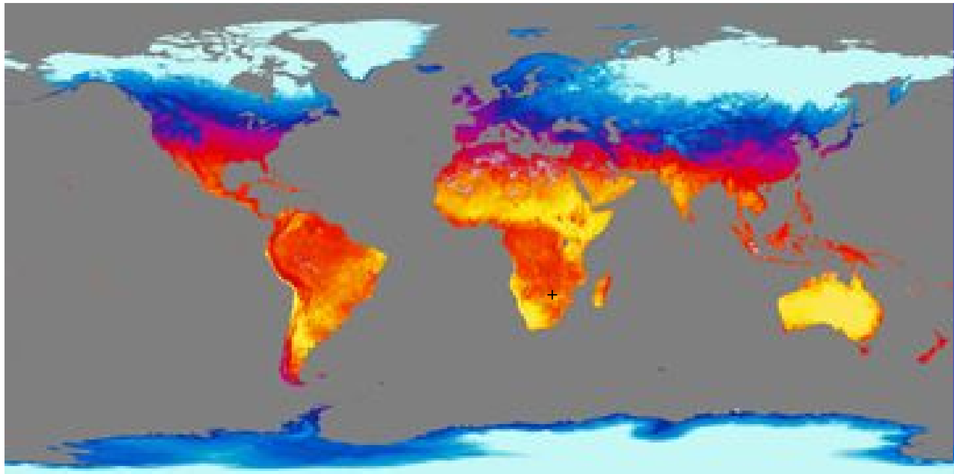


Figure 32 : Daytime Land Temperature - January 2006

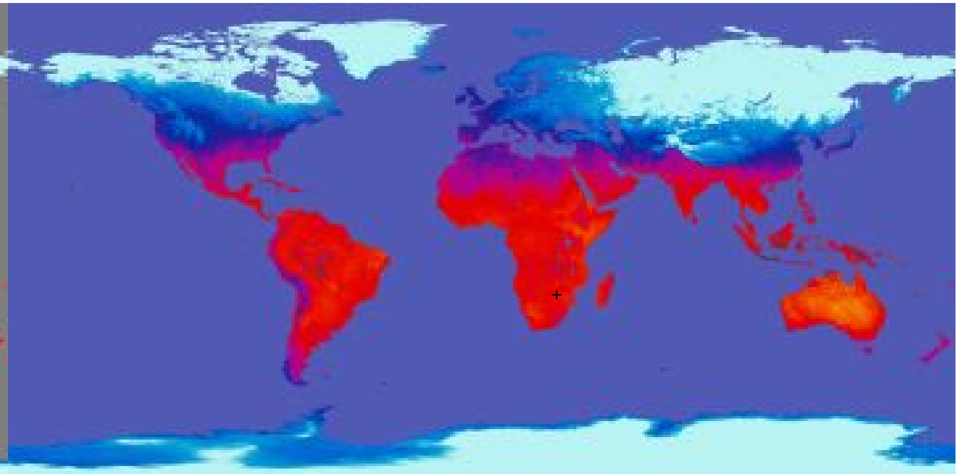
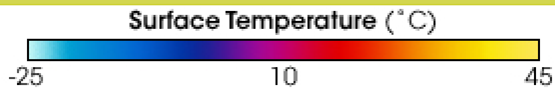


Figure 33 : Night-time Land Temperature - January 2006

"Land surface temperature is a good indicator of the energy balance at the Earth's surface, and serves as an important indicator of the greenhouse effect. "



The graphics illustrate the release of heat energy back into the atmosphere during the middle months due to lesser cloud cover being present in the southern hemisphere winters, and the retention of this radiant heat under cloud cover during the summer months - consequently raising night-time land temperatures and possibly necessitating a night-cooling strategy for buildings.

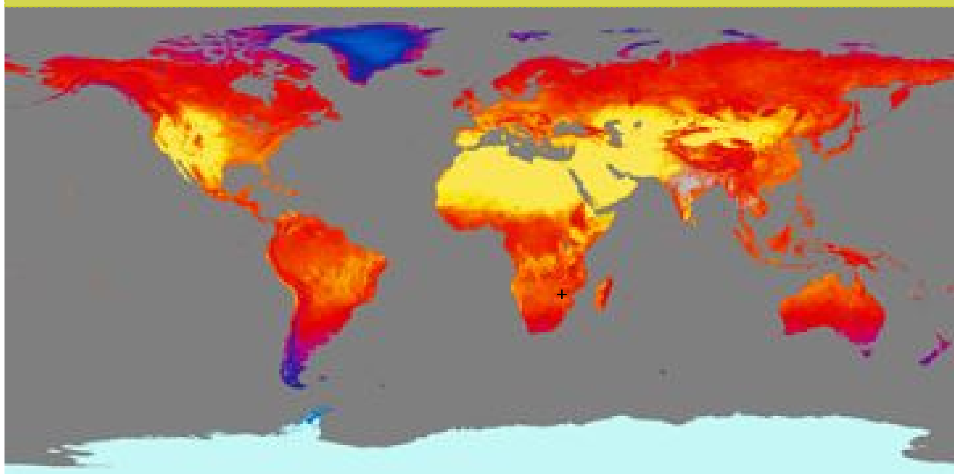


Figure 34 : Daytime Land Temperature - June 2006

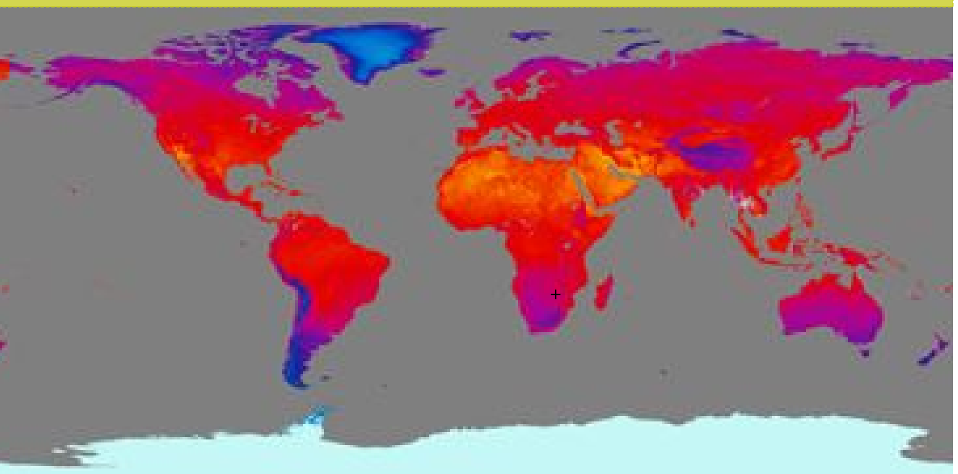
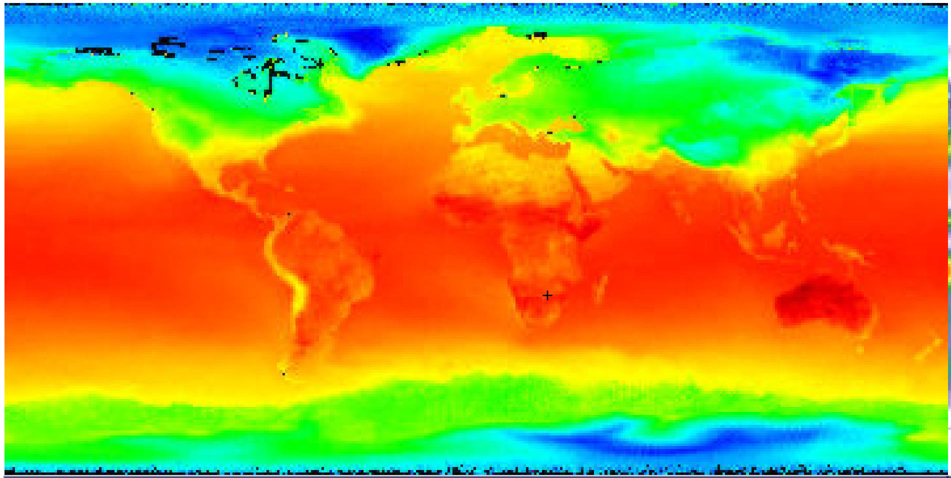


Figure 35 : Night-time Land Temperature - June 2006

(source : NASA Earth Observatory)



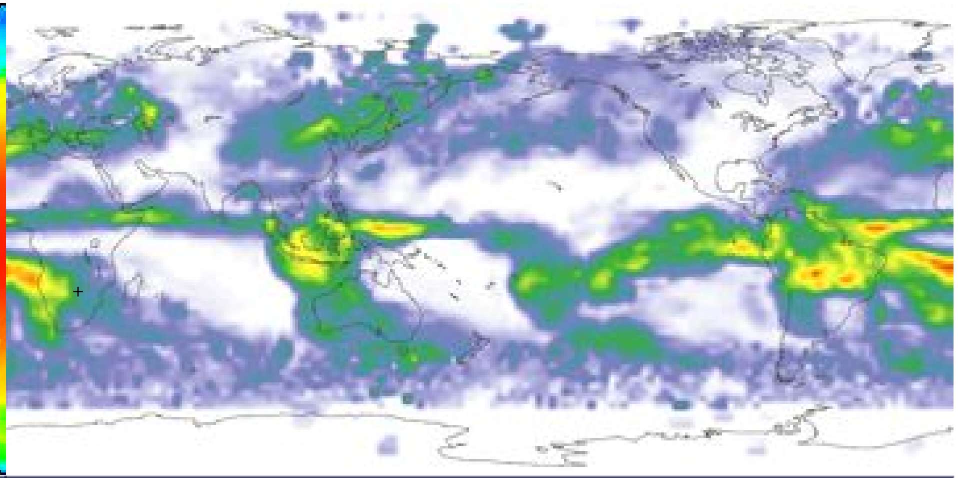
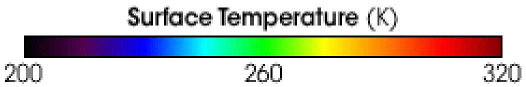
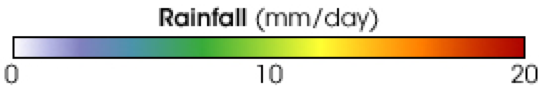


Figure 36 : Surface Temperature - January 2006

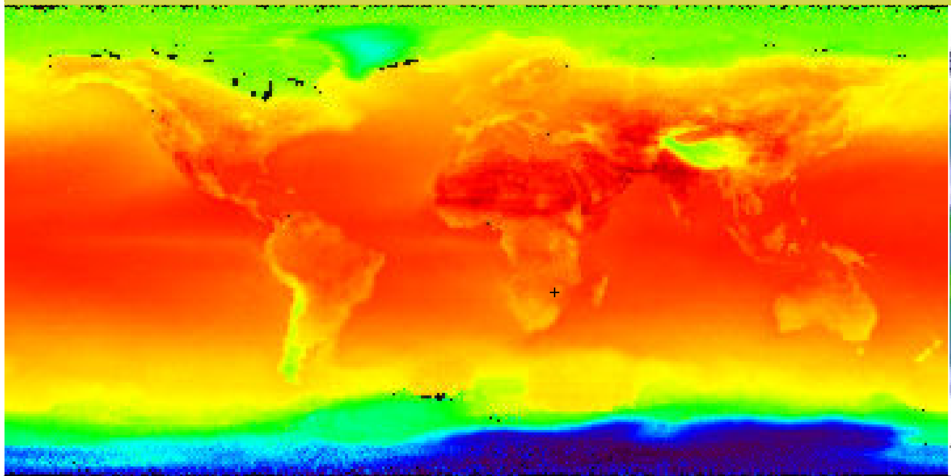
Figure 36 : Rainfall - January 2006

"Surface temperature influences the rate at which water evaporates, as well as wind & precipitation patterns and cloud formations."





The surface temperature values can be seen to be fairly moderate during the southern hemisphere winter months, and dramatically high close to the equator virtually all year through. (Australia's torturous drought conditions are evidenced in the southern summer). The dry, clear sky southern hemisphere winters and wet, cloudy summer months are also apparent in the rainfall graphics



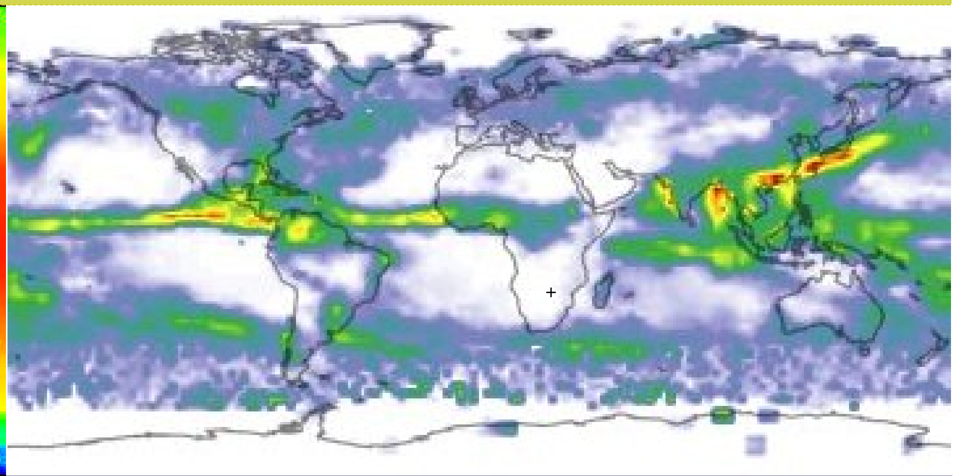
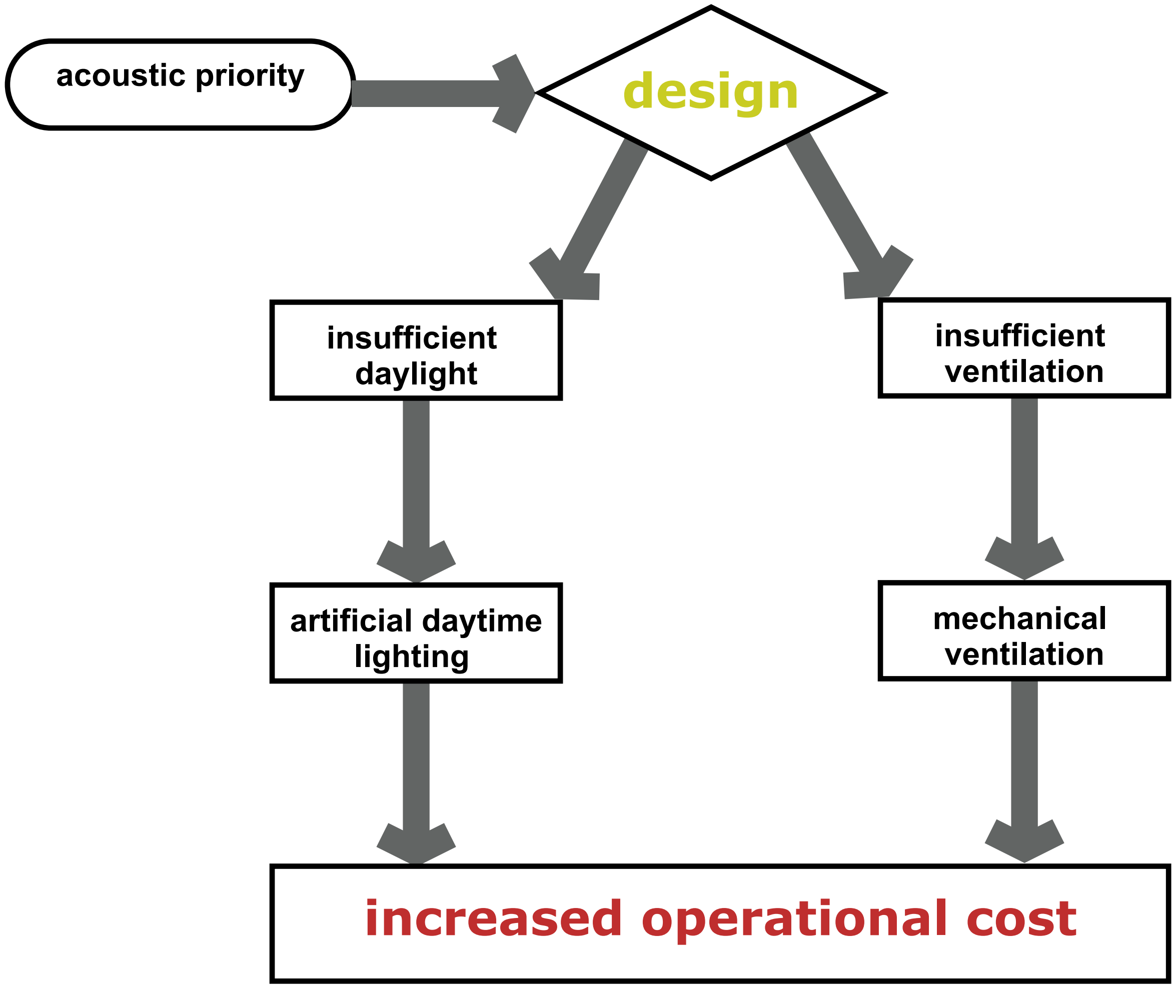


Figure 37 : Surface Temperature - June 2006

Figure 38 : Rainfall - June 2006

(source : NASA Earth Observatory)



The southern facade of Boukunde II bears the characteristics of an acoustic enclosure - with 7" thick concrete panels punctuated by narrow 'slivers' of fenestration which are not sufficient in terms of daylight or natural ventilation requirements.

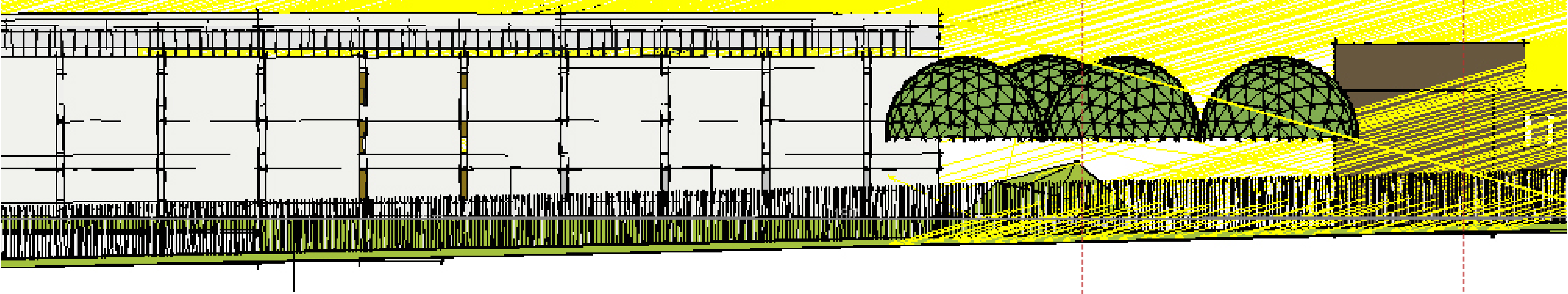
The sacrifice of these 2 elements has been offset by the provision of artificial lighting and mechanical ventilation, which to all intents are not remiss by virtue of their existence in the building, but rather by their requirement to serve beyond the 'call of duty'.

The fluorescent lights in room 2-25 (on the groundfloor) or the 4th year studio (1st floor) are called upon to provide adequate task lighting virtually 24/7 - 365 (or approx. 10/5 - 300 as the academic programme might require). Nonetheless, even an educational institution has to concern itself with the bottom line and/or triple bottom line as it were.

The lack of natural ventilation on all levels of the southern flank is catered for by the central HVAC unit, which is not entirely relied upon to maintain comfort levels within the zones it serves. The double-glazed studio 'sliver' windows on the ground- & first floor levels are invariably left open when these spaces are consistently inhabited, indicating either a lack of faith in- or a lack of perfomance by- the HVAC system.

For the building to be considered sustainable in it's current form it needs to evolve from being a product of a consumptive era to an exemplar of contemporary ideals. However, there cannot be a wholesale sacrifice of functionality nor an abandonment of the original design intent and constructs of the brief.

To enact this statement is to investigate the prevalent conditions - and the existing building's response thereto.



TRAFFIC NOISE

The primary consideration for the design of the southern facade.

ESTIMATING VEHICLE NOISE LEVELS

L10 denotes the level in dB(A) which is exceeded for one-tenth of any specified hour. The levels experienced are indicative for a distance of 10m from the road verge.

No. of vehicles/hour:

q = average number of vehicles using this particular section of lynnwood road per hour from 8:00am - 10:00am (weekdays) - as surveyed by the author (12/03/2008).

L10(1 hour)

= 41.2 + 10log q dB(A)

= 41.2 + 10log (1480) dB(A)

= 41.2 + 31.70 dB(A)

= 72.90 dB(A)

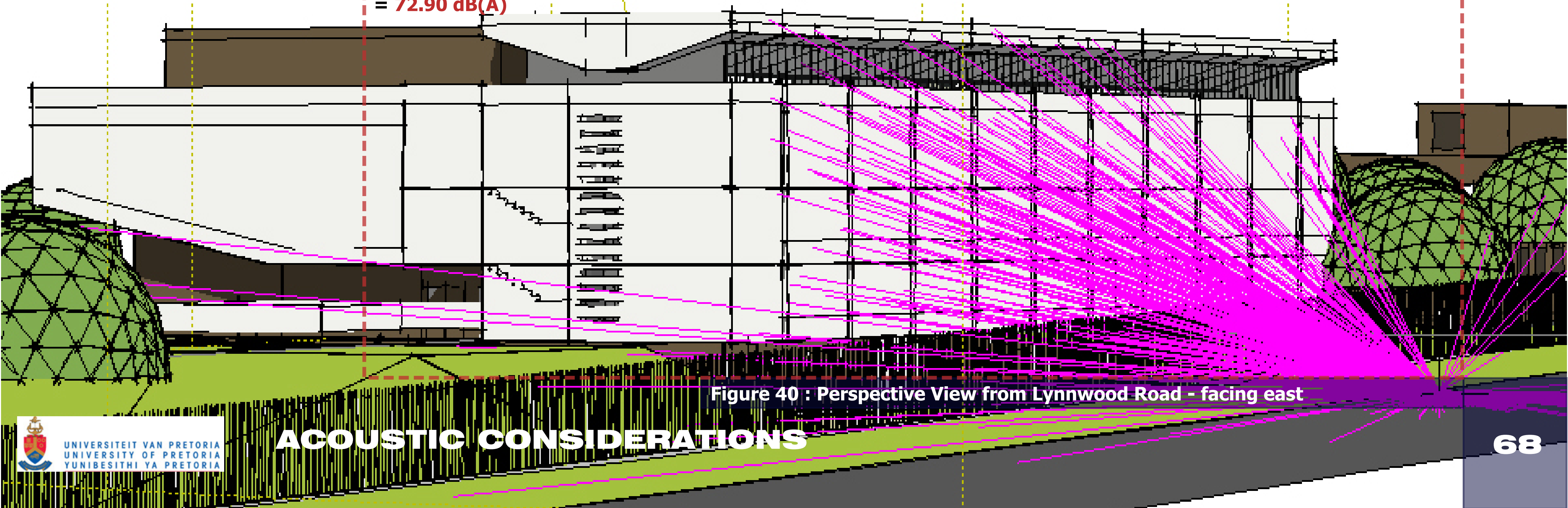
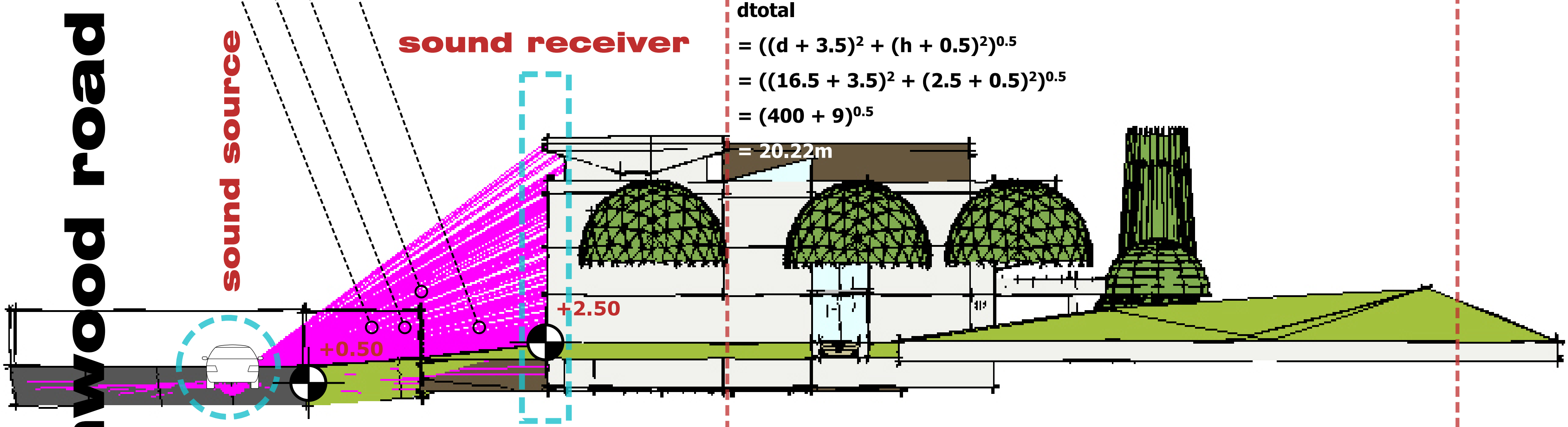


