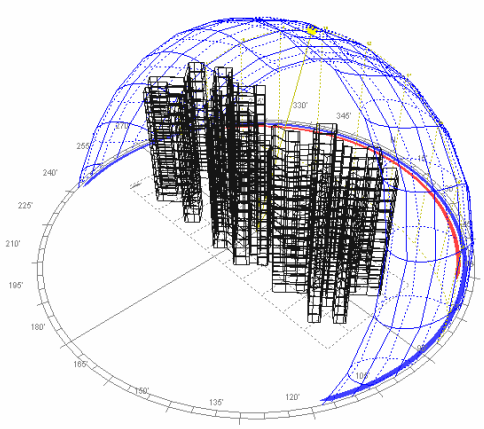
Draft

Hourly Comfort Assessment Using Various Glass Option in Apartments

Sci-Knowledge Interlinks Pvt. Ltd.

Pune INDIA



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GLOBAL EVOLUTIONARY ENERGY DESIGN

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Preface

The report has been prepared for Sci-Knowledge Interlink Pvt. Ltd. for assessment of different available glass options for the apartment tower in Pune. The methodology followed for creating a ranking of different glazing option is based on the hours of comfort. The definitions of comfort were derived out of simple Psychrometry. The ranking was also evaluated in terms of solar gain in the building because of high use of glass. The ranking based on sun gain was especially useful in determining the heat load in the building if air conditioned.

The results were depicted and plotted in graphs and tables etc. it is recommended that one should see the hourly excel ™ reports to understand the scenario in a better sense. Please refer to section 5.1, 5.2 and 5.3 i.e. east block, center block and west block respectively for understanding the coding of apartment names before going further in the report.

1 Questions Addressed in the Report

1. What are the profiles of Hourly out side and inside temperature RH and Comfort flag, for various apartments and pent houses?
2. What is the Hourly solar heat transmittance in various apartments?
3. What is the impact of various glass options on internal comfort?
4. Which is the best glass option available among all the seven options?
5. What side sun is actually over heating the space in summer?
6. Which all sides of the building are not benefiting form solar passive heating in winter?
7. What is the ranking of different glass in terms of comfort rating within occupant space?
8. What is the ranking of different glass in terms of solar heat gain within the occupant space?
9. What is the criteria of selection of glass from different glass options?
10. What is the philosophy behind the analysis?

2 Summery of Results

Following Sections Summarizes the best and the poorest glazing options. The analysis has been done for each apartment with all the available seven glazing options. There are two ways by which the glass can be selected, i.e. Air conditioned and non- air conditioned (naturally ventilated apartment).

Lower shading from sun can lead to high solar gain and heat load in the building. If the apartment is to be air conditioned then the glass selected should be the one which saves more from solar gain and the conductive and convective heat transfer as well.

In case of the naturally ventilated apartment. The heat stored in the day time should escape out of the occupant space as soon as possible. Understanding this fact, naturally ventilated apartment should have glazing which should have high shading coefficient and lower conductive and convective heat transfer capabilities. This would lead to high heat transfer from occupant space in the evening

2.1 Ranking of Best to poorest Glass option from Hour of Comfort point of View

	Best						**Poorest**
Rank	1	2	3	4	5	6	7
7101-East	Single glazing Unit (6 mm, coating face 2) Light Gold	Single Glazing 6mm Synergy clear	Single glazing Unit (6 mm, coating face 2) Sparkling Ice / Single Glazing 6mm Super silver clear		Double glazed Unit (Outer 6mm with coating face 2 -12 mm air gap –inner 6 mm planitherm total (low E	Double glazed Unit (outer 6 mm, with coating face 2 – 12mm Air gap-inner 6 mm clear glass) pristine white	Single Glazing 6mm Clear float glass

7082-East	Single glazing Unit (6 mm, coating face 2) Light Gold	Single Glazing 6mm Synergy clear	Single glazing Unit (6 mm, coating face 2) Sparkling Ice / Single Glazing 6mm Super silver clear		Double glazed Unit (Outer 6mm with coating face 2 -12 mm air gap –inner 6 mm planitherm total (low E	Double glazed Unit (outer 6 mm, with coating face 2 – 12mm Air gap-inner 6 mm clear glass) pristine white	Single Glazing 6mm Clear float glass
7935-Center	Single glazing Unit (6 mm, coating face 2) Light Gold	Single Glazing 6mm Synergy clear	Double glazed Unit (Outer 6mm with coating face 2 -12 mm air gap – inner 6 mm planitherm total (low E	Single glazing Unit (6 mm, coating face 2) Sparkling Ice / Single Glazing 6mm Super silver clear		Double glazed Unit (outer 6 mm, with coating face 2 – 12mm Air gap-inner 6 mm clear glass) pristine white	Single Glazing 6mm Clear float glass
7908-Center	Single glazing Unit (6 mm, coating face 2) Light Gold	Single Glazing 6mm Synergy clear	Double glazed Unit (Outer 6mm with coating face 2 -12 mm air gap – inner 6 mm planitherm total (low E	Double glazed Unit (outer 6 mm, with coating face 2 – 12mm Air gap-inner 6 mm clear glass) pristine white	Single glazing Unit (6 mm, coating face 2) Sparkling Ice / Single Glazing 6mm Super silver clear		Single Glazing 6mm Clear float glass
7874-Center	Single glazing Unit (6 mm, coating face 2) Light Gold	Single Glazing 6mm Synergy clear	Single glazing Unit (6 mm, coating face 2) Sparkling Ice / Single Glazing 6mm Super silver clear		Double glazed Unit (Outer 6mm with coating face 2 -12 mm air gap –inner 6 mm planitherm total (low E	Double glazed Unit (outer 6 mm, with coating face 2 – 12mm Air gap-inner 6 mm clear glass) pristine white	Single Glazing 6mm Clear float glass
7847-Center	Single glazing Unit (6 mm, coating face 2) Light Gold	Single Glazing 6mm Synergy clear	Double glazed Unit (Outer 6mm with coating face 2 -12 mm air gap – inner 6 mm planitherm total (low E	Double glazed Unit (outer 6 mm, with coating face 2 – 12mm Air gap-inner 6 mm clear glass) pristine white	Single glazing Unit (6 mm, coating face 2) Sparkling Ice / Single Glazing 6mm Super silver clear		Single Glazing 6mm Clear float glass
7813-Center	Single glazing Unit (6 mm, coating face 2) Light Gold	Single Glazing 6mm Synergy clear	Double glazed Unit (Outer 6mm with coating face 2 -12 mm air gap – inner 6 mm planitherm total (low E	Single glazing Unit (6 mm, coating face 2) Sparkling Ice / Single Glazing 6mm Super silver clear		Double glazed Unit (outer 6 mm, with coating face 2 – 12mm Air gap-inner 6 mm clear glass) pristine white	Single Glazing 6mm Clear float glass

