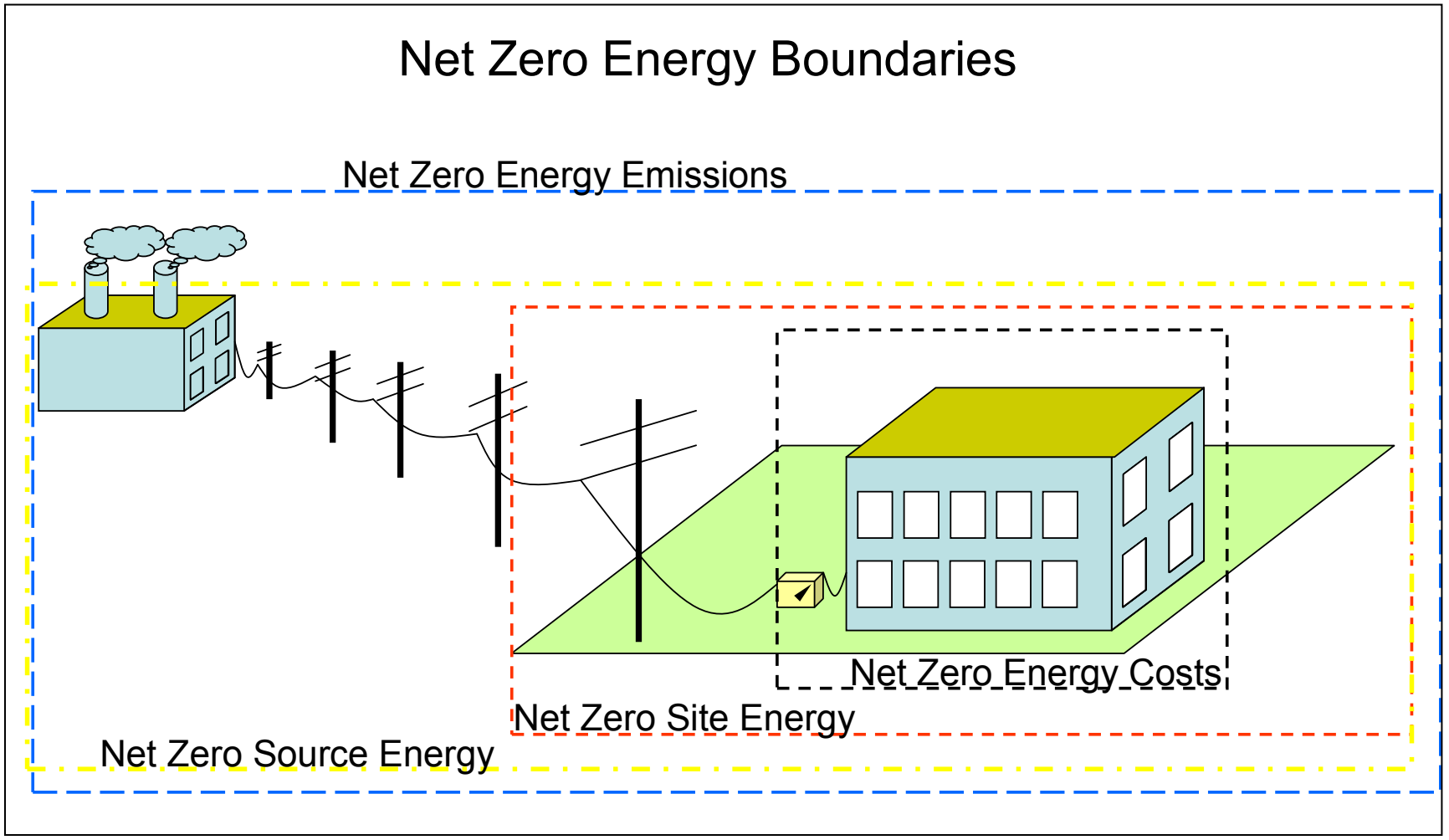
Moving towards Zero Energy Buildings

Ms. Roshni Engineer

Architect

Board of Director - Sustainable Urban Climate Change & Energy Efficiency Development (SUCCEED)

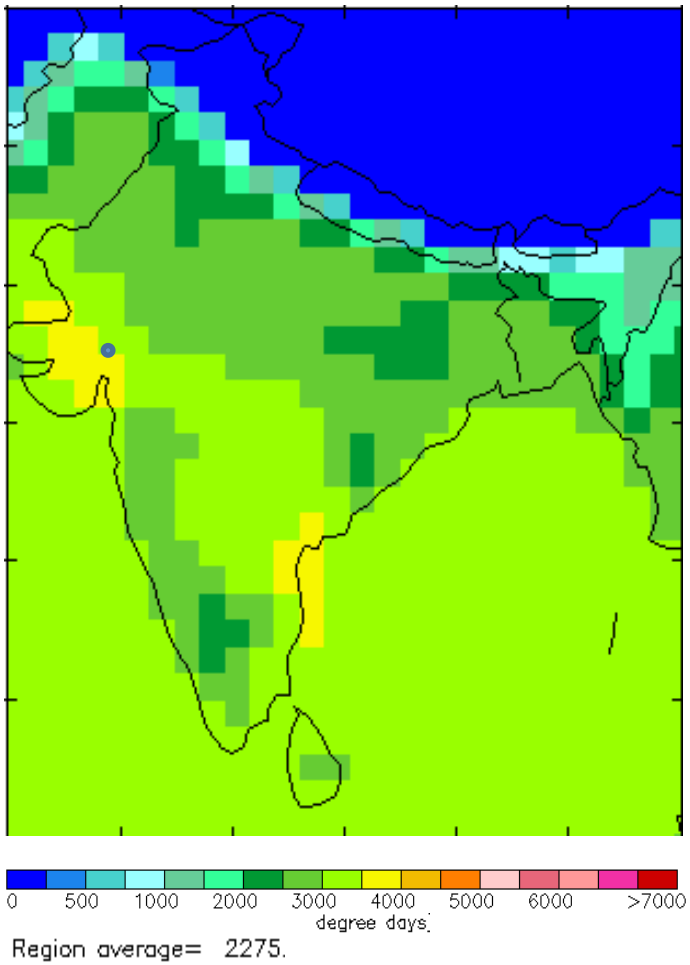
Defining Net Zero Boundary



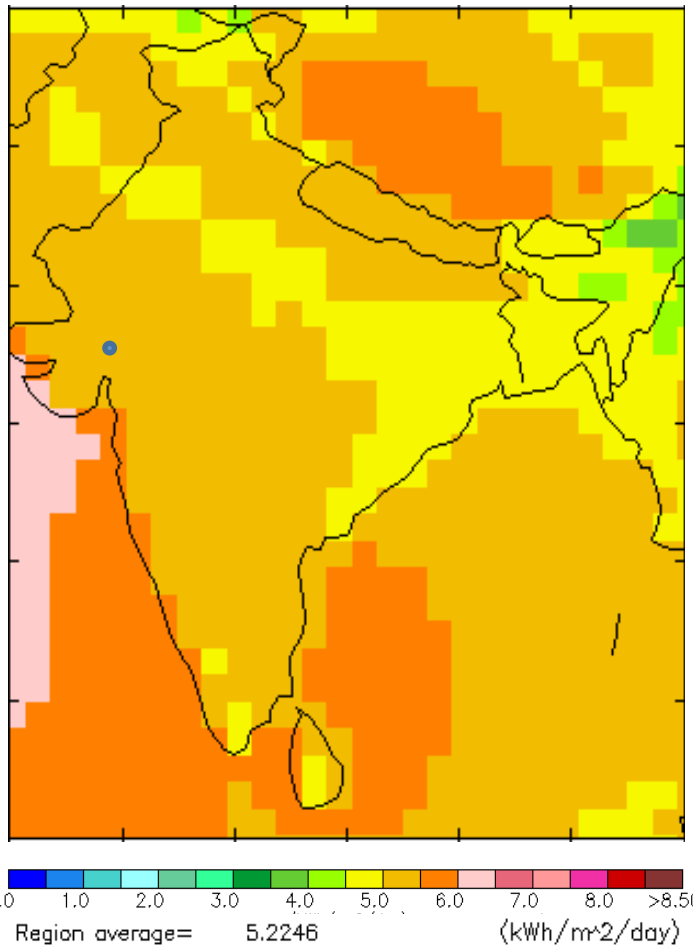
Survey of House holds

- Determined that the cooling is mostly localized cooling
- Operations of each occupied area is operated for different hour of the day
- Roofs are more flat roofs, concrete slab.
- Concrete high mass buildings
- Family average 4 people, 2 adults, 2 children

Cooling Degree Days

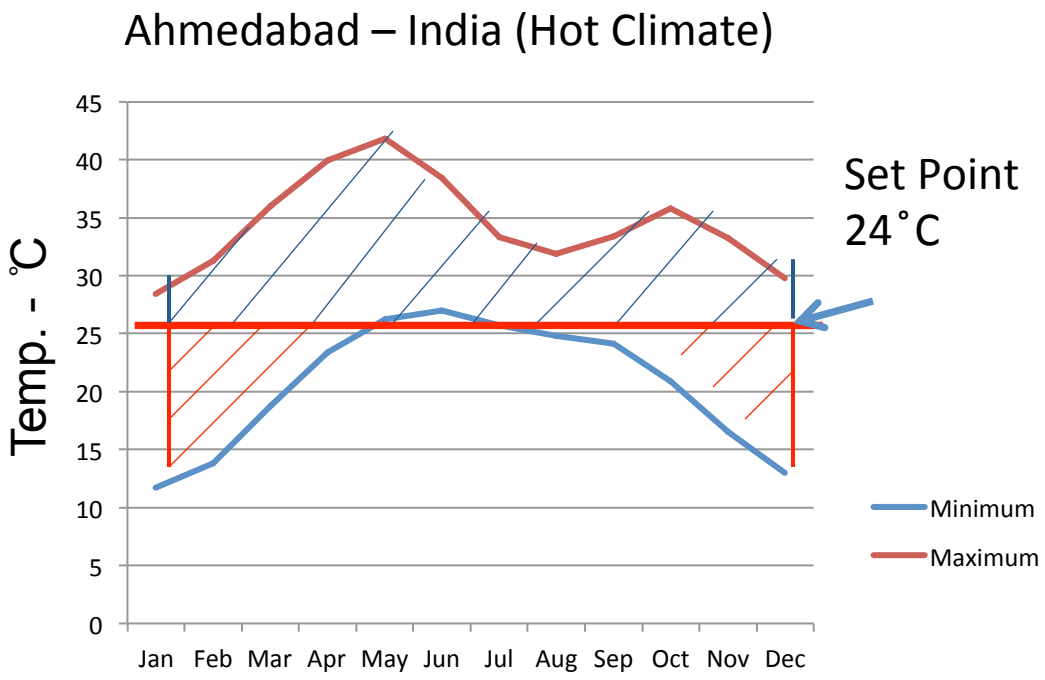


Solar Intensity



	Ahmedabad
Annual - Cooling Degree Days (18 deg. C)	2275
Maximum Direct Solar of	7429 Wh/m^2 on Apr 5

Temperatur e

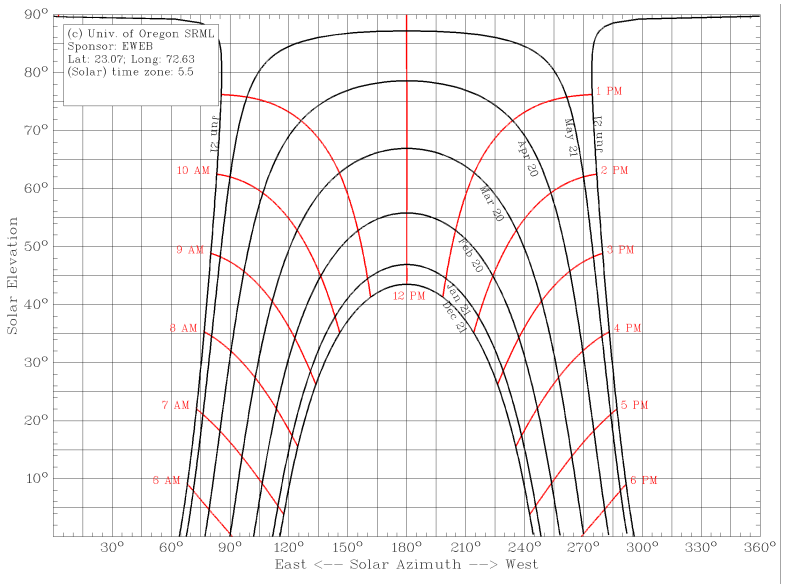


Ahmedabad is a Cooling dominated climate:

- Reduced Solar Gain helps heating
- U-Factor less dominant
- Lower Air leakage

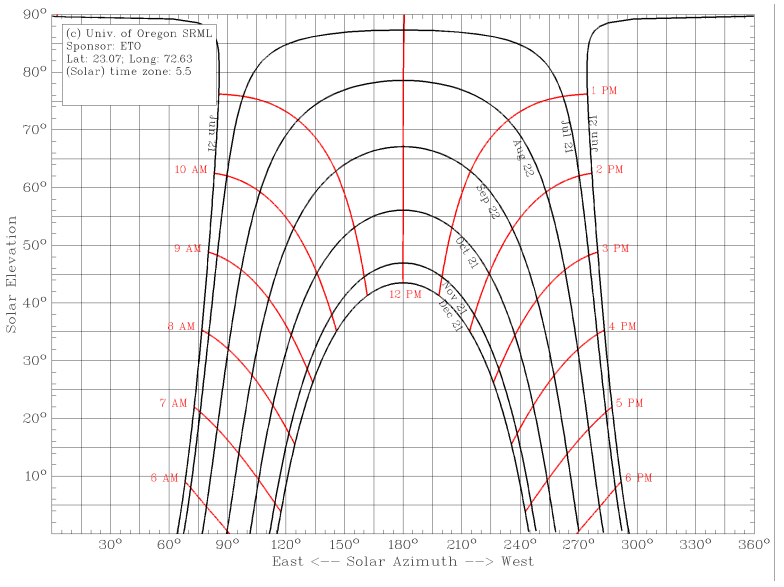
Sun Angle – Shading Design

Boston – USA (Cold Climate)



December to June

Ahmedabad – India (Hot Climate)



June to December

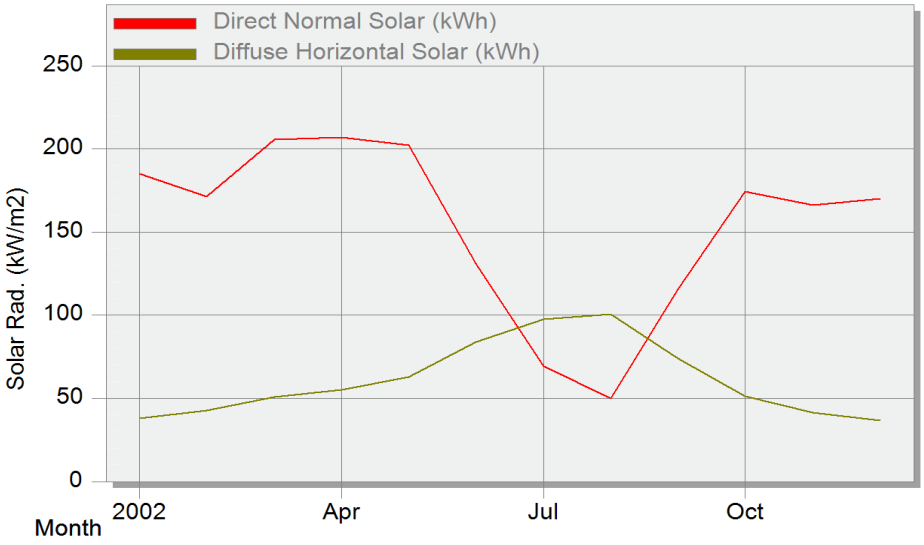
Direct Solar Radiation

Ahmedabad – India (Hot Climate)