Figure 40 : Perspective View from Lynnwood Road - facing east



NOISE LEVEL FACTOR CORRECTIONS

Inverse Square Law & ground cover:

d = distance from road verge to sound receiver

h = height of receiver (relative to sound source) - vehicle / engine height taken at 0.5m above road datum level

dtotal = total distance between source & receiver

dtotal

$= ((d + 3.5)^2 + (h + 0.5)^2)^{0.5}$

$= ((16.5 + 3.5)^2 + (2.5 + 0.5)^2)^{0.5}$

$= (400 + 9)^{0.5}$

= 20.22m

Factor correction (soft ground)

= -10log (dtotal/13.5) + 5.2log (3h/(d + 3.5)) dB(A)

= -10log (20.22/13.5) + 5.2log (3x2.5/(16.5 + 3.5)) dB(A)

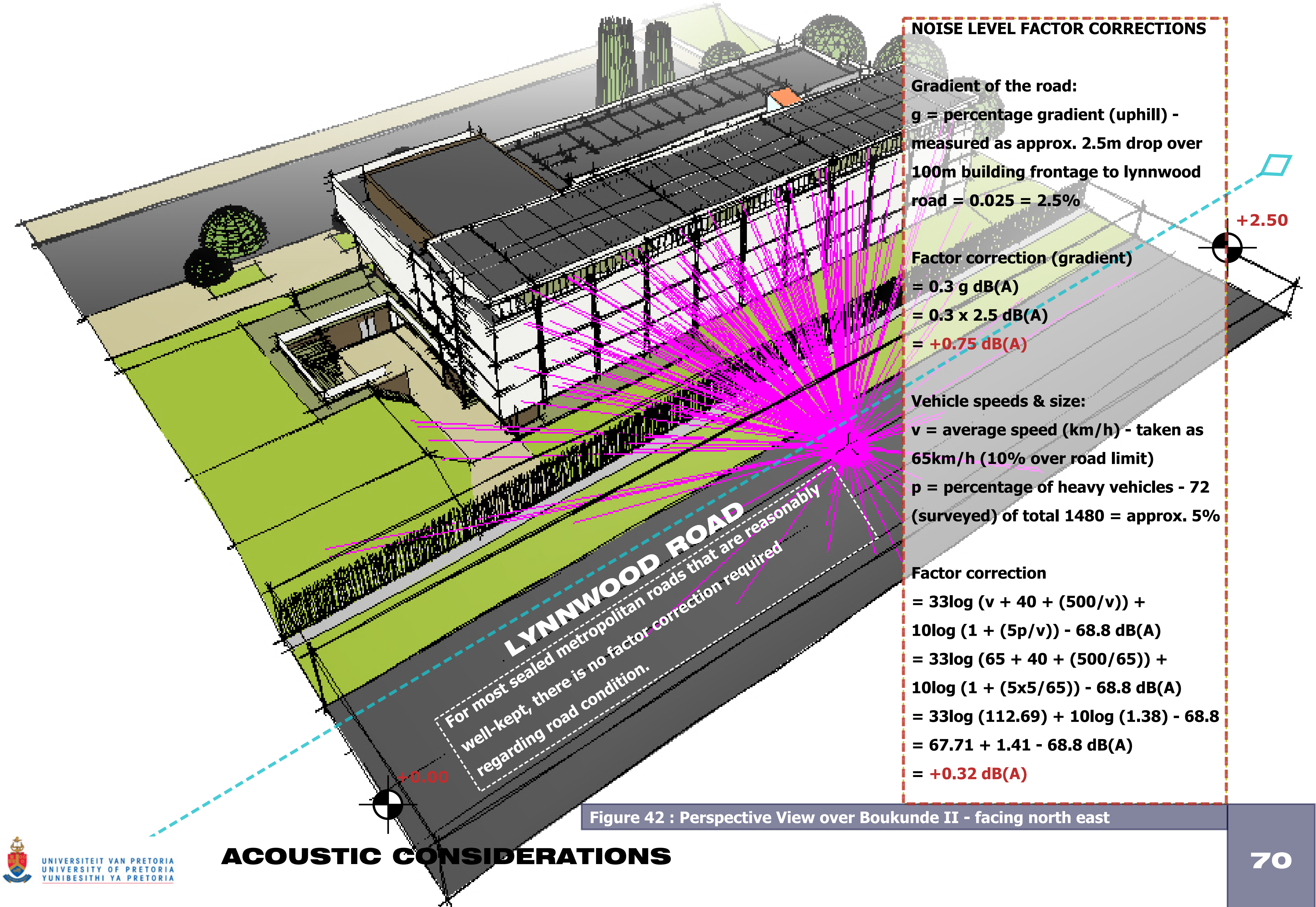
= -10log (1.5) + 5.2log (0.375)

= (-1.76) + (-2.21) dB(A)

= -3.97 dB(A)

The predominant ground cover between the source & receiver is soft & the barrier will have no effect i.to. absorption (being steel palisade), and negligible deflection (being situated approx. midway between the 2

Figure 41 : Boukunde II - East Elevation



NOISE LEVEL FACTOR CORRECTIONS

Gradient of the road:

g = percentage gradient (uphill) - measured as approx. 2.5m drop over 100m building frontage to lynnwood road = 0.025 = 2.5%

Factor correction (gradient)

= 0.3 g dB(A)

= 0.3 x 2.5 dB(A)

= +0.75 dB(A)

Vehicle speeds & size:

v = average speed (km/h) - taken as 65km/h (10% over road limit)

p = percentage of heavy vehicles - 72 (surveyed) of total 1480 = approx. 5%

Factor correction

= 33log (v + 40 + (500/v)) + 10log (1 + (5p/v)) - 68.8 dB(A)

= 33log (65 + 40 + (500/65)) + 10log (1 + (5x5/65)) - 68.8 dB(A)

= 33log (112.69) + 10log (1.38) - 68.8

= 67.71 + 1.41 - 68.8 dB(A)

= +0.32 dB(A)

Figure 42 : Perspective View over Boukunde II - facing north east

No factor correction is considered for noise reflectance from structures on the opposing side of Lynnwood Road, as these structures do not exceed 5m in height & their effect is therefore classified as negligible.

TRAFFIC NOISE

TOTAL ESTIMATED NOISE LEVELS

L10(1 hour):
72.90 dB(A)
Factor correction (soft ground):
-3.97 dB(A) - ground floor
-2.33 dB(A) - first floor
-1.54 dB(A) - second floor
Factor correction (gradient):
+0.75 dB(A)
Factor correction (speed & size):
+0.32 dB(A)

TOTAL AS AT BOUKUNDE SOUTH FACADE:
(ground floor) = 70.00 dB(A)
(first floor) = 71.64 dB(A)
(second floor) = 72.43 dB(A)

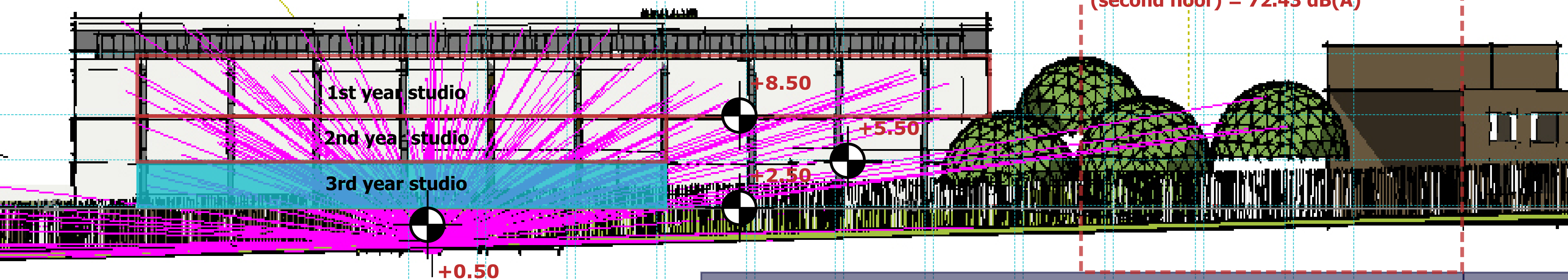


Figure 43 : Boukunde II - South Elevation (Old weather building to the right)

SOUTH FACADE NOISE REDUCTION

ground floor plan - south flank

Panel A - 3 x 3m high x 6m wide x 180mm thick reinforced concrete panels - smooth faced

Ia = 52 dB(A)

Total Area = $54m^2$

Panel B - 3 x 2m high x 500mm wide x 4mm thick double glazed steel windows (100mm air gap)

Ia = 39 dB(A)

Total Area = $3.0m^2$

Panel C - 3 x 1m high x 500mm wide x 150mm thick plastered brickwork window sill panel

Ia = 48 dB(A)

Total Area = $1.5m^2$

TOTAL NOISE REDUCTION CAPACITY

Airborne Insulation Index (Ia) figures indicating average values for octave bands 100-3150Hz.

3rd year studio (west) wall panels:

Panel A + B relationship:
Area Ratio (high R : low R)
$54m^2 : 3m^2 = 18 : 1$
dR = R1 - R2
= 52 - 39
= 13
Net R_(AB)
= 52 - 3.2
= 48.8 dB(A)

Panel (AB) + C relationship:
Area Ratio (high R : low R)
$57m^2 : 1.5m^2 = 38 : 1$
dR = R1 - R2
= 48.8 - 48
= 0.8
Net R_(ABC)
= 48.8 - 0.1
= 48.7 dB(A)

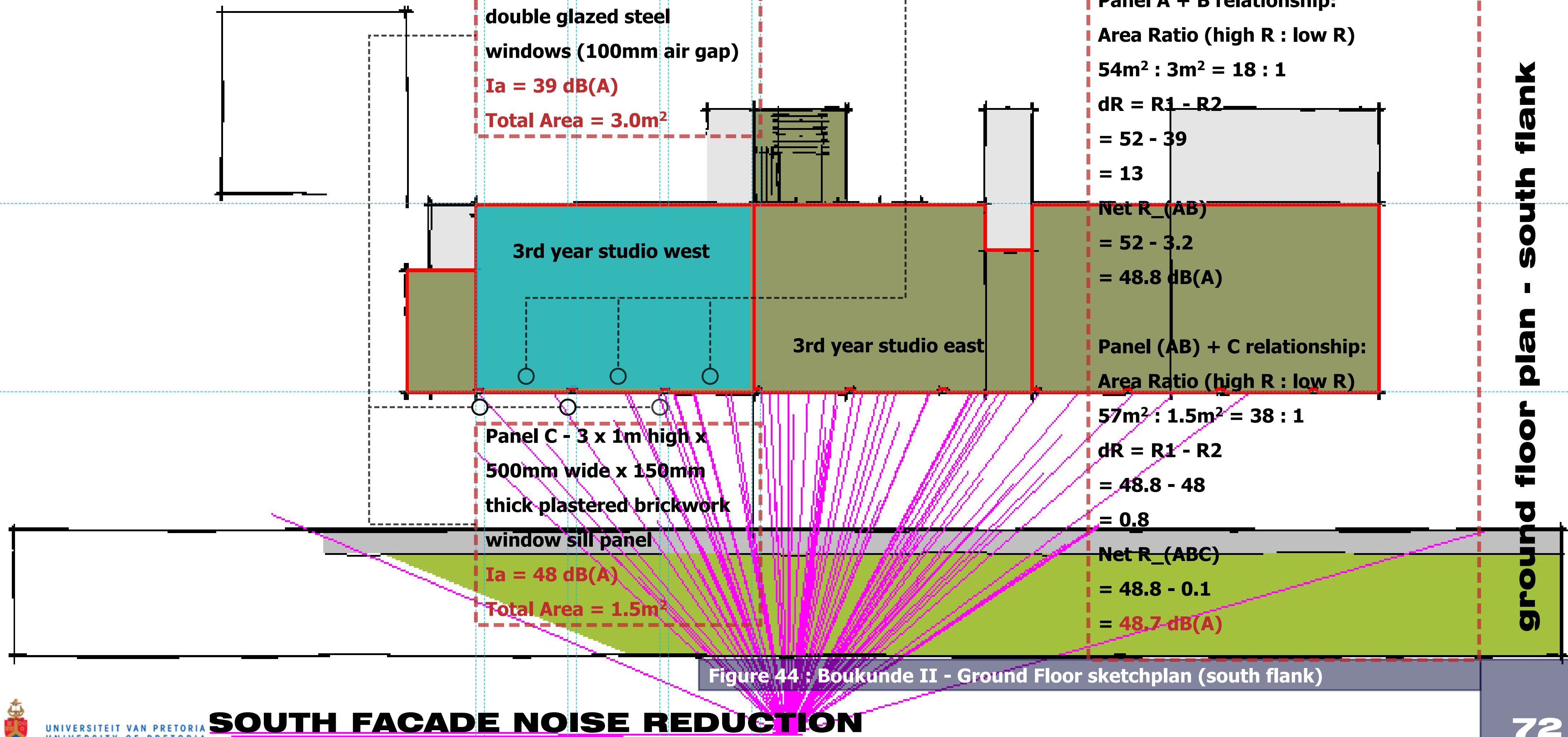


Figure 44 : Boukunde II - Ground Floor sketchplan (south flank)

A post-occupancy evaluation of Boukunde I would presumably have informed decision-making in the design of Boukunde II.

The fact that the 2nd building was realised as robustly as it is - with specific attention given to certain aspects of location and environment - would seem to indicate perceived shortfalls in the first design.

The latter's acoustic fixation might have been an overt response to the former buildings inability to keep noise out.

Panel A - 2m high x 2.1m wide x 6mm thick single glazed steel window (fixed pane)
Ia = 27 dB(A)
Total Area = 4.2m²

Panel B - 2m high x 1.1m wide x 4mm thick single glazed steel window (side hung - 30° open)
Ia = 9 dB(A)
Total Area = 2.2m²

TOTAL NOISE REDUCTION CAPACITY

Boukunde I south facade is comprised of curtain wall glazing exclusively - resulting in a noise reduction capacity as follows:

Panel A + B relationship:
Area Ratio (high R : low R)
4.2m² : 2.2m² = 1.9 : 1
dR = R1 - R2
= 27 - 9
= 18
Net R_(AB)
= 27 - 17
= 10 dB(A)

The current version of the Boukunde building performs markedly better in excluding traffic noise than the 1960's "glass box".

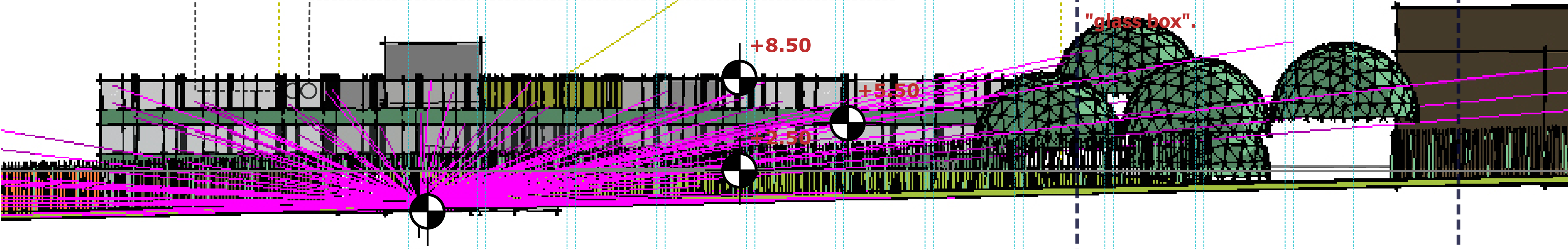


Figure 45 : Boukunde I - South Elevation (Old weather building to the right)

ACOUSTIC CONSIDERATIONS - BOUKUNDE I

"The Darwinian mechanism of vary-and-select, vary-and-select has one enormous difference from the process of design. It operates by hindsight rather than foresight. Evolution is always away from known problems rather than toward imagined goals. It doesnt seek to maximize theoretical fitness; it minimizes experienced unfitness. Hindsight is better than foresight." (Brand. 1994:188)

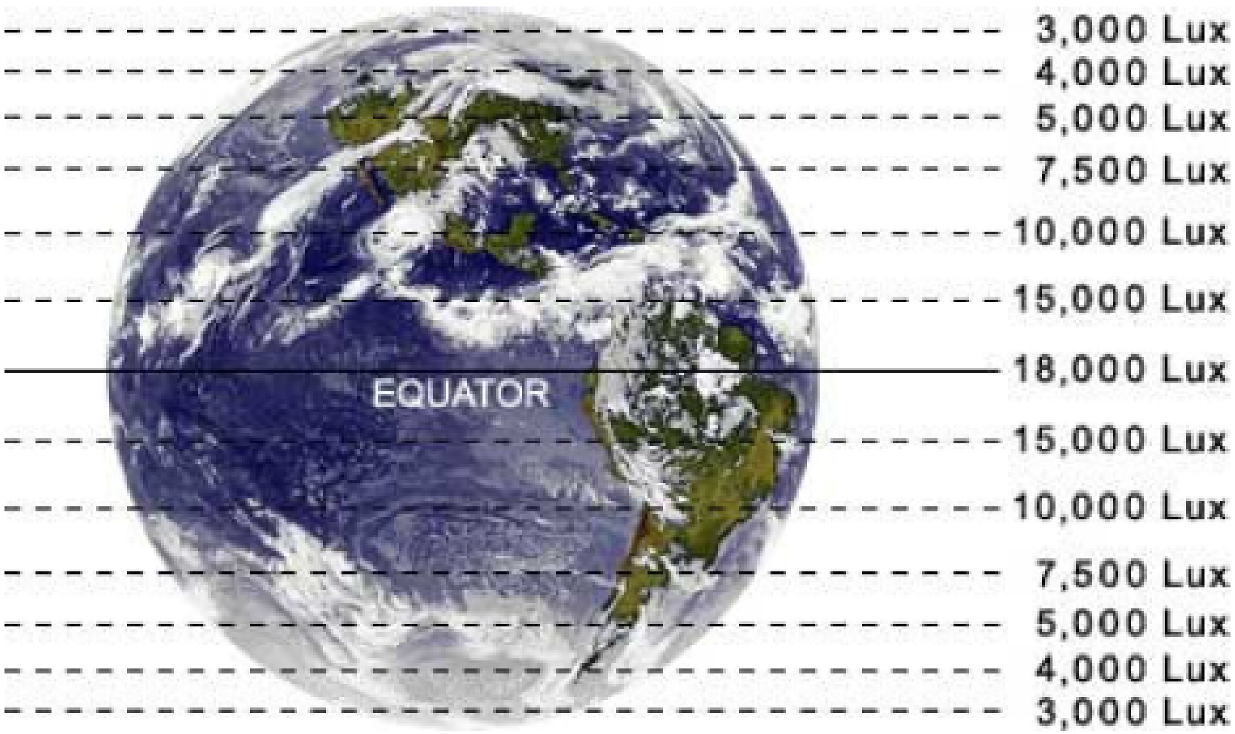


Figure 46 : Design sky illuminance values as function of latitude (www.squ1.org)

"Design Sky values are derived from a statistical analysis of dynamic outdoor sky illuminance levels. They represent the horizontal illuminance value that is exceeded 85% of the time between 9am - 5pm throughout the working year and provide a 'worst-case scenario basis for building design light levels." (www.squ1.org)

Site Location - Pretoria, South Africa
Latitude - 25' 7° South
Design Sky Illuminance - Approx. 10 500 lux

DAYLIGHT FACTOR:

"The amount of daylight entering and bouncing around a space is broadly a function of the size of each window aperture, the amount of sky visible from each window and the reflectance of internal surfaces." (www.squ1.org)

Average daylight factor equation:

$$DF_{avg} = \frac{\sum (W\, T\, \phi\, M)}{A\,(1 - R^2)} \quad \%$$

W = area of each window (m^2)
T = Transmittance of each glazing material (0.8 for clear single glazing or 0.7 for clear double glazing)
θ = Vertical sky angle (as from the centre of each window)
M = Maintenance factor (based upon glazing angle & the cleanliness of its environment)
A = Total internal surface area of the space (including walls, floors, ceilings and windows - m^2)
R = Area weighted average reflectance of all surfaces making up A

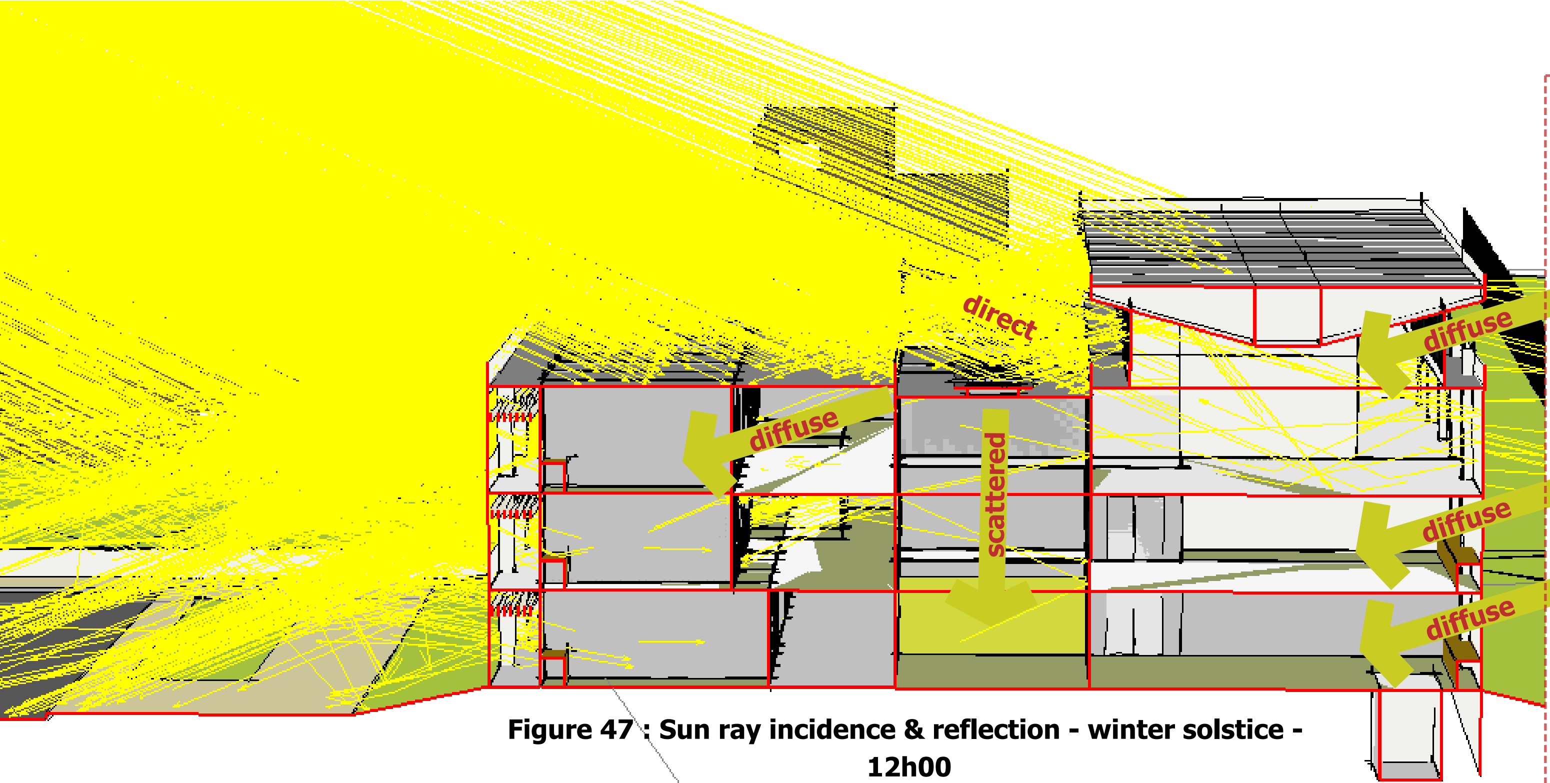


Figure 47 : Sun ray incidence & reflection - winter solstice - 12h00

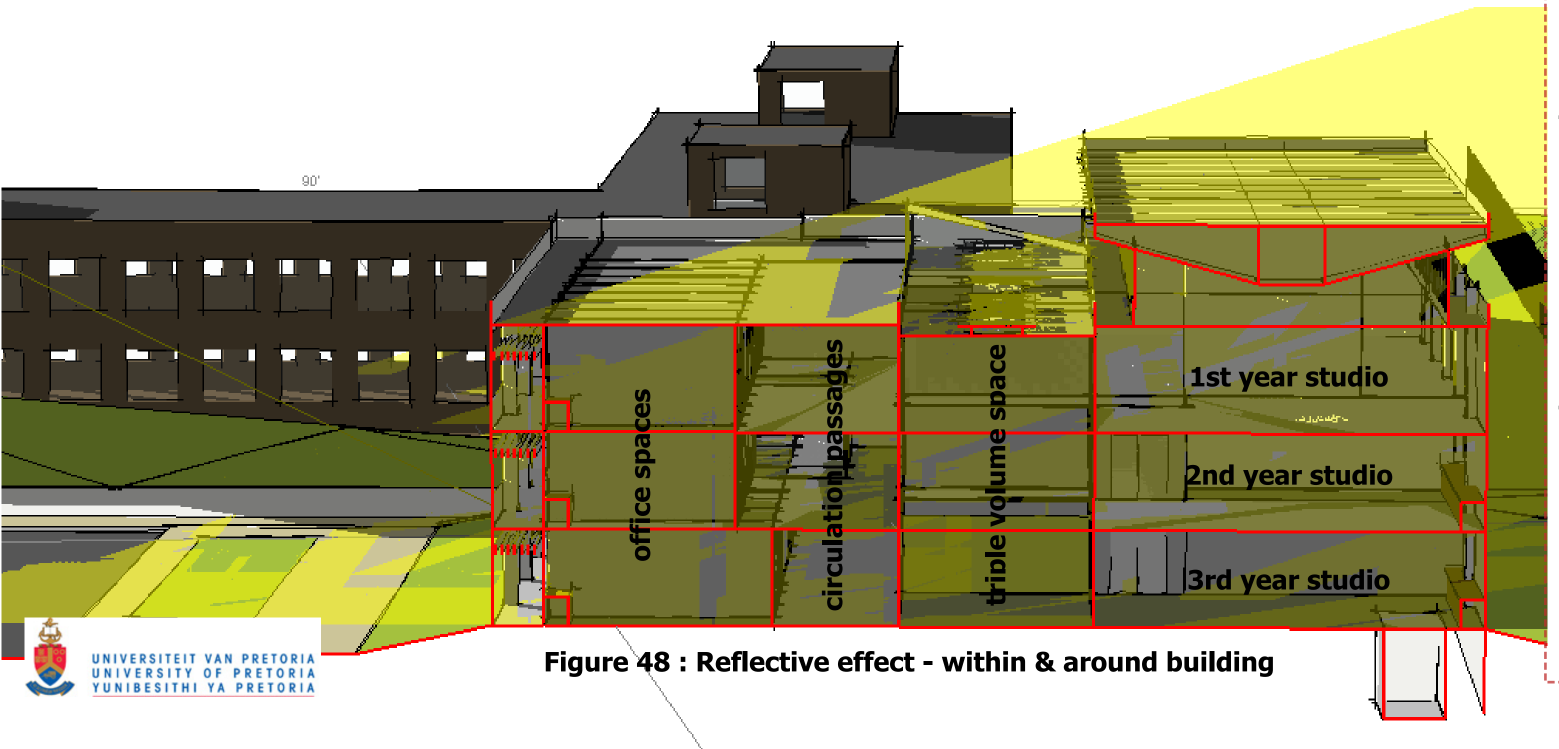


Figure 48 : Reflective effect - within & around building

The 1st year studio on the uppermost level (2nd floor) does benefit from significant daylight levels by virtue of it's clerestory band to the north (and south), but the ground- & first floor studio spaces have no such access to direct northern exposure. They rely primarily upon the minimal amounts of scattered diffuse light available from the shaded south and the sunken clerestory bands & skylights above the triple volume gallery space.