8328-West	Single glazing Unit (6 mm, coating face 2) Light Gold	Single Glazing 6mm Synergy clear	Single glazing Unit (6 mm, coating face 2) Sparkling Ice / Single Glazing 6mm Super silver clear	Double glazed Unit (Outer 6mm with coating face 2 -12 mm air gap –inner 6 mm planitherm total (low E	Double glazed Unit (outer 6 mm, with coating face 2 – 12mm Air gap-inner 6 mm clear glass) pristine white	Single Glazing 6mm Clear float glass
8307-West	Single glazing Unit (6 mm, coating face 2) Light Gold	Single Glazing 6mm Synergy clear	Single glazing Unit (6 mm, coating face 2) Sparkling Ice / Single Glazing 6mm Super silver clear	Double glazed Unit (Outer 6mm with coating face 2 -12 mm air gap –inner 6 mm planitherm total (low E	Double glazed Unit (outer 6 mm, with coating face 2 – 12mm Air gap-inner 6 mm clear glass) pristine white	Single Glazing 6mm Clear float glass

2.2 Ranking of Best to poorest Glass Option from Sun Gain Point of View

	Best						**Poorest**
Rank	1	2	3	4	5	6	7
7101-East	Double glazed Unit (Outer 6mm with coating face 2 -12 mm air gap –inner 6 mm planitherm total (low E	Single glazing Unit (6 mm, coating face 2) Light Gold	Double glazed Unit (outer 6 mm, with coating face 2 – 12mm Air gap-inner 6 mm clear glass) pristine white	Single Glazing 6mm Synergy clear	Single glazing Unit (6 mm, coating face 2) Sparkling Ice / Single Glazing 6mm Super silver clear		Single Glazing 6mm Clear float glass
7082-East	Double glazed Unit (Outer 6mm with coating face 2 -12 mm air gap –inner 6 mm planitherm total (low E	Single glazing Unit (6 mm, coating face 2) Light Gold	Double glazed Unit (outer 6 mm, with coating face 2 – 12mm Air gap-inner 6 mm clear glass) pristine white	Single Glazing 6mm Synergy clear	Single Glazing 6mm Super silver clear	Single glazing Unit (6 mm, coating face 2) Sparkling Ice	Single Glazing 6mm Clear float glass
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8307-West	Double glazed Unit (Outer 6mm with coating face 2 -12 mm air gap –inner 6 mm planitherm total (low E	Single glazing Unit (6 mm, coating face 2) Light Gold	Double glazed Unit (outer 6 mm, with coating face 2 – 12mm Air gap-inner 6 mm clear glass) pristine white	Single Glazing 6mm Synergy clear	Single glazing Unit (6 mm, coating face 2) Sparkling Ice / Single Glazing 6mm Super silver clear	Single Glazing 6mm Clear float glass

3 Introduction

Accurate energy simulation can be a very useful tool for determining the internal comfort situation for any occupant space. In the following analysis, the objective is to sort out the best glazing option for the PALASH Apartment Tower in Pune India.

The tower houses nine apartments on a typical floor and few of them are duplex. The apartment tower is east west oriented which makes it more thermally neutral. Good amount of glazing is used in the design which makes the tower more prone to solar heat gain. This makes the case quite important for occupant comfort point of view. To analyze the internal comfort situation the weather data has been obtained from ISHARE, material and fabric definition were provided by architects and consultants, and schedule of operation were loaded from standard Building energy simulation template.

The energy simulation were performed for all the cases, result were obtained and analyzed for various indications depicting glass performance.

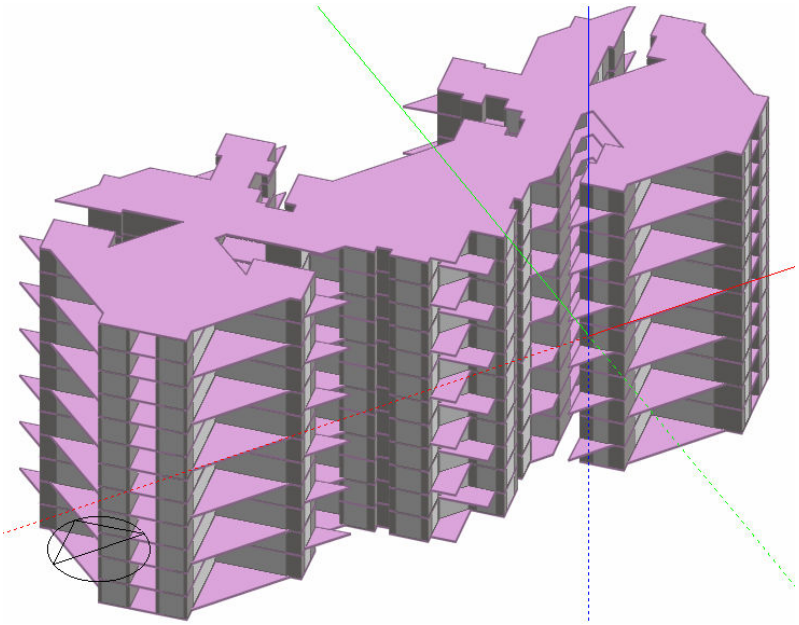


Figure 3a: Approximate Thermal Envelop

Figure 3a shows the approximate thermal envelop and the shading elements. There is a north indication to assist in understanding of orientation of the building. Medium Concrete has been used to replicate the effect of thermal mass and heat storing capability of the building.

