DETAILED ANALYSIS REPORT

COMBINED ANALYSIS OF RESIDENCE AT PUNE

Quality Control

Date	Version	Revision Description	Prepared by	Approved by
May 26, 2024	1	Detailed overall report	Aritro De	-

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Figures

Tables

1 Introduction

1.1 Temperature Heat-map

The above image shows the heat-map for comfort situations over the year for Pune. Here the month of March and May has a sweltering heat condition during post-noon hours. Also it is observed that maximum of the period in the year it is hot and warm.

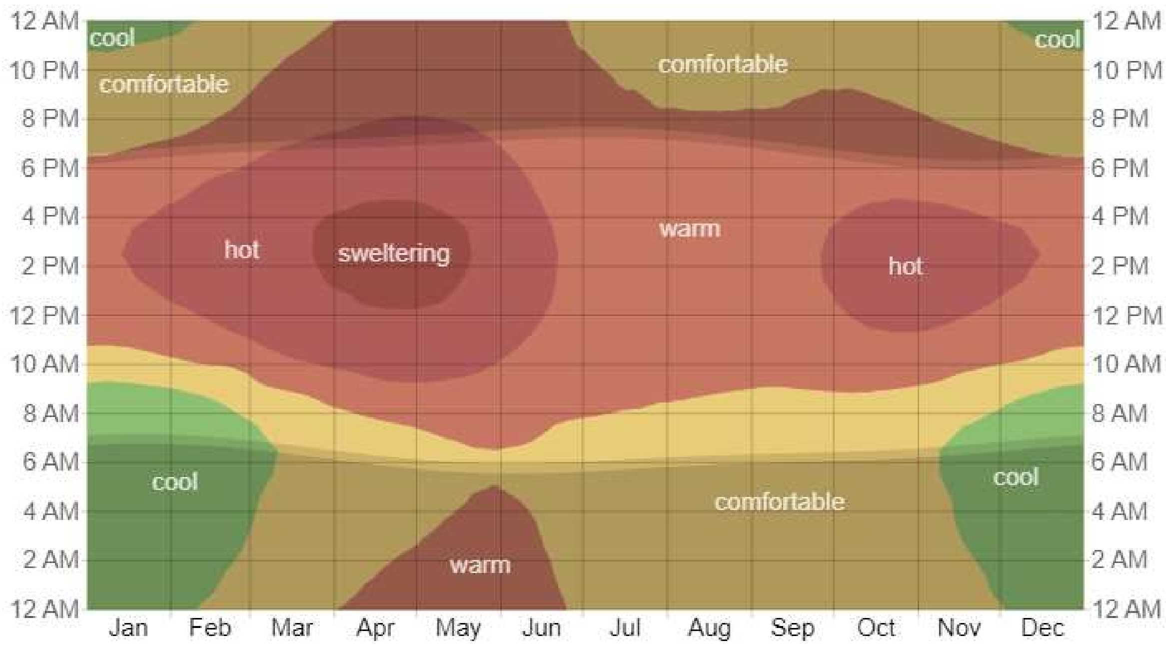

Figure 1: Pune Heat-map

1.2 Humidity

In Pune, there are significant fluctuations in perceived humidity throughout the year. The muggiest stretch extends for approximately 6.3 months, spanning from April 29 to November 8. During this period, the comfort level is often categorized as muggy, oppressive, or even miserable for at least a quarter of the time. July stands out as the month with the highest frequency of muggy days, totaling around 30.5 days.

Conversely, February experiences the fewest muggy days in Pune, with only 0.3 days reaching muggy or worse conditions.