Based upon the solar exposure data for the southern facade windows, there is clearly scarce benefit to be derived from pursuing an improvement in daylighting conditions from the south. The building is divided into 4 structural 'slices' along the east-west grid for all but the western-most end. The middle 2 being a combination of circulation & exhibition / ablution facilities.

The potential for extracting daylighting gains via this mid-section is a factor of solar availibility + the relative 'loose-ness' of the construction + the localised effect to be borne by these 'relay' spaces.

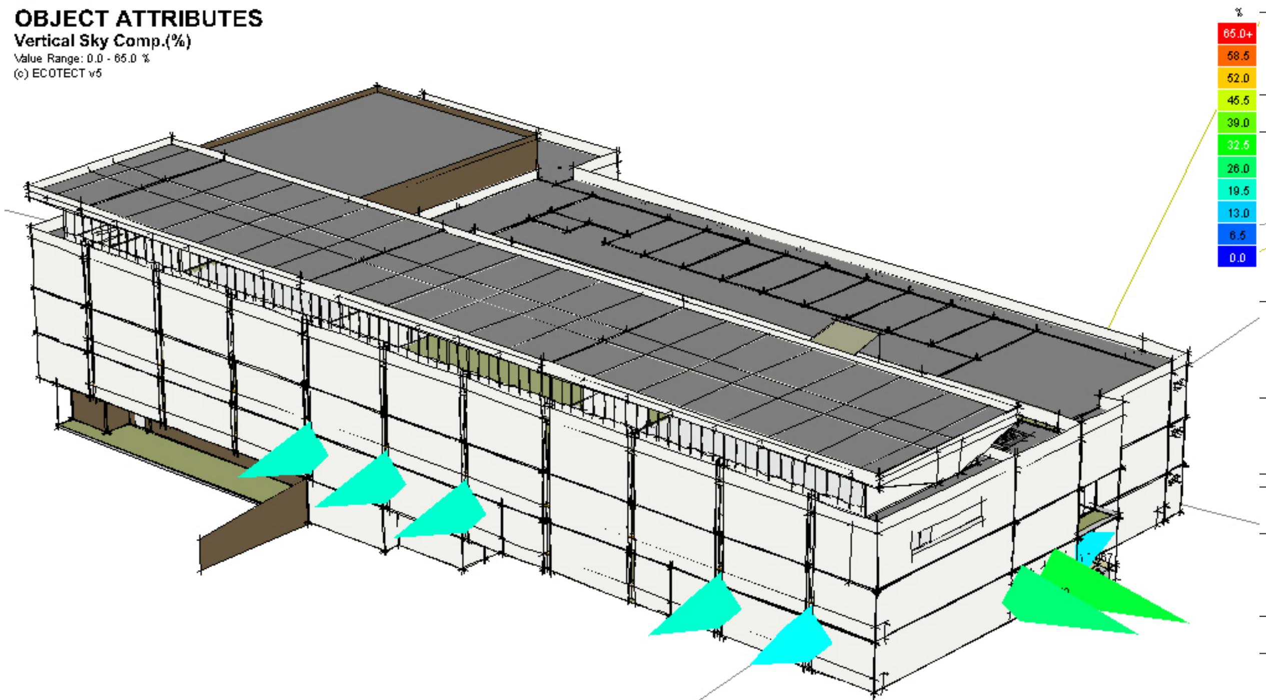


Figure 49 : Vertical Sky Component (3rd year studio east & 5th year studio)

***sky percentage visible from each window in the various zones represented as directional vectors**

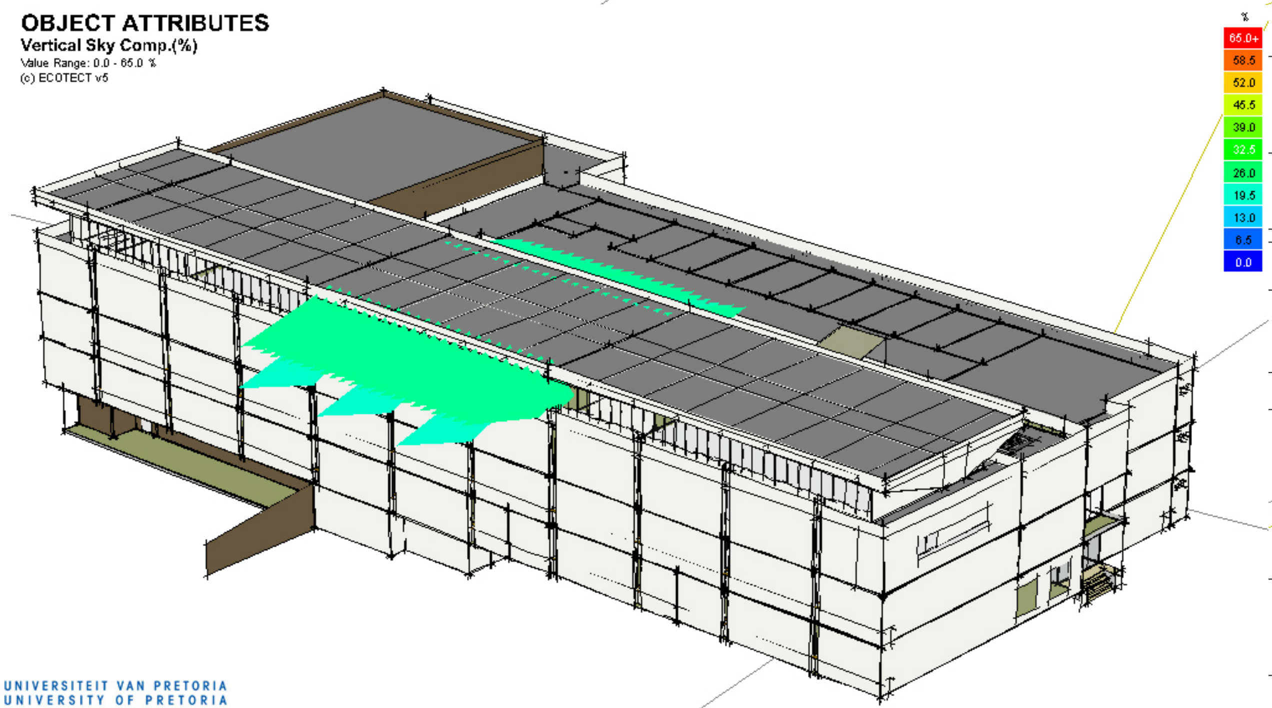
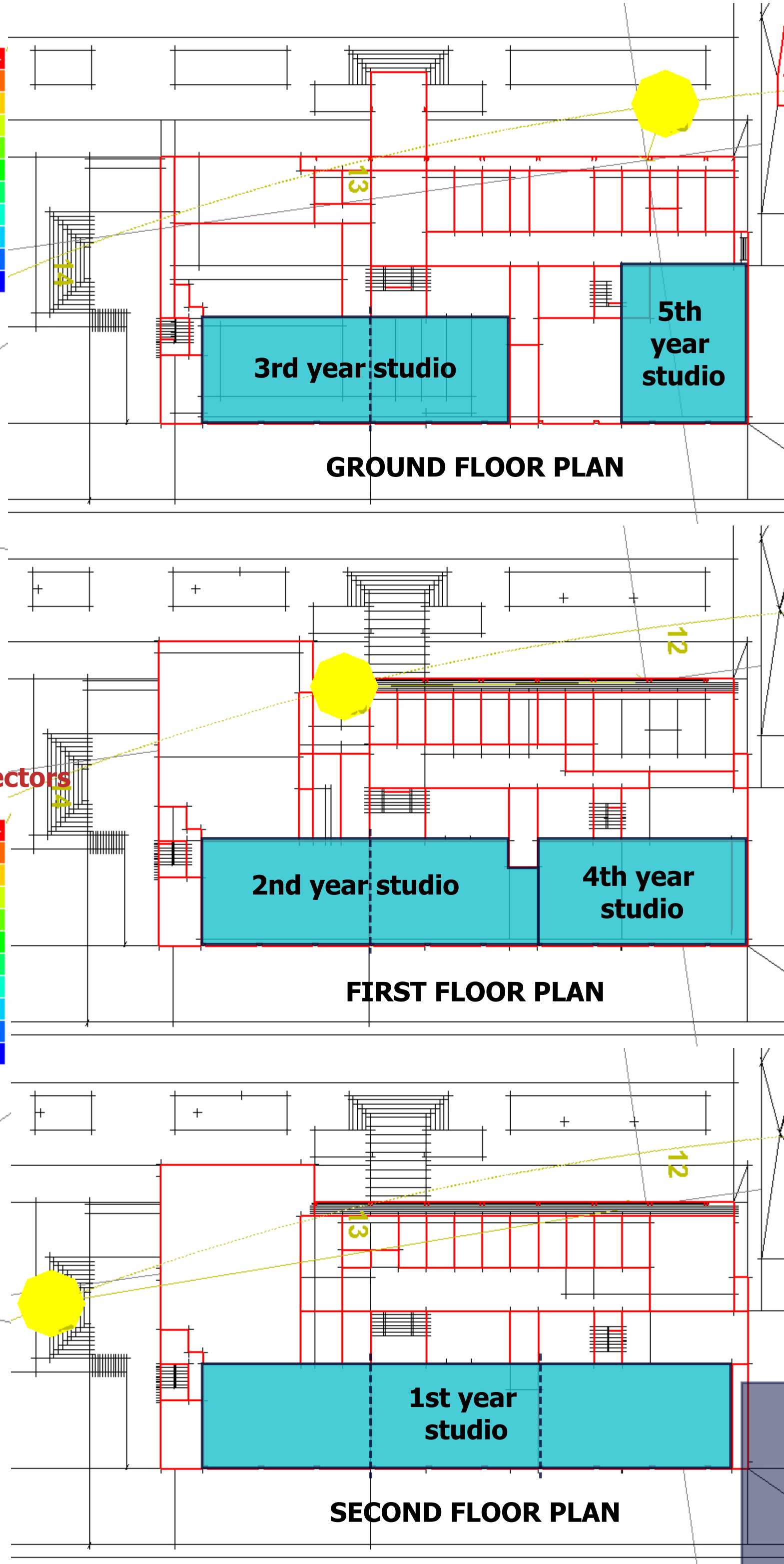


Figure 50 : Vertical Sky Component (1st year studio central)



SECOND FLOOR		FACTOR
1st year studio (central)	- - - - (cyan)	5.34
1st year studio (eastern)	- - - - (green)	4.19
1st year studio (western)	- - - - (yellow)	3.41
FIRST FLOOR		
4th year studio		0.25
2nd year studio (eastern)		0.29
2nd year studio (western)		0.24
GROUND FLOOR		
5th year studio	- - - - (dark blue)	1.01
3rd year studio (eastern)		0.17
3rd year studio (western)		0.15

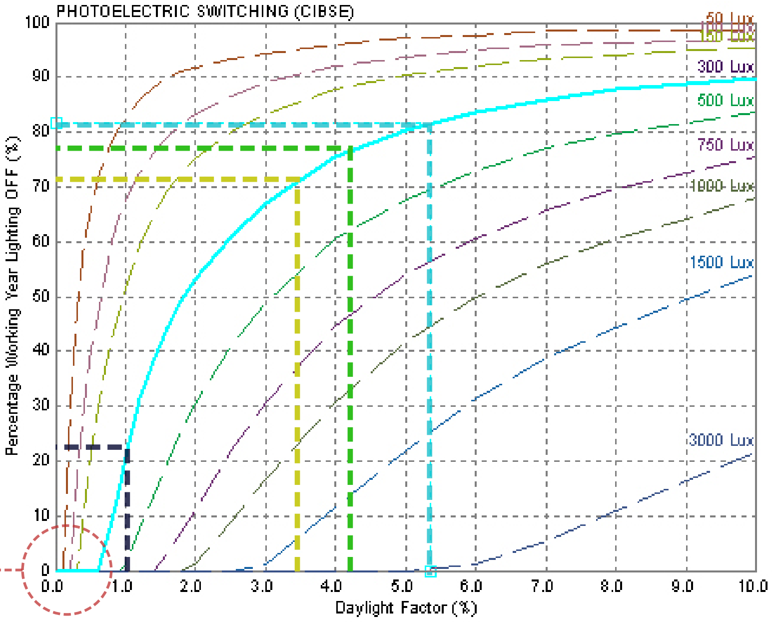


Table 3 : Average Daylight Factor - existing studios

2nd / 3rd / 4th year studio average daylight factor values don't register on the graph as they never reach a level sufficient to completely exclude artificial lighting from these zones.

SECOND FLOOR	FACTOR
1st year studio (central)	22.71
1st year studio (eastern)	21.05
1st year studio (western)	20.18
FIRST FLOOR	
4th year studio	2.78
2nd year studio (eastern)	2.48
2nd year studio (western)	1.97
GROUND FLOOR	
5th year studio	1.64
3rd year studio (eastern)	1.81
3rd year studio (western)	1.97

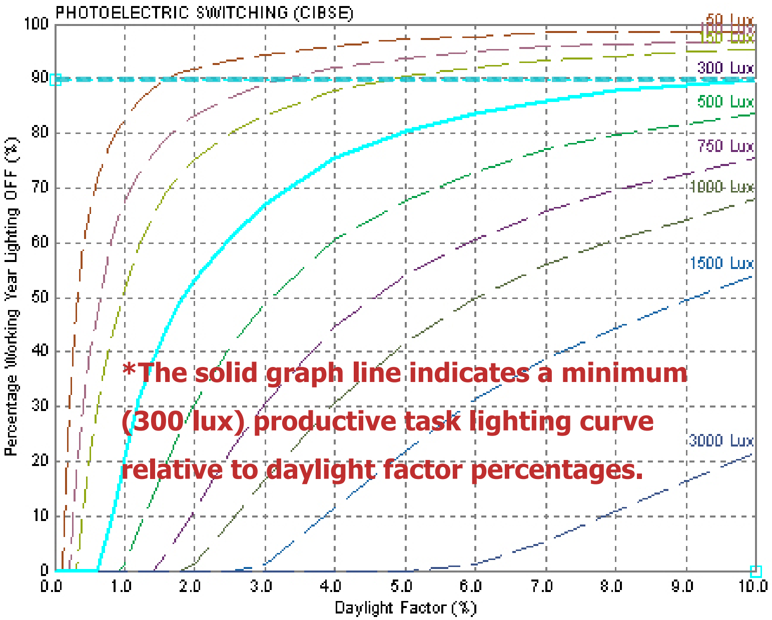


Table 4 : Mid-zone Daylight Factor - existing studios

Daylight Factor values are generated for each zones centre point, which offers a 'best case scenario' for levels in that zone based upon the sum total of all surface reflectance being measurable at this point. An average value is then derived to carry the impact of window size & location, as well as general zone orientation.

The graphs shown use the 1st year studio (central space) as base reference due to it's optimal orientation i.t.o. overshadowing from external elements (raised roof elements, trees, adjacent buildings etc.), and it's fenestration : floor surface area ratio being the greatest of all the studio zones.

The remaining zone values are plotted against this reference and the significance of the variation in daylight levels illustrated. The most important aspect of the analysis however, is the vertical axis which illustrates the percentage of operational time that artificial lighting in these zones can be excluded due to the presence of adequate daylighting conditions.

The fact that the building's southern locales are seemingly unable to offer sufficient lighting conditions during the daytime (when it is needed most) - independant of the national electrical grid, not only exposes these critical functional spaces to risk i.t.o. the unpredicability of supply. It also puts the entire institution under an unnecessary financial burden. The cost of this essential service is set to escalate at levels that bear no relation to the university's inflationary-linked cost recovery mechanisms - such as course fees.

Budgetary allotments from the Education Department would presumably be adjusted to cover any shortfalls, but money added into the operational column is invariably money subtracted from elsewhere in the balance sheet.

A pro-active approach to mitigate operational cost inflation would be to assess, rectify & reduce the problem in terms of it's localised cause and effect. In the case of Boukunde II, the starting point becomes the daylight

LIGHT SOURCE	EFFICACY (LUMENS/WATT)
Direct Sun (low altitude)	90 lm/w
Direct Sun (high altitude)	117 lm/w
Direct Sun (mean altitude)	100 lm/w
Diffuse Sky (clear)	**150 lm/w**
Diffuse Sky (average)	**125 lm/w**
Global (average of sky and sun)	115 lm/w
Incandescent (150 w)	16-40 lm/w
Fluorescent (40 w, CWX)	50-80 lm/w
High Pressure Sodium	40-140 lm/w

Table 5 - Efficacy of various forms of daylight & electric lamps (www.naturalfrequency.com)

In order of escalating retrofit cost - the elements that have direct impact upon a given zone's daylight factor comprise:

1 - Internal reflectance

2 - Maintenance factor (cleanliness, not glazing angle)

3 - Window area

4 - Vertical sky angle (possible obstacle removal eg. trees, light construction etc.)

5 - Internal space surface area

Glazing transmittance values are considered suitable (unless a daylight reduction is required).

WINDOW AREA:	EXISTING	TEST PROPOSAL 1	FACTOR	TEST PROPOSAL 2	FACTOR
1st year studio (central)	81.12m^2	81.12m^2	5.34	81.12m^2	5.34
1st year studio (eastern)	81.76m^2	81.76m^2	4.19	81.76m^2	4.19
1st year studio (western)	53.40m^2	53.40m^2	3.41	53.40m^2	3.41
4th year studio	4.00m^2	4 x (2m x 1m) = 12.00m^2	1.57	4 x (4m x 1m) = 20.00m^2	2.80
2nd year studio (eastern)	3.00m^2	3 x (2m x 1m) = 9.00m^2	1.44	3 x (4m x 1m) = 15.00m^2	2.58
2nd year studio (western)	3.00m^2	3 x (2m x 1m) = 9.00m^2	1.49	3 x (4m x 1m) = 15.00m^2	2.66
5th year studio	8.48m^2	2 x (2m x 1m) = 12.48m^2	1.50	2 x (4m x 1m) = 16.48m^2	1.97
3rd year studio (eastern)	3.00m^2	3 x (2m x 1m) = 9.00m^2	0.81	2 x (4m x 1m) = 11.00m^2	1.38
3rd year studio (western)	3.00m^2	3 x (2m x 1m) = 9.00m^2	0.97	3 x (4m x 1m) = 15.00m^2	1.73

TEST PROPOSAL 3

	SECOND FLOOR	**FACTOR**
81.12m^2	1st year studio (central)	5.34
81.76m^2	1st year studio (eastern)	4.19
53.40m^2	1st year studio (western)	3.41
	FIRST FLOOR	
3 x (5.4m x 2m) = 36.40m^2	4th year studio	5.42
3 x (5.4m x 2m) = 35.40m^2	2nd year studio (eastern)	6.58
3 x (5.4m x 2m) = 35.40m^2	2nd year studio (western)	6.79
	GROUND FLOOR	
1 x (5.4m x 2m) = 19.28m^2	5th year studio	2.30
2 x (5.4m x 2m) = 24.60m^2	3rd year studio (eastern)	3.36
3 x (5.4m x 2m) = 35.40m^2	3rd year studio (western)	4.38

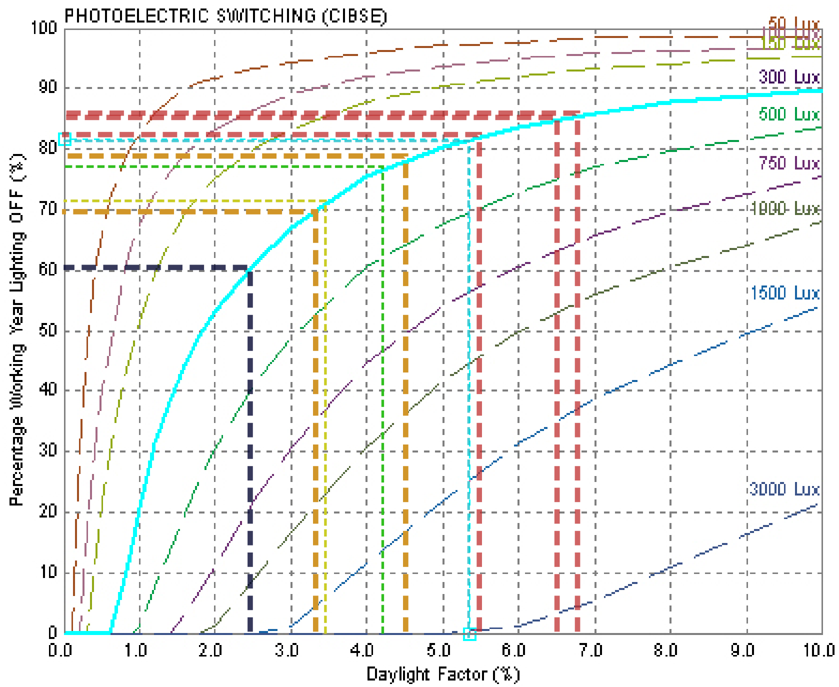


Table 6 : Average Daylight Factor - test proposal 3

DAYLIGHT FACTOR INCREASE

ETROFIT PROPOSALS - WINDOW AREA

SOUTH FACADE - SKIN / SERVICES / STUFF

The existing building facade comprises 7" (180mm) thick off-shutter concrete panels of surface area 5.4m wide x 3m high - spanning between 250mm thick concrete column sets. Internally, beyond this 'skin' - the 'services' and 'stuff' are housed, and these need to be accommodated within the parameters of a retrofit proposal. In this instance, based upon the current premise that the a/c return ducting cannot be removed or relocated, the extent of the skin modification to facilitate increased ground- & first floor daylight values would be max. 5.4m wide x 2m high - spanning from approx. window sill height to flush under the floor slab above.