4 Weather Data and Design Conditions

Location : Pune

Latitude (°N) : 18.5

Longitude (°E) : 73.9

Altitude (m) : 559

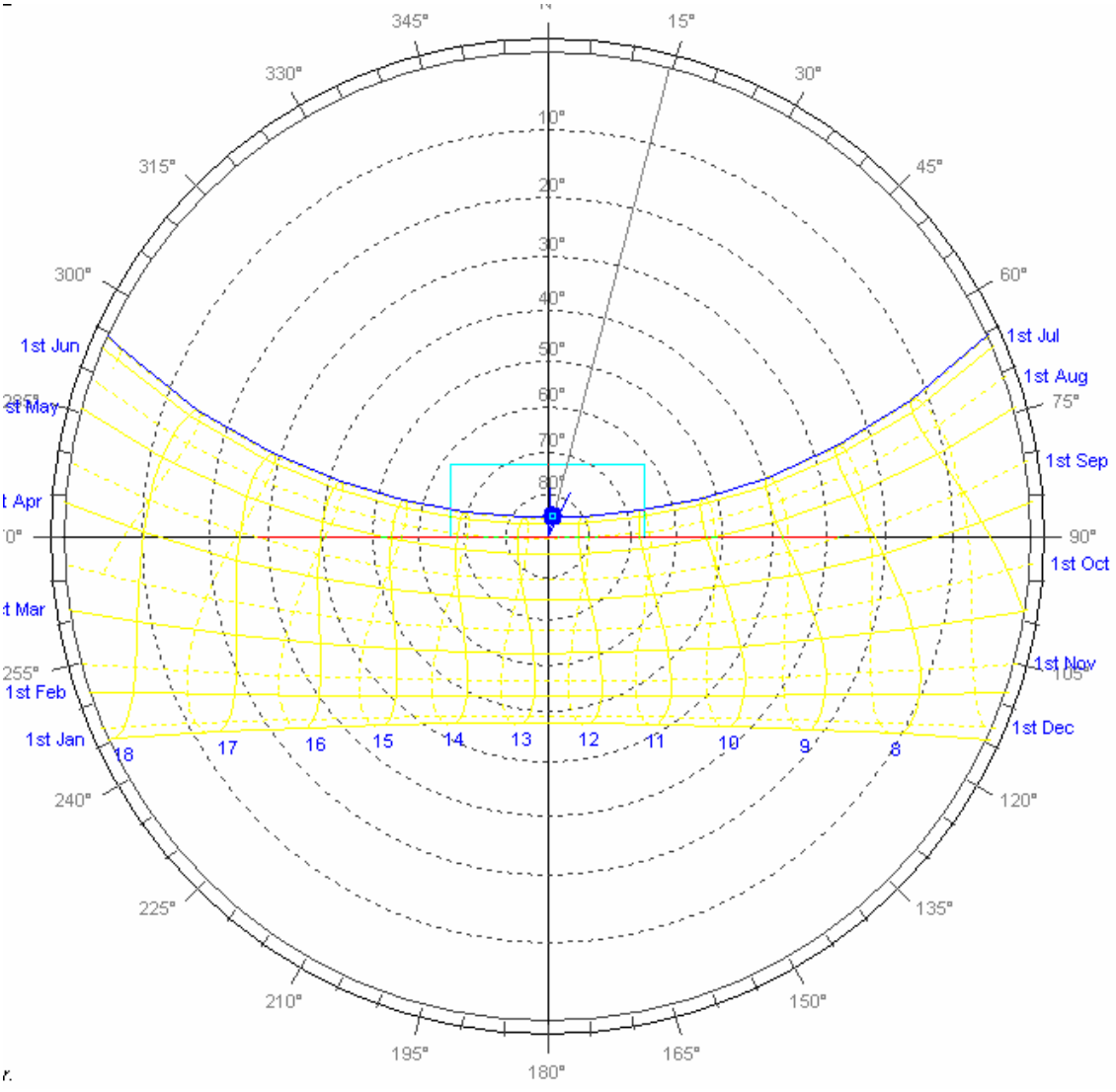


Figure 4a: Annual sun path diagram

	Design Dry Bulb Temperatures		Design Wet Bulb Temperatures	
	Dry Bulb	Mean Coincident Wet Bulb	Wet Bulb	Mean Coincident Dry Bulb
0.4%	38.0	19.5	29.7	24.6
1%	37.0	19.6	28.8	24.1
2%	35.9	19.6	28.2	23.7