Weather Data

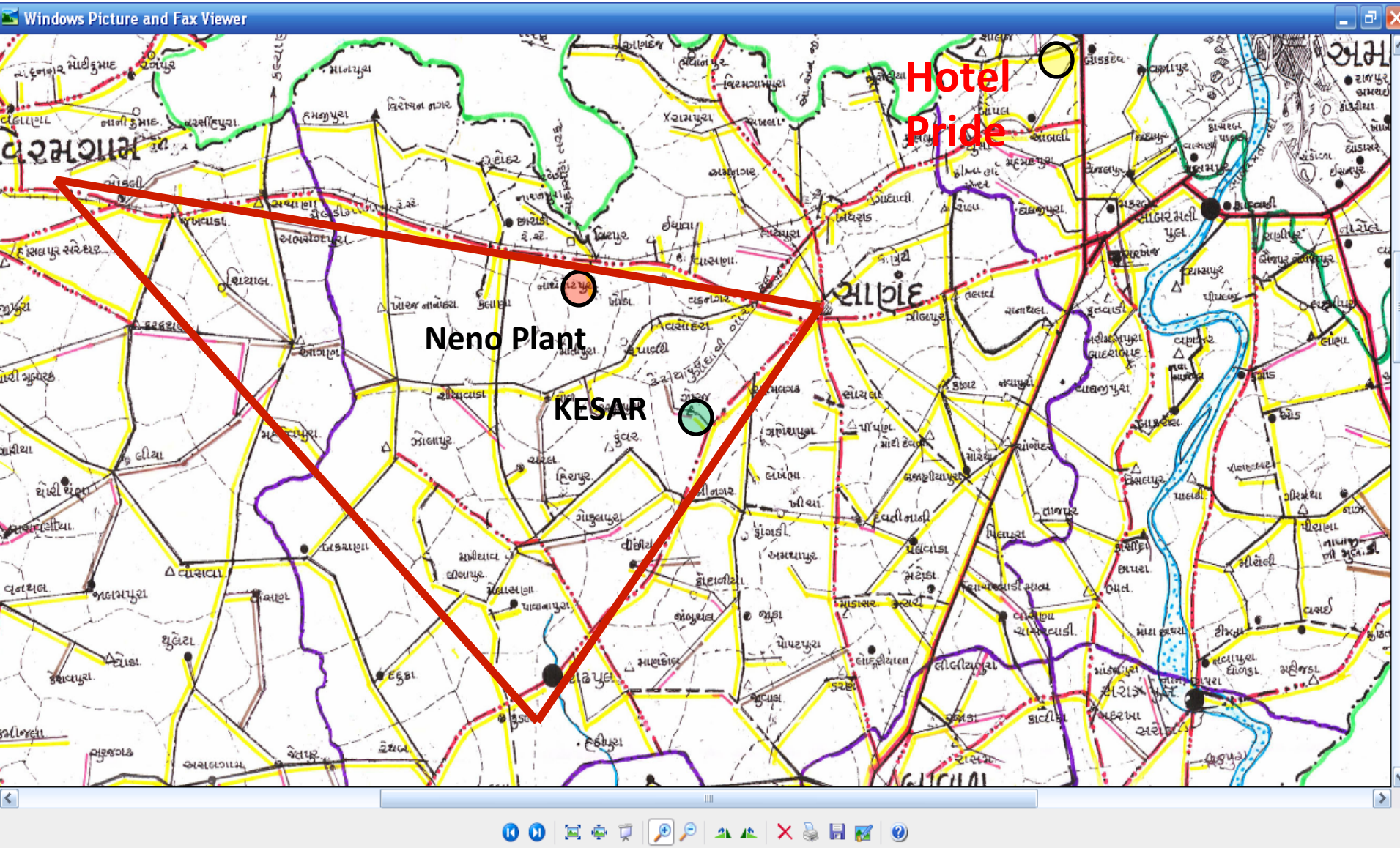
Solar radiation - Ahamadabad

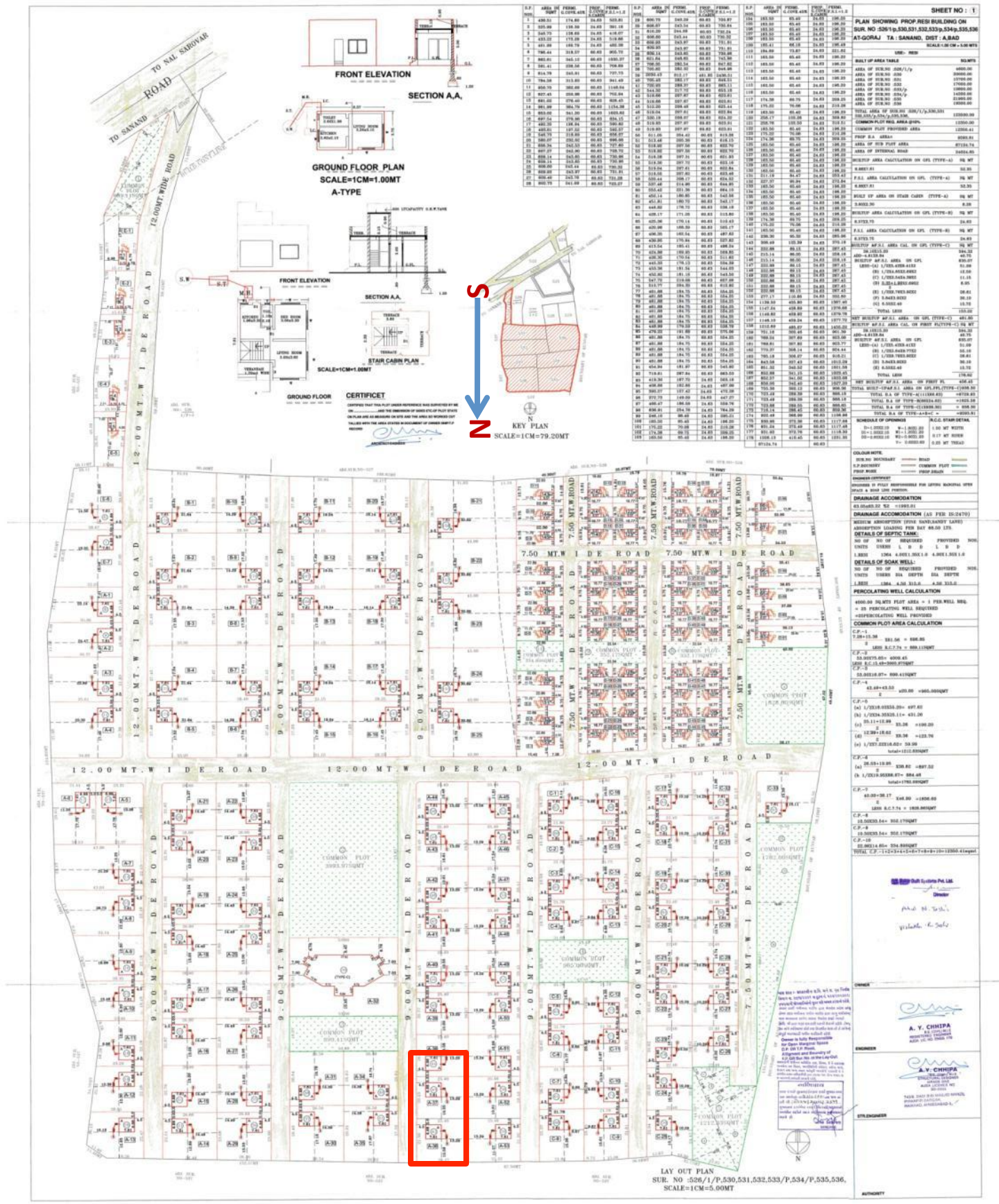
Monthly



Direct Normal Solar (kWh)	185.09	171.14	205.65	206.99	202.31	130.95	69.08	49.76	115.56	174.46	166.13	170.26
Diffuse Horizontal Solar (kWh)	37.75	42.63	51.01	54.96	62.99	84.03	97.43	100.54	73.90	51.33	41.47	36.86

Project Site - Background





SHEET NO : 1

PLAN SHOWING PROP.RESI BUILDING ON

SUR. NO :526/1/p,530,531,532,533/p,534/p,535,536

AT-GORAJ TA : SANAND, DIST : A,BAD

SCALE=1.00 CM = 5.00 MTS

USE:- RESI

BUILT UP AREA TABLE	SQ.MTS
AREA OF SUR.NO :526/1/p	4600.00
AREA OF SUR.NO :530	20000.00
AREA OF SUR.NO :531	15700.00
AREA OF SUR.NO :532	17000.00
AREA OF SUR.NO :533/p	19800.00
AREA OF SUR.NO :534/p	14350.00
AREA OF SUR.NO :535	21900.00
AREA OF SUR.NO :536	18000.00
TOTAL AREA OF SUR.NO :526/1/p,530,531 532,533/p,534/p,535,536,	132300.00
COMMON PLOT REQ. AREA @10%	13350.00
COMMON PLOT PROVIDED AREA	12350.41
PROP B.U. AREA=	8093.91
AREA OF SUR PLOT AREA	87184.75
AREA OF INTERNAL ROAD	34654.85
BUILTUP AREA CALCULATION ON GPL (TYPE-A)	SQ MT
6.9857.91	53.35
F.S.I. AREA CALCULATION ON GPL (TYPE-A)	SQ MT
6.9857.91	53.35
BUILT UP AREA ON STAIR CASE (TYPE-A)	SQ MT
3.9032.30	8.38
BUILTUP AREA CALCULATION ON GPL (TYPE-B)	SQ MT
6.5723.75	24.83
F.S.I. AREA CALCULATION ON GPL (TYPE-B)	SQ MT
6.5723.75	24.83
BUILTUP AP.S.I. AREA CAL. ON GPL (TYPE-C)	SQ MT
SR.10215.00	594.32
ADD-4.6138.84	40.75
BUILTUP AP.S.I. AREA ON GPL	635.07
LESS-(A) 1/ZES.4928.4152	51.08
(B) 1/ZE4.9552.4962	12.58
(C) 1/ZES.7855.9862	11.15
(D) 0.5E4-1.E852.4962	8.95
F.S.I. AREA CALCULATION ON GPL (TYPE-B)	SQ MT
(E) 1/ZES.7855.9262	08.61
(F) 1/ZE4.9552.4962	12.58
(G) 0.5552.40	13.72
TOTAL LESS	153.22
NET BUILTUP AP.S.I. AREA ON GPL (TYPE-C)	481.85
BUILTUP AP.S.I. AREA CAL. ON FIRST FL(TYPE-C)	SQ MT
SR.10215.00	594.32
ADD-4.6138.84	40.75
BUILTUP AP.S.I. AREA ON GPL	635.07
LESS-(A) 1/ZES.4928.4152	51.08
(B) 1/ZE4.9552.4962	12.58
(C) 1/ZES.7855.9862	08.61
(D) 0.5E4-1.E852.4962	30.10
(E) 0.5552.40	13.72
TOTAL LESS	176.82
NET BUILTUP AP.S.I. AREA ON FIRST FL	458.25
TOTAL BUILT-UPAP.S.I. AREA ON GPL,FFL(TYPE-C)=458.25	
TOTAL B.A. OF TYPE-A(1)=6.9857.91	=6728.65
TOTAL B.A OF TYPE-B(8)=24.83)	=1925.28
TOTAL B.A OF TYPE-C(13)=38.30)	= 498.90
TOTAL B.A OF TYPE-A+B+C =	=9283.91

SCHEDULE OF OPENINGS	R.C.C. STAIR DETAIL
D=1.0092.10 W=1.0092.10	1.00 MT WIDTH
D1=1.0092.10 W1=1.0092.10	0.17 MT RISER
D2=0.9092.10 W2=0.9092.10	
V= 0.6092.10	0.25 MT TREAD

COLOUR NOTE:

SUR.NO BOUNDARY — ROAD

S.P.BOUNDRY — COMMON PLOT

PROP.WORK — PROP.DRAIN

ENGINEER CERTIFICET

ENGINEER IS FULLY RESPONSIBLE FOR LEVING MARGINAL OPEN SPACE & ROAD LINE PORTION.

DRAINAGE ACCOMODATION

83.00x83.22 SQ =1992.01

DRAINAGE ACCOMODATION (AS PER IS:2470)

MEDIUM ABSORPTION (FINE SAND,SANDY LOAM) ABSORPTION LOADING PER DAY 68.00 LTS.

DETAILS OF SEPTIC TANK:

NO OF UNITS	REQUIRED USERS	L	B	D	PROVIDED USERS	L	B	D	NOS.
1.RESI	1364	4.00X1.30X1.0			4.30X1.30X1.0				

DETAILS OF SOAK WELL:

NO OF UNITS	REQUIRED USERS	DIA	DEPTH	PROVIDED DIA	DEPTH	NOS.
1.RESI	1364	4.50	310.0	4.50	310.0	

PERCOLATING WELL CALCULATION

4000.00 SQ.MTS PLOT AREA = 1 PER.WELL REQ.

= 20 PERCOLATING WELL REQUIRED

=20PERCOLATING WELL PROVIDED

COMMON PLOT AREA CALCULATION

C.P.-1
7.28+15.38 / 2 × $81.56 = 596.85
LESS S.C.7.7% = 889.115SMT

C.P.-2
53.00X75.65= 4009.45
LESS S.C.15.69=3900.875SMT

C.P.-3
53.00X18.97= 899.415SMT

C.P.-4
43.49+43.50 / 2 ×20.00 =960.0850SMT

C.P.-5
(a) 1/2X18.03X53.20= 497.62
(b) 1/2X34.35X25.11= 431.26
(c) 25.11+12.99 / 2 X5.26 =100.20
(d) 12.99+18.62 / 2 X9.36 =123.76
(e) 1/2X7.22X18.62= 59.99
total=1212.8350SMT

C.P.-6
26.59+19.95 / 2 X30.82 =697.52
(b 1/2X19.95X88.87= 884.48
total=1782.0850SMT

C.P.-7
40.00+38.17 / 2 X48.90 =1856.00
LESS S.C.7.7% = 1808.8650SMT

C.P.-8
19.00X30.54= 902.1750SMT

C.P.-9
19.00X30.54= 902.1750SMT

C.P.-10
22.00X14.80= 334.8350SMT

TOTAL C.P.-1+2+3+4+5+6+7+8+9+10=12350.41sqmt

OWNER

A. Y. CHHIPA
B.E.(CIVIL),M.E.
ARCHITECTURAL ENGINEER
REGD. NO. 3966

ENGINEER

A.Y. CHHIPA
(CIVIL ENGINEER)
STRUCTURAL ENGINEER
REGD. NO. 3966

STR.ENGINEER

AUTHORITY

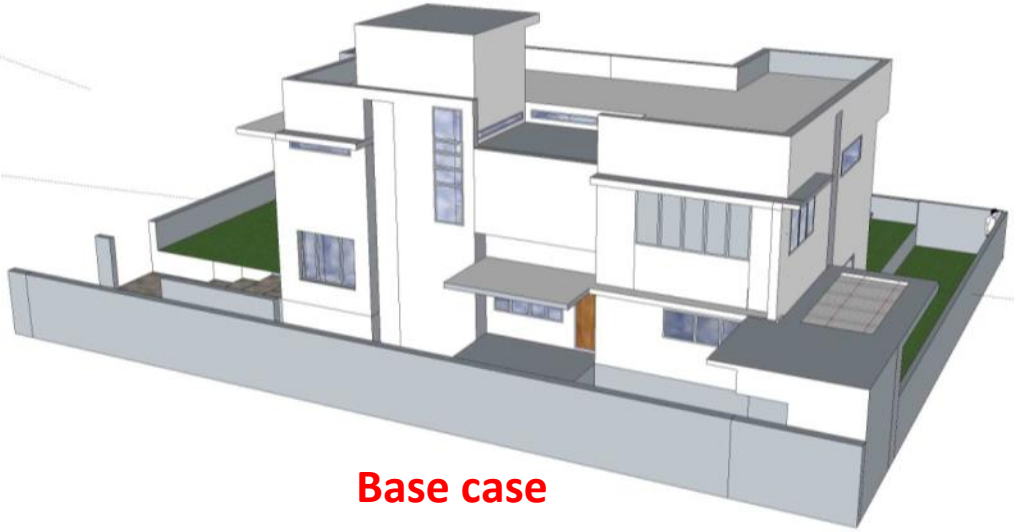
Sensitivity Analysis

Retrofit case

- Same geometry
- Only retrofit technology

ZEB case

- freedom to change geometry orientation etc.
- Advance technology
- Renewable or on site generation