Figure 51 : Perspective section view - facing south east

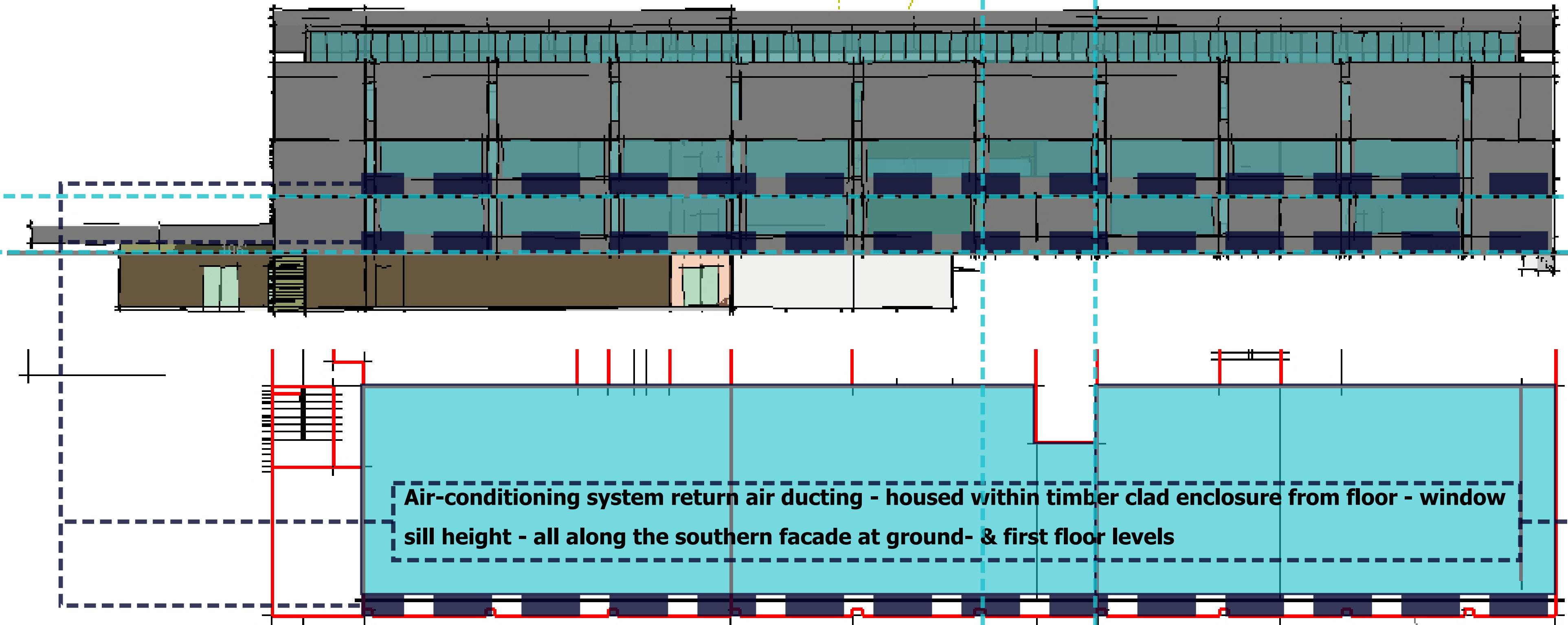


Figure 52 : Boukunde II - south elevation & sketchplan view - test proposal 3 - a/c ducting runs

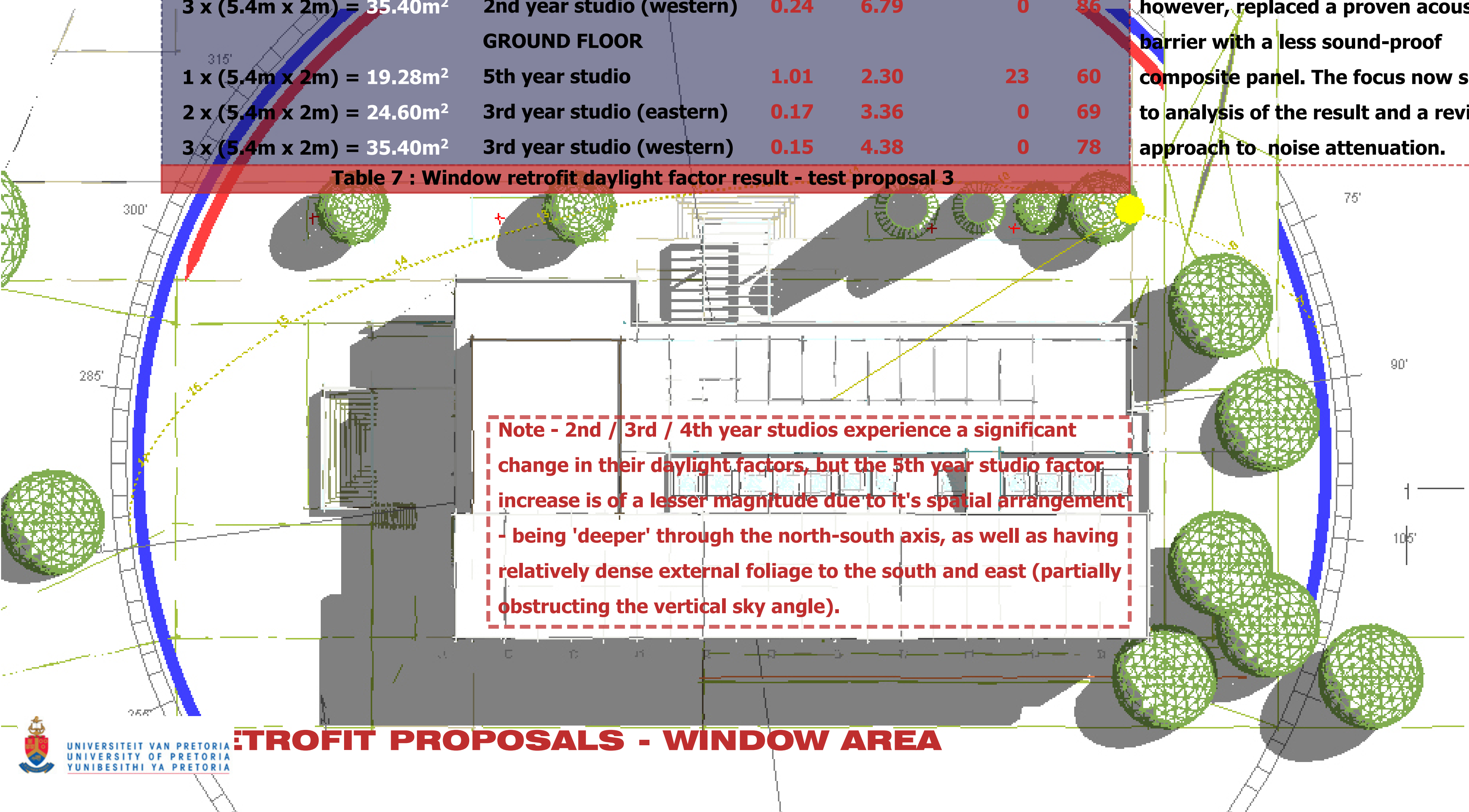
TEST PROPOSAL 3

	SECOND FLOOR	FACTOR		% lights off	
81.12m²	1st year studio (central)		5.34		82
81.76m²	1st year studio (eastern)		4.19		77
53.40m²	1st year studio (western)		3.41		72
	FIRST FLOOR				
3 x (5.4m x 2m) = 36.40m²	4th year studio	0.25	5.42	0	83
3 x (5.4m x 2m) = 35.40m²	2nd year studio (eastern)	0.29	6.58	0	85
3 x (5.4m x 2m) = 35.40m²	2nd year studio (western)	0.24	6.79	0	86
	GROUND FLOOR				
1 x (5.4m x 2m) = 19.28m²	5th year studio	1.01	2.30	23	60
2 x (5.4m x 2m) = 24.60m²	3rd year studio (eastern)	0.17	3.36	0	69
3 x (5.4m x 2m) = 35.40m²	3rd year studio (western)	0.15	4.38	0	78

Table 7 : Window retrofit daylight factor result - test proposal 3

The daylight factor correction yields a vast improvement in terms of natural light availibility to these previously disadvantaged spaces, and liberates them from the mercy of the electricity grid during daylight hours.

The retrofit strategy adopted has however, replaced a proven acoustic barrier with a less sound-proof composite panel. The focus now shifts to analysis of the result and a revised approach to noise attenuation.



Note - 2nd / 3rd / 4th year studios experience a significant change in their daylight factors, but the 5th year studio factor increase is of a lesser magnitude due to it's spatial arrangement - being 'deeper' through the north-south axis, as well as having relatively dense external foliage to the south and east (partially obstructing the vertical sky angle).

noise reduction capacity analysis

Panel A1 - 3 x 1m high x 6m wide x 180mm thick reinforced concrete panels - smooth faced

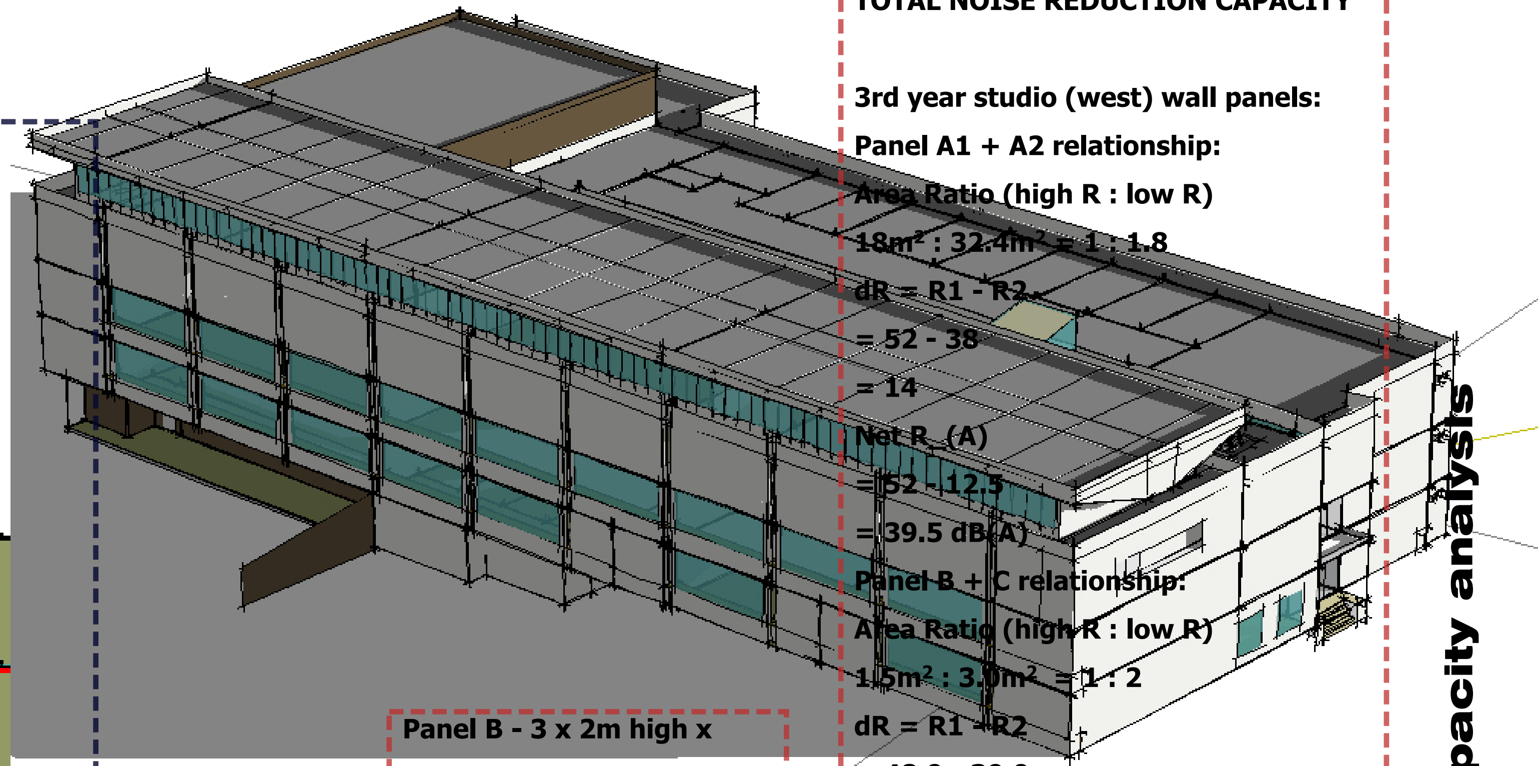
Ia = 52 dB(A)

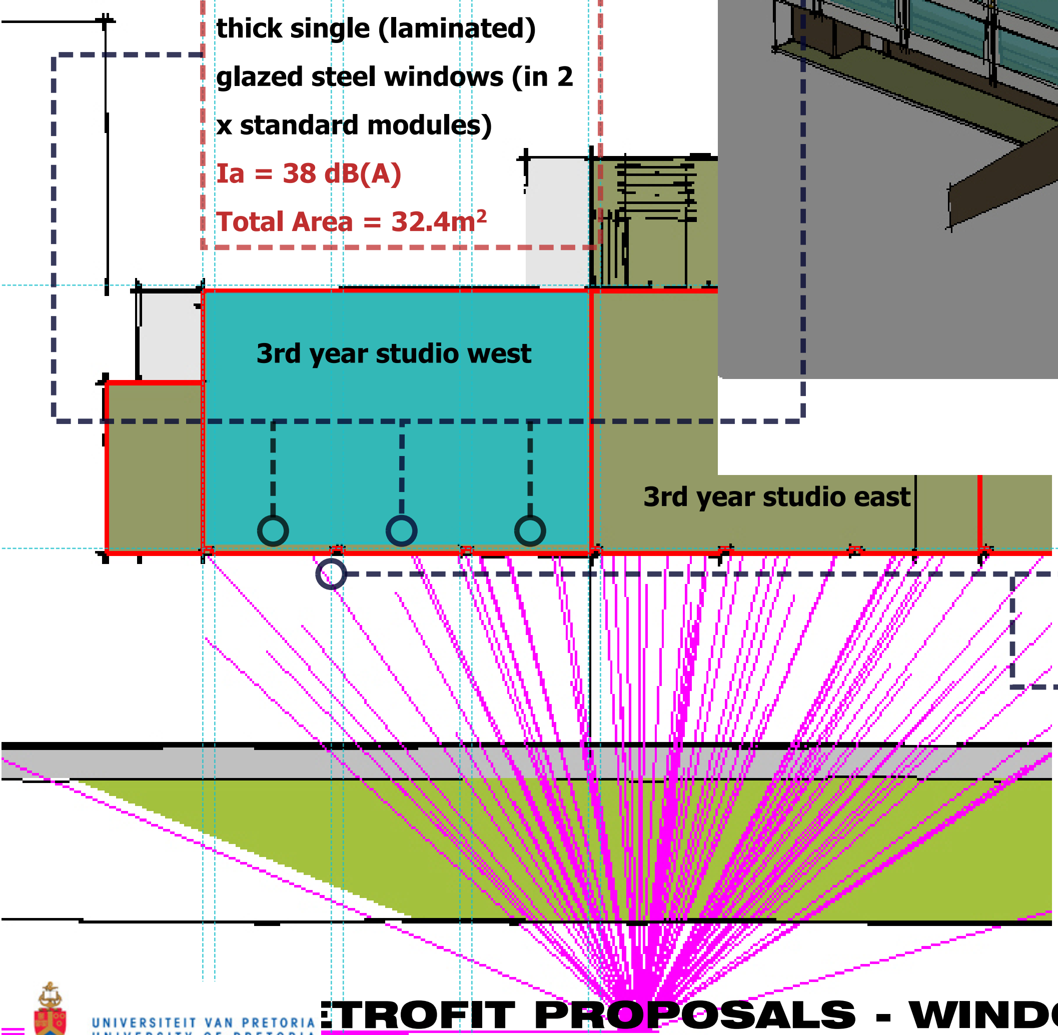
Total Area = 18m²

Panel A2 - 3 x 2m high x 5.4mm wide x 8.76mm thick single (laminated) glazed steel windows (in 2 x standard modules)

Ia = 38 dB(A)

Total Area = 32.4m²





Panel B - 3 x 2m high x 500mm wide x 4mm thick double glazed steel windows (100mm air gap)

Ia = 39 dB(A)

Total Area = 3.0m2

Panel C - 3 x 1m high x 500mm wide x 150mm thick plastered brickwork window sill panel

Ia = 48 dB(A)

Total Area = 1.5m2

TOTAL NOISE REDUCTION CAPACITY

3rd year studio (west) wall panels:

Panel A1 + A2 relationship:

Area Ratio (high R : low R)

18m² : 32.4m² = 1 : 1.8

dR = R1 - R2

= 52 - 38

= 14

Net R_(A)

= 52 - 12.5

= 39.5 dB(A)

Panel B + C relationship:

Area Ratio (high R : low R)

1.5m² : 3.0m² = 1 : 2

dR = R1 - R2

= 48.0 - 39.0

= 9

Net R_(BC)

= 48.0 - 7.5

= 40.5 dB(A)

Panel (A) + (BC) relationship:

Area Ratio (high R : low R)

4.5m² : 50.4m² = 1 : 11.2

dR = R1 - R2

= 40.5 - 39.5

= 1

Net R_(ABC)

= 40.5 - 1.0

= 39.5 dB(A) - previously 48.7 dB(A)

ETROFIT PROPOSALS - WINDOW AREA

Material	Thickness mm	Surface Density kg/m²	Transmission Loss * (TL) dB
Polycarbonate	8-12	10-14	30-33
Acrylic [Poly-Methyl-Meta- Acrylate (PMMA)]	15	18	32
Concrete Block 200x200x400 light weight	200	151	34
Dense concrete	100	244	40
Light concrete	150	244	39
Light concrete	100	161	36
Brick	150	288	40
Steel, 18 ga	1.27	9.8	25
Steel, 20 ga	0.95	7.3	22
Steel, 22 ga	0.79	6.1	20
Steel, 24 ga	0.64	4.9	18
Aluminium Sheet	1.59	4.4	23
Aluminium Sheet	3.18	8.8	25
Aluminium Sheet	6.35	17.1	27
Wood	25	18	21
Plywood	13	8.3	20
Plywood	25	16.1	23
Absorptive panels with polyester film backed by metal sheet	50-125	20-30	30-47

* Values assuming no openings or gaps in the barriers

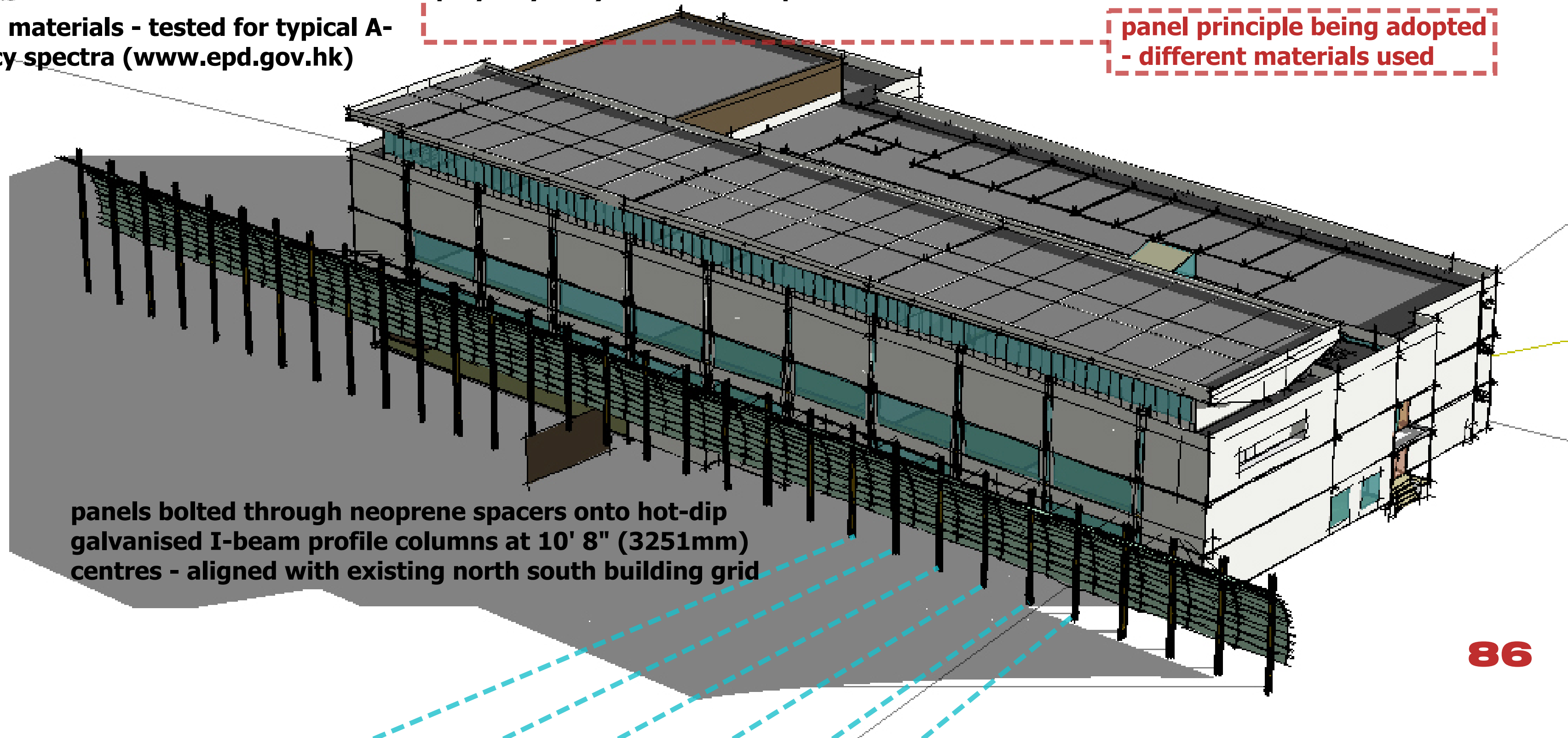
Table 8 : TL values for common materials - tested for typical A-weighted traffic noise frequency spectra (www.epd.gov.hk)

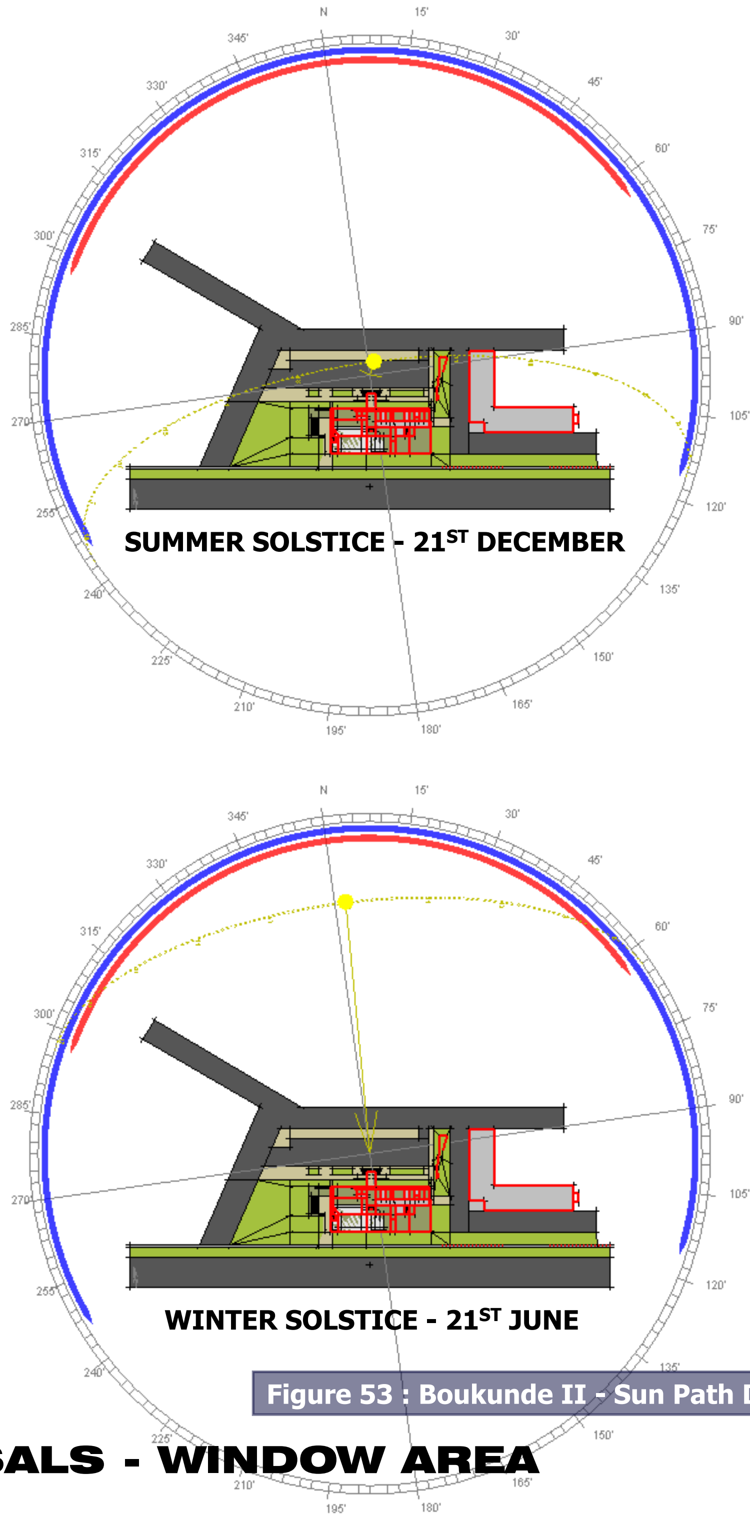
Boukunde II conceded a trade-off between daylight factor and traffic noise reduction - with the former sacrificed to the benefit of the latter. The merits of a 'daylight corrective' proposal are surely void if they are merely a reversal of fortunes.

The daylighting proposal as it currently stands, sees a noise reduction capacity drop. The previous concrete building skin, acting as a reasonably effective acoustic barrier construction has been compromised, and the noise attenuation strategy now changes from primary sound transmission loss via barrier design only - to a combination of transmission loss & external sound absorption.

Having acoustically degraded the building skin by breaking through glazing panels (albeit glazing with a high Airborne Sound Insulation rating), the 'noise-proofing' of the southern facade could be supplemented via absorptive acoustic baffles. The proposed panels comprise a primary absorbent core material (low-density polyethylene) with an absorption co-efficient of 0.35-0.95 in the mid-octave bands.

3m wide x 1.5m high x 50mm thick sandwich panel comprising stainless steel wire mesh outer skin with 50mm thick SONDOR Quash polyethylene foam panel mounted in a welded stainless steel 304 U-profile





The building is to be analyzed with reference to the solar positional extremes - winter & summer solstice. They represent annual set-points at which time a major climatic factor becomes measurable - the angle of the Sun relative to the project site.