Table 4- ISHRAE Cooling Design Temperatures for Pune India

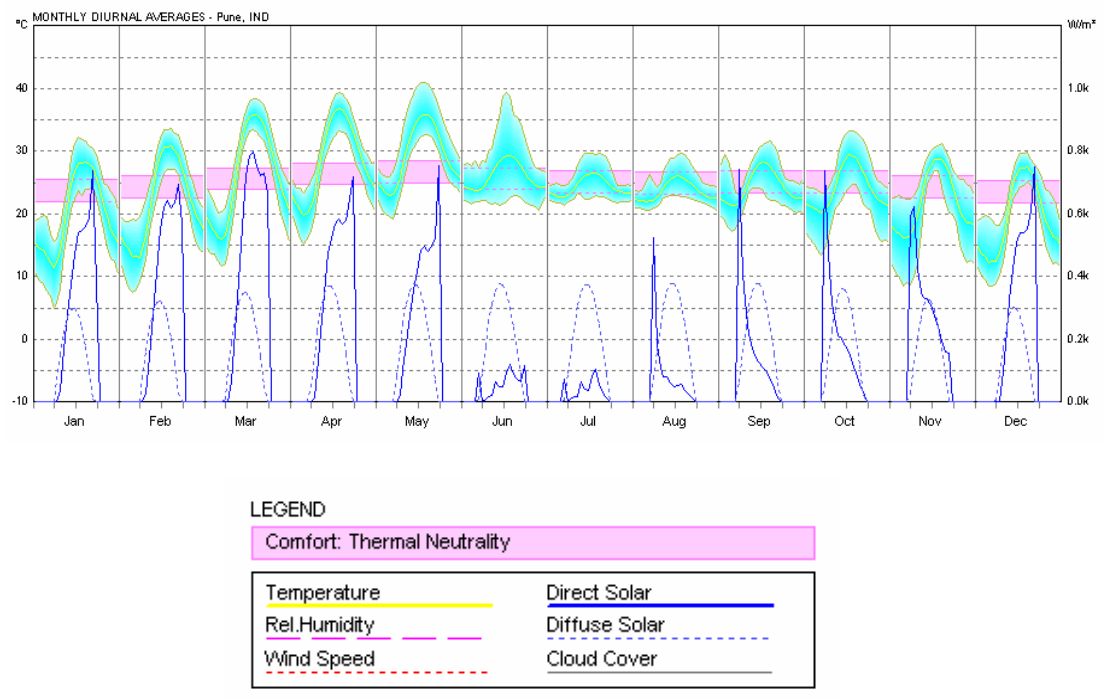


Figure 4b: Hourly Temperature Profile in Pune

4.1 Understanding the Climate

The Climate Data source is WMO Station 430630. This is Using Design Conditions from "Climate Design Data 2005 ASHRAE Handbook". The design conditions are carefully generated from a period of record (typically 30 years) to be representative of that location and be suitable for use in heating/cooling load calculations.

There are 5138 annual cooling degree-days at (10°C baseline), 0 annual heating degree-days (10°C baseline) and 2228 annual cooling degree-days (18°C baseline) 10 annual heating degree-days (18°C baseline).

Climate type is "BSh" (Köppen classification), Hot subtropical steppe (lat. 15-30°N) Climate type "4B" (ASHRAE Standards 90.1-2004 and 90.2-2004 Climate Zone) Mixed - Dry, Probable Köppen classification=BSk/BWh/H, Semiarid Mid Latitude/Arid Subtropical/Highlands

4.2 Typical/Extreme Period Determination

- Wet Period=May:Oct

Week closest to this period average temperature selected for Typical Period

Typical Week Period selected: Oct 2:Oct 8, Average Temp= 25.31°C, Deviation=| 0.194|°C

- Dry Period=Nov:Apr

Week closest to this period average temperature selected for Typical Period

Typical Week Period selected: Nov 8:Nov 14, Average Temp= 22.82°C, Deviation=| 0.291|°C

- Summer is Apr:Jun

Extreme Summer Week (nearest maximum temperature for summer)

Extreme Hot Week Period selected: May 6:May 12, Maximum Temp= 41.00°C, Deviation=|10.600|°C

Typical Summer Week (nearest average temperature for summer)

Typical Week Period selected: May 13:May 19, Average Temp= 27.89°C, Deviation=| 0.436|°C

- Winter is Oct:Dec

Extreme Winter Week (nearest minimum temperature for winter)

Extreme Cold Week Period selected: Dec 10:Dec 16, Minimum Temp= 8.50°C, Deviation=| 9.763|°C

Typical Winter Week (nearest average temperature for winter)

Typical Week Period selected: Nov 5:Nov 11, Average Temp= 21.83°C, Deviation=| 0.104|°C

- Autumn is Jul:Sep

Typical Autumn Week (nearest average temperature for autumn)

Typical Week Period selected: Jul 22:Jul 28, Average Temp= 24.12°C, Deviation=| 0.017|°C

- Spring is Jan:Mar

Typical Spring Week (nearest average temperature for spring)

Typical Week Period selected: Feb 12:Feb 18, Average Temp= 22.48°C, Deviation=| 0.020|°C

5 Building Energy Modeling - Typical Floors

A Typical Floor has been modeled to understand the Thermal behavior of the occupant space. To reduce the computational complexity, single flat has been regarded as a single zone. CAD geometry has been created which depicts the thermal, and shading information associated with the building (See Figure 3.1)

The building operational data like lighting gain, occupant density and other heat load factor taken were standard factor used for HVAC Design (Refer the input file templates of Energy Plus for details). The envelop material like wall, roof and flooring etc has been taken form the building data sheet sent by architects. In the current analysis notional building envelop data has been used.

There were seven different glass options, each of them has been evaluated separately keeping the other envelop detail like wall, roof and slab same for each case. Each apartment has been identified as a zone which is dealt separately. In section 5.1, 5.2 and 5.3 apartment zone with their identification codes are presented. There is an arrow which is depicting the north reference for the building.

5.1 East Block Apartments

The east blocks of the building have two penthouses that has been analyzed for temperature variations, internal comfort hours and solar heat gain the name of apartment zones are ***7101 and 7082***

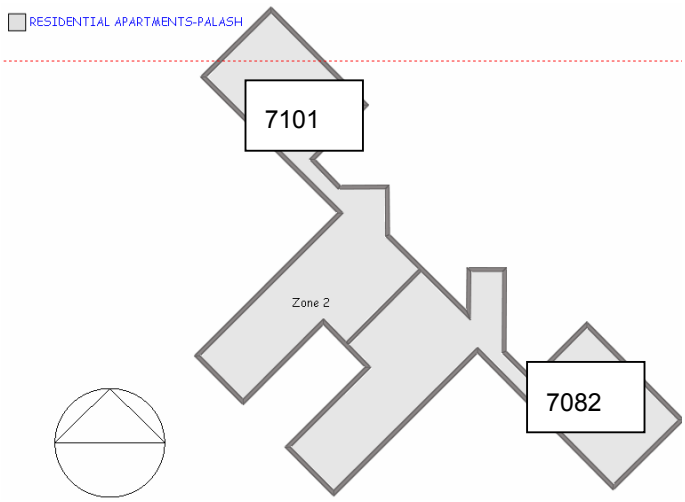


Figure 5a: East Block.