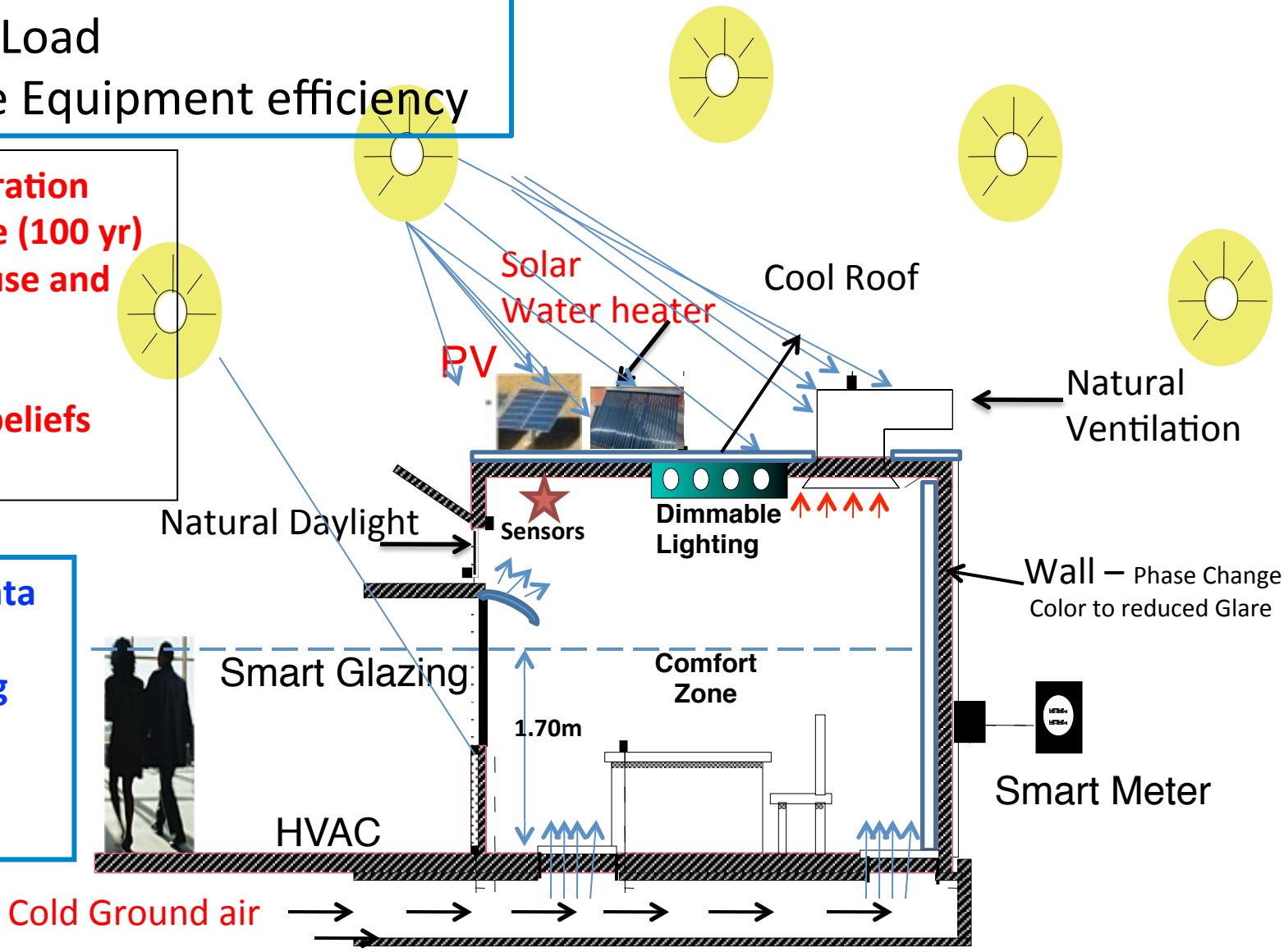
Base case

ZEB Strategy

1) Reduce Load
2) Increase Equipment efficiency

Local consideration
- **Life of House (100 yr)**
- **Equipment use and schedule**
- **Local issues**
  - **Religious beliefs**
  - **Wild life**

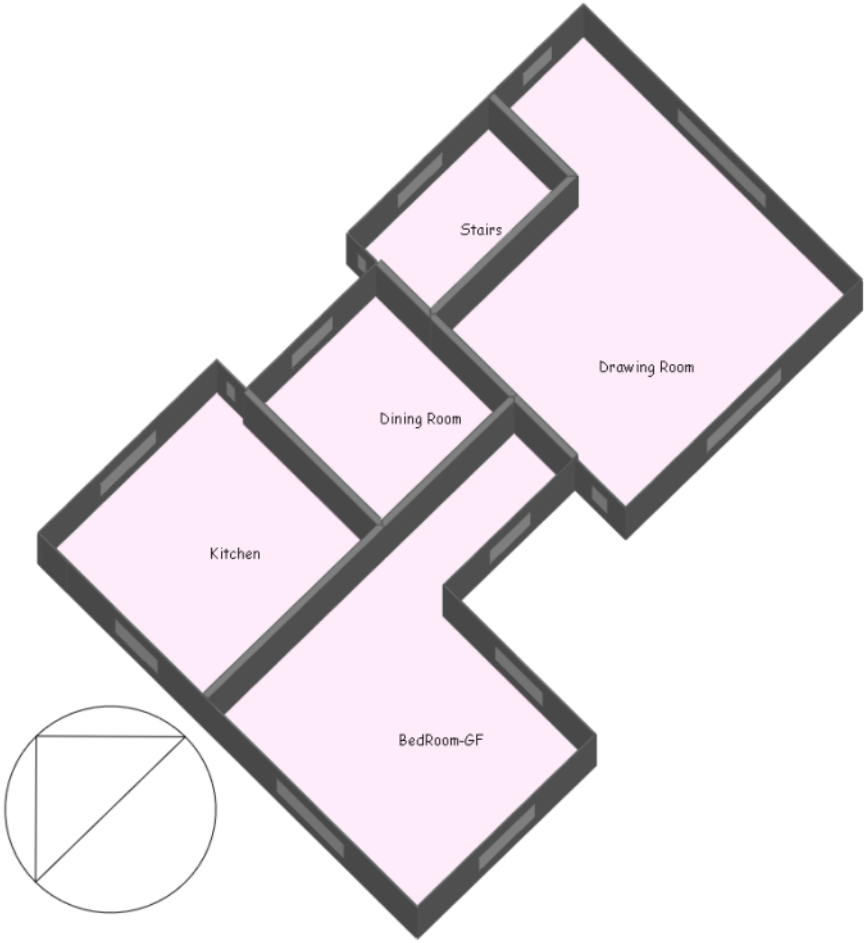
- **Weather Data**
- **Site**
- **Surrounding**
- **Orientation**
- **Shadowing**
- **Vegetation**



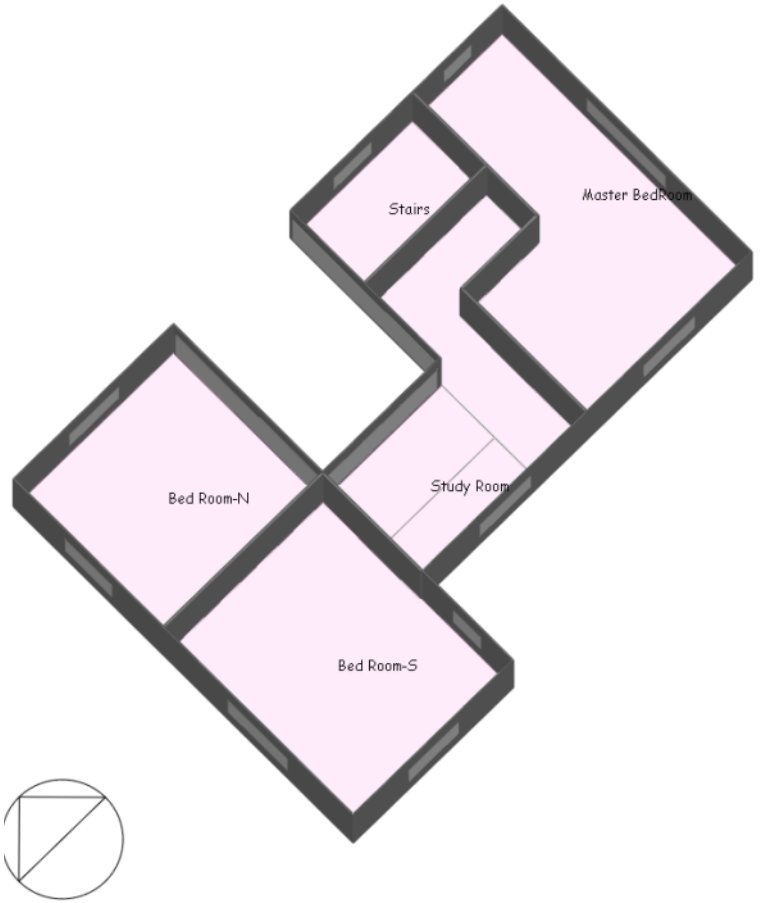
House Input data Assumptions

Input Parameters	Values
Total Floor area	230 m^2 (2 Floors)
Wall Construction	Brick wall (228 mm)
Roof Construction	Concrete roof (152 mm)
Occupancy	4
Average Lighting/Equipment Loads	4.3W/m2 (560 W, distributed in whole house along with the schedules)
HVAC Schedule	Whole house cooling and localized cooling (Kid's bedrooms (5pm – 6 am), Family room (4pm – 8 am), Kid's bedrooms (5pm – 6 am), dining room (12-1pm and 6-8pm), Family room(4pm – 8pm), Guest room (9pm-6am, May1-20)
Set Point	25 Deg C.

Floor Layouts



Ground Floor

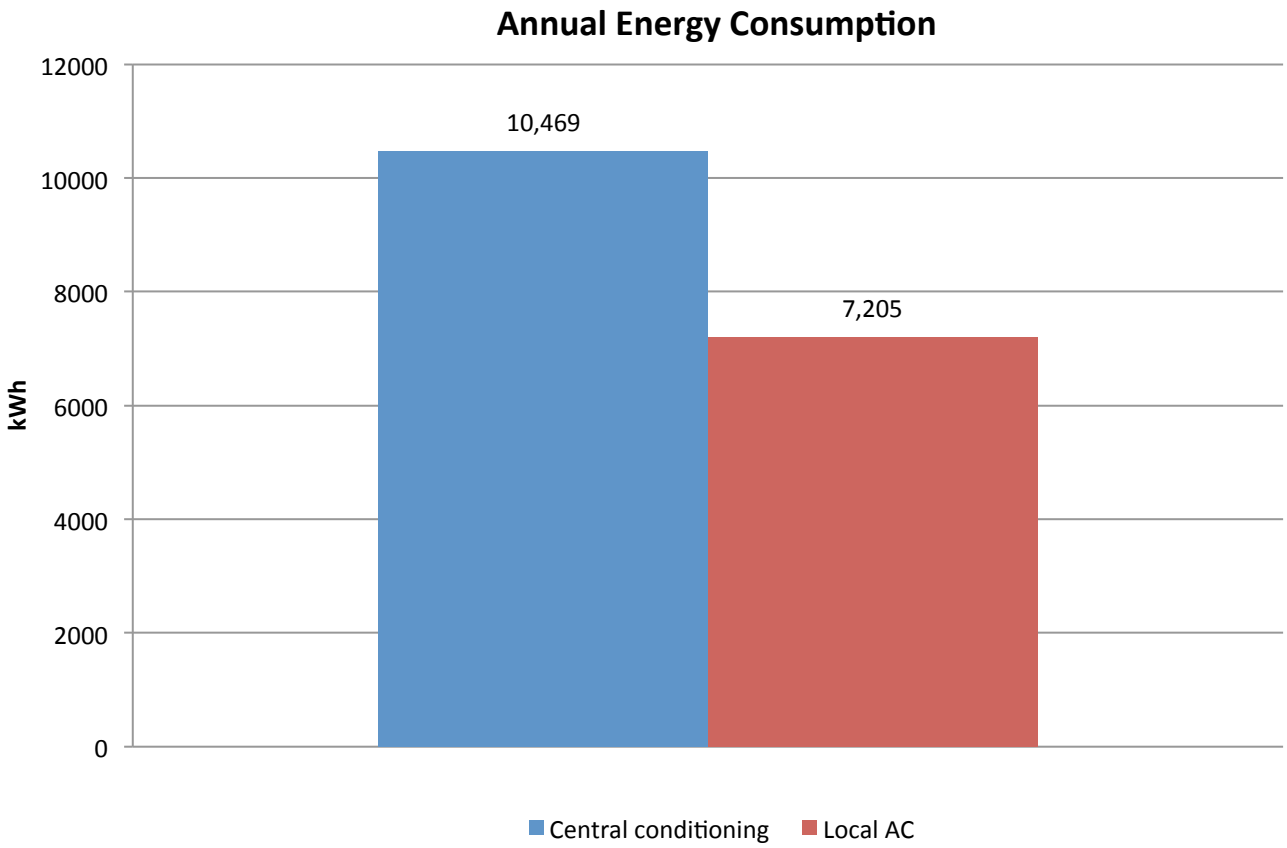


First Floor

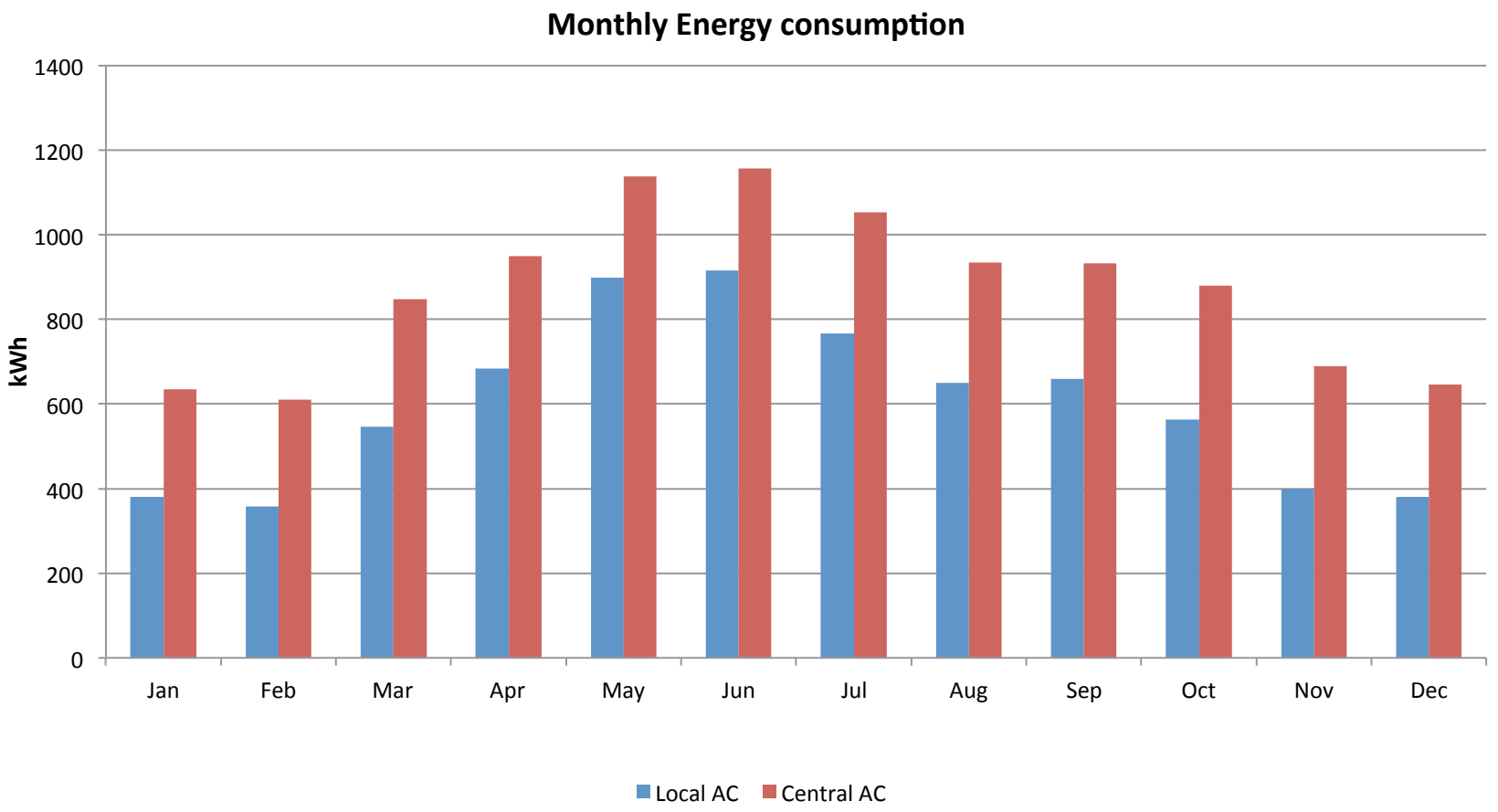
Analysis – Overview

- Analyze the house assuming the whole house is centrally cooled
- Optimize various energy efficiency measures, WWR, window type, Cool roof types, roof insulation, cool walls, wall insulation
- Analyze the house assuming the whole house is locally cooled
- Run the energy efficiency features
- Create the final model with a set optimized energy efficiency features