These 2 dates do not necessarily represent climatic extremes i.t.o. temperature, rainfall, wind speed etc., but the analysis specifically relates to the impact of the Sun's position on the building in question.

The ultimate intent is to maximize passive design potential primarily driven by solar concepts - with the impact of climate factors and the building's operational profile viewed as supplementary elements.

The sum total of all these factors will then reflect an annual variation in conditions that need to be catered for in isolated zones- as well as through the length & breadth of the building.

Figure 53 : Boukunde II - Sun Path Diagrams - Summer & Winter Solstice

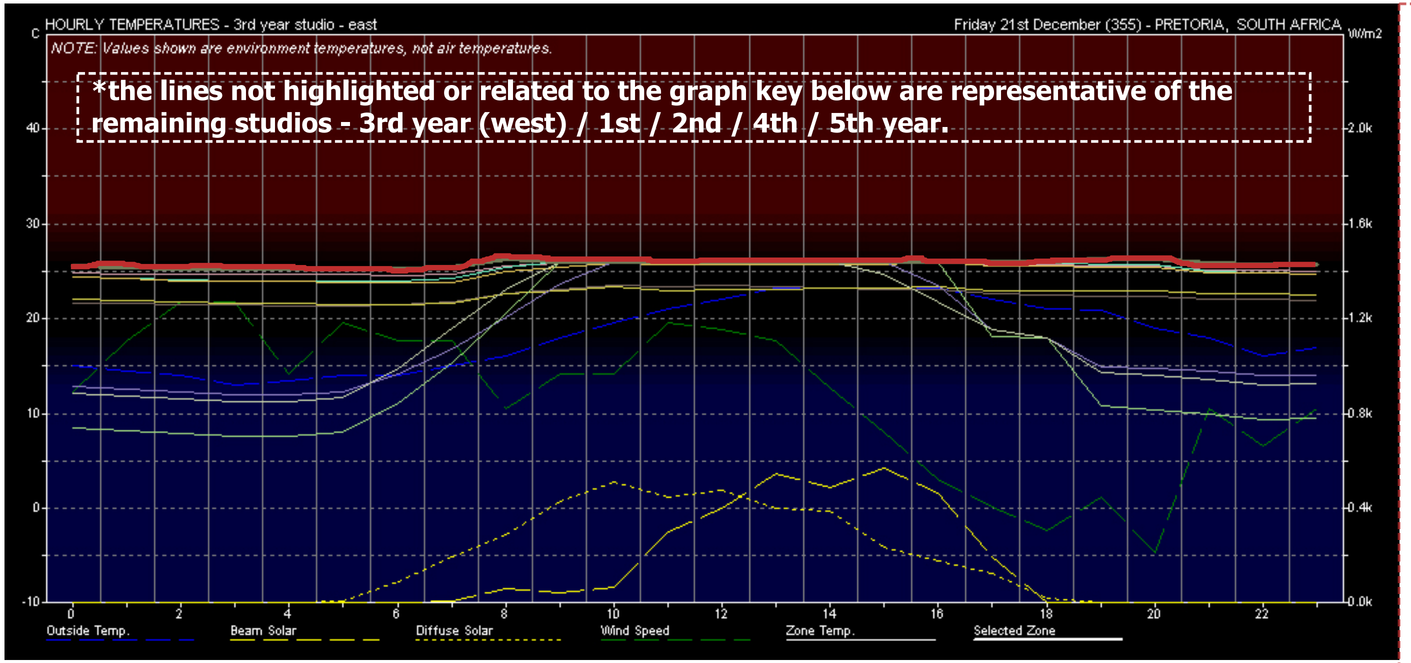
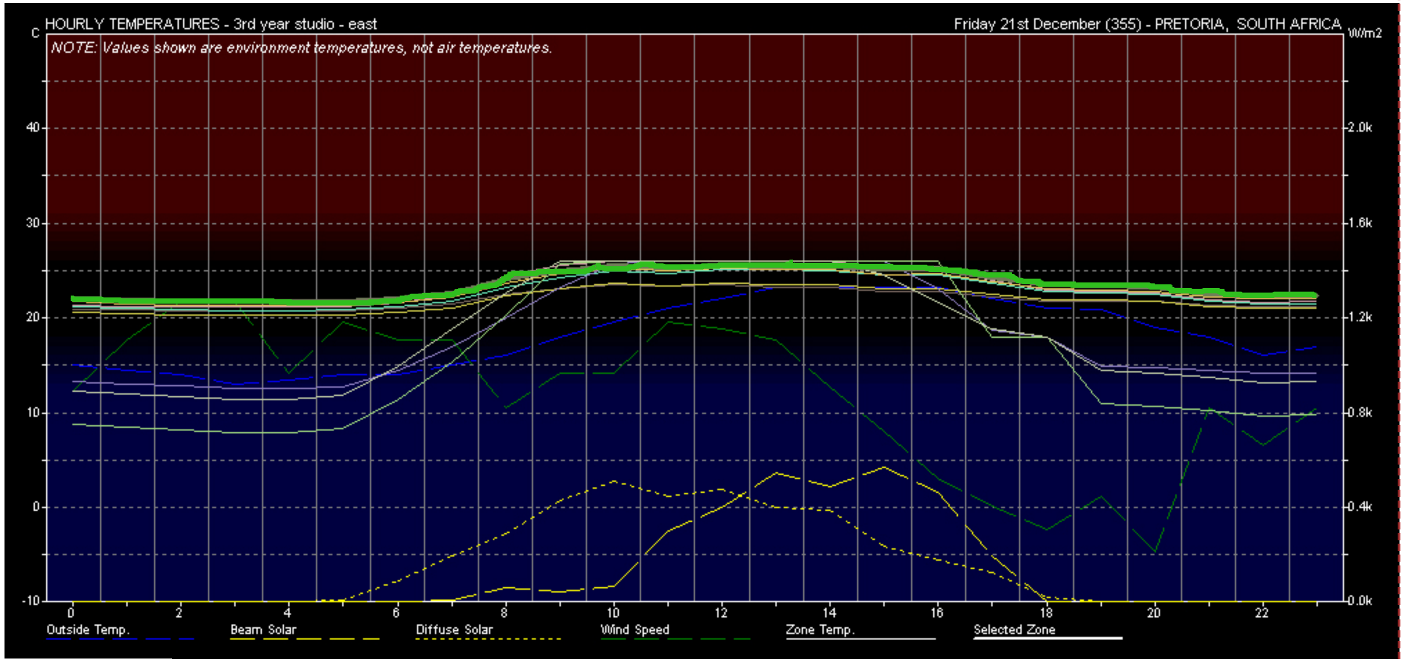


Table 9 : Environment Temperature (hourly) - summer solstice - 3rd year studio (east) - EXISTING



) : Environment Temperature (hourly) - summer solstice - 3rd year studio (east) - TEST PROPOSAL 3

All studio spaces have the following common characteristics:

- **Mixed-mode air-conditioning (being a combination of natural ventilation during summer months & central air-conditioning to cover the set-points during summer and winter).**
- **Comfort zone a/c set-points from min. 18ºC - 26ºC (represented by the middle un-shaded band of the graph).**
- **Academic year programme from 01/02 - 30/06 & 15/07 - 30/09 & 08/10 - 20/12**
- **Operational weekday office hours from 08h00 - 18h00**
- **Operational weekend hours from 09h00 - 15h00**
- **Summer months from 01/02 - 31/04 & 01/09 - 30/11 (applicable to natural ventilation rates - windows being opened)**
- **Ventilation air change rate of 0.5 x zone volume per hour (0.5 ACH)**

These aspects have been kept constant for the existing building condition as well as any retrofit proposals - so as to substantively analyze the retrofit impact on a zone-by-zone basis.

Table 11 : Hourly Temperature comparison - winter solstice

EXISTING

Zone: 3rd year studio - east
Avg. Temperature: 10.0 C (Ground 15.9 C)
Total Surface Area: 594.200 m2 (309.5% flr area).
Total Exposed Area: 77.556 m2 (40.4% flr area).
Total North Window: 0.000 m2 (0.0% flr area).
Total Window Area: 2.000 m2 (1.0% flr area).
Total Conductance (AU): 219 W/°K
Total Admittance (AY): 2966 W/°K
Response Factor: 9.74

HOUR	INSIDE (C)	OUTSIDE (C)	TEMP.DIF (C)
0	16	7	9
1	15.9	7	8.9
2	15.9	8	7.9
3	15.7	6	9.7
4	15.7	7.1	8.6
5	15.7	6.5	9.2
6	15.7	6	9.7
7	15.7	8.8	6.9
8	16.6	10.6	6
9	18	12.3	5.7
10	18	14.1	3.9
11	18	16	2
12	18	17	1
13	18	17.9	0.1
14	18	18	0
15	18	16.5	1.5
16	18	15	3
17	18	13.6	4.4
18	18	12.3	5.7
19	17	10.9	6.1
20	17	10.4	6.6
21	16.3	10	6.3
22	16.3	8.9	7.4
23	16.2	8.9	7.3

TEST PROPOSAL 3

Zone: 3rd year studio - east
Avg. Temperature: 10.0 C (Ground 15.9 C)
Total Surface Area: 594.200 m2 (309.5% flr area).
Total Exposed Area: 130.676 m2 (68.1% flr area).
Total North Window: 0.000 m2 (0.0% flr area).
Total Window Area: 23.600 m2 (12.3% flr area).
Total Conductance (AU): 333 W/°K
Total Admittance (AY): 2494 W/°K
Response Factor: 6.05

HOUR	INSIDE (C)	OUTSIDE (C)	TEMP.DIF (C)
0	13.7	7	6.7
1	13.6	7	6.6
2	13.7	8	5.7
3	13.4	6	7.4
4	13.4	7.1	6.3
5	13.4	6.5	6.9
6	13.3	6	7.3
7	13.6	8.8	4.8
8	14.7	10.6	4.1
9	18	12.3	5.7
10	18	14.1	3.9
11	18	16	2
12	18	17	1
13	18	17.9	0.1
14	18	18	0
15	18	16.5	1.5
16	18	15	3
17	18	13.6	4.4
18	18	12.3	5.7
19	14.8	10.9	3.9
20	14.8	10.4	4.4
21	14.2	10	4.2
22	14.1	8.9	5.2
23	14	8.9	5.1

Table 12 : Hourly Temperature comparison - summer solstice

EXISTING

Zone: 3rd year studio - east
Avg. Temperature: 18.4 C (Ground 15.9 C)
Total Surface Area: 594.200 m2 (309.5% flr area).
Total Exposed Area: 77.556 m2 (40.4% flr area).
Total North Window: 0.000 m2 (0.0% flr area).
Total Window Area: 2.000 m2 (1.0% flr area).
Total Conductance (AU): 219 W/°K
Total Admittance (AY): 2966 W/°K
Response Factor: 9.74

HOUR	INSIDE (C)	OUTSIDE (C)	TEMP.DIF (C)
0	25.5	15	10.5
1	25.4	14.4	11
2	25.3	14	11.3
3	25.3	13	12.3
4	25.2	13.4	11.8
5	25.2	14	11.2
6	25.2	14	11.2
7	25.3	15	10.3
8	26.3	16	10.3
9	26	18	8
10	26	19.6	6.4
11	26	21	5
12	26	22.1	3.9
13	26	23.2	2.8
14	26	23.2	2.8
15	26	23.2	2.8
16	26	23.2	2.8
17	26	22.1	3.9
18	26	21	5
19	26.3	20.9	5.4
20	26.3	19	7.3
21	25.8	18	7.8
22	25.8	16	9.8
23	25.7	17	8.7

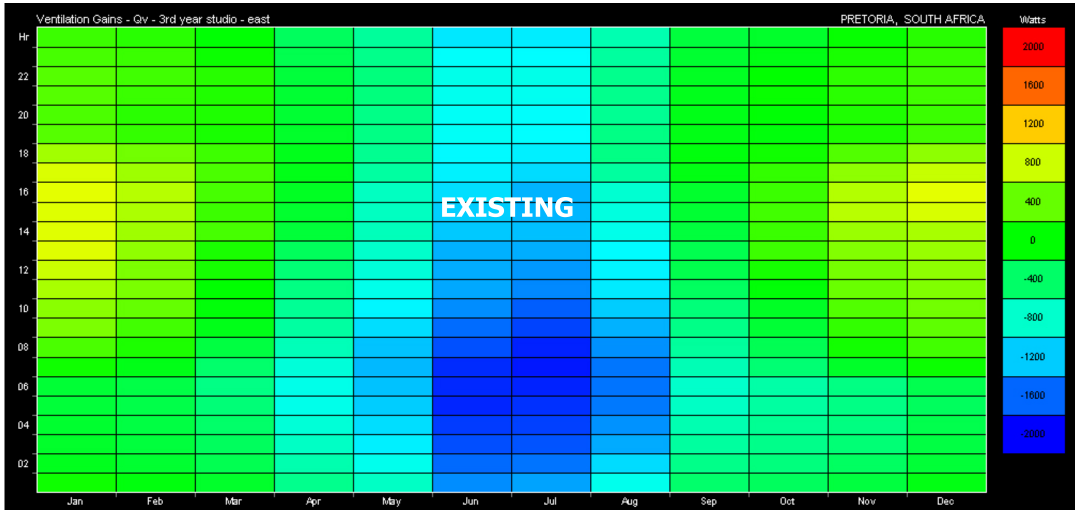
TEST PROPOSAL 3

Zone: 3rd year studio - east
Avg. Temperature: 18.4 C (Ground 15.9 C)
Total Surface Area: 594.200 m2 (309.5% flr area).
Total Exposed Area: 130.676 m2 (68.1% flr area).
Total North Window: 0.000 m2 (0.0% flr area).
Total Window Area: 23.600 m2 (12.3% flr area).
Total Conductance (AU): 333 W/°K
Total Admittance (AY): 2494 W/°K
Response Factor: 6.05

HOUR	INSIDE (C)	OUTSIDE (C)	TEMP.DIF (C)
0	22.1	15	7.1
1	21.9	14.4	7.5
2	21.8	14	7.8
3	21.7	13	8.7
4	21.7	13.4	8.3
5	21.7	14	7.7
6	22	14	8
7	22.6	15	7.6
8	24.2	16	8.2
9	25	18	7
10	25.6	19.6	6
11	25.3	21	4.3
12	25.5	22.1	3.4
13	25.4	23.2	2.2
14	25.5	23.2	2.3
15	25.1	23.2	1.9
16	25.1	23.2	1.9
17	24.2	22.1	2.1
18	23.5	21	2.5
19	23.4	20.9	2.5
20	23.2	19	4.2
21	22.5	18	4.5
22	22.3	16	6.3
23	22.4	17	5.4

Winter Solstice Comparison: In winter the most evident trend is an increase in night-time heat losses through the glazed panels. Due to the fact that this glazing will not be exposed to any incident solar radiation in winter, it does not contribute to zonal heat gain through the course of the day. The daytime constants however, are deceptive as the zone is currently a mixed-mode volume that is served by a combination of natural ventilation (through the fenestration slivers) & central a/c which has a lower set-point of 18ºC - the zone can never dip below this set-point during office hours according to the operational schedule assigned to it - only if the a/c is completely set aside will the zone operate under ambient conditions.

Summer Solstice Comparison: With the a/c upper set-point at max. 26ºC the existing scenario illustrates the slight thermal lag capacity inherent in the concrete building skin from direct (beam) solar peaking at approx. 15h00, whereas the glazing proposal indicates a fairly rapid temperature drop commensurate with the external ambient conditions. Summer heat loss through the glazed skin is therefore seen to be ... in both seasons, with heat gain being negligible in summer & non-existent in winter.



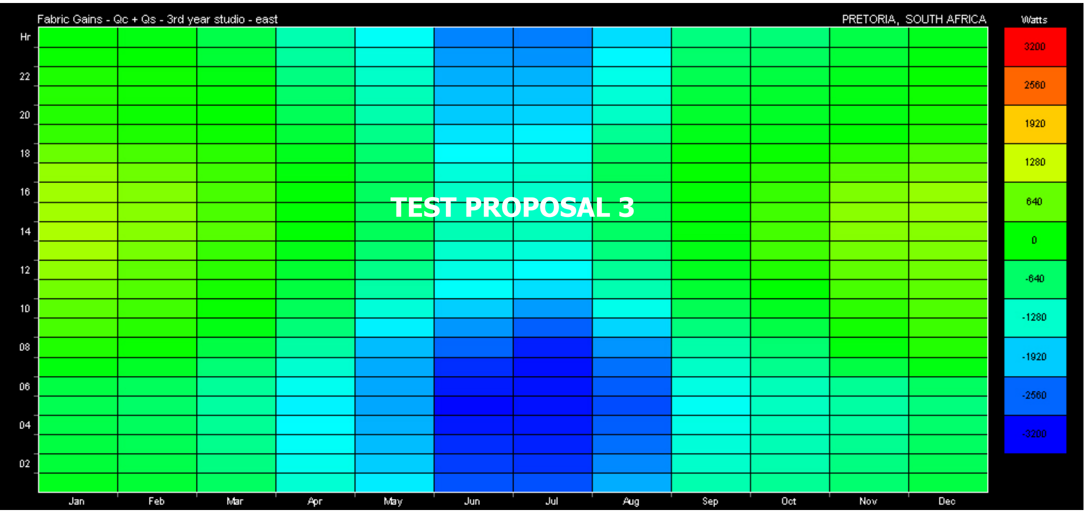


Table 13 & 14 : Fabric Gains / Losses (annual) - 3rd year studio (east)

COMPARISON:

(7 842 Wh gain) + (1 529 Wh loss) = 6 313 Watt hours nett heat loss - Mid-summer - (7 479 Wh gain) + (3 994 Wh loss) = 3 485 Watt hours nett heat loss

32 146 Watt hours nett heat loss - Mid-winter - 50 478 Watt hours nett heat loss

ANNUAL LOADS TABLE - EXISTING

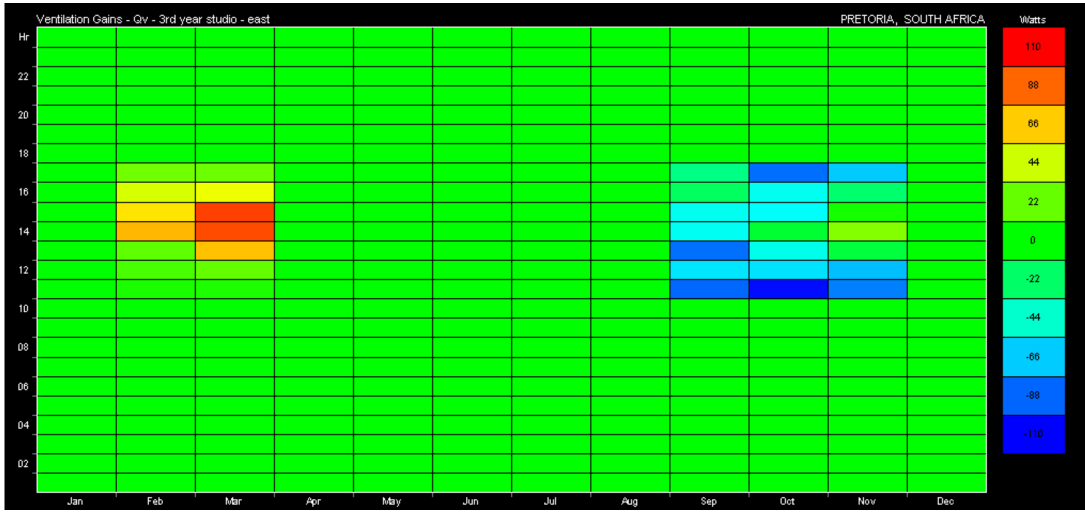
Fabric Gains - Qc + Qs
3rd year studio - east - Monthly Averages

HOUR	JAN (Wh)	FEB (Wh)	MAR (Wh)	APR (Wh)	MAY (Wh)	JUN (Wh)	JUL (Wh)	AUG (Wh)	SEP (Wh)	OCT (Wh)	NOV (Wh)	DEC (Wh)
0	51	-49	-167	-550	-766	-1443	-1356	-928	-420	-367	-245	-76
1	-116	-191	-318	-680	-924	-1583	-1545	-1138	-536	-490	-378	-214
2	-168	-238	-366	-770	-1062	-1692	-1673	-1329	-618	-543	-458	-265
3	-187	-261	-407	-841	-1130	-1769	-1746	-1424	-688	-578	-503	-305
4	-225	-285	-463	-918	-1198	-1853	-1812	-1525	-772	-632	-521	-361
5	-210	-277	-518	-914	-1242	-1841	-1865	-1545	-790	-655	-512	-308
6	59	-90	-417	-850	-1275	-1830	-1907	-1537	-707	-448	-164	49
7	290	110	-258	-721	-1236	-1686	-1870	-1432	-611	-326	73	259
8	481	256	-95	-629	-1131	-1575	-1735	-1301	-529	-210	196	366
9	535	391	-32	-584	-1038	-1449	-1632	-1195	-474	-145	322	442
10	661	479	0	-512	-915	-1339	-1463	-1080	-373	-28	414	501
11	791	484	88	-461	-846	-1324	-1401	-1039	-304	87	464	555
12	871	563	98	-357	-794	-1307	-1317	-1013	-308	236	511	596
13	877	624	276	-221	-729	-1212	-1245	-914	-241	224	605	659
14	868	674	233	-183	-756	-1189	-1286	-874	-200	255	721	840
15	894	708	277	-139	-752	-1128	-1293	-817	-177	225	702	894
16	851	621	291	-91	-631	-1054	-1140	-623	-73	198	551	770
17	629	444	244	-106	-563	-1021	-1060	-516	-50	65	319	552
18	338	204	95	-166	-522	-962	-998	-517	-83	-40	108	255
19	293	163	118	-201	-530	-963	-986	-571	-90	-16	121	229
20	336	226	127	-201	-490	-934	-942	-551	-106	29	164	256
[illegible]	[illegible]	[illegible]	152	-234	-486	-917	-911	-550	-135	6	176	252
[illegible]	[illegible]	[illegible]	47	-310	-546	-983	-1008	-620	-191	-80	98	212
[illegible]	[illegible]	[illegible]	-11	-364	-609	-1092	-1073	-689	-238	-165	25	155

ANNUAL LOADS TABLE - TEST PROPOSAL 3

Fabric Gains - Qc + Qs
3rd year studio - east - Monthly Averages

HOUR	JAN (Wh)	FEB (Wh)	MAR (Wh)	APR (Wh)	MAY (Wh)	JUN (Wh)	JUL (Wh)	AUG (Wh)	SEP (Wh)	OCT (Wh)	NOV (Wh)	DEC (Wh)
0	-186	-337	-607	-1325	-1718	-2693	-2694	-2119	-1091	-934	-694	-414
1	-352	-467	-807	-1490	-1909	-2817	-2898	-2336	-1273	-1093	-803	-546
2	-409	-530	-881	-1558	-2019	-2924	-2997	-2502	-1360	-1132	-912	-609
3	-455	-587	-934	-1613	-2085	-3051	-3060	-2611	-1439	-1165	-1009	-673
4	-512	-642	-1000	-1671	-2154	-3156	-3098	-2727	-1531	-1210	-1017	-776
5	-421	-572	-957	-1504	-2143	-3033	-3091	-2618	-1423	-1161	-932	-606
6	-87	-244	-730	-1301	-2123	-2917	-3106	-2491	-1240	-885	-422	-109
7	202	54	-426	-1028	-2017	-2572	-3010	-2266	-1057	-701	-65	214
8	455	234	-123	-747	-1682	-2244	-2602	-1858	-766	-434	112	370
9	565	405	44	-553	-1353	-1901	-2221	-1471	-525	-195	281	489
10	715	518	132	-396	-1043	-1570	-1796	-1103	-304	5	454	571
11	901	582	267	-301	-851	-1427	-1583	-939	-178	199	604	688
12	1031	736	337	-134	-676	-1285	-1357	-779	-122	406	717	778
13	1073	844	536	-17	-558	-1137	-1171	-633	-54	424	833	836
14	1011	847	465	-19	-585	-1169	-1249	-619	-31	400	866	942
15	1001	818	454	-25	-594	-1247	-1273	-606	-16	333	788	932
16	936	683	389	-64	-575	-1373	-1277	-527	26	243	561	746
17	667	448	265	-180	-687	-1590	-1457	-646	-35	48	264	501
18	325	171	75	-360	-860	-1757	-1663	-924	-160	-157	-24	182
19	212	80	16	-538	-1083	-1926	-1868	-1242	-278	-238	-114	107
20	226	101	-36	-656	-1151	-2000	-1968	-1348	-376	-285	-121	88
21	177	84	-105	-809	-1259	-2094	-2080	-1465	-508	-404	-176	35
22	53	12	-329	-992	-1407	-2223	-2275	-1639	-663	-586	-337	-84
23	-22	-101	-451	-1105	-1554	-2372	-2418	-1807	-797	-747	-447	-177



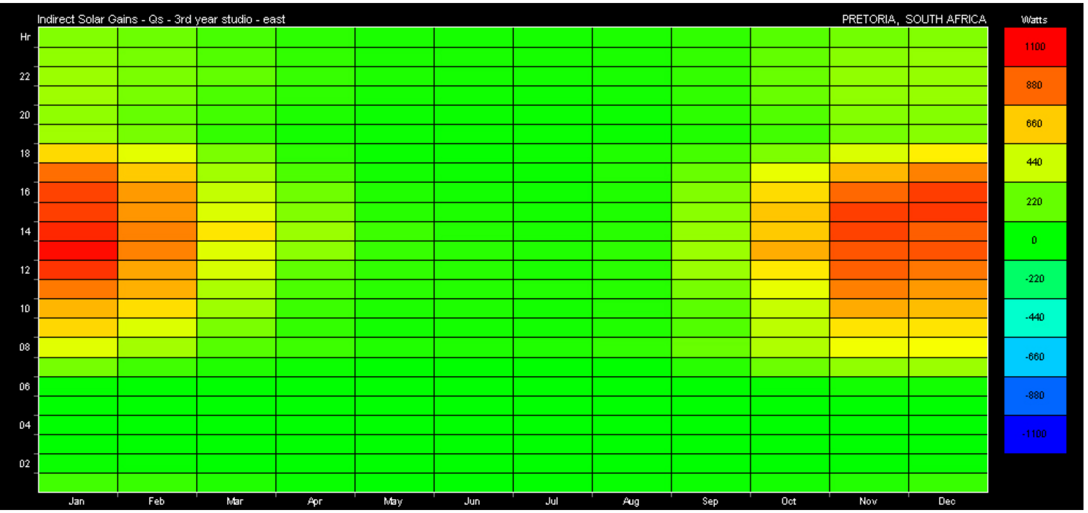


Table 15 & 16 : Ventilation / Infiltration Gains / Losses (annual) & Indirect Solar Gains (annual) - 3rd year studio (east) - EXISTING & TEST PROPOSAL 3

Ventilation / Infiltration : The gains & losses for both scenarios differ by an insignificant margin (less than 1 Wh) in most instances, which is attributed to infiltration via the less airtight glazed panels vs. homogenous full concrete panels - with ventilation rates identical due to new glazing being fixed pane.