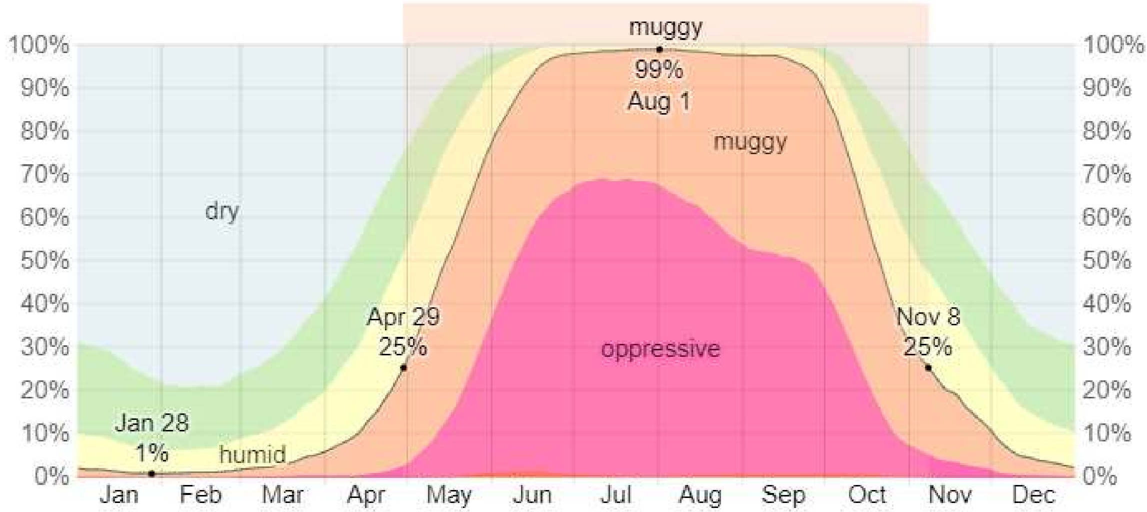

Figure 2: Relative Humidity of Pune

1.3 Wind direction

In Pune, the prevailing average hourly wind direction shifts across the seasons. Northwesterly winds dominate for approximately 1.9 weeks, spanning from January 31 to February 13, peaking at 34% on February 12. Westerly winds prevail for the majority of the year, around 7.7 months, from February 13 to October 5, reaching a peak of 99% on August 2. During the remaining 3.8 months, from October 5 to January 31, easterly winds become most common, peaking at 55% on January 1.

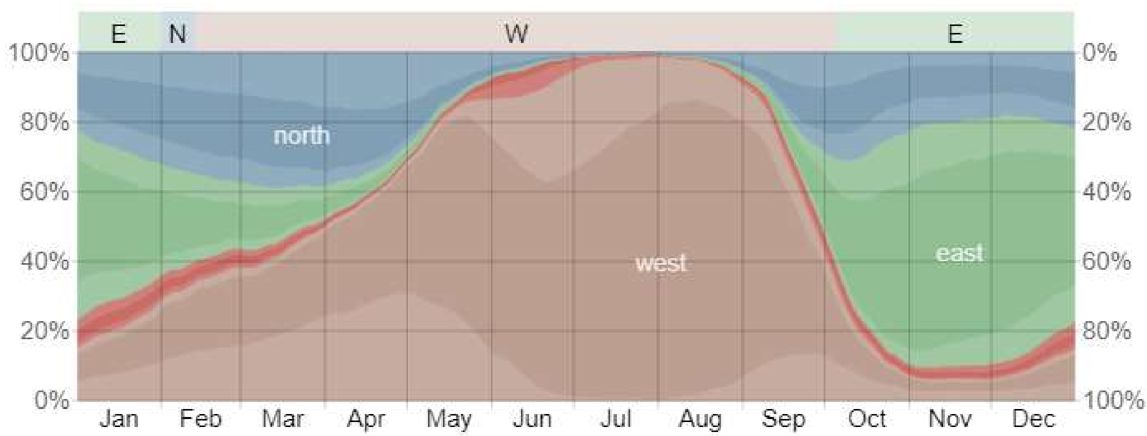

Figure 3: Prevalent wind direction

2 Thermal Comfort Analysis

A thermal comfort analysis was done on the as-is case of design to analyse the occupant thermal comfort in terms of Total comfortable hours indoors.

2.1 Determining thermal comfort performance

This part outlines the procedure for calculating the Comfortable Hours. The equation (1) uses the 30-day running mean outdoor temperature ($T_{out\text{-}30DRM}$) to calculate the neutral temperature (T_{neut}). 'Comfortable hours' is defined as the number of hours the indoor operative temperature falls within the 80% acceptability range. 80% acceptability range is defined as deviation of 3.6°C around the neutral temperature (T_{neut}).

$$T_{neut} = 0.42\ (T_{out\text{-}30DRM}) + 17.60 \quad (1)$$

$$Comfort\ hours = \sum_{i=1}^{8760} C_{hours},\ where\ f(x) \leq 3.6 \quad (2)$$

2.2 Energy Plus model

The energy plus model describes the 3-D geometry (Figure 4), thermal characteristics of the construction assemblies, internal loads and operational schedule of the building. The hourly operative temperature outputs for the overall building and selected zones were used to calculate the comfortable hours for the spaces.