5.2 Center Block Apartments

The center block contains five different apartments (zones) which are named as ***7935, 7908, 7874, 7847 and 7813***

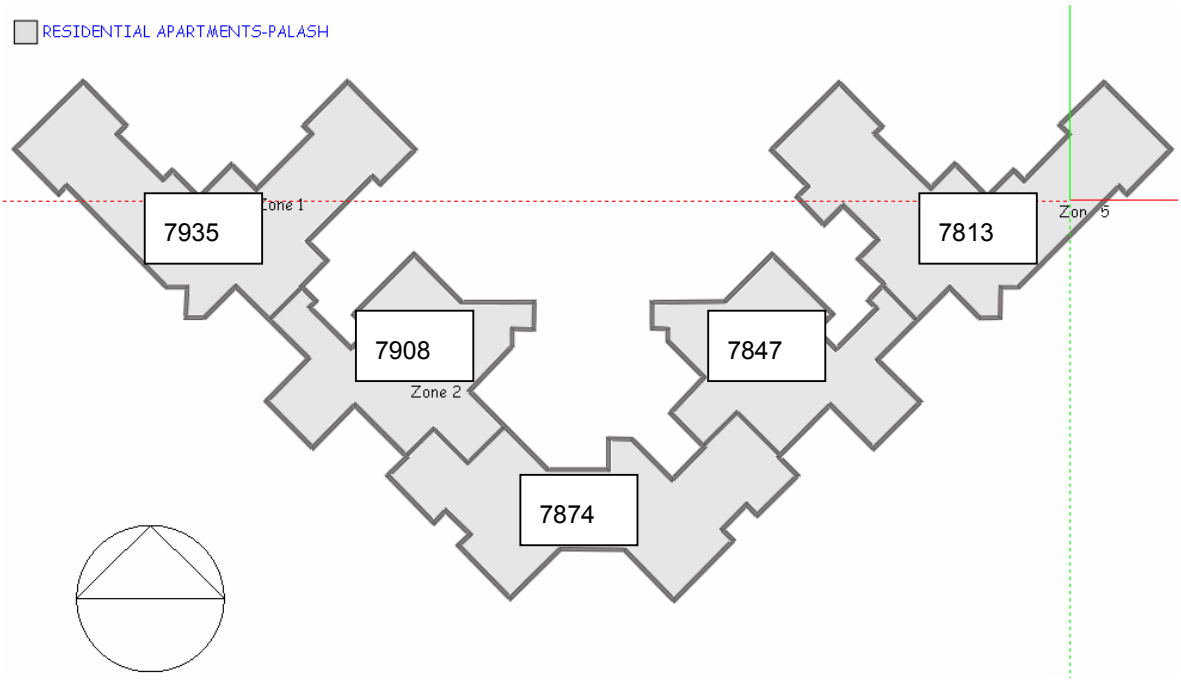


Figure 5b: Center Block.

5.4 West Block Apartments

Again the west block also contain two pent houses which are name as ***8328 and 8307***

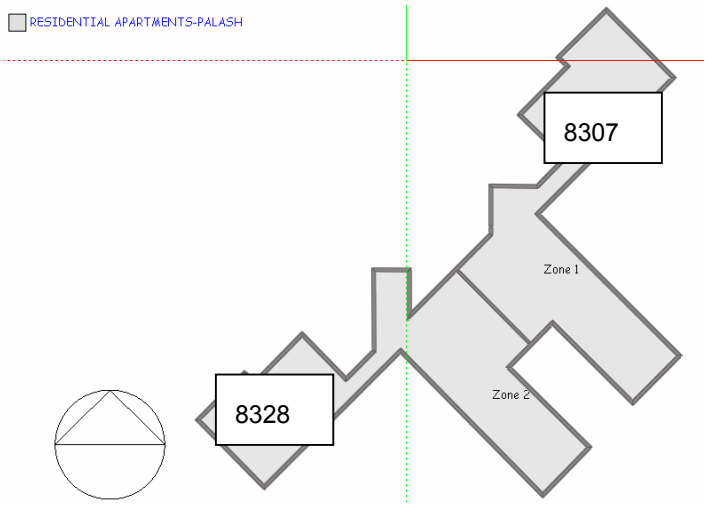


Figure 5b: West Block.

6 Various Glass Options

Various glazing option has been summarized in the following table with there thermo physical properties.

Sr.No.	Type of glass	U value	Uvalue summer	U value winter	SHGC	VLT
Unit		W/sqm K	W/sqm K	W/sqm K	SF	(%)
SG-SAINT GOBAIN						
1.	Single glazing Unit (6 mm ,coating face 2) Light Gold	5.7	6	6	0.52	32
2.	Single glazing Unit (6 mm ,coating face 2) Sparkling Ice	5.6	5.86	6.3	0.67	37
3.	Double glazed Unit (outer 6.. ,with coating face 2 – 12mm Air gap-inner 6 mm clear glass) Pristine white	1.77	1.95	1.76	0.54	75
4.	Double glazed Unit (Outer 6mm with coating face 2 -12 mm air gap –inner 6 mm planitherm total (low E coating on Face 3) Pristine white	1.7	1.8	1.66	0.51	71
AIS-ASAHI INDIA SOLUTIONS						
5.	Single Glazing 6mm Clear float glass	5.6	-	-	81	86
6.	Single Glazing 6mm Super silver clear	5.7	-	-	67	63
7.	Single Glazing 6mm Synergy clear	4.2	-	-	60	68

Table 6: Available Glass Options

7 Results and Conclusion

Seven different Glass option were evaluated for a typical floor for optimized comfort. The comfort criteria were selected based on normal Psychrometric of human comfort (See Appendix 2) and hour of comfort, discomfort and moderated comfort were reported for each zone (Apartment) and for each glazing options (See Appendix 1). Similarly solar heat gain in the occupant space is another good indication of sun's influence on any closed building space and it is also reported in terms of KWh of Heat pumped in the occupant space.

Another rough indication is annual maximum and minimum temperature for each zone and hence this is also reported for each zone and for each glass option

7.1 Comfort

Comfort is the prime parameter for selection of glass for various apartments. In Appendix 2 Comfort Psychrometric chart has be displayed and the Pune's whether data has been overlaid on it. There is a blue polygon which sets the limits for comfort.