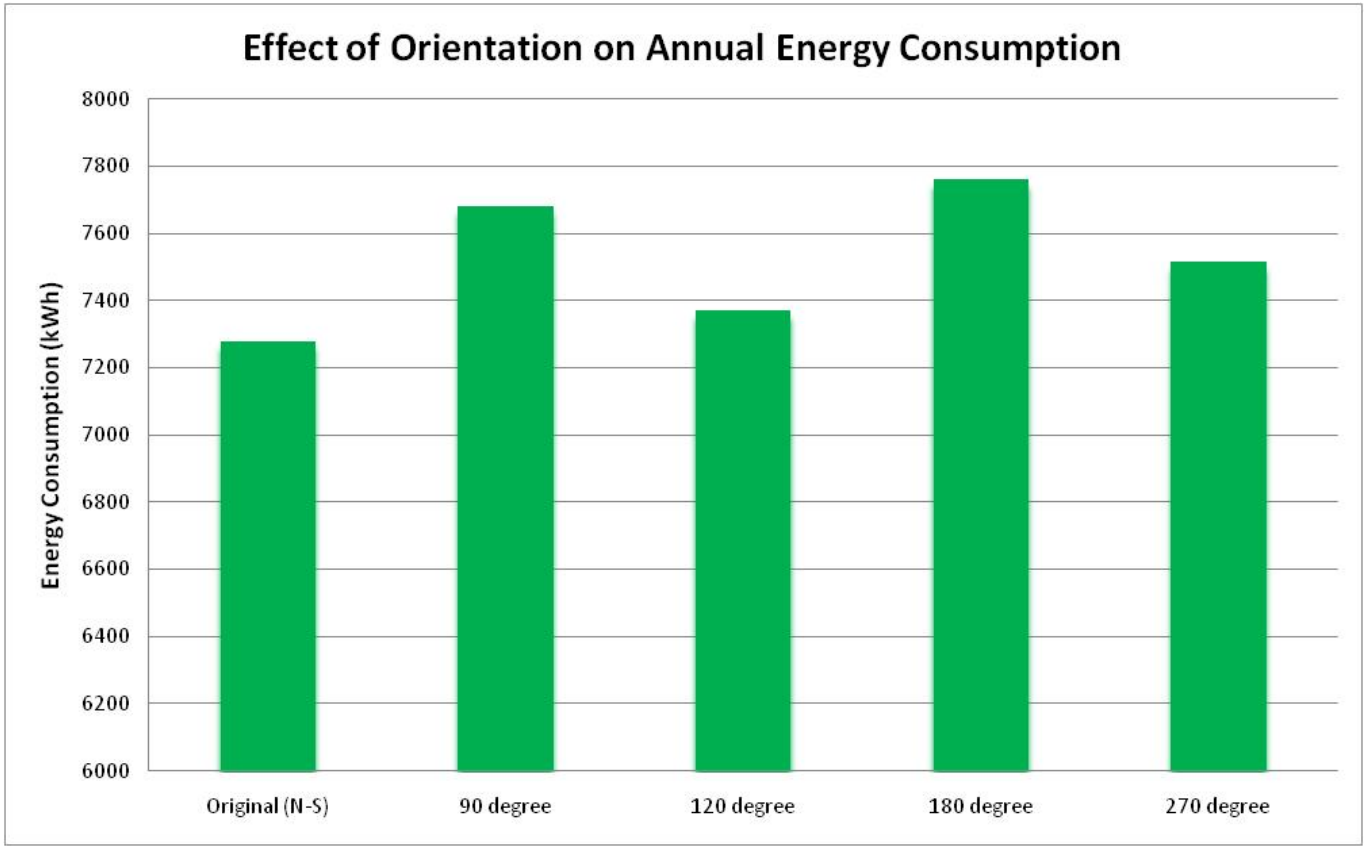
Annual Energy consumption



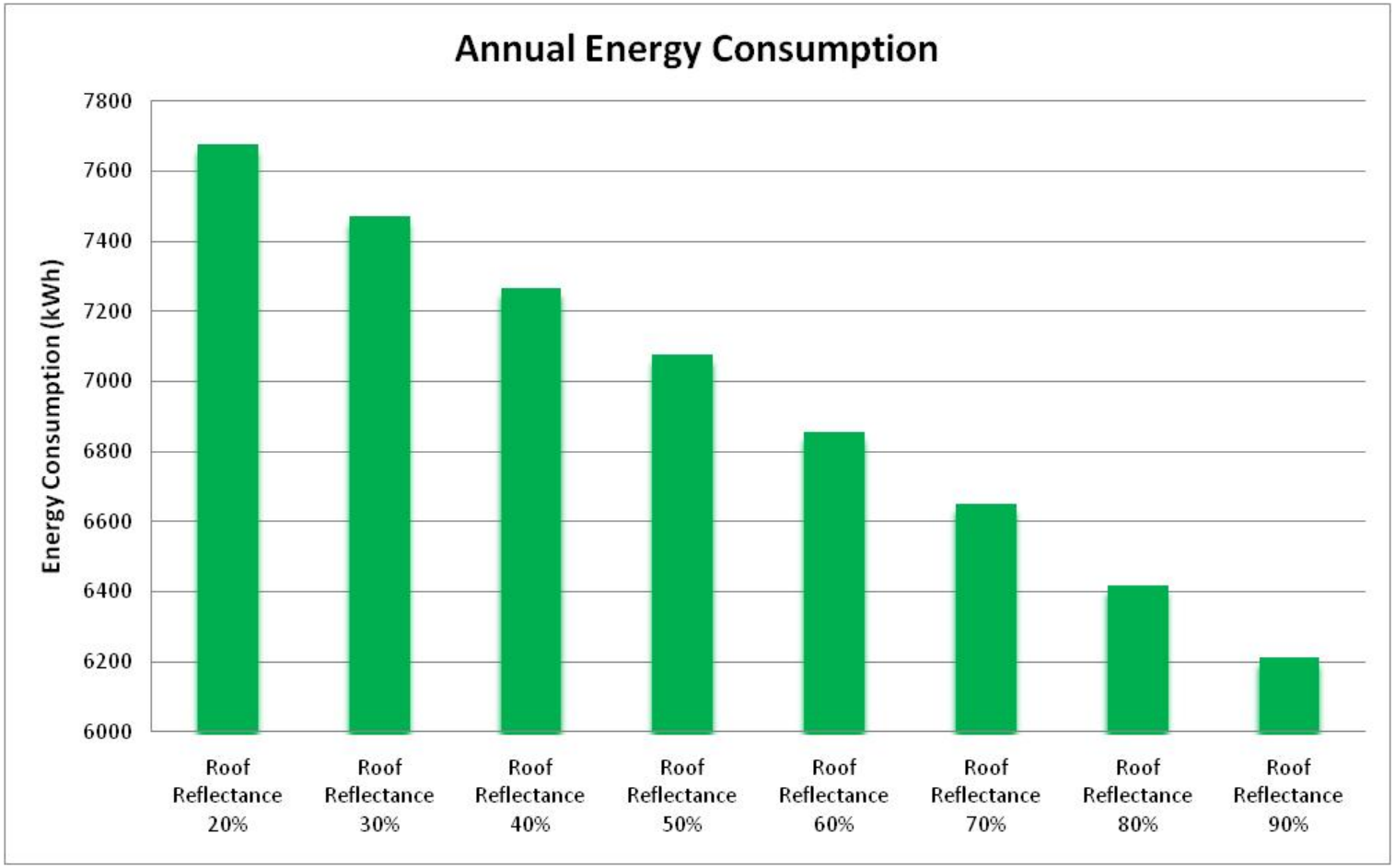
Monthly Energy consumption



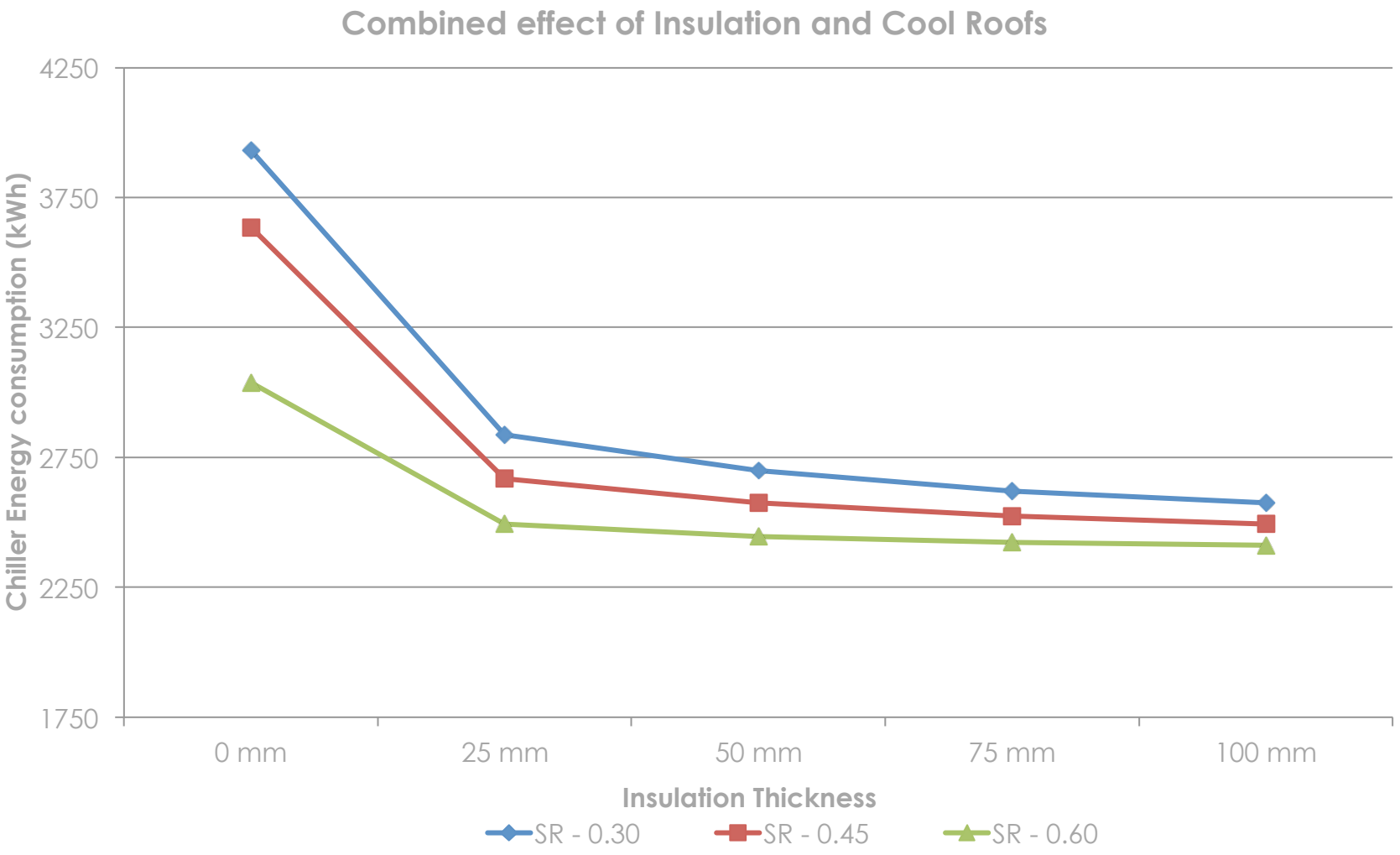
Analysis - Orientation



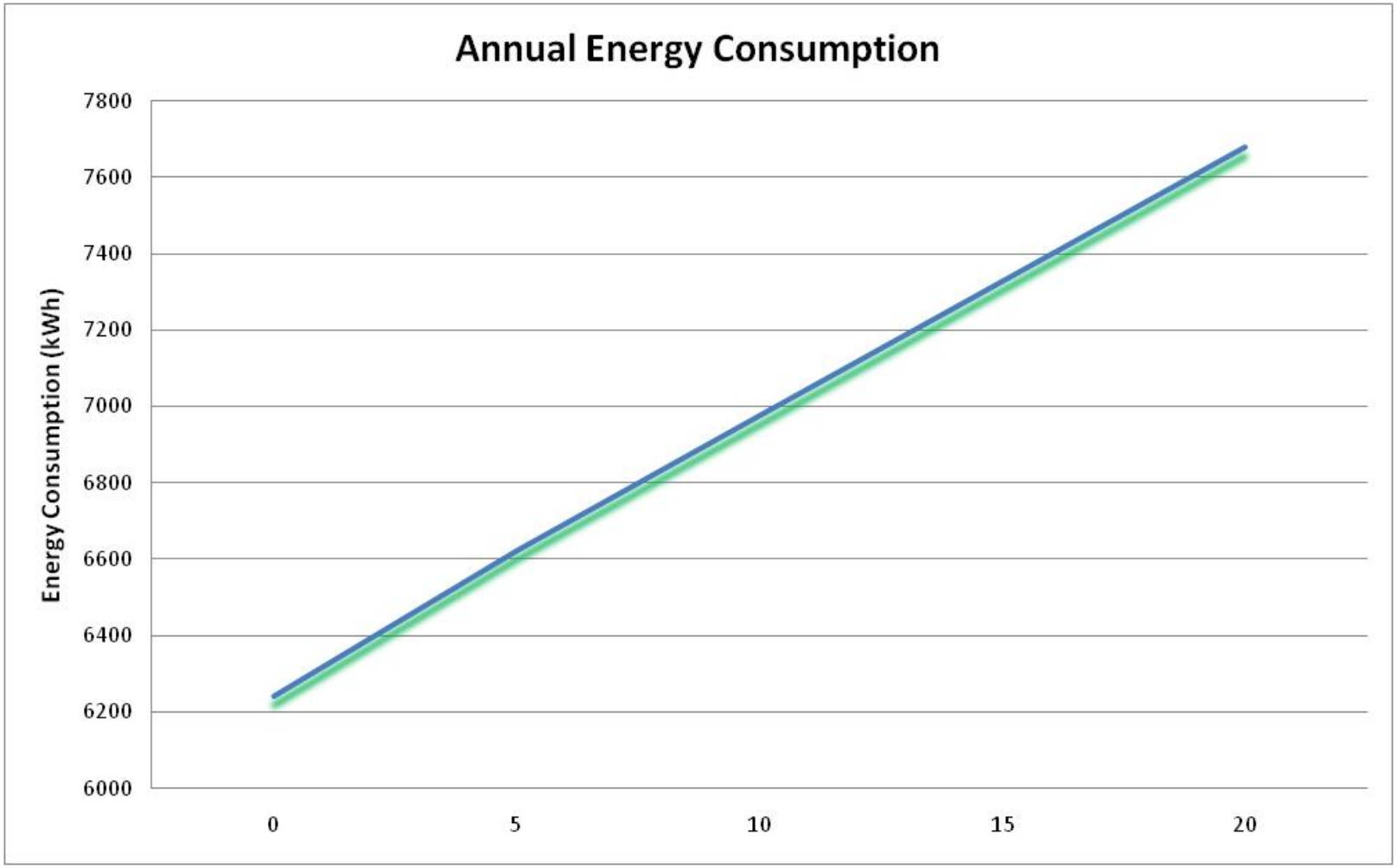
Analysis – Cool Roof



Cool Roof and Insulation

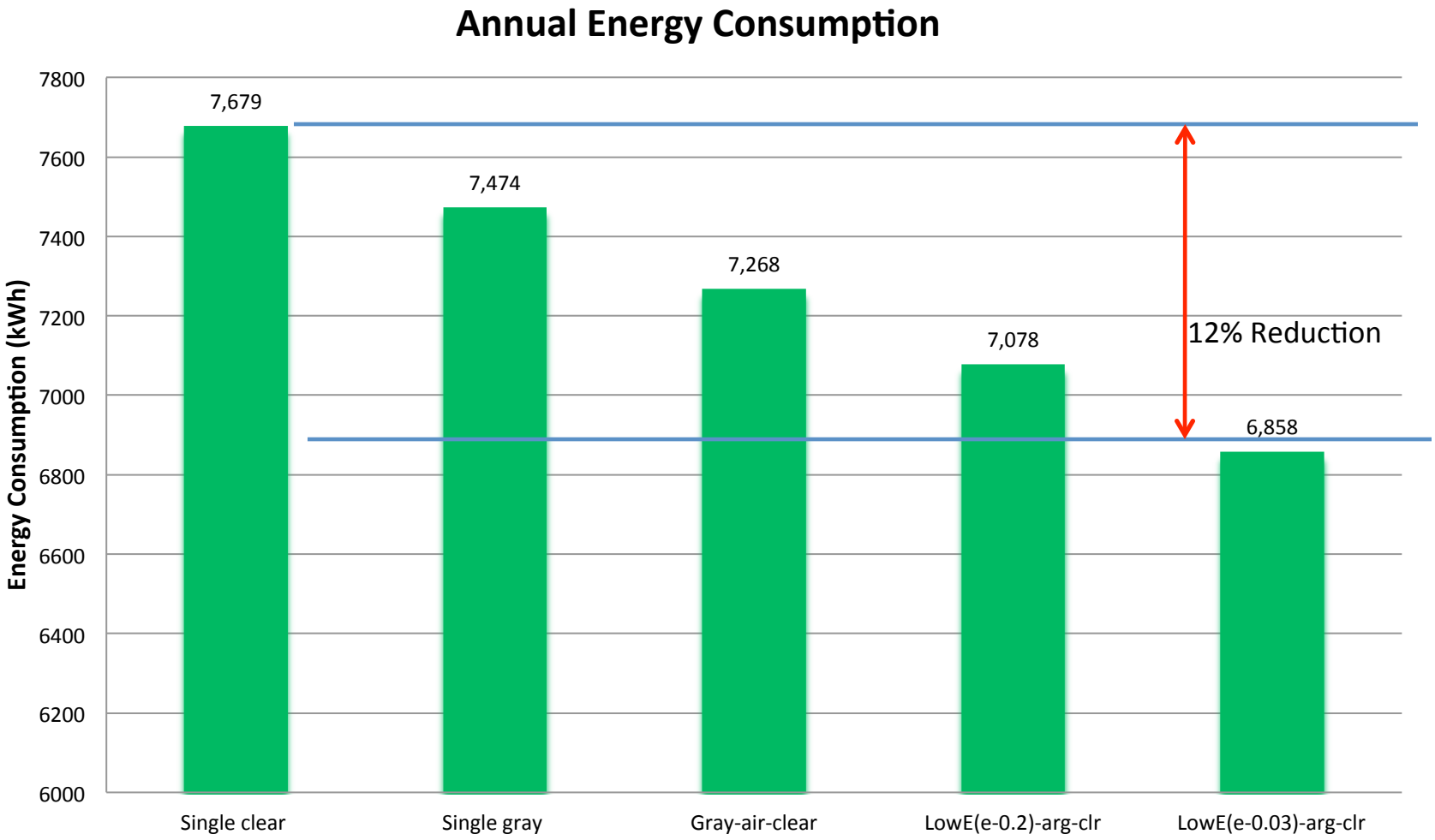


Analysis – Glazing % (WWR)

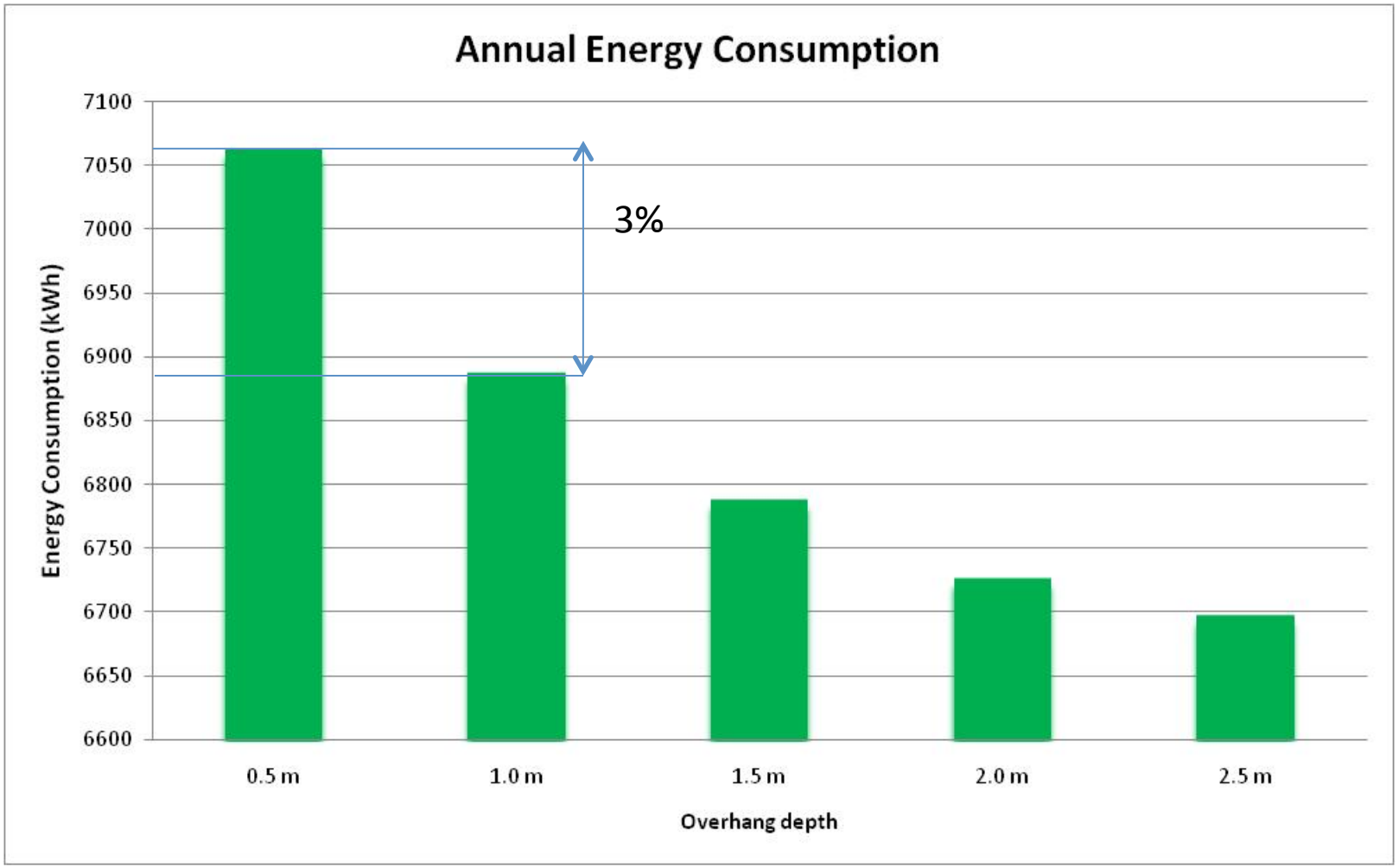


Analysis – Glazing type

More WWR can be possible if more energy efficient windows are used. Hence more natural daylighting



Analysis – Overhang Depth



Optimized set

Energy Efficiency Measure	Optimized value
Orientation	As is (E-W)
Roof	Cool Roof (CR 70)
Roof/Wall Insulation	1 inch (insulated bricks)
Glazing area	15% WWR
Glazing Type	Double glazed Low-E
Overhang depth	1.0 m
Cost of Energy Conservation Measures (ECM)	Not more than 10% of base house construction cost without subsidies

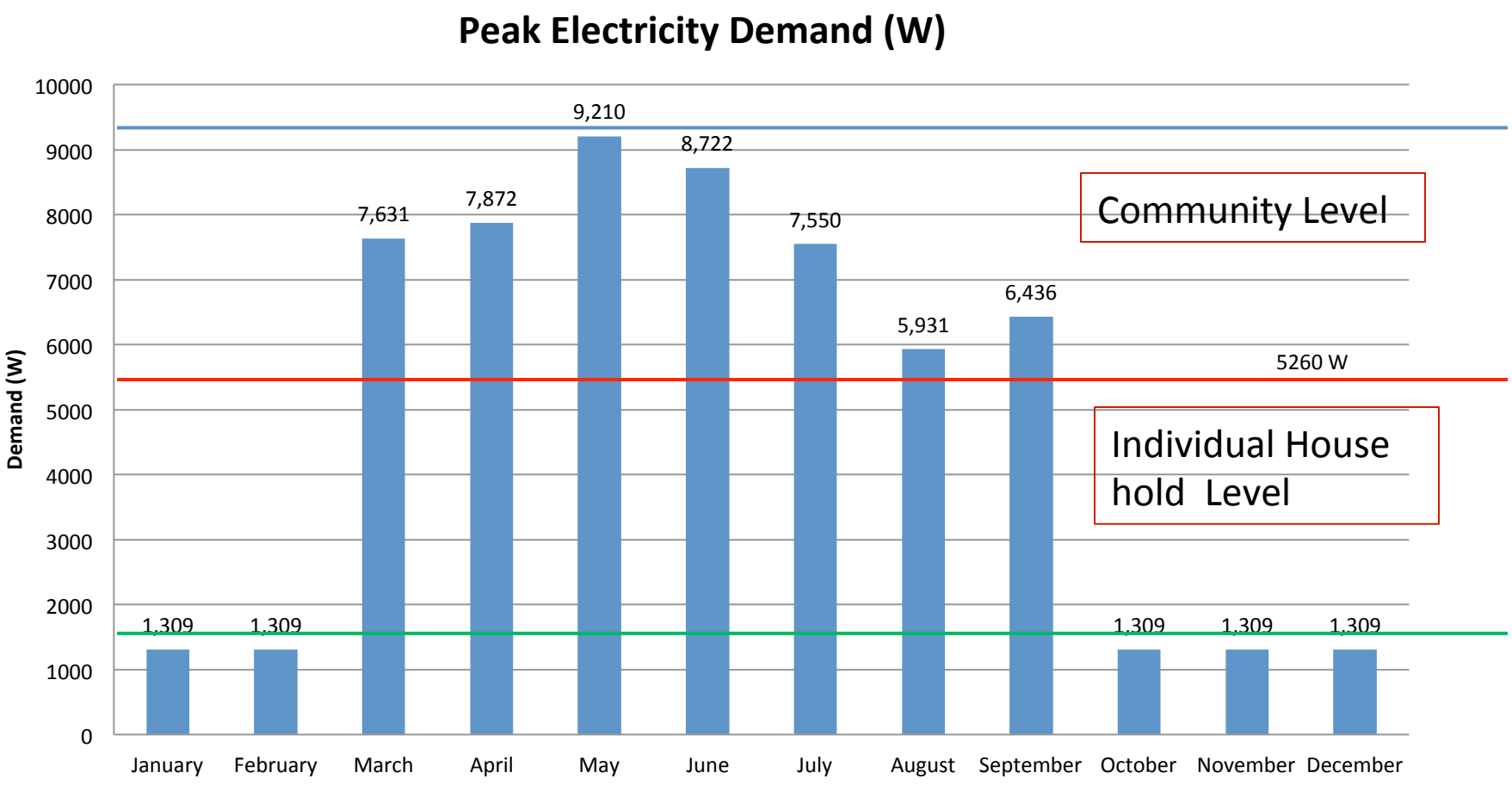
Net Zero case Summary

Date/Time	Equipment	Lighting	Chiller	Total Energy Consumption	Energy Generation from PV	Surplus from PV
	kWh	kWh	kWh	kWh	kWh	kWh
Jan	306.59	84.14	0.50	391.23	525.00	133.77
Feb	277.56	76.34	3.11	357.00	560.00	203.00
Mar	308.23	85.02	37.35	430.60	596.00	165.40
Apr	296.91	81.54	113.10	491.55	568.00	76.45
May	306.59	84.03	182.06	572.68	562.00	-10.68
Jun	298.55	82.13	166.51	547.19	459.00	-88.19
Jul	306.59	84.14	108.04	498.77	371.00	-127.77
Aug	307.41	84.58	76.48	468.47	368.00	-100.47
Sep	297.73	81.98	103.20	482.91	461.00	-21.91