Indirect Solar : The lesser capacity of glass to prevent solar gain or loss - even diffuse solar - is demonstrated, and the pattern of greater daytime gains coupled with greater night-time losses is evident for the glazing proposal over the existing concrete facade.

ANNUAL LOADS TABLE - EXISTING & TEST PROPOSAL 3

Ventilation Gains - Qv
3rd year studio - east - Monthly Averages

HOUR	JAN (Wh)	FEB (Wh)	MAR (Wh)	APR (Wh)	MAY (Wh)	JUN (Wh)	JUL (Wh)	AUG (Wh)	SEP (Wh)	OCT (Wh)	NOV (Wh)	DEC (Wh)
0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0
10	0	6	6	0	0	0	0	0	-88	-107	-83	0
11	0	16	21	0	0	0	0	0	-60	-61	-69	0
12	0	20	68	0	0	0	0	0	-86	-51	-13	0
13	0	70	94	0	0	0	0	0	-52	-11	29	0
14	0	61	96	0	0	0	0	0	-52	-54	4	0
15	0	46	51	0	0	0	0	0	-21	-52	-24	0
16	0	24	23	0	0	0	0	0	-29	-86	-66	0
17	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0
				0	0	0	0	0	0	0	0	0
				0	0	0	0	0	0	0	0	0
				0	0	0	0	0	0	0	0	0

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ANNUAL LOADS TABLE - EXISTING & TEST PROPOSAL 3

Indirect Solar Gains - Qs
3rd year studio - east - Monthly Averages

HOUR	JAN (Wh)		FEB (Wh)		MAR (Wh)		APR (Wh)	MAY (Wh)	JUN (Wh)		JUL (Wh)	AUG (Wh)	SEP (Wh)	OCT (Wh)		NOV (Wh)		DEC (Wh)	
0	141	81	121	72	68	43	17	2	0	0	4	13	26	42	24	73	41	121	69
1	23	13	14	8	1	1	0	0	0	0	0	0	0	0	0	3	1	13	7
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	8	8	0	0	0	0	0	0	0	0	0	0	0	8	8	38	38	39	39
6	251	251	139	139	68	68	26	0	0	0	0	5	88	230	230	312	312	333	333
7	485	485	351	351	187	187	130	71	64	64	68	107	223	380	380	521	521	533	533
8	637	637	474	474	263	263	109	37	41	41	38	70	177	406	406	608	608	609	609
9	708	708	621	621	341	341	125	60	63	63	43	73	199	429	429	732	732	693	693
10	842	843	722	722	370	370	162	91	77	77	73	81	257	500	501	824	830	770	776
11	986	1019	742	762	463	474	206	104	80	80	58	90	331	596	630	896	936	845	884
12	1076	1129	820	863	480	510	302	115	87	106	67	98	336	727	776	918	978	921	976
13	1015	1088	819	882	605	643	332	129	73	82	56	88	321	665	716	957	1019	897	953
14	964	1009	776	843	472	513	279	84	60	73	42	66	297	673	699	966	1011	980	1006
15	956	981	767	815	421	451	241	68	38	51	28	68	278	627	644	875	903	968	971
16	862	881	663	695	346	372	163	38	25	37	21	71	224	501	524	704	714	822	810
17	631	648	489	504	264	277	94	19	12	21	25	69	145	270	306	469	461	584	564
18	345	335	256	260	108	128	43	22	17	22	16	21	68	140	153	253	242	294	258
19	308	257	218	200	142	126	62	27	20	22	15	26	93	177	170	284	253	283	235
20	342	273	259	218	163	134	100	43	32	29	27	40	105	224	188	308	250	323	259
21	334	259	262	206	209	151	116	59	42	38	39	51	111	223	175	315	235	321	248
22	311	221	253	176	176	126	106	58	50	44	48	56	111	212	148	292	201	317	221
23	280	175	231	144	154	98	93	56	48	45	49	59	104	184	111	244	142	280	168

Table 17 : Internal Gains (annual) - 3rd year studio (east) - EXISTING & TEST PROPOSAL 3

There is no difference between the scenarios in terms of internal gains, which are assigned the following characteristics :

General :

- **Academic year programme from 01/02 - 30/06 & 15/07 - 30/09 & 08/10 - 20/12**
- **Operational weekday office hours from 08h00 - 18h00**
- **Operational weekend hours from 09h00 - 15h00**

Zone Specific :

- **30 students resident during operational hours**
- **Each student generating 70 Watts of heat energy through sedentary activity levels**
- **Sensible heat gain of 5 watts/m^2 & latent heat gain of 2 watts/m^2 through small power and lighting sources in the zone**
- **Zone floor surface area = 192m^2**

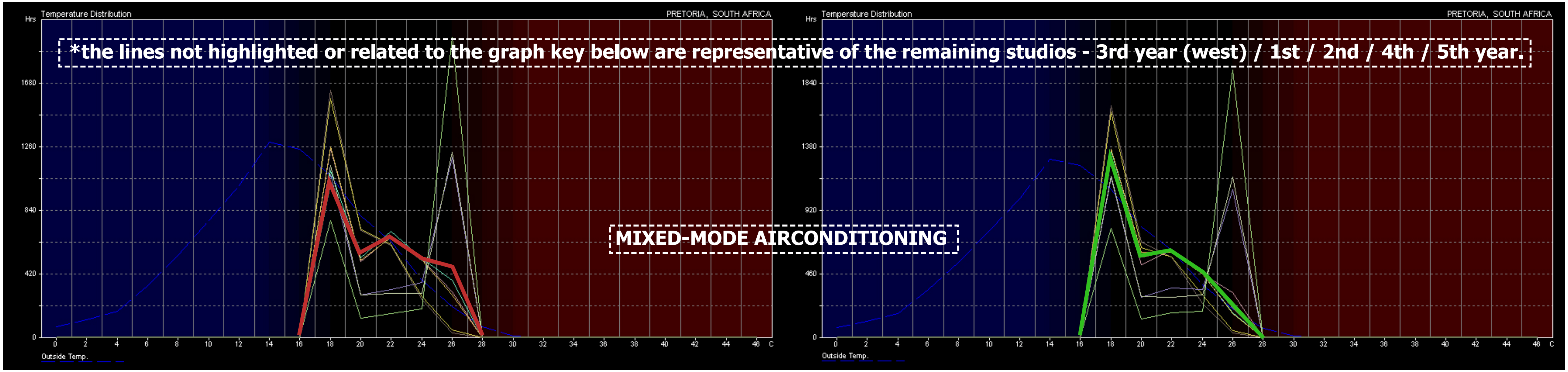


Table 18 & 19 : Temperature Distribution (annual) - 3rd year studio (east) - EXISTING & TEST PROPOSAL 3

Mixed-Mode: The impact of central air-conditioning on the zone is evident when the annual temperature distribution graphs are compared. The system 'overrides' environmental fluctuations to maintain comfort levels throughout the year, and the only noticeable difference due to increased glazing is a slight drop in the time spent at the higher comfort set temperatures (22-26°C) & more time within the lower comfort levels (18-21°C) - again, likely as a result of conductive heat loss through the glazing and not ventilation (the glazing is fixed).

Natural Ventilation: Same general trend - indicative of heat loss, but not of a significant magnitude.

*** SEE TABLE ON OVERLEAF FOR DETAIL BREAKDOWN OF GRAPH VALUES & MAGNITUDE OF VARIATION.**

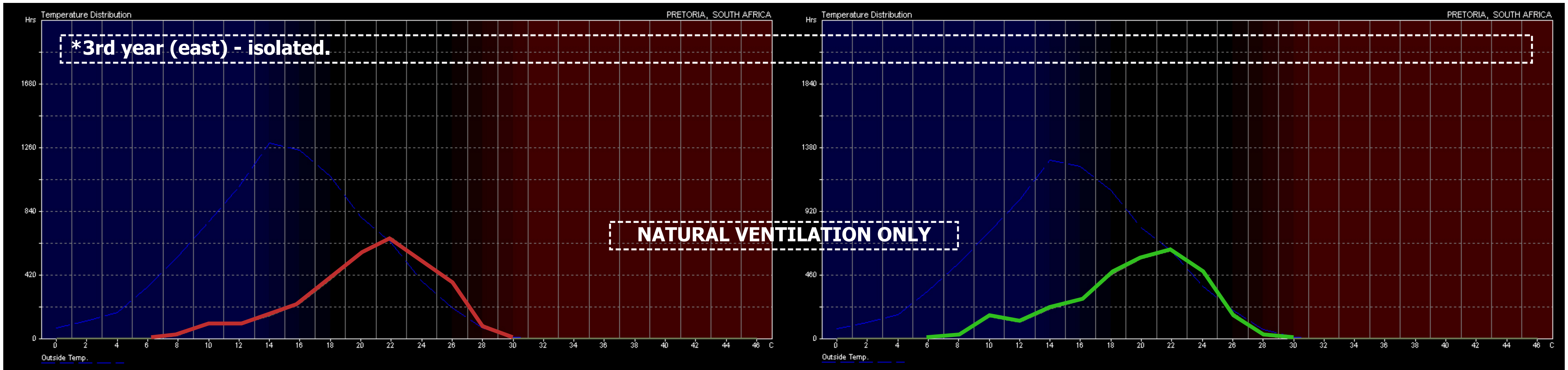


Table 20 & 21 : Temperature Distribution (annual) - 3rd year studio (east) - EXISTING & TEST PROPOSAL 3

Table 22 : Temperature Distribution comparison - mixed mode a/c vs. natural ventilation

3rd year studio - east
Operation: Weekdays 08-18, Weekends 09-15.
Comfort Band: 18.0 - 26.0 C

EXISTING						TEST PROPOSAL 3					
Mixed Mode scenario In Comfort: 3234 Hrs (100.0%)			Natural Ventilation In Comfort: 2507 Hrs (77.5%)			Mixed Mode scenario In Comfort: 3234 Hrs (100.0%)			Natural Ventilation In Comfort: 2366 Hrs (73.2%)		
TEMP.	HOURS	PERCENT	TEMP.	HOURS	PERCENT	TEMP.	HOURS	PERCENT	TEMP.	HOURS	PERCENT
0	0	0.00%	0	0	0.00%	0	0	0.00%	0	0	0.00%
2	0	0.00%	2	0	0.00%	2	0	0.00%	2	0	0.00%
4	0	0.00%	4	0	0.00%	4	0	0.00%	4	0	0.00%
6	0	0.00%	6	3	0.10%	6	0	0.00%	6	10	0.30%
8	0	0.00%	8	28	0.90%	8	0	0.00%	8	34	1.10%
10	0	0.00%	10	103	3.20%	10	0	0.00%	10	166	5.10%
12	0	0.00%	12	102	3.20%	12	0	0.00%	12	127	3.90%
14	0	0.00%	14	157	4.90%	14	0	0.00%	14	220	6.80%
16	0	0.00%	16	238	7.40%	16	0	0.00%	16	282	8.70%
18	1025	31.70%	18	395	12.20%	18	1304	40.30%	18	466	14.40%
20	565	17.50%	20	564	17.40%	20	585	18.10%	20	584	18.10%
22	666	20.60%	22	666	20.60%	22	636	19.70%	22	638	19.70%
24	511	15.80%	24	511	15.80%	24	486	15.00%	24	493	15.20%
26	467	14.40%	26	371	11.50%	26	223	6.90%	26	185	5.70%
28	0	0.00%	28	96	3.00%	28	0	0.00%	28	29	0.90%
30	0	0.00%	30	0	0.00%	30	0	0.00%	30	0	0.00%
32	0	0.00%	32	0	0.00%	32	0	0.00%	32	0	0.00%
34	0	0.00%	34	0	0.00%	34	0	0.00%	34	0	0.00%
36	0	0.00%	36	0	0.00%	36	0	0.00%	36	0	0.00%
38	0	0.00%	38	0	0.00%	38	0	0.00%	38	0	0.00%
40	0	0.00%	40	0	0.00%	40	0	0.00%	40	0	0.00%
42	0	0.00%	42	0	0.00%	42	0	0.00%	42	0	0.00%
44	0	0.00%	44	0	0.00%	44	0	0.00%	44	0	0.00%
46	0	0.00%	46	0	0.00%	46	0	0.00%	46	0	0.00%
COMFORT	3234	100.00%	COMFORT	2507	77.50%	COMFORT	3234	100.00%	COMFORT	2366	73.20%

As the graph would seem to indicate - there is a relatively minor variation in the amount of time spent in the designated comfort band owing to the additional glazing of the studio space. The lesser capacity of the glazed surface in keeping heat within the zone seems to be the primary factor to which the 4.30% difference can be attributed - as time spent below the comfort band temperatures is substantially more (208 hours) and time above the band is less (67 hours) - than those when the zone still had a concrete skin.

The extra glazing is currently assigned as fixed pane, and thus the projected air change rate has remained as it was. In both cases the variation in time spent within the comfort band seems to indicate an acceptable level of thermal comfort that could possibly reach fairly close to 100% air-conditioned levels with the addition of a less energy-intensive heating strategy.

Table 23 : Monthly Heating & Cooling loads comparison

Zone: 3rd year studio - east
Operation: Weekdays 08-18, Weekends 09-15.
Thermostat Settings: 18.0 - 26.0 C

Floor Area: 192.000 m2

EXISTING
Max Heating: 8672 W at 10:00 on 22nd July
Max Cooling: 6919 W at 15:00 on 2nd March

MONTH	HEATING (Wh)	COOLING (Wh)	TOTAL (Wh)
Jan	0	25653	25653
Feb	0	135714	135714
Mar	0	190403	190403
Apr	13305	17145	30450
May	16919	0	16919
Jun	154492	0	154492
Jul	459380	0	459380
Aug	44980	0	44980
Sep	5021	12210	17231
Oct	1145	55550	56695
Nov	0	93419	93419
Dec	0	92913	92913
TOTAL	695242	623007	1318249
PER M²	3621	3245	6866

TEST PROPOSAL 3
Max Heating: 6647 W at 10:00 on 21st July
Max Cooling: 10473 W at 13:00 on 6th February

MONTH	HEATING (Wh)	COOLING (Wh)	TOTAL (Wh)
Jan	0	67722	67722
Feb	0	174610	174610
Mar	0	188802	188802
Apr	12271	0	12271
May	31433	0	31433
Jun	202015	0	202015
Jul	466213	0	466213
Aug	41804	0	41804
Sep	988	0	988
Oct	0	76739	76739
Nov	0	117504	117504
Dec	0	26170	26170
TOTAL	754724	651547	1406272
PER M²	3931	3393	7324

Table 24 : Monthly Heating & Cooling loads comparison - varied orientation

Zone: 5th year studio - gf
Operation: Weekdays 08-18, Weekends 09-15.
Thermostat Settings: 18.0 - 26.0 C

Floor Area: 259.200 m2

Max Heating: 7164 W at 11:00 on 21st July
Max Cooling: 10534 W at 12:00 on 30th October

MONTH	HEATING (Wh)	COOLING (Wh)	TOTAL (Wh)
Jan	0	0	0
Feb	0	94184	94184
Mar	0	87109	87109
Apr	13048	0	13048
May	59599	0	59599
Jun	309761	0	309761
Jul	533259	0	533259
Aug	74877	0	74877
Sep	4185	0	4185
Oct	2825	57874	60700
Nov	0	0	0
Dec	0	0	0
TOTAL	997554	239168	1236722
PER M²	3849	923	4771

Zone: 1st year studio middle - sf
Operation: Weekdays 08-18, Weekends 09-15.
Thermostat Settings: 18.0 - 26.0 C

Floor Area: 230.400 m2

Max Heating: 38116 W at 18:00 on 20th July
Max Cooling: 341644 W at 13:00 on 9th February

MONTH	HEATING (Wh)	COOLING (Wh)	TOTAL (Wh)
Jan	0	10779658	10779658
Feb	0	11957398	11957398
Mar	0	12324979	12324979
Apr	81749	5212197	5293946
May	292025	10312901	10604926
Jun	790276	10495085	11285361
Jul	728061	12948470	13676531
Aug	233587	10736713	10970300
Sep	32474	4537664	4570138
Oct	45829	11159110	11204939
Nov	23734	10387669	10411403
Dec	0	9053516	9053516
TOTAL	2227735	119905360	122133096
PER M²	9669	520423	530092

From prior anaylsis it is clear that the presence of a central air-conditioning unit can correct most thermal imbalances within a building comprising varying zone conditions. The extent of these loads - being thermal losses and/or gains - will ultimately impact upon the building's energy consumption and it's reliance upon artificial conditioning of internal spaces. Illustrated by the monthly heating/cooling loads generated for the 3rd year studio (east) - as it currently exists, and upon breaking through the glazing panels - there is an increase in overall loads of approx. 7%. These loads are not directly related to kWh of electrical consumption, which becomes a factor air-conditioning efficiency (conversion of electrical - thermal energy), but they do offer a fair reflection of 'cause & effect.'

The 3rd year studio has been the reference in all thermal analyses as it was a locale in desperate need of daylight factor correction and is centrally located in relation to the remaining studio zones under analysis. Of these studios, it is worth noting that the existing 1st year studio (central) is the studio with the most favourable daylight conditions, but is also the space that requires the most energy to be expended in keeping it within the 18-26oC comfort band - just over 72x more energy/m² of floor area than the altered 3rd year scenario. The primary reasons for this are self-evident in the form of generous double volumes with clerestory exposure on both sides - and the merits of these aspects are not being questioned, but an alternative strategy to offset the resultant loads is needed. The existing 5th year studio condition illustrates the value of protected glazing on the eastern & northern facades (as well as the south facade), and renders a ...rate heating/cooling load in comparison - 44% less than the existing 3rd year studio condition.

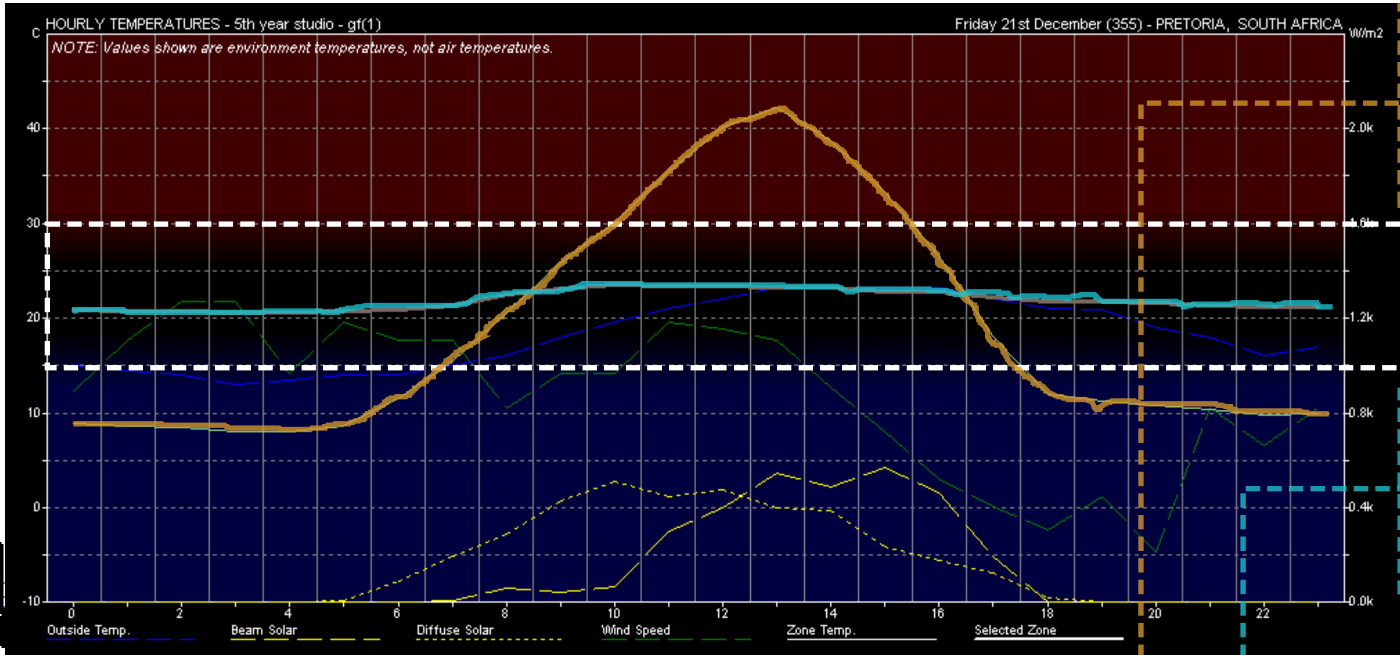


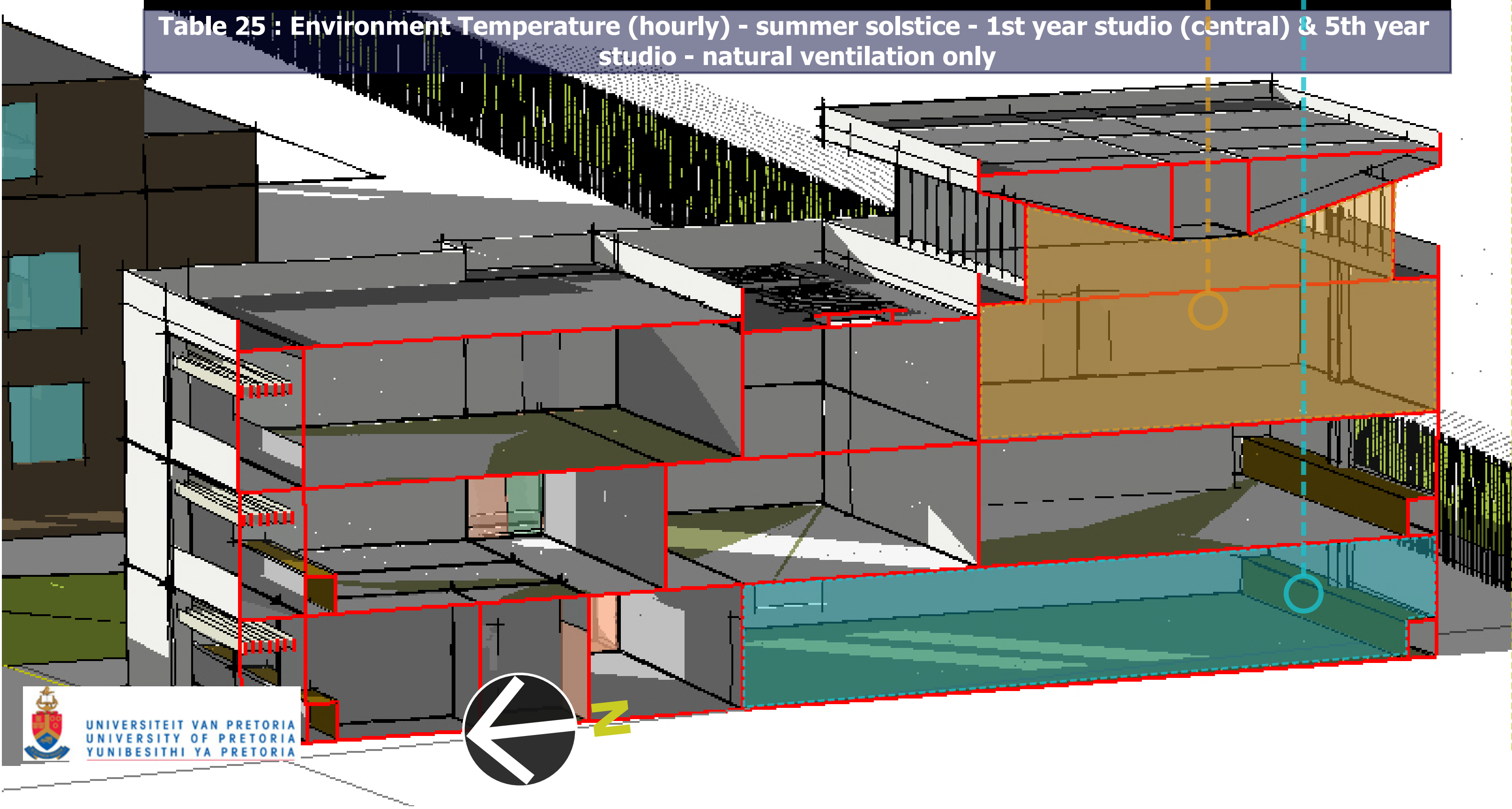
Table 25 : Environment Temperature (hourly) - summer solstice - 1st year studio (central) & 5th year studio - natural ventilation only

1st year studio (central):
- thermally in-efficient
- floor area = 230.40m²
- space volume = 1 474.59m³
- heating/cooling load = 530 092 Wh/m²
- north window area = 32.40m² (exposed)

COMFORT BAND

18 - 26ºC

5th year studio:
- thermally efficient
- floor area = 259.20m²
- space volume = 777.59m³
- heating/cooling load = 4 771 Wh/m²
- north window area = 4.00m² (protected)



The graph illustrates the vast disparity in thermal performance between the 2 locales in summer. The 1st year studio is severely exposed via it's clerestory band and concrete roof, and being that the clerestory is all fixed pane - it serves to trap heated air for necessary extraction via the ceiling mounted a/c return ducts. Over-exposure works in the volume's favour during winter - with the large temperature swing being a perennial feature of the space, but a levelling out of this diurnal thermal trend would offer greater overall efficiency.