	Single glazing Unit (6 mm, coating face 2) Light Gold	Single glazing Unit (6 mm, coating face 2) Sparkling Ice	Double glazed Unit (outer 6 mm, with coating face 2 – 12mm Air gap-inner 6 mm clear glass) pristine white	Double glazed Unit (Outer 6mm with coating face 2 -12 mm air gap – inner 6 mm planitherm total (low E coating on Face 3) pristine white	Single Glazing 6mm Clear float glass	Single Glazing 6mm Super silver clear	Single Glazing 6mm Synergy clear
7101-East	*1473*	*1409*	*1386*	*1398*	*1334*	*1409*	*1434*
7082-East	*1290*	*1111*	*1070*	*1086*	*1018*	*1111*	*1153*
7935-Center	*2084*	*2069*	*2063*	*2070*	*2048*	*2069*	*2078*
7908-Center	*1973*	*1909*	*1914*	*1927*	*1859*	*1909*	*1937*
7874-Center	*1185*	*1054*	*1030*	*1046*	*949*	*1054*	*1100*
7847-Center	*2004*	*1941*	*1944*	*1956*	*1885*	*1941*	*1967*
7813-Center	*1999*	*1971*	*1969*	*1975*	*1948*	*1971*	*1977*
8328-West	*1369*	*1282*	*1243*	*1270*	*1191*	*1282*	*1315*
8307-West	*1458*	*1382*	*1351*	*1365*	*1305*	*1382*	*1413*

7.2 Solar Heat Gain

In appendix 1, last column of corresponding glass table, lists the solar heat gain in the individual apartment. The solar heat gain in the building is an indication of how well shaded the apartment is or how much protection does the apartment have from sun. Higher sun gain is not good for Pune's climate (See section 4 understanding the climate) as it tend to increase the discomfort hour in the apartment. In conclusion lesser the heat gain better is the comfort in the occupant space

Following table list the values for solar heat gain in the occupant space for each flat with each glass option

	Single glazing Unit (6 mm, coating face 2) Light Gold	Single glazing Unit (6 mm, coating face 2) Sparkling Ice	Double glazed Unit (outer 6 mm, with coating face 2 – 12mm Air gap-inner 6 mm clear glass) pristine white	Double glazed Unit (Outer 6mm with coating face 2 -12 mm air gap –inner 6 mm planitherm total (low E coating on Face 3) pristine white	Single Glazing 6mm Clear float glass	Single Glazing 6mm Super silver clear	Single Glazing 6mm Synergy clear
7101-East	*15571*	*20586*	*16228*	*15244*	*25476*	*20586*	*18219*
7082-East	*16266*	*21488*	*16950*	*15926*	*26574*	*21488*	*19024*
7935-Center	*5386*	*7122*	*5613*	*5273*	*8816*	*7122*	*6302*
7908-Center	*4601*	*6086*	*4795*	*4504*	*7535*	*6086*	*5385*
7874-Center	*16191*	*21416*	*16875*	*15851*	*26516*	*21416*	*18949*
7847-Center	*4286*	*5668*	*4467*	*4196*	*7017*	*5668*	*5016*
7813-Center	*8915*	*11795*	*9291*	*8727*	*14610*	*11795*	*10435*
8328-West	*11839*	*15635*	*12336*	*11591*	*19331*	*15635*	*13844*
8307-West	*16085*	*21265*	*16764*	*15748*	*26318*	*21265*	*18820*

7.3 Recommended Glazing

There are two ways in which the glazing options can be recommended to for an apartment i.e. air conditioned and non air conditioned. Appendix 3 and 4, are the bar plots depicting the comparative value for different glass option for respective apartments

If the apartment is non air-conditioned or naturally ventilated, the best glazing is ***"Single glazing Unit (6 mm, coating face 2) Light Gold".*** If the apartment are going to be air conditioned then selection would be based on solar heat gain scenario and minimum heat load criteria. The best glass option fulfilling these criterias would be ***"Double glazed Unit (Outer 6mm with coating face 2 -12 mm air gap –inner 6 mm planitherm total (low E)".***

8 Appendix-1- Peak Temperatures Comfort and Solar Heat Gain Due to Glazing Alternatives

8.1 Single glazing Unit (6 mm, coating face 2) Light Gold

Apartment Name	Annual Peak Temperature (°C)	Annual Minimum Temperature (°C)	Hours of Discomfort(Hour)	Hours of Moderate (Hour)	Hours of Comfort (Hour)	Solar Gain (KWh)
7101-East	42.51	18.62	7141	145	1473	15571
7082-East	38.39	19.41	7390	150	1290	16266
7935-Center	37.16	19.24	6588	87	2084	5386
7908-Center	36.18	19.56	6702	84	1973	4601
7874-Center	37.84	20.61	7454	120	1185	16191
7847-Center	36.02	19.55	6671	84	2004	4286
7813-Center	37.95	18.73	6668	92	1999	8915
8328-West	37.46	19.46	7252	138	1369	11839
8307-West	38.85	18.78	7165	136	1458	16085

8.2 Single glazing Unit (6 mm, coating face 2) Sparkling Ice

Apartment Name	Annual Peak Temperature (°C)	Annual Minimum Temperature (°C)	Hours of Discomfort(Hour)	Hours of Moderate (Hour)	Hours of Comfort (Hour)	Solar Gain (KWh)
7101-East	43.05	18.75	7219	131	1409	20586
7082-East	38.62	19.75	7505	143	1111	21488
7935-Center	37.34	19.28	6607	83	2069	7122
7908-Center	36.35	19.7	6747	103	1909	6086
7874-Center	38.09	20.94	7589	116	1054	21416
7847-Center	36.16	19.68	6729	89	1941	5668
7813-Center	38.2	18.8	6688	100	1971	11795
8328-West	37.68	19.74	7347	130	1282	15635
8307-West	39.22	18.98	7252	125	1382	21265