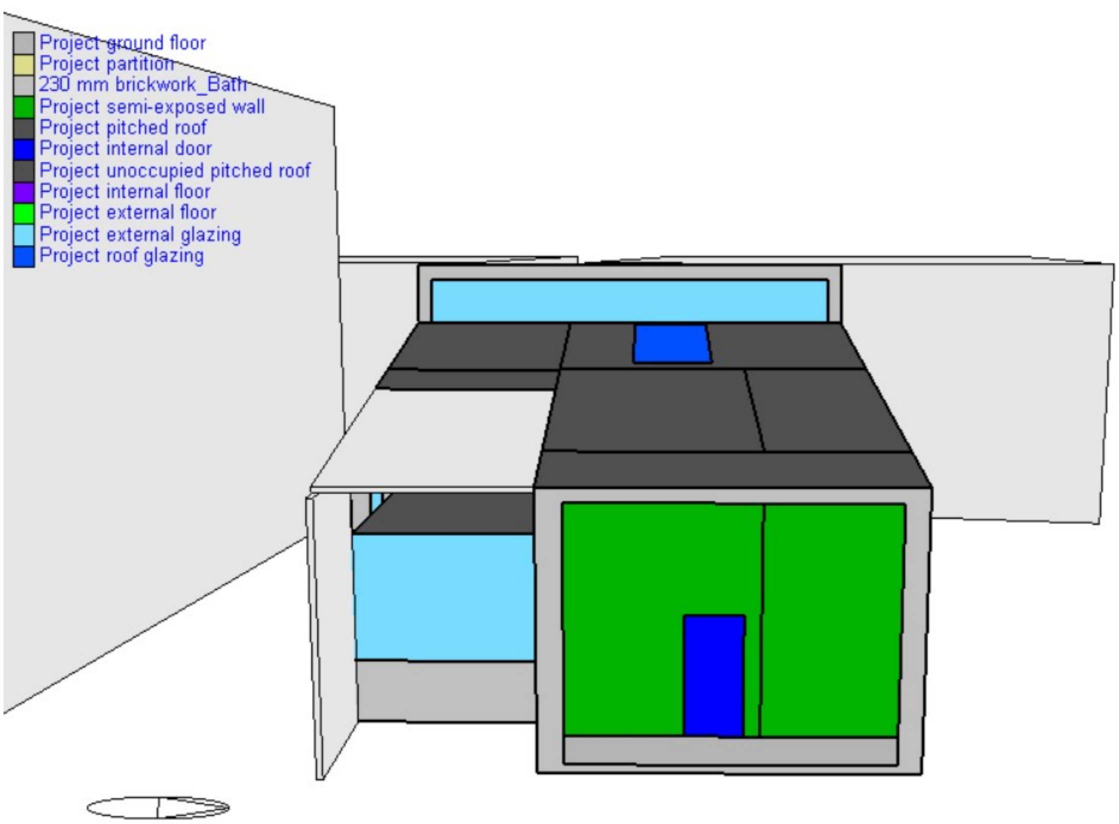

Figure 4: Energy Plus thermal model

2.3 Building Materials

As this was as-is case, 230mm brickwork was used for the exterior walls and 115mm walls for internal partitions. The roofing considered here was clay tile with wooden purlins and rafters.

2.4 Cases

2.4.1 As-is case

Computing the above formula for total comfortable hours it was found out that the as-is case (Figure 5) has a total of **1676 comfortable hours** of the **total 8760 hours** in a year. However, different rooms and their orientations gave out different results. The living room had a **total of 976 hours** comfortable compared to bedroom 1 & 2 with **1168 and 1239** respectively. Here the kitchen and dining area has a **2609 hours** comfortable of the total hours, which is also found to be the **most comfortable.** As Pune falls in the warm and humid climate zone of India, relative humidity was taken into consideration for determining the comfortable hours.

A comparison was also done without taking into account the effect of relative humidity. As, anticipated, the overall comfort hours have increased. The following can be found in the below figure.