Oct	306.59	84.14	78.05	468.78	532.00	63.22
Nov	297.73	81.98	24.93	404.64	489.00	84.36
Dec	307.41	84.58	2.54	394.52	496.00	101.48
Annual Energy Consumption	**3,617.91**	**994.57**	**895.87**	**5,508.34**	**5,987.00**	**478.66**

Total Energy Consumption

Date/Time	Base Case	Re trofit case	Net Zero case	% reduction in Net Zero case
	kWh	kWh	kWh	
Jan	1,082.50	540.20	402.55	62.81%
Feb	1,052.29	519.03	367.23	65.10%
Mar	988.89	718.13	441.93	55.31%
Apr	1,121.41	836.32	502.51	55.19%
May	1,349.69	1,029.04	584.01	56.73%
Jun	1,304.40	1,011.11	558.16	57.21%
Jul	1,098.23	842.42	510.10	53.55%
Aug	967.35	733.48	479.80	50.40%
Sep	1,022.92	760.87	493.87	51.72%
Oct	1,005.25	733.41	480.11	52.24%
Nov	1,152.33	573.29	415.61	63.93%
Dec	1,098.58	547.10	405.85	63.06%
Annual Energy Consumption	**13,243.83**	**8,844.42**	**5,641.74**	**57.40%**

Analysis – Peak Electricity Demand



Conclusion

- Hot and humid climate have high in-solar gain - roof and walls with high reflectance and emissivity are the most cost effective solution. Proper implementation of cool surfaces are key to technology success.
- Renewable source is required to meet Net Zero requirement. Solution is expensive however cost effectiveness is possible if the divide is between individual home owner and community.
- Design of renewable needs to meet peak load demand, there will be Net Surplus. Feed in tariff needs to be set up to promote ZEB
- Cost Effectiveness for ZEB is very critical for mass adoption.
- Initial Government subsidy will promote ZEB.