8.3 Double glazed Unit (outer 6 mm, with coating face 2 – 12mm Air gap-inner 6 mm clear glass) pristine white

Apartment Name	Annual Peak Temperature (°C)	Annual Minimum Temperature (°C)	Hours of Discomfort(Hour)	Hours of Moderate (Hour)	Hours of Comfort (Hour)	Solar Gain (KWh)
7101-East	43.08	19.11	7241	132	1386	16228
7082-East	38.57	20.08	7561	128	1070	16950
7935-Center	37.25	19.43	6609	87	2063	5613
7908-Center	36.23	19.87	6748	97	1914	4795
7874-Center	38.01	21.15	7621	108	1030	16875
7847-Center	36.07	19.82	6724	91	1944	4467
7813-Center	38.12	19.04	6682	108	1969	9291
8328-West	37.57	19.99	7383	133	1243	12336
8307-West	39.29	19.28	7282	126	1351	16764

8.4 Double glazed Unit (Outer 6mm with coating face 2 -12 mm air gap –inner 6 mm planitherm total (low E coating on Face 3) pristine white

Apartment Name	Annual Peak Temperature (°C)	Annual Minimum Temperature (°C)	Hours of Discomfort(Hour)	Hours of Moderate (Hour)	Hours of Comfort (Hour)	Solar Gain (KWh)
7101-East	42.97	19.09	7223	138	1398	15244
7082-East	38.52	20.01	7533	140	1086	15926
7935-Center	37.22	19.42	6606	83	2070	5273
7908-Center	36.19	19.84	6733	99	1927	4504
7874-Center	37.96	21.09	7599	114	1046	15851
7847-Center	36.04	19.79	6711	92	1956	4196
7813-Center	38.08	19.02	6680	104	1975	8727
8328-West	37.53	19.93	7363	126	1270	11591
8307-West	39.02	19.24	7266	128	1365	15748

8.5 Single Glazing 6mm Clear float glass

Apartment Name	Annual Peak Temperature (°C)	Annual Minimum Temperature (°C)	Hours of Discomfort(Hour)	Hours of Moderate (Hour)	Hours of Comfort (Hour)	Solar Gain (KWh)
7101-East	43.59	18.87	7284	141	1334	25476
7082-East	38.81	19.97	7601	140	1018	26574
7935-Center	37.51	19.32	6626	85	2048	8816
7908-Center	36.51	19.83	6787	113	1859	7535
7874-Center	38.32	21.25	7694	116	949	26516
7847-Center	36.3	19.8	6768	106	1885	7017
7813-Center	38.43	18.87	6709	102	1948	14610
8328-West	37.89	20.01	7450	118	1191	19331
8307-West	39.55	19.15	7329	125	1305	26318

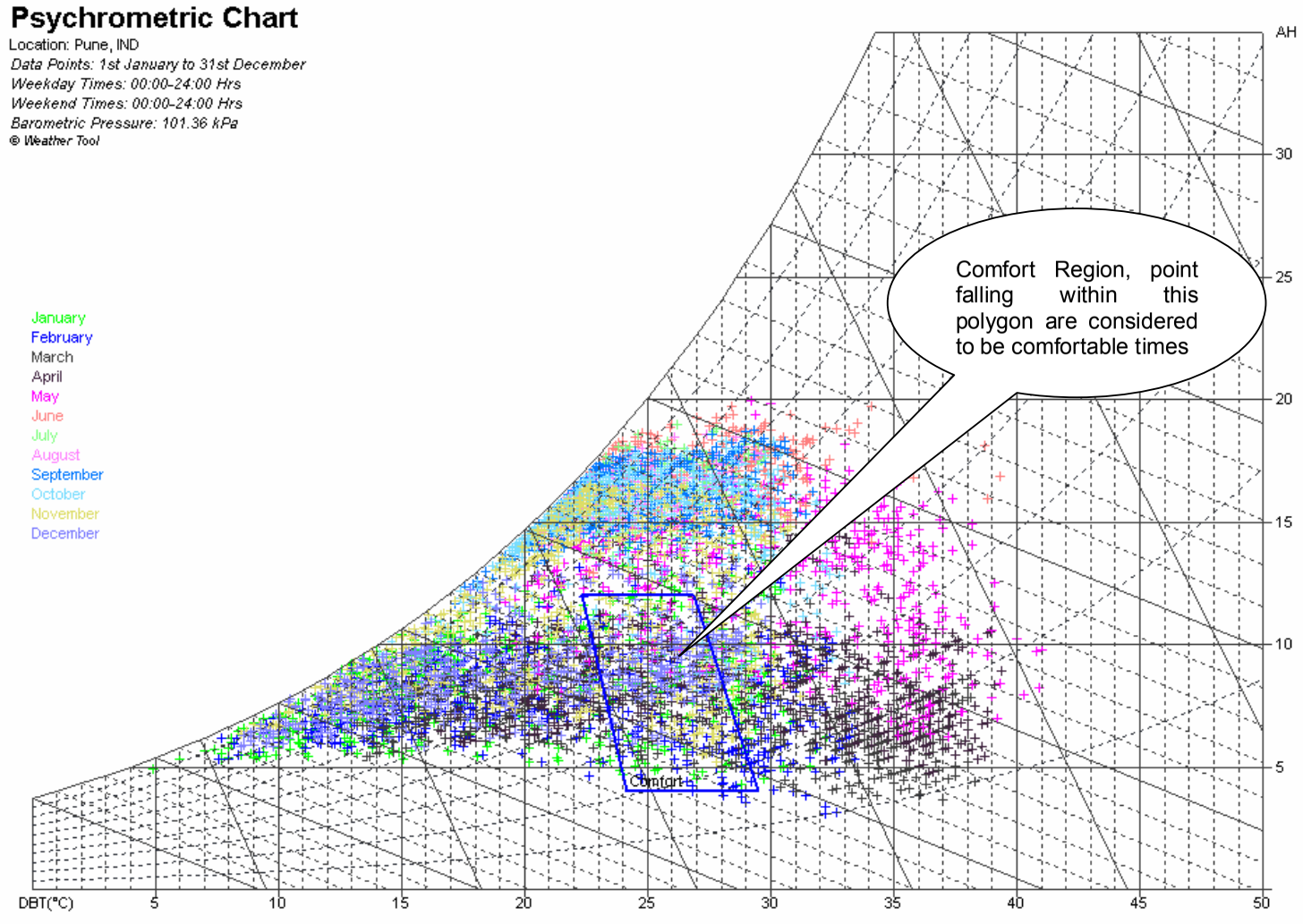
8.6 Single Glazing 6mm Super silver clear