A thermal load comparision of these 2 adjacent zones of virtually equal floor area and similar elemental exposure reveals a disparate thermal response. The primary reasons being their differing operational profiles - with the computer lab having a greater internal heat load, and a greater exposed horizontal surface area on the part of the PC lab - all contributing to a greater overall cooling load/m^2, and virtually no heating load. The crit hall in turn, has a double volume which will see most of the internal heat generated lost via convective transfer to the upper reaches. Horizontal surface fabric gains (of benefit in winter) are also reduced due to the fact that the roof surface is sunk below the level of adjacent structures and is thus overshadowed. The sunken roof is also segmented by the raised panels with glass block inlays, which serve to 'break up' what would otherwise have been a continuous conductive roof surface.

Table 26 : Monthly Heating & Cooling loads comparison - varied orientation

Zone: Computer lab - sf
Operation: Weekdays 08-18, Weekends 09-15.
Thermostat Settings: 18.0 - 26.0 C
*Served by dedicated split units

Floor Area: 104.640 m2

Max Heating: 3530 W at 18:00 on 18th June
Max Cooling: 12813 W at 13:00 on 2nd March

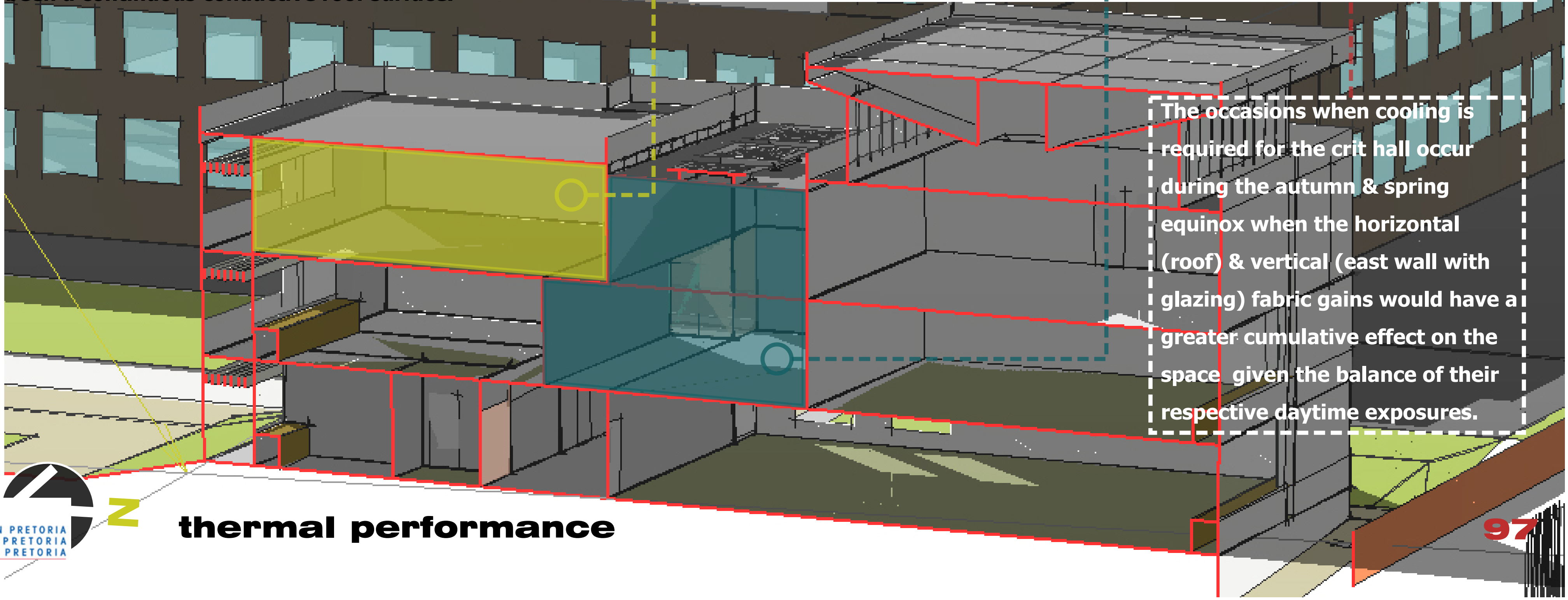
MONTH	HEATING (Wh)	COOLING (Wh)	TOTAL (Wh)
Jan	0	460838	460838
Feb	0	1573250	1573250
Mar	0	1459974	1459974
Apr	387	522594	522981
May	2323	98996	101318
Jun	10699	0	10699
Jul	35375	0	35375
Aug	0	110173	110173
Sep	0	547515	547515
Oct	0	541779	541779
Nov	0	1274248	1274248
Dec	0	1047727	1047727
TOTAL	48783	7637095	7685878
PER M²	466	72984	73451

Zone: Crit hall - double volume - ff/sf
Operation: Weekdays 08-18, Weekends 09-15.
Thermostat Settings: 18.0 - 26.0 C
*Served by central air-conditioning

Floor Area: 105.120 m2

Max Heating: 9777 W at 10:00 on 21st July
Max Cooling: 2093 W at 15:00 on 2nd March

MONTH	HEATING (Wh)	COOLING (Wh)	TOTAL (Wh)
Jan	3618	0	3618
Feb	25361	16182	41543
Mar	27	23524	23551
Apr	91553	0	91553
May	375140	0	375140
Jun	1153576	0	1153576
Jul	1496488	0	1496488
Aug	501203	0	501203
Sep	126719	0	126719
Oct	77123	6764	83887
Nov	22307	0	22307
Dec	2780	0	2780
TOTAL	3877895	46470	3924365
PER M²	36890	442	37332



The occasions when cooling is required for the crit hall occur during the autumn & spring equinox when the horizontal (roof) & vertical (east wall with glazing) fabric gains would have a greater cumulative effect on the space given the balance of their respective daytime exposures.

According to Mitchell's Practical Thermal Design in Buildings, "Lightweight buildings respond quickly to control and when intermittent heating or night setback of temperature are employed their temperature will drop rapidly, thus reducing the heat loss compared with a more massive building." (Burberry. 1983:36)

In the case of Boukunde, it is possible to compare 2 buildings with distinctly variant construction - particularily in respect of building skins - which are subject to identical ambient conditions and operational profiles.

The 2 buildings had decidedly different environmental strategies. Boukunde II is a deep-set well insulated box that 'guarantees' thermal comfort via conditioned air. Boukunde I has a relatively shallow space format that is severely exposed to the elements, and relies on its capacity to effectively cross ventilate.

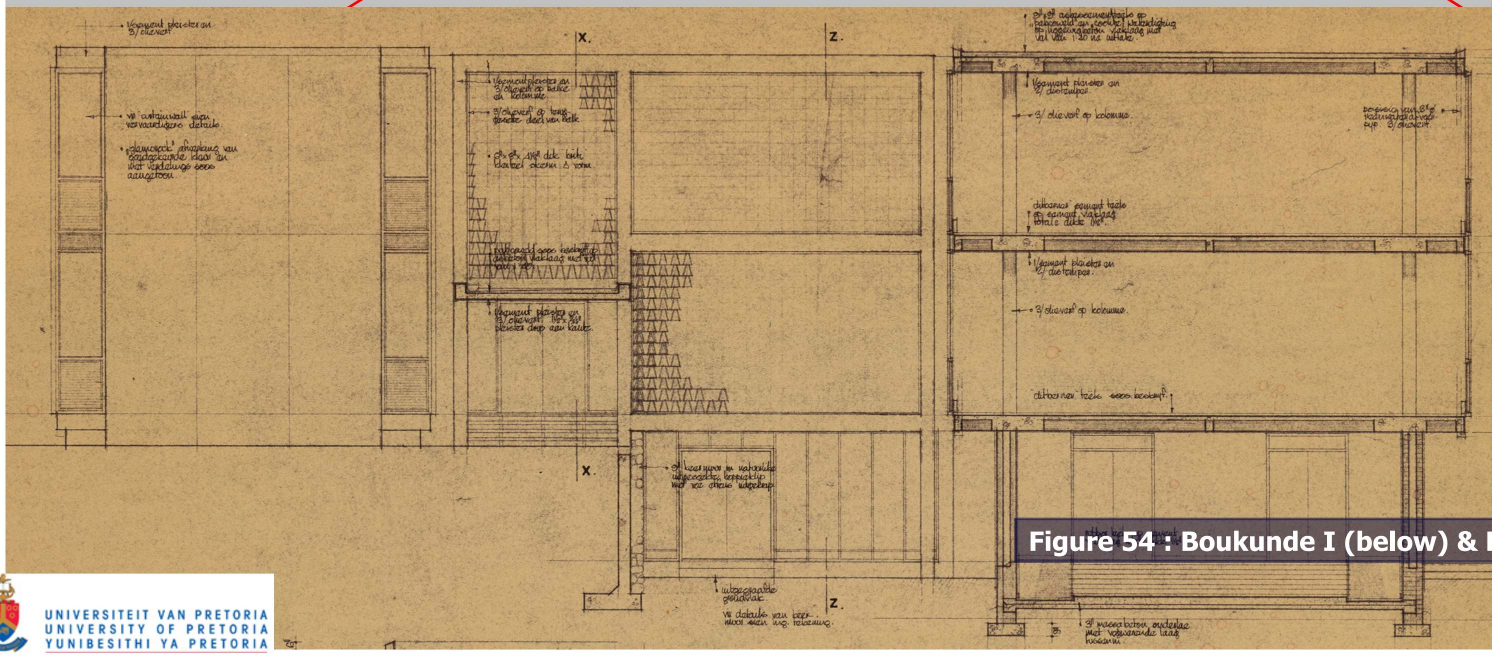


Figure 54 : Boukunde I (below) & Boukunde II - section view north-south

FIRST FLOOR		FACTOR
4th year studio	(cyan)	46.31
2nd year studio (eastern)	(yellow)	38.54
2nd year studio (western)	(yellow)	40.85
GROUND FLOOR		
5th year studio	(grey-blue)	51.65
3rd year studio (eastern)	(green)	48.66
3rd year studio (western)	(green)	52.87

*** all the studios register values above the graph threshold - with set point @ 300lux**

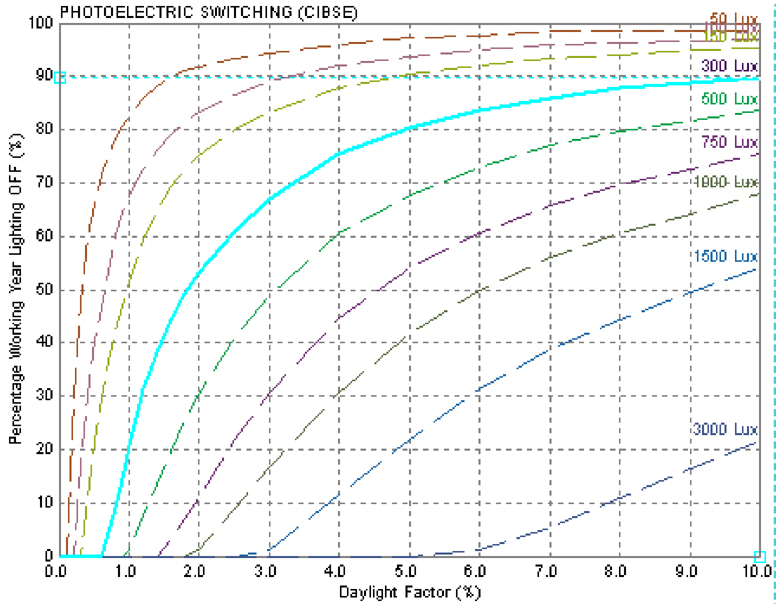


Table 27 : Average Daylight Factor - BOUKUNDE I

The studio zones of Boukunde II are simulated into the footprint and building skin of Boukunde I to determine the difference in average daylight factor that was available to the students almost 50 years ago.

The result indicates (as expected) that the studios on the southern flank of the building would have been working in a well-lit environment for approx. 90% of the working year (low winter sun angles accounting for the remaining 10%).

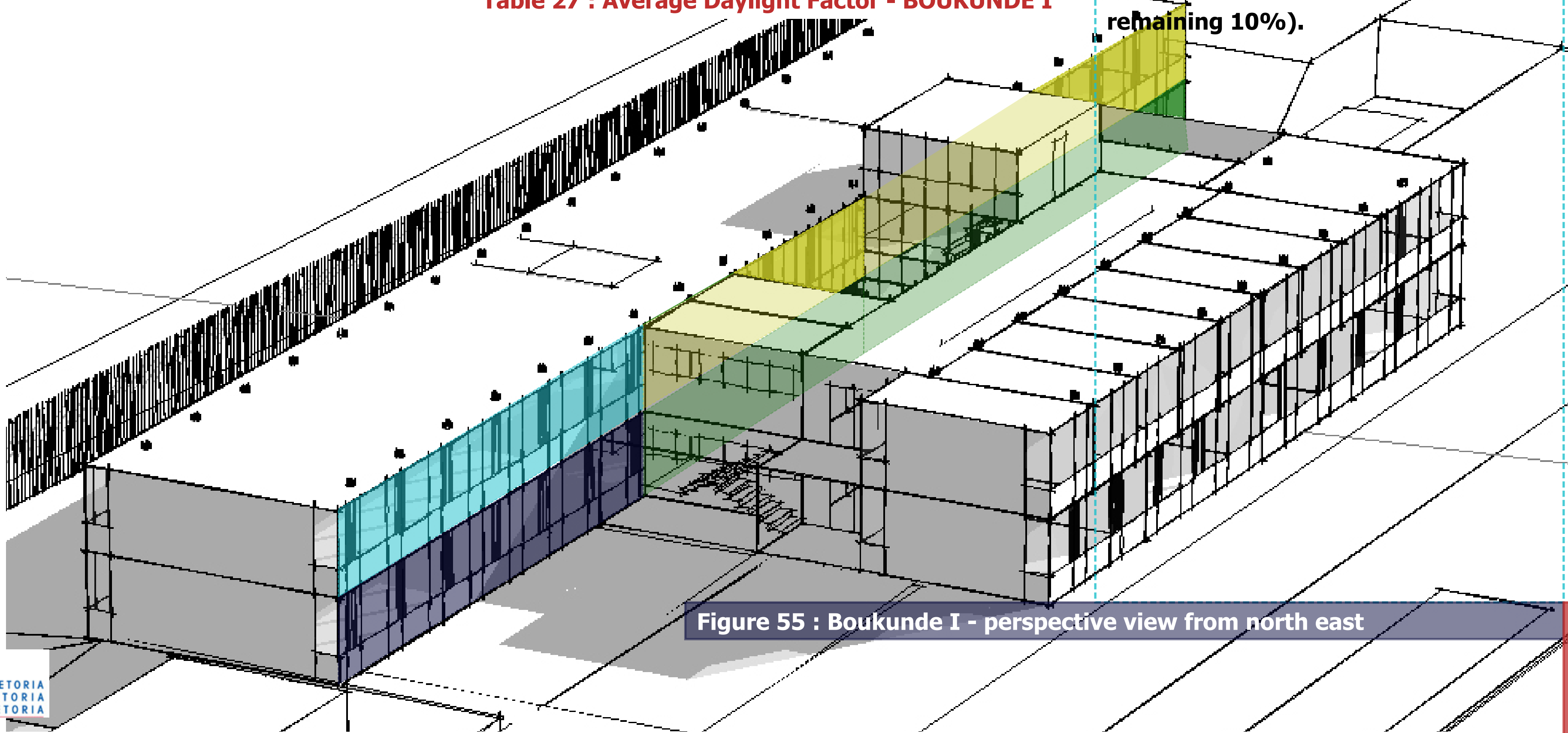


Figure 55 : Boukunde I - perspective view from north east

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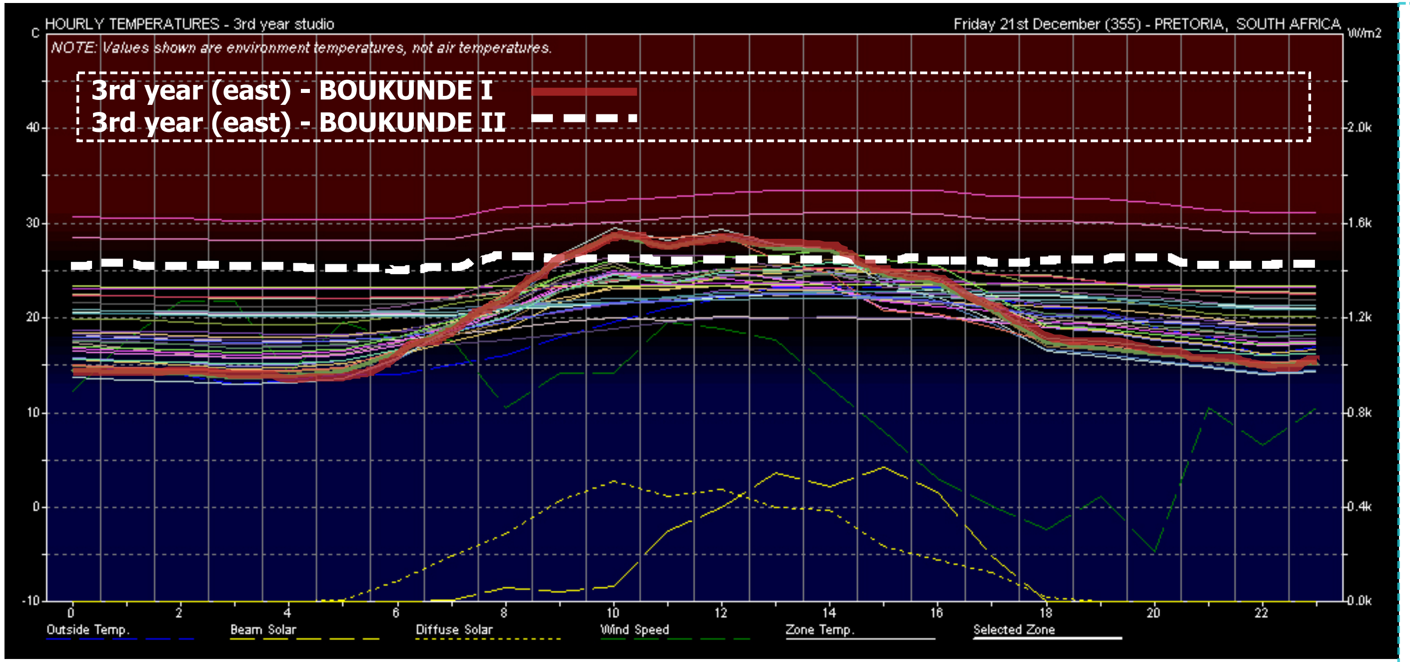
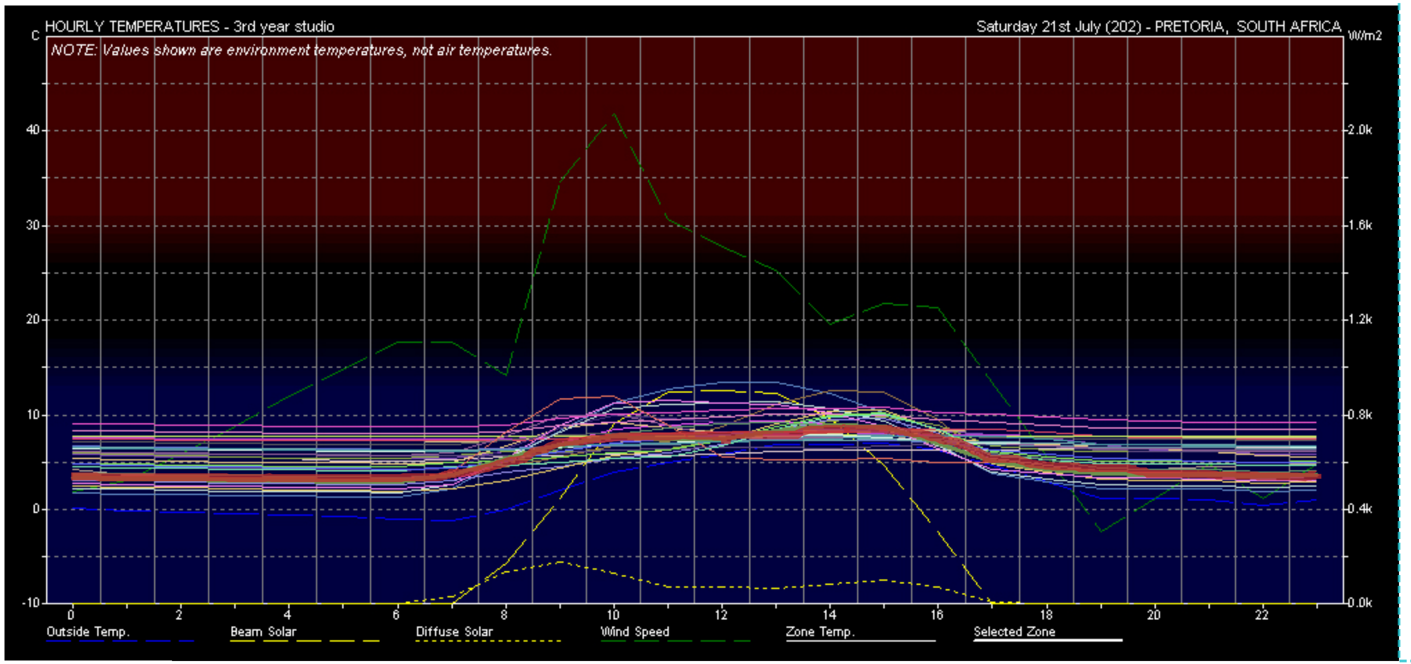


Table 28 : Environment Temperature (hourly) - summer solstice - all thermal zones - BOUKUNDE I



: Environment Temperature (hourly) - winter solstice - all thermal zones - BOUKUNDE I

The glass curtain wall construction provides more-than-adequate daylight conditions, but trades this benefit off against significant thermal 'leakage'. The glazed skin is at the mercy of the outside temperature condition and offers no protective lag in summer. The summer solstice graph relates thermal response for a diurnal range of min. 14 - max. 24ºC, so any increase in this 'mild' range would push the response well into the 'red'. The same is true in winter, with the envelope incapable of 'hanging-on' to its heat - garnered via direct solar penetration or otherwise.