Contact

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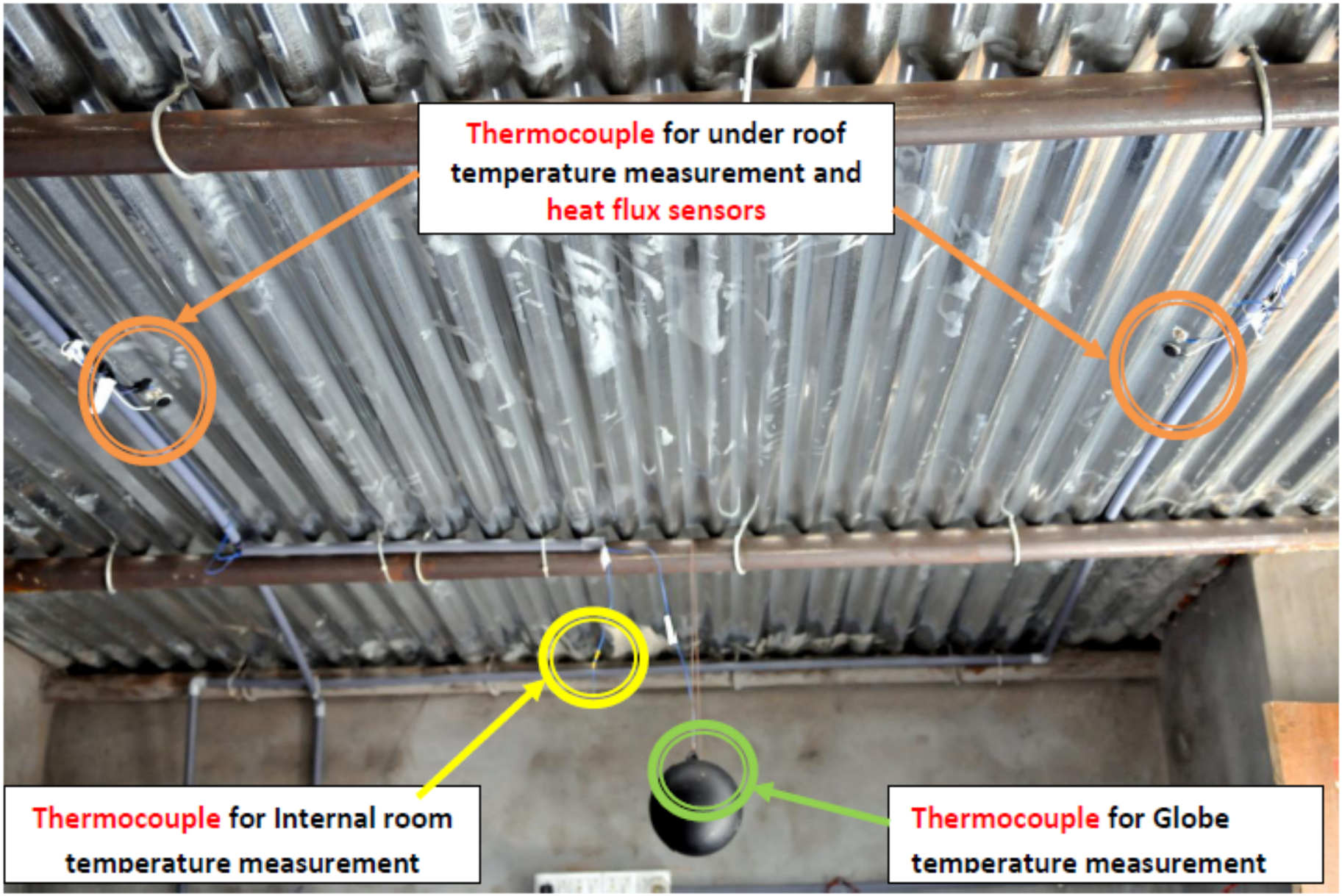
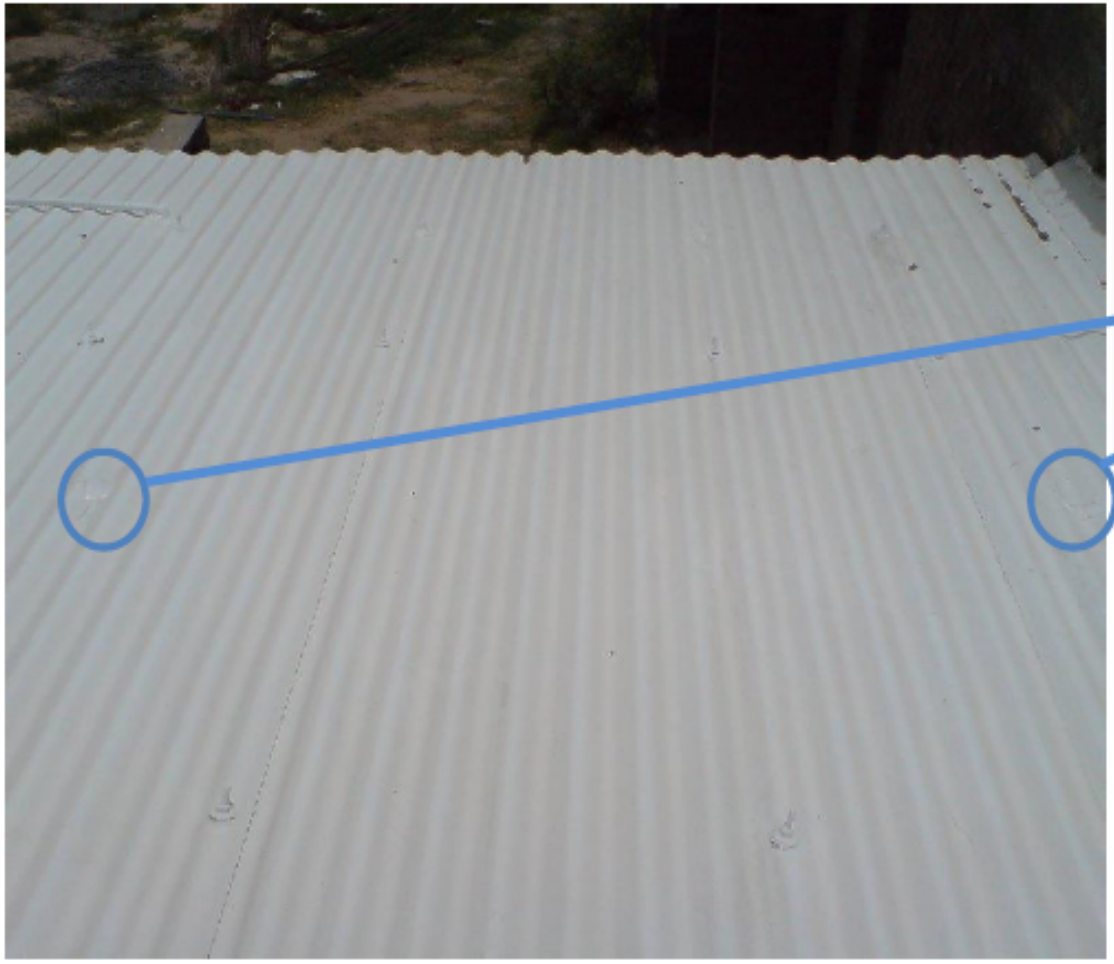
Study of Cool Roof on Low Income House Group

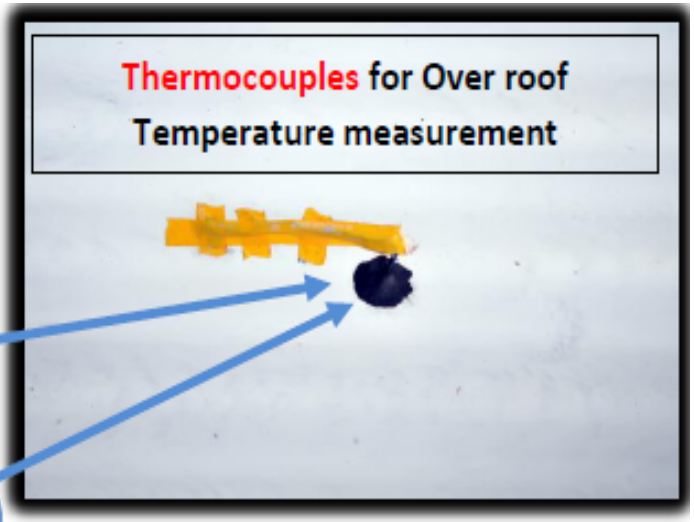
Sanand (Ahmedabad)

INSTRUMENTS AND SENSORS USED



INSTRUMENTS AND SENSORS USED

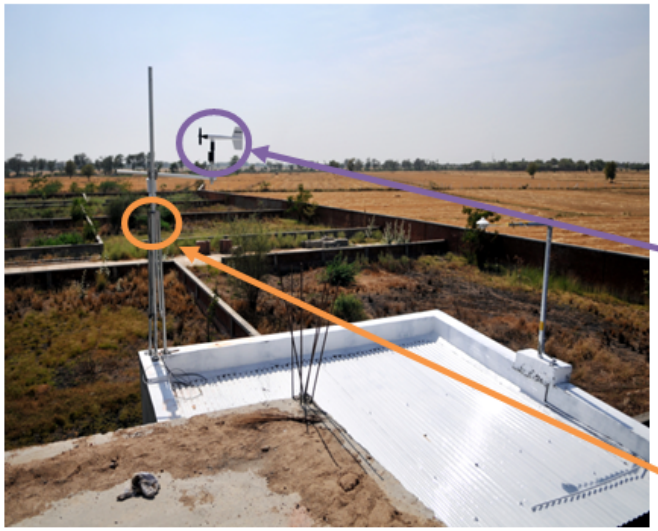




INSTRUMENTS AND SENSORS USED

Upward Facing Pyranometer measures **Direct Incident light**

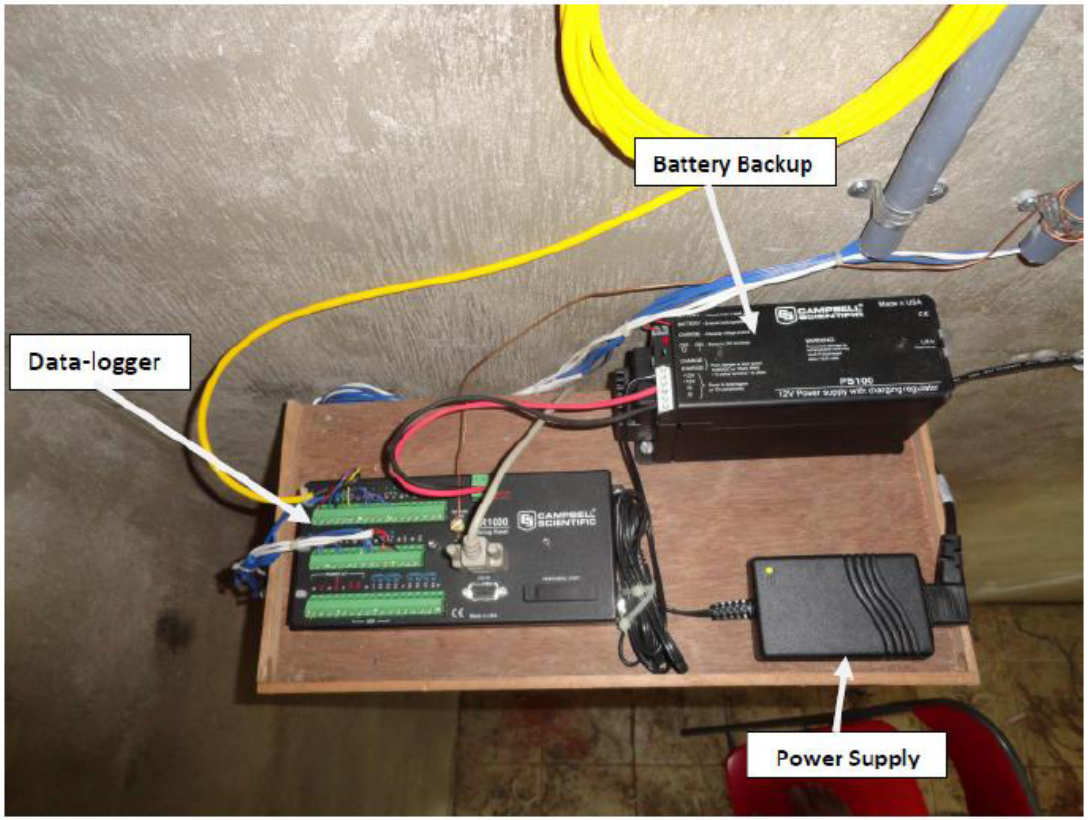
Downward Facing Pyranometer measures **Reflected light** from the white roof



Anemometer measures Wind direction and Wind Velocity

Hygrometer measures relative humidity

INSTRUMENTS AND SENSORS USED



TIMESTAMP	RECORD	BattV	PTemp_C	GLB_Surf	Out_TC_A	In_TC_A	Out_TC_B	In_TC_B	Amb_TC	Globe_TC	HF_A	HF_B
2012-06-02 12:50:00	0	12.99	37.29	37.7	58.82	58.56	59.91	54.06	37.82	37.63	18.62	16.57
2012-06-02 13:00:00	1	13	37.55	37.98	57.96	57.71	59.51	54.39	38.18	37.86	17.42	15.09
2012-06-02 13:10:00	2	13	37.79	38.29	57.73	57.5	58.45	54.41	38.52	38.14	15.89	14.43
2012-06-02 13:20:00	3	13	38.02	38.48	54.82	54.56	55.86	51.35	38.69	38.35	17.13	13.4
2012-06-02 13:30:00	4	13	38.22	38.54	57.87	57.68	58.86	53.73	38.81	38.48	15.93	15.37