Apartment Name	Annual Peak Temperature (°C)	Annual Minimum Temperature (°C)	Hours of Discomfort(Hour)	Hours of Moderate (Hour)	Hours of Comfort (Hour)	Solar Gain (KWh)
7101-East	43.05	18.75	7219	131	1409	20586
7082-East	38.62	19.75	7505	143	1111	21488
7935-Center	37.34	19.28	6607	83	2069	7122
7908-Center	36.35	19.7	6747	103	1909	6086
7874-Center	38.09	20.94	7589	116	1054	21416
7847-Center	36.16	19.68	6729	89	1941	5668
7813-Center	38.2	18.8	6688	100	1971	11795
8328-West	37.68	19.74	7347	130	1282	15635
8307-West	39.22	18.98	7252	125	1382	21265

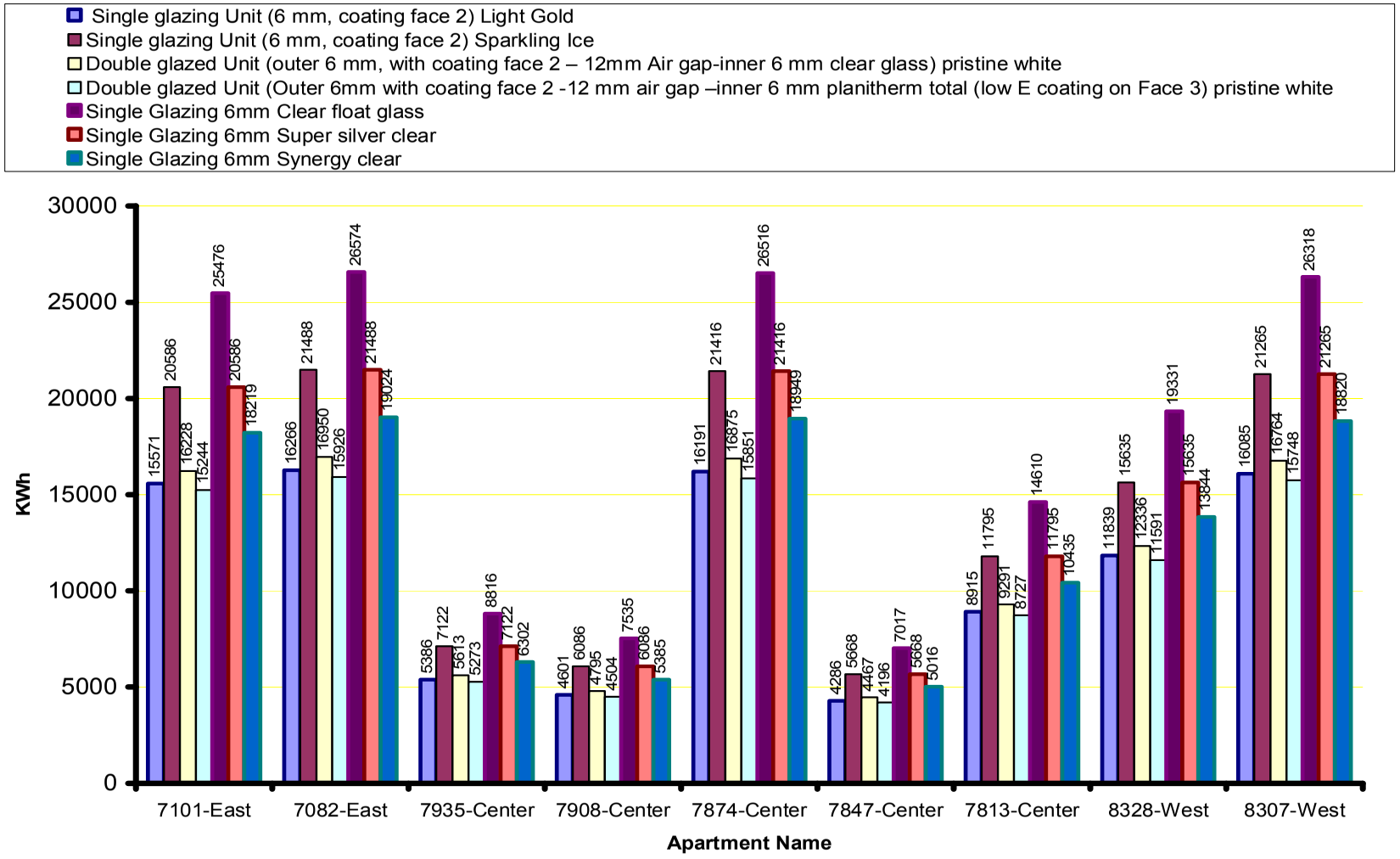
8.7 Single Glazing 6mm Synergy clear

Apartment Name	Annual Peak Temperature (°C)	Annual Minimum Temperature (°C)	Hours of Discomfort(Hour)	Hours of Moderate (Hour)	Hours of Comfort (Hour)	Solar Gain (KWh)
7101-East	42.8	18.71	7193	132	1434	18219
7082-East	38.52	19.64	7459	147	1153	19024
7935-Center	37.26	19.27	6598	83	2078	6302
7908-Center	36.27	19.65	6725	97	1937	5385
7874-Center	37.98	20.81	7537	122	1100	18949
7847-Center	36.1	19.63	6705	87	1967	5016
7813-Center	38.09	18.78	6680	102	1977	10435
8328-West	37.58	19.64	7311	133	1315	13844
8307-West	39.06	18.91	7219	128	1413	18820

9 Appendix-2- Temperatures Comfort and Discomfort (Psychrometric)



10 Appendix-3- Comparative Study of Solar Gain in Each Apartment with Seven Glass Options



11 Appendix-4- Comparative Study of Comfort Hours for Apartments with Seven Glass Options