DISCOMFORT DEGREE HOURS

Zone: 3rd year studio
Zone is not air-conditioned.
Occupancy: Weekdays 08-18, Weekends 10-14.
Comfort: Band = 18.0 - 26.0 C

MONTH	TOO HOT (DegHrs)	TOO COOL (DegHrs)	TOTAL (DegHrs)
Jan	118	0	118
Feb	272	5	277
Mar	216	1	217
Apr	11	71	82
May	6	272	278
Jun	11	1017	1028
Jul	0	1057	1057
Aug	7	452	459
Sep	41	57	98
Oct	82	47	130
Nov	172	16	188
Dec	136	0	136
TOTAL	1072.3	2995.3	4067.6

Hr	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Hr	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0
	522.965	319.367	26.8714	0	0	0	0	0	0	0	64.79	318.397
18	2797.88	2698.2	1878.49	409.109	36.4257	0	102.709	315.565	612.293	913.971	1494.73	2360.54
	4871.98	4652.82	4052.54	2989.31	2781.95	2949.35	3021.96	3164.13	3622.13	3300.49	3701.91	4392.36
16	6183.33	5754.14	4977.57	4376.75	4553.53	4378.65	4583.42	4702.98	5035.39	5063.29	5330.62	5881.47
	7192.9	6621.86	5742.53	4844.94	4362.39	4143.27	4157.97	4414.67	5189.99	6102.68	6697.13	7010.33
14	8120.56	7117.46	6842.06	5090.64	3662.12	3206.16	3023.11	3577.35	4695.8	6518.6	7648.6	7486.42
	8703.4	7520.5	6521.07	5129.28	2628.66	2132.81	2029.58	2846.53	4427.45	6855.88	8012.73	8039.91
12	8284.36	7093.58	6400.72	4746.21	3012.12	2624.21	2770.9	3370.96	4831.92	6375.07	7848.98	7571.38
	7545.24	7073.99	6021.21	5009.02	4124.77	3842.35	4070.83	4647.06	5395.02	6420.83	7407.82	7224.69
10	6801.55	6668.26	6043.79	5264.47	4795.36	4502.68	4593.53	5167.21	5853.26	6453.86	6980.12	7040.18
	6021.79	5705.5	5461.33	4782.04	4505.86	4039.21	4087.79	4608.5	5466.71	5958.49	6217.66	6320.49
08	4277.03	3763.75	3444.57	2757.1	2511.39	1843.96	1568.85	2147.15	3492.68	4336.45	4721.62	4860.86
	1748.92	994.133	413.864	152.411	0	0	0	31.6486	552.534	1646.14	2421.29	2387.28
06	48.014	0	0	0	0	0	0	0	0	45.98	222.754	226.456
	0	0	0	0	0	0	0	0	0	0	0	0
04	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
02	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0

Direct Solar Gains - Qg - 3rd year studio — PRETORIA, SOUTH AFRICA

Watts: 9000, 7200, 5400, 3600, 1800, 0, -1800, -3600, -5400, -7200, -9000

Table 30 : Direct Solar gains (annual) - 3rd year studio (east) - BOUKUNDE I

MONTHLY HEATING/COOLING LOADS - COMPARISON

Zone: 3rd year studio - east
Operation: Weekdays 08-18, Weekends 09-15.
Thermostat Settings: 18.0 - 26.0 C

Floor Area: 192.000 m2

BOUKUNDE I
Max Heating: 23179 W at 18:00 on 18th June
Max Cooling: 48669 W at 11:00 on 1st December

MONTH	HEATING (Wh)	COOLING (Wh)	TOTAL (Wh)
Jan	2899	1012246	1015145
Feb	3570	712039	715609
Mar	4449	840782	845231
Apr	87726	30913	118639
May	379608	0	379608
Jun	1208436	0	1208436
Jul	1434624	0	1434624
Aug	352414	0	352414
Sep	35198	9920	45118
Oct	54923	472322	527245
Nov	21059	821118	842177
Dec	0	1042995	1042995
TOTAL	3584907	4942335	8527242
	22732	31340	54073

BOUKUNDE II
Max Heating: 8672 W at 10:00 on 22nd July
Max Cooling: 6919 W at 15:00 on 2nd March

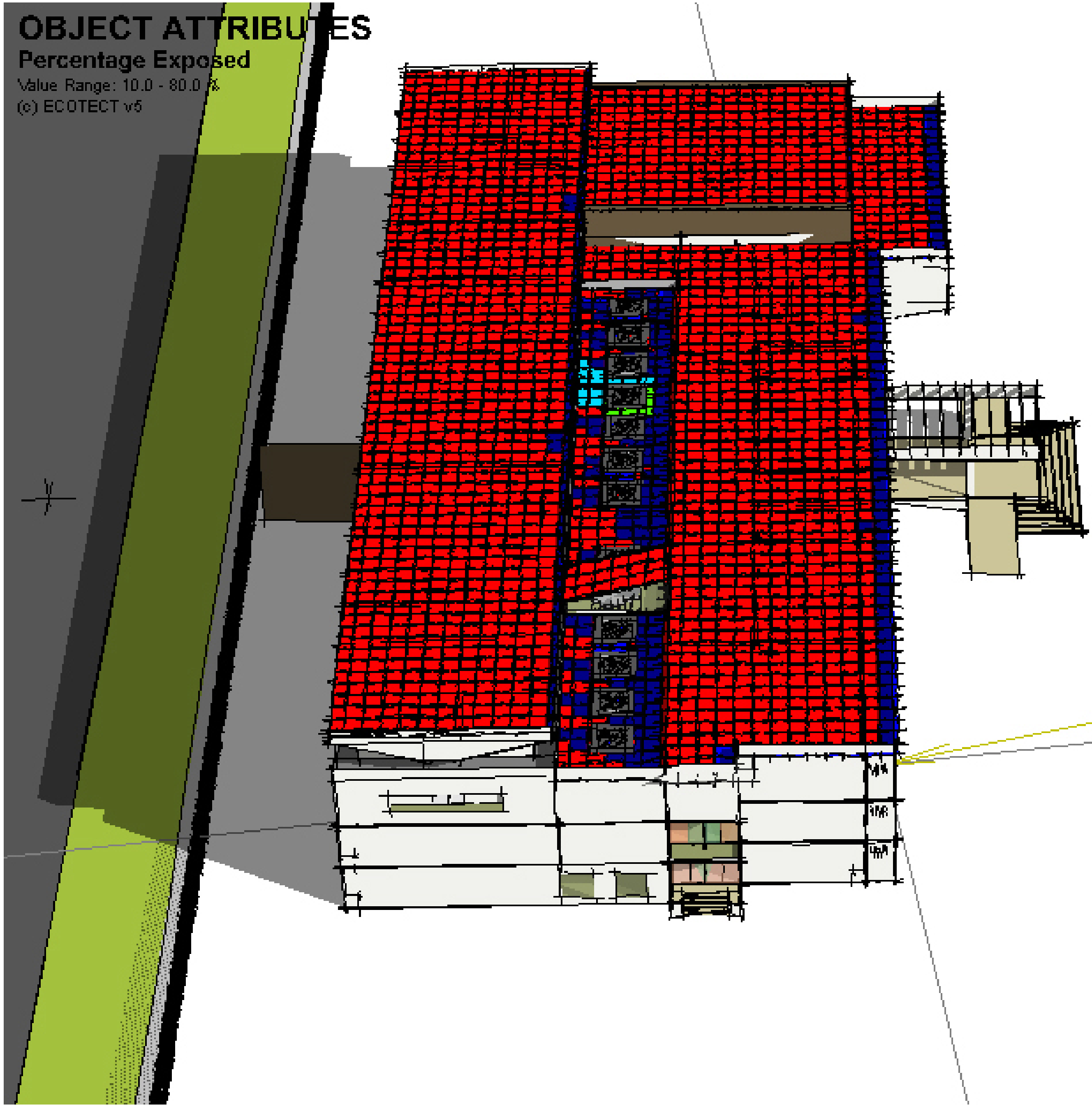
MONTH	HEATING (Wh)	COOLING (Wh)	TOTAL (Wh)
Jan	0	25653	25653
Feb	0	135714	135714
Mar	0	190403	190403
Apr	13305	17145	30450
May	16919	0	16919
Jun	154492	0	154492
Jul	459380	0	459380
Aug	44980	0	44980
Sep	5021	12210	17231
Oct	1145	55550	56695
Nov	0	93419	93419
Dec	0	92913	92913
TOTAL	695242	623007	1318249
PER M²	3621	3245	6866

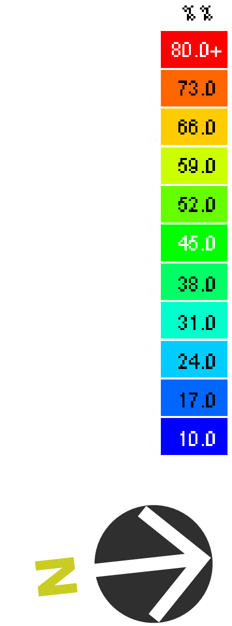
The solar gains graph is indicative of a building zone with little, or no thermal lag capacity. Heat from the sun is instantaneously projected through the building skin, and leaves the building just as quickly if the envelope is not absolutely sealed.

This fact is further demonstrated when comparing the heating & cooling loads applicable to the 3rd year (east) zone within the 2 versions of the building. The load that would be placed upon an air-conditioning unit in the older building would have been almost 6.5x the current loads.

The potential energy savings extracted via the substantially more favourable daylight conditions of the original building would be rendered insignificant by the far more energy intensive heating/cooling requirement to maintain comfort levels.

The solution then, must surely be found in a hybrid of the 2 building envelope extremes - a protected glass box, or a hard shell with holes punched through it...





The illustration and key attached indicates the typical level of solar exposure of the existing roof planes in the middle of winter.

Comfort levels on the upper levels of the building are primarily dependant on the thermal performance of this facet of the building envelope - more so than any of the remaining elements, and more so during summer than the winter conditions indicated.

And thus, in terms of overall thermal efficiency, the roof planes become a primary focal point.

Figure 56 : Boukunde II roof - Percentage exposure (10h00 - winter solstice)

The roof comprises an off-shutter concrete slab (12" - 305mm thick for all roofs except over 1st year studio) with cement screed laid to fall and a 'torched-on' thermally bonded waterproofing membrane coated with reflective aluminium paint.

The surfaces have weathered relatively well with minor maintenance upkeep, but there is evidence of fatigue - most notably the reflective paint covering, which has essentially dissipated.

Figure 58 : Boukunde II roof detail - view of main building roof surface - as at 23/08/2008

This has left the exposed surface a worn matt, charcoal hue - the colour of the original un-coated membrane.

Accordingly, the thermal profile of the roof covering has been altered from that of a heat reflector to an almost ideal absorber.

Absorption coefficients:
- Aluminium reflective coat = 0.3
- Charcoal matt surface = approx. 0.9
(www.naturalfrequency.com)

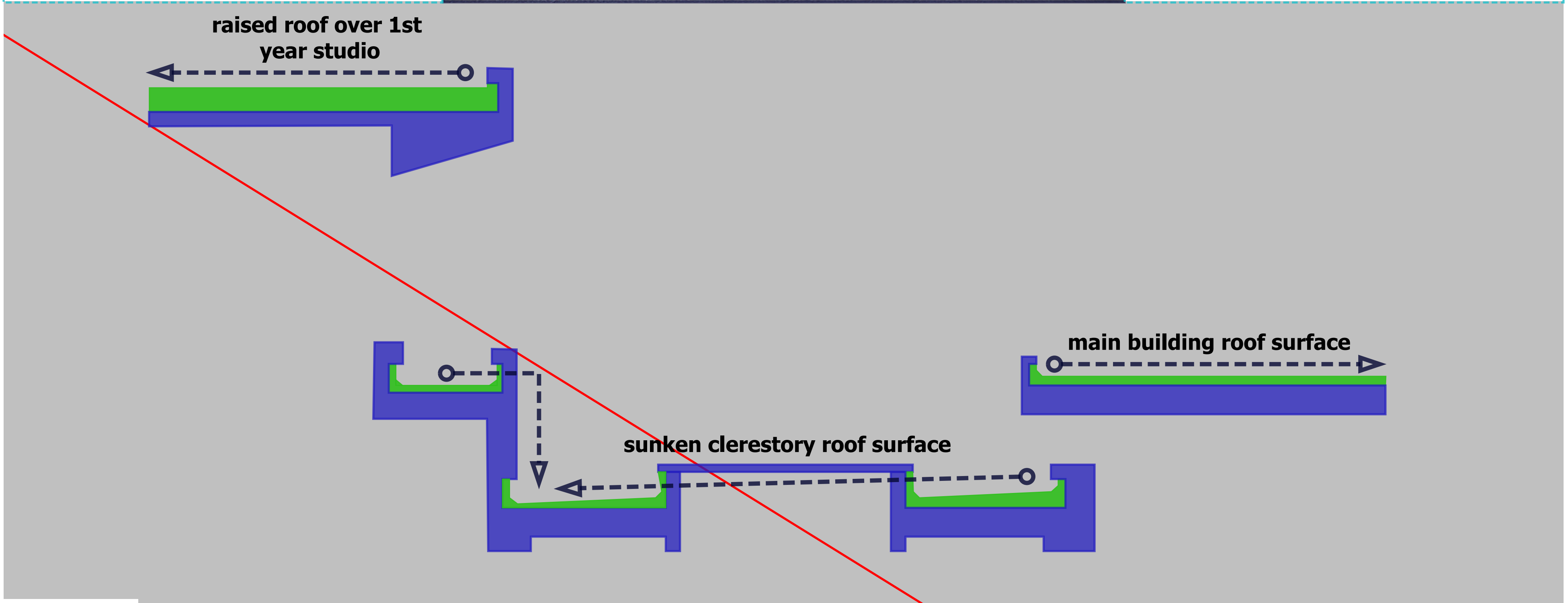


Figure 57 : Boukunde II roof detail - adapted from drawing number 43 - 32 - revised 3/2/1973 (D.S. De Beer Architects)

Figure 59 : Aerial View over Pretoria - facing west - circa 1986 (Sutherland. 1986:35)

Roof surface reflective coat still intact.

Figure 60 : Boukunde II roof detail - view of sunken clerestory roof surface - as at 23/08/2008

The sunken clerestory roof surface also seems to indicate that the raised 'glasscrete' panels have made the 'slope to fall' more complicated - resulting in surface staining from water that is not able to reach the fullbore outlets.

The entire roof surface then, may be deemed due for significant repair. At such time perhaps further benefit can be extracted via an alternative approach to the roof's thermal profile and general functionality.

The resultant retrofit proposal seeks to deal with the following aspects:

- rainwater re-routing to collection
- roof surface re-sealing & insulation
- roof surface protection & shading

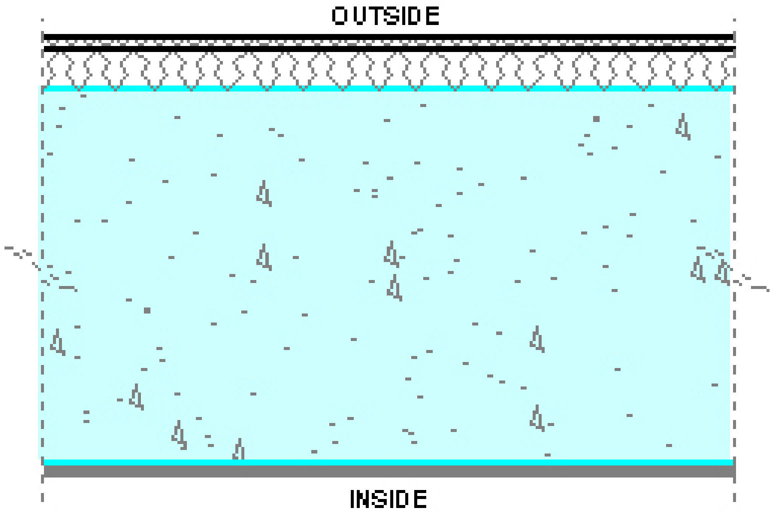


Figure 61 : Detail Section - Boukunde II roof - EXISTING

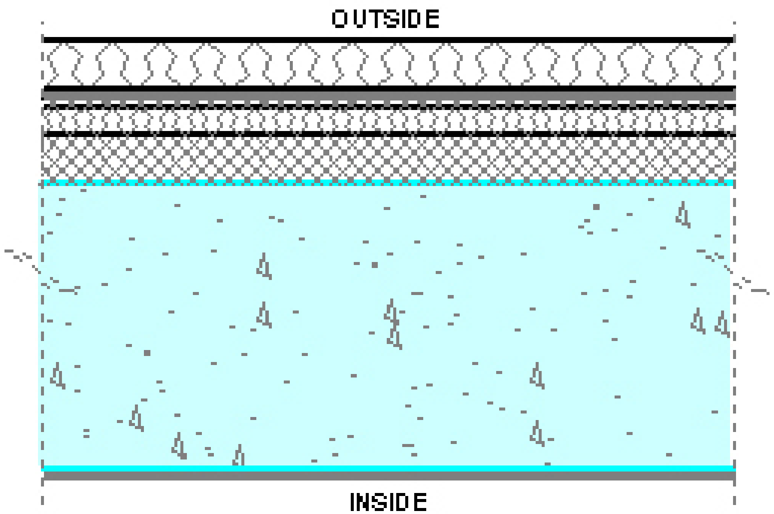


Figure 62 : Detail Section - Boukunde II roof - RETROFIT PROPOSAL

The existing roof surface is to be stripped to expose the original concrete slab and re-sealed according to the specification.

EXISTING ROOF SURFACE:

- 4mm thick waterproofing membrane (75mm side laps & 100mm end laps)
- min. 30mm cement screed - laid to fall
- 12" (305mm) thick reinforced in-situ concrete roof slab - existing

U-value : 2.27 (W/m^2.K)

Thermal Decrement : 0.23

RETROFIT PROPOSAL:

- 50mm thick sandstone gravel bed (25mm grade)
- 1 coat bituminous aluminium reflective paint
- 4mm thick waterproofing membrane (75mm side laps & 100mm end laps)
- min. 30mm cement screed - laid to fall
- 50mm thick expanded polystyrene rigid foam board
- 12" (305mm) thick reinforced in-situ concrete roof slab - existing

U-value : 0.49 (W/m^2.K)

Thermal Decrement : 0.06

Fabric Gains - Qc + Qs - BOUKUNDE II ROOF — PRETORIA, SOUTH AFRICA

Hr	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Hr	325.79	308.054	267.882	139.542	72.106	-51.1062	5.61096	126.58	188.999	168.491	203.318	266.263
	468.395	448.911	421.699	303.471	255.172	147.824	200.393	318.65	366.65	341.942	360.754	425.575
22	577.798	561.154	534.318	430.412	390.232	296.959	337.093	464.896	505.076	489.518	486.734	555.175
	648.96	624.281	602.674	509.076	473.271	384.046	430.503	554.085	594.812	600.52	585.544	647.502
20	669.941	640.279	640.083	556.385	496.296	391.571	421.298	567.637	632.181	655.453	648.5	692.471
	648.214	609.526	618.078	547.967	453.776	347.708	353.166	517.399	614.756	653.114	631.496	689.94
18	581.521	530.664	542.576	482.404	352.556	248.866	230.007	408.47	539.508	592.814	581.377	634.815
	476.788	428.855	419.828	347.767	189.773	83.062	46.2269	217.991	394.002	459.709	471.784	528.608
16	333.773	283.246	252.905	166.057	-9.85623	-107.245	-164.846	-10.1767	198.929	271.623	340.829	380.987
	168.454	126.088	58.4724	-35.7267	-213.853	-294.291	-367.103	-234.268	-17.6113	70.3687	173.814	211.36
14	21.1204	-14.8528	-87.146	-157.393	-284.673	-381.765	-411.722	-326.973	-153.066	-79.0013	5.70421	44.1194
	-61.211	-85.6534	-136.893	-199.738	-294.749	-406.418	-415.312	-356.362	-199.738	-159.814	-125.642	-82.2799
12	-80.5565	-100.014	-152.992	-235.761	-302.509	-432.028	-423.188	-382.768	-225.468	-174.649	-148.996	-119.077
	-73.7126	-92.8339	-146.506	-233.965	-297.644	-420.3	-424.462	-371.303	-217.929	-173.027	-150.791	-104.836
10	-66.5321	-84.1147	-141.178	-231.692	-293.128	-403.067	-421.219	-360.995	-210.868	-171.638	-135.592	-96.219
	-61.2588	-76.806	-133.535	-230.136	-287.684	-394.33	-417.281	-350.34	-204.047	-171.406	-123.385	-90.1156
08	-46.5612	-66.6763	-110.603	-212.185	-266.953	-385.953	-397.94	-330.651	-180.949	-153.223	-116.444	-79.2251
	-35.2295	-45.5194	-96.7055	-193.754	-245.528	-373.866	-378.483	-309.921	-153.903	-134.461	-103.041	-61.9919
06	-30.2928	-34.2357	-82.8077	-179.274	-225.144	-358.069	-359.837	-288.495	-133.438	-116.626	-95.9797	-54.931
	-19.0733	-25.6447	-49.3372	-151.988	-202.676	-342.032	-334.126	-259.773	-106.272	-94.7366	-74.1988	-38.6552
04	-10.4342	-22.5674	-34.0496	-125.061	-181.25	-320.251	-308.531	-231.63	-81.0202	-76.0904	-65.9411	-29.2008
	-9.08785	-20.9004	-22.8155	-100.408	-159.593	-305.412	-283.862	-204.529	-60.7951	-64.1615	-61.5132	-21.5416
02	20.3963	-0.523663	-10.6561	-68.215	-112.92	-271.903	-239.737	-142.105	-35.7829	-44.5888	-39.6951	1.26293
	159.254	138.762	93.9842	-22.0041	-69.7736	-226.905	-182.156	-70.9653	9.29348	14.5938	49.7667	117.1

Watts: 700, 560, 420, 280, 140, 0, -140, -280, -420, -560, -700

Table 31 : Average Fabric Gains/Losses (annual) - Boukunde II roof - **EXISTING**

***The retrofit proposal graph legend range has been altered / reduced to register a visible variation.**

Fabric Gains - Qc + Qs - BOUKUNDE II ROOF — PRETORIA, SOUTH AFRICA

Hr		Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Hr	4.51426	3.84421	3.65961	0.726583	-1.33755	-7.98644	-5.77284	-0.372432	1.8002	1.0148	1.83543	2.89189
	6.17649	5.79448	5.88055	3.04997	1.3185	-3.93282	-2.4835	2.32572	3.96632	3.39594	4.24983	5.17541
22	7.51727	7.40493	7.29665	4.77852	3.22073	-0.930412	-0.397516	4.48085	5.62706	5.45441	5.92972	6.84607
	8.49062	8.28057	8.10661	5.83948	4.40266	0.761647	1.48344	5.82925	6.69993	7.15328	7.3345	8.01905
20	8.35681	7.99159	8.35846	6.23068	4.07099	0.0213403	0.0914763	5.22438	6.88113	7.49377	7.72404	8.292
	7.90092	7.1892	7.8776	5.88022	2.44072	-1.3765	-2.19642	3.60851	6.4431	7.01467	7.09521	8.19263
18	6.99641	6.07252	6.76107	4.81862	-0.180068	-3.76108	-5.4561	1.08422	5.24338	5.82038	6.10361	7.4794
	5.6078	4.70716	4.78718	2.35656	-4.32291	-8.22473	-10.7234	-4.0232	2.23714	3.26548	4.10805	6.21295
16	3.39465	2.62577	1.81371	-1.40973	-9.33586	-13.1113	-16.3817	-9.99039	-2.08754	-0.875461	2.10338	4.00177
	0.599533	0.263139	-2.29628	-6.17546	-14.6372	-18.1173	-22.1949	-16.1389	-7.30673	-5.16003	-0.649023	1.30254
14	-1.75013	-2.36315	-5.65293	-9.15326	-16.0302	-21.4976	-23.1845	-18.4725	-9.64102	-7.43998	-4.00758	-1.87083
	-3.53831	-4.82323	-7.7086	-11.2475	-16.5976	-22.8858	-23.3867	-20.0671	-11.2475	-9.08685	-7.49932	-5.0646
12	-4.53622	-5.63192	-8.61511	-13.2759	-17.0346	-24.328	-23.8301	-21.5541	-12.6964	-9.83466	-8.39012	-6.70535
	-4.15083	-5.22758	-8.2499	-13.1748	-16.7607	-23.6675	-23.9019	-20.9084	-12.2718	-9.74336	-8.4912	-5.90341
10	-3.74649	-4.73659	-7.94991	-13.0468	-16.5063	-22.6971	-23.7193	-20.328	-11.8742	-9.6651	-7.63534	-5.41819
	-3.44955	-4.32503	-7.51947	-12.9592	-16.1998	-22.2052	-23.4975	-19.728	-11.4901	-9.65206	-6.94796	-5.0745
08	-2.62191	-3.75461	-6.22818	-11.9483	-15.0324	-21.7334	-22.4084	-18.6193	-10.1894	-8.62815	-6.55709	-4.46125
	-1.98381	-2.56325	-5.44558	-10.9105	-13.8259	-21.0528	-21.3128	-17.452	-8.66642	-7.57165	-5.80232	-3.49083
06	-1.70582	-1.92785	-4.66299	-10.0951	-12.6781	-20.1632	-20.2628	-16.2455	-7.51404	-6.56731	-5.40472	-3.09322
	-1.07404	-1.44408	-2.77823	-8.55859	-11.4129	-19.2602	-18.815	-14.6281	-5.98428	-5.33472	-4.17821	-2.17671
04	-0.587561	-1.27079	-1.91737	-7.0423	-10.2064	-18.0337	-17.3737	-13.0433	-4.56234	-4.28473	-3.71322	-1.64433
	-0.511746	-1.17693	-1.28477	-5.65406	-8.98685	-17.1981	-15.9846	-11.5173	-3.42344	-3.613	-3.46387	-1.21303
02	0.132109	-0.658631	-0.651239	-3.84126	-6.35862	-15.3111	-13.4998	-8.00207	-2.01498	-2.51084	-2.35868	-0.535338
	2.0866	1.23297	1.17574	-2.07096	-3.99841	-12.7772	-10.453	-4.60198	-0.808964	-1.11487	-0.495	0.97974

Watts: 30, 24, 18, 12, 6, 0, -6, -12, -18, -24, -30

32 : Average Fabric Gains/Losses (annual) - Boukunde II roof - **RETROFIT PROPOSAL**

As the graphs illustrate - the repair & re-layering of the roof's surface will have a dramatic effect in terms of it's efficacy as a heat barrier. The existing roof condition accommodates a far larger gradient of thermal gain / losses than the refurbished model.

Both graphs would seem to indicate an approx. 8 hour thermal lag, but the primary distinction remains in terms of the massive disparity in heat energy that ultimately passes through the skin of the building.

The seasonal variation is also apparent - with the protected roof experiencing a relatively insignificant differential between peak winter- & peak summer conditions, whereas the existing roof will suffer through relative extremes in the space of 52 weeks.

Considering the fact that the core component in the roof's construction is concrete - which has a determining influence on thermal performance, the surface treatment is employed to extract maximum benefit from the roof as a unit.