OBSERVATIONS

28/06/2012

AVERAGE INCIDENT FLUX (6.30AM-7PM) : 568 W/m^2

MAXIMUM INCIDENT FLUX: 1033 W/m^2

REFLECTIVITY OF PAINT: 52%

Average Ambient Temperature : 36.29 ^oC **MAX:** 42.6 ^oC **MIN:** 24.7 ^oC

Average Relative Humidity : 31%

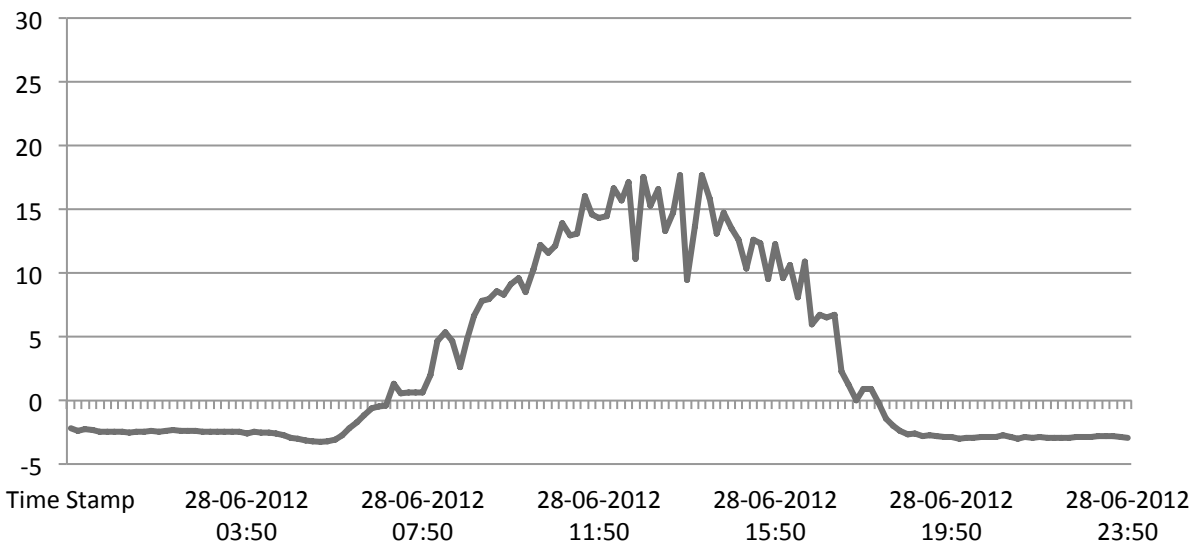
Average Wind Speed: 2.6 m/s

Galvanized Roof
White Roof

HEAT FLUX

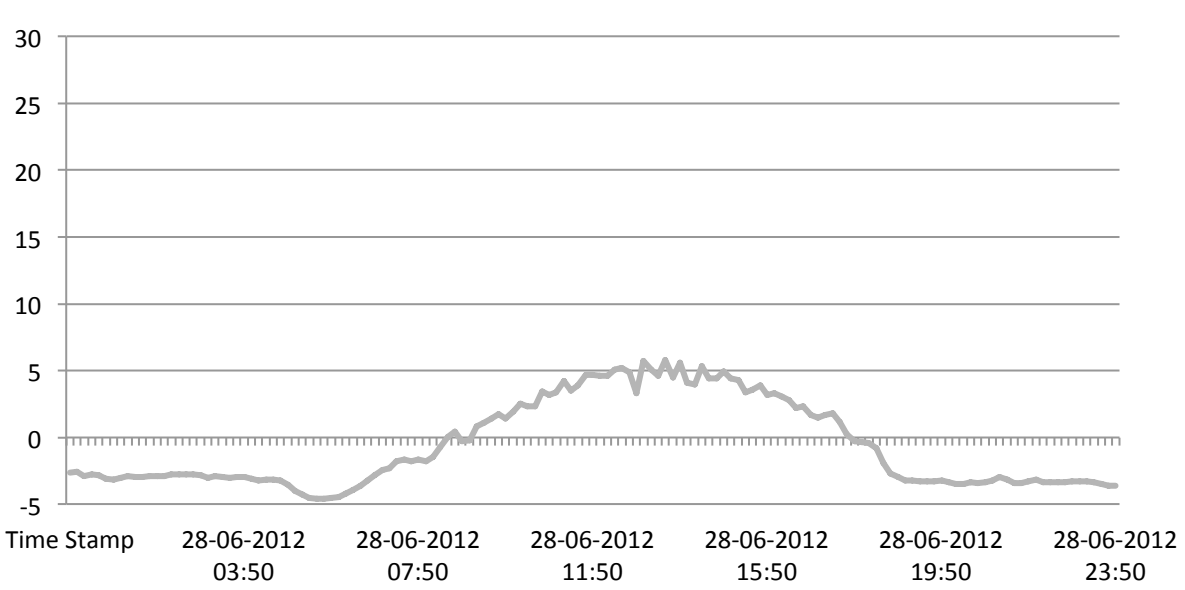
GALVANIZED ROOF HEAT FLUX READINGS (mV)

MAX	MIN
17.72 mV	-3.23 mV



WHITE ROOF HEAT FLUX READINGS (mV)

MAX	MIN
5.8 mV	-4.9 mV

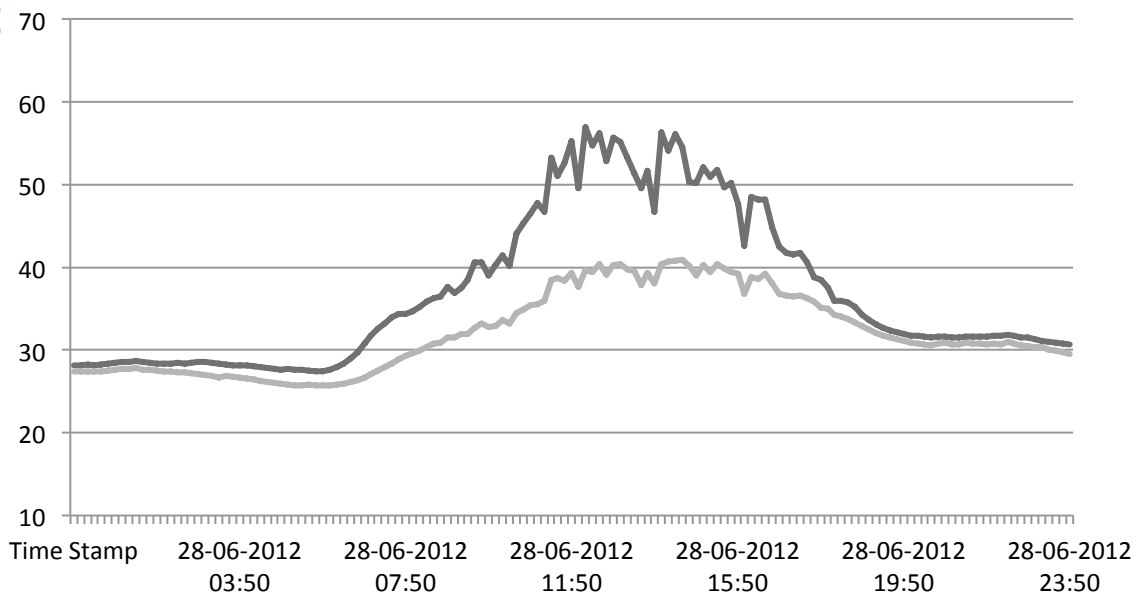


Galvanized Roof
White Roof

OVER ROOF TEMPERATURE

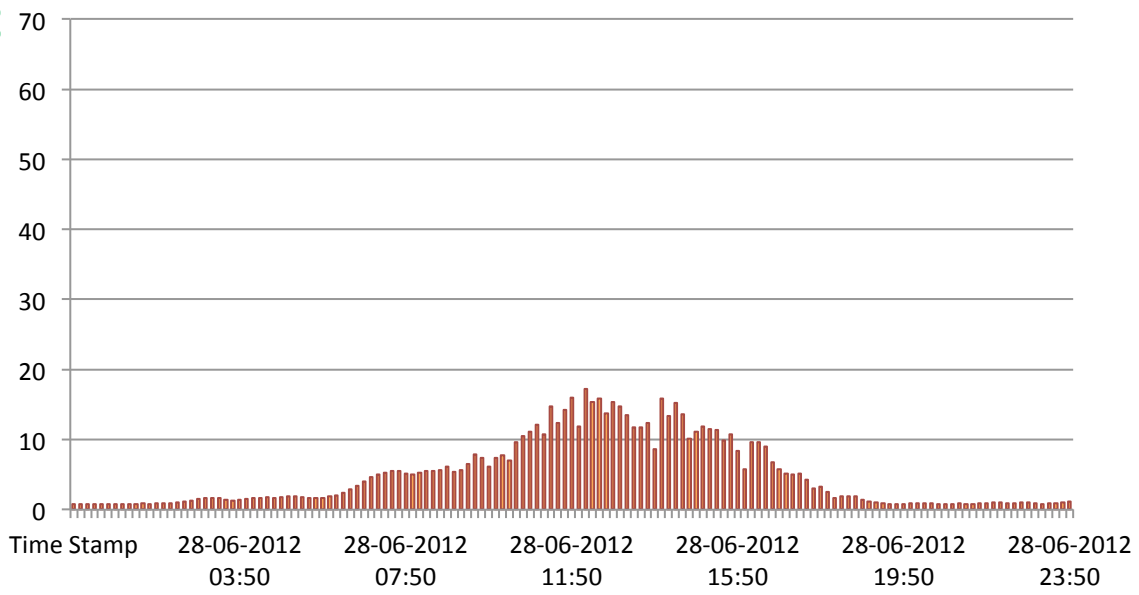
OVER ROOF TEMPERATURE

	GALV.	COOL	DIFF.
MAX	57°C	41°C	16°C
MIN	28°C	26°C	2°C
AVG	37°C	32°C	5°C



HOW MUCH WARMER IS GALVANIZED OVER ROOF COMPARED TO WHITE OVER ROOF(°C)?

MAX	MIN
18°C	0.8°C

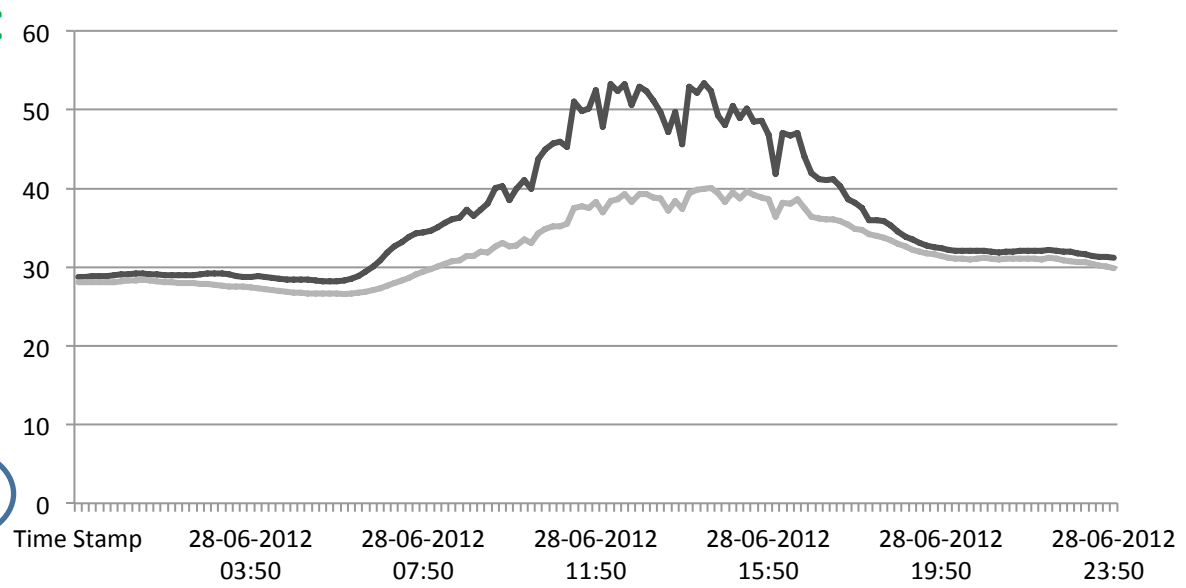


Galvanized Roof
White Roof

UNDER ROOF TEMPERATURE

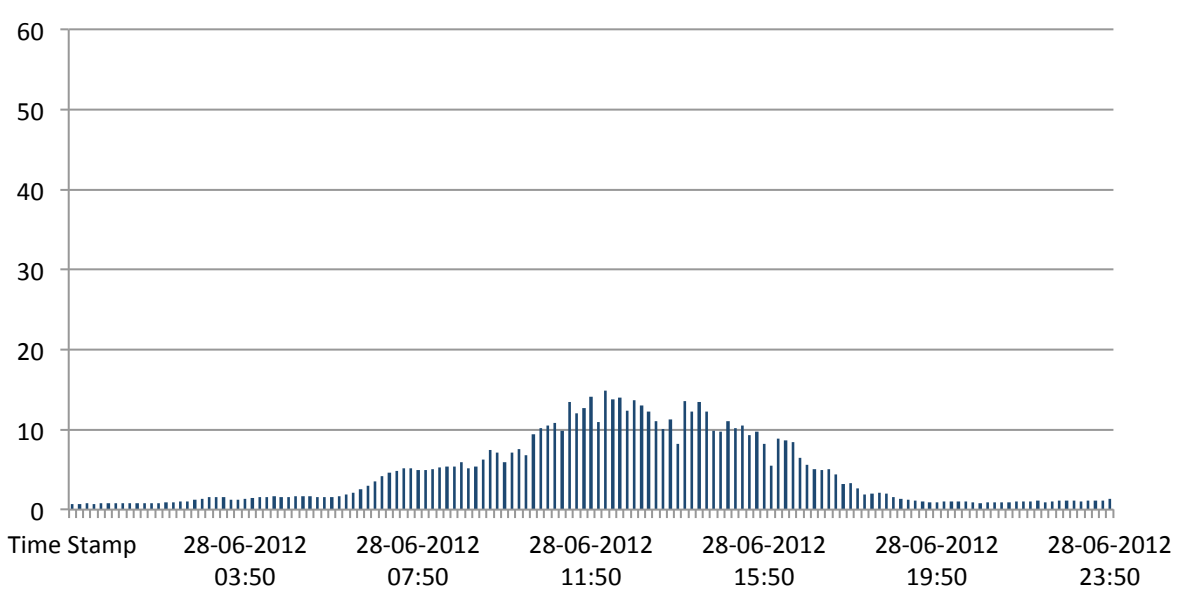
UNDER ROOF TEMPERATURE

	GALV.	COOL	DIFF.
MAX	54°C	40°C	14°C
MIN	27.5°C	25.8°C	1.7°C
AVG	36.5°C	32°C	4.5°C



HOW MUCH WARMER IS GALVANIZED UNDER ROOF COMPARED TO WHITE OVER ROOF(°C)?

MAX	MIN
15°C	0.7°C

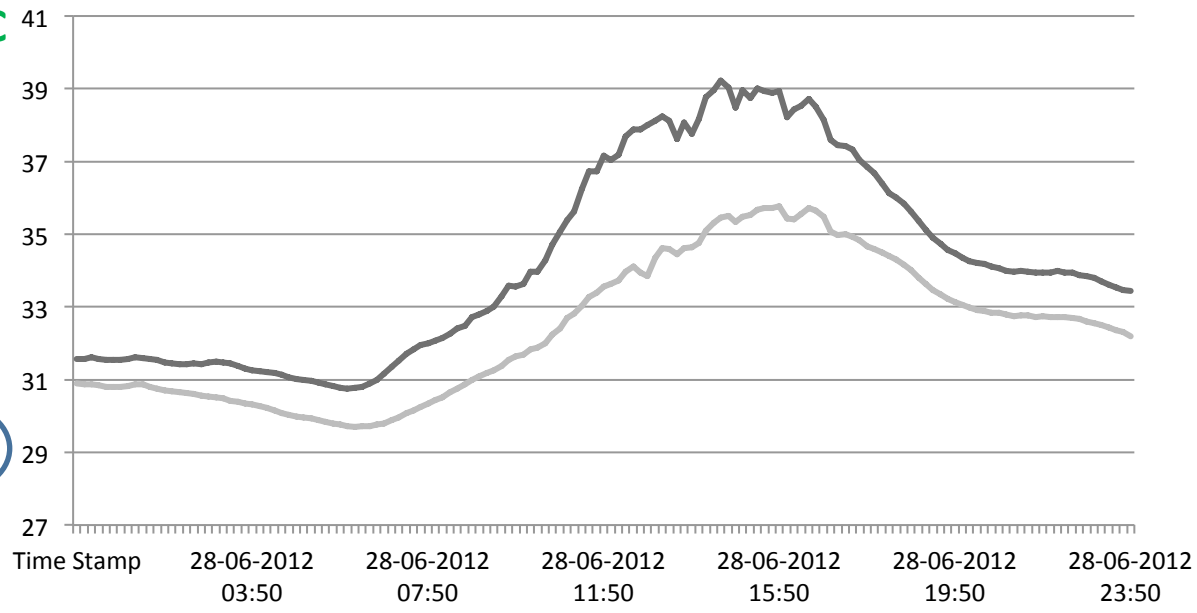


Galvanized Roof
White Roof

INTERNAL ROOM TEMPERATURE

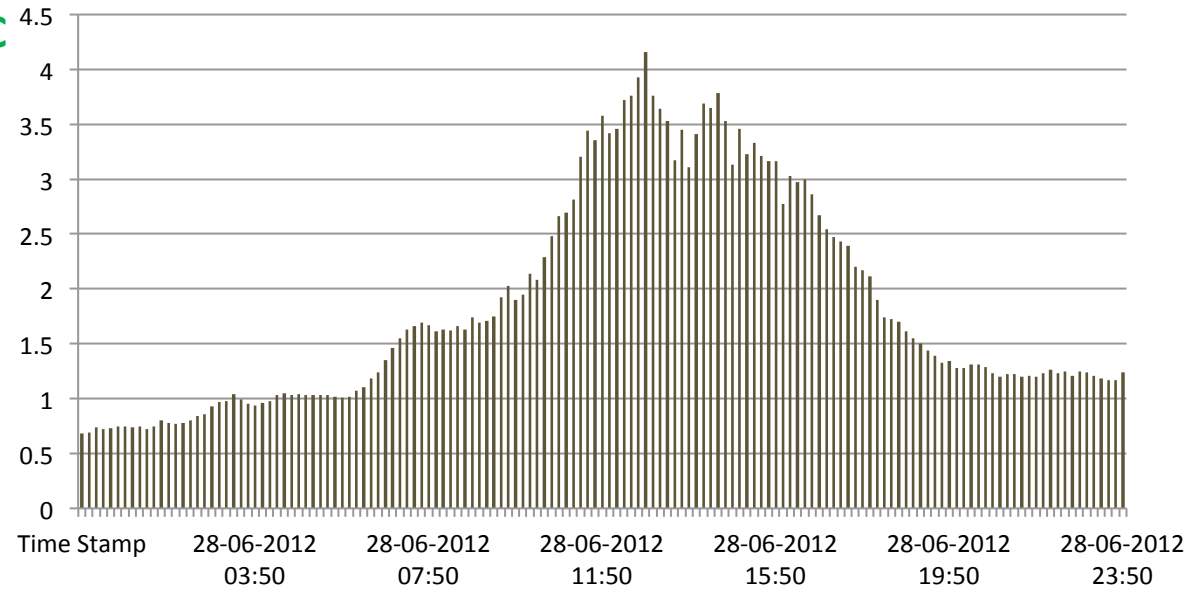
INTERNAL ROOM TEMPERATURE

	GALV.	COOL	DIFF.
MAX	39.2°C	35.4°C	3.8°C
MIN	30.8°C	29.7°C	1.1°C
AVG	35.2°C	31.8°C	3.4°C



GALVANIZED – WHITE (INTERNAL ROOM TEMPERATURE)

MAX	MIN
4.2°C	0.7°C

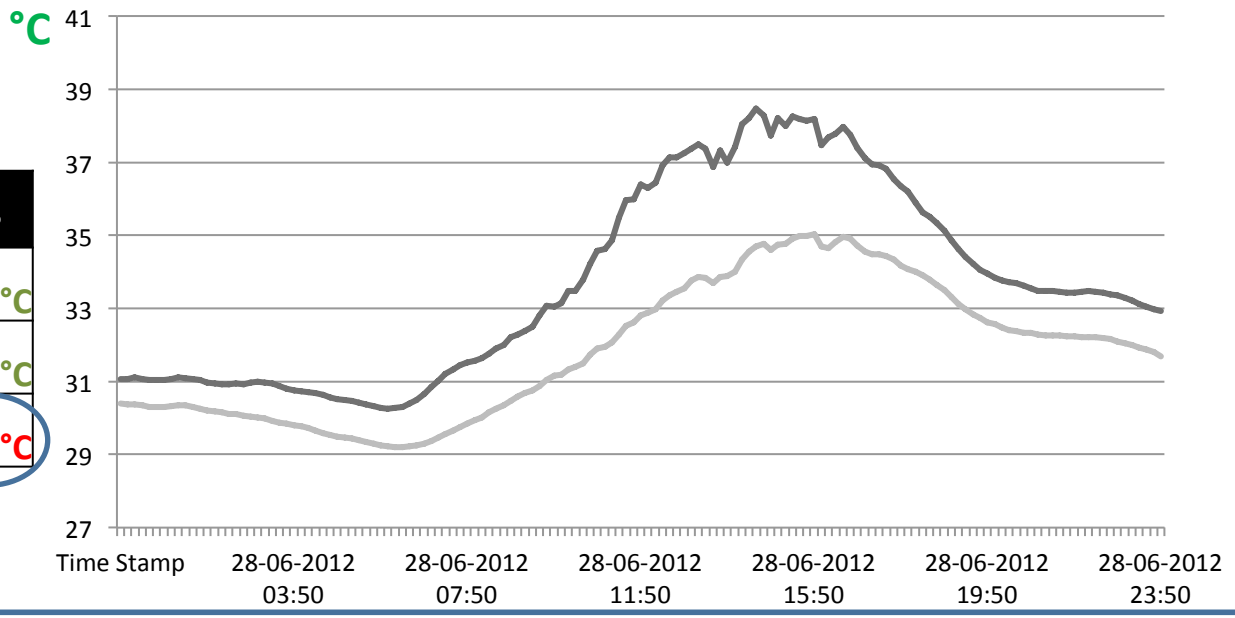


GLOBE SURFACE TEMPERATURE

Galvanized Roof
White Roof

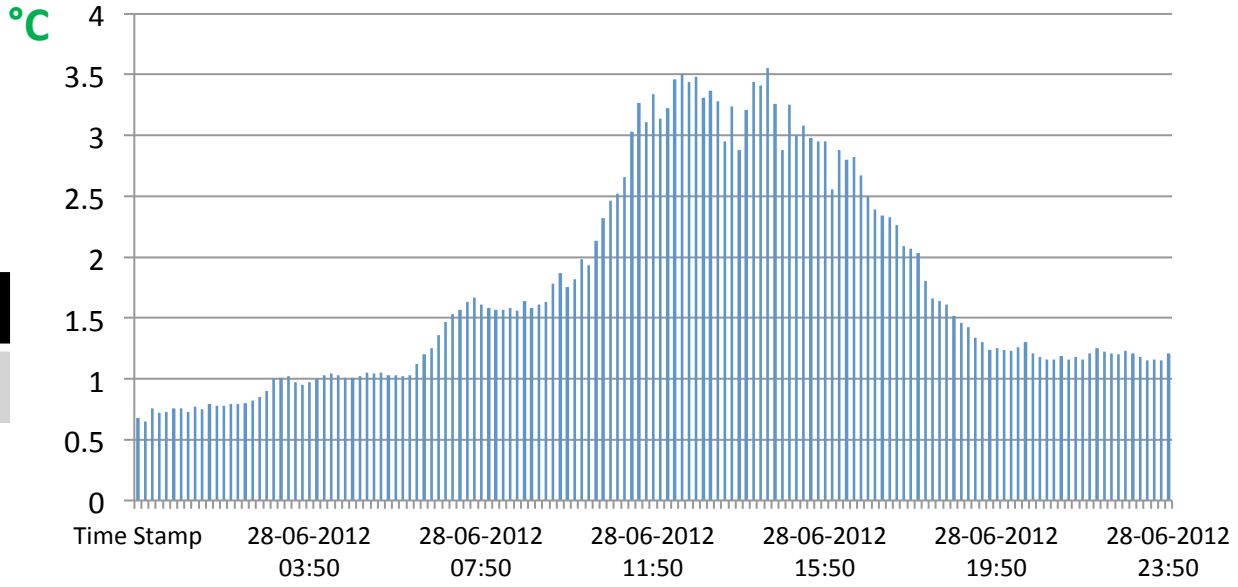
GLOBE SURFACE TEMPERATURE

	GALV.	COOL	DIFF.
MAX	38.5°C	35°C	3.5°C
MIN	30.3°C	29.2°C	1.1°C
AVG	34.3°C	31.2°C	3.1°C



GALVANIZED – WHITE (GLOBE TEMPERATURE)

MAX	MIN
3.55°C	0.7°C

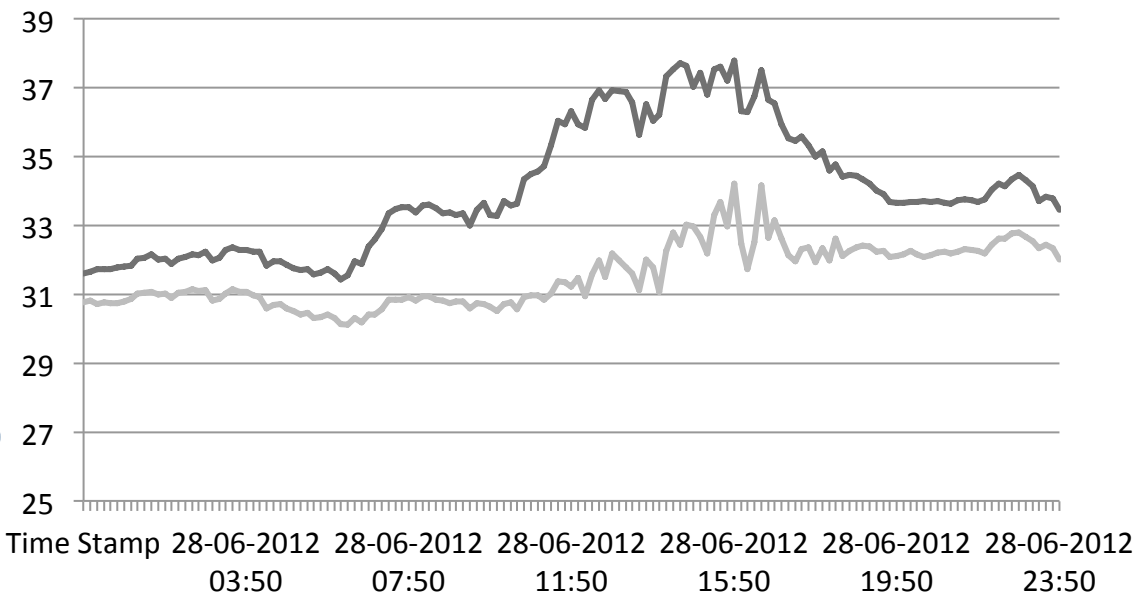


Galvanized Roof
White Roof

MEAN RADIANT TEMPERATURE

MEAN RADIANT TEMPERATURE

	GALV.	COOL	DIFF.
MAX	37.8°C	34.2°C	3.6°C
MIN	31.6°C	30.3°C	1.3°C
AVG	35.4°C	31.5°C	3.9°C

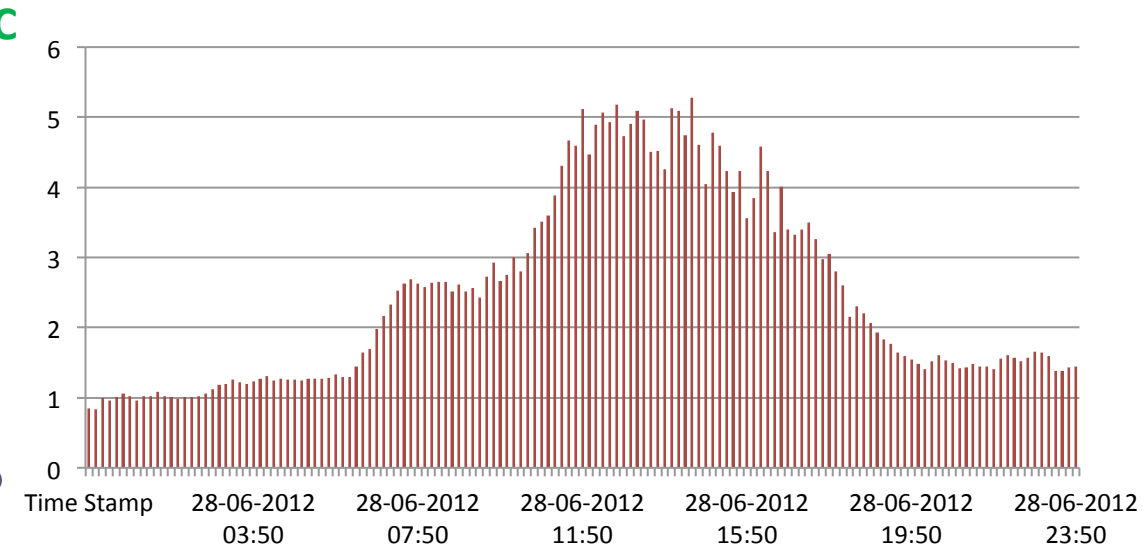


GALVANIZED – WHITE (MRT)

MAX	MIN
5.2°C	0.8°C

$$T_{mrt} = \left[(T_g + 273.15)^4 + \frac{1.1 \times 10^8 V_a^{0.6}}{\varepsilon D^{0.4}} \times (T_g - T_a) \right]^{1/4} - 273.15$$

T_g = the globe temperature (°C)
V_a = the air velocity (ms^{-1})
T_a = the air temperature (°C)
D = the globe diameter (mm)
ε = the globe emissivity



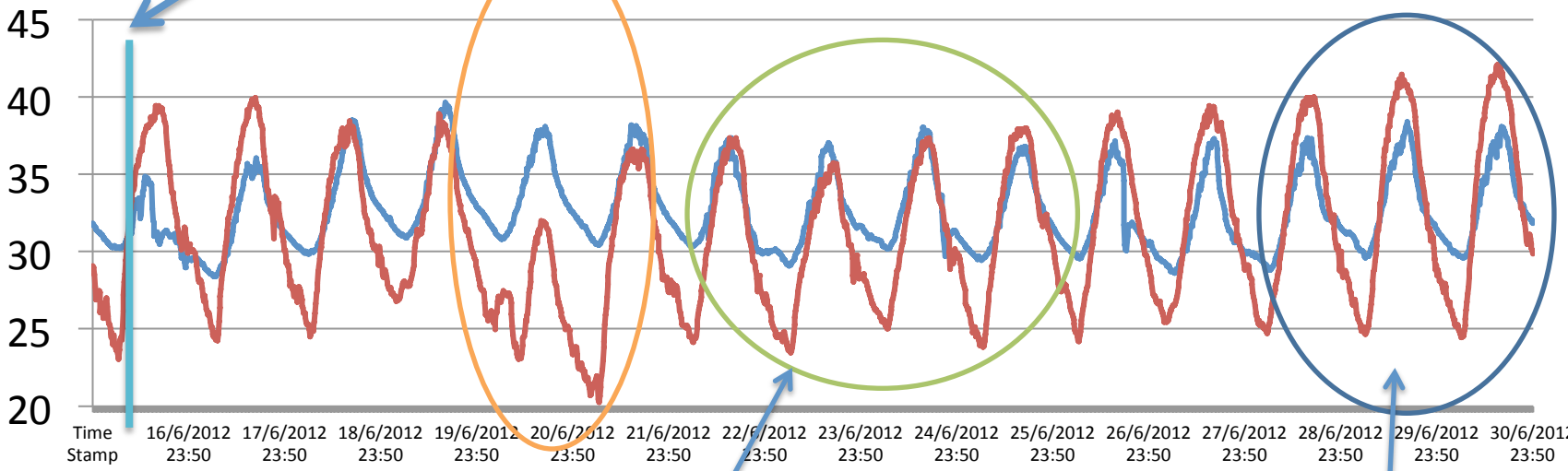
OUTSIDE AMBIENT

WHITE ROOF INTERNAL ROOM TEMP

Maximum Direct Incident Flux : 978 W/ m^2
WIND Speed : 2.7 m/s (AVG) 4.8 m/s (MAX)
Relative Humidity : 71% (AVG)
Ambient Temp.: MAX: 32°C MIN:19°C

During this period, maximum humdity was observed. With humidity reaching its peaks at 90% and with average of 71% during the period, it is observed that white coated internal room temperature was 37°C where as average outside ambient temperature dropped to 28°C. The white coated room stayed cooler than Galvanized room by 1-3°C.

Under Roof Painted With Grey Color



Maximum Direct Incident Flux : 978 W/ m^2
WIND Speed : 2.3 m/s (AVG) 2.34m/s (MAX)
Relative Humidity : 42% (AVG)
Ambient Temp.: MAX: 38°C MIN:24°C

Outside Ambient temp remained between 36°C and 37°C. White Roof Internal Temperature remained equal to outside ambient temperature. Even White coated room stayed cooler than the Galvanized room by 1- 2°C.

Maximum Direct Incident Flux : 1063 W/ m^2
WIND Speed : 3.1 m/s (AVG) 6.5m/s (MAX)
Relative Humidity : 31% (AVG)
Ambient Temp.: MAX: 42°C MIN:26°C

Outside Ambient temp rose from 39°C to 42°C. But Still White coated roof is cooler with peak temperature of 36°C. Even White coated room stayed cooler than the Galvanized room by 4- 7°C during Day time

Conclusion and Next Steps

- Thermal comfort
- Health benefits and better living conditions
- In Industry application Increases productivity
- Skill development for advance technology applications
- Organize training centers to develop trained construction workers
- Community development will help Heat island effect. Thus reducing Air Conditioning loads in a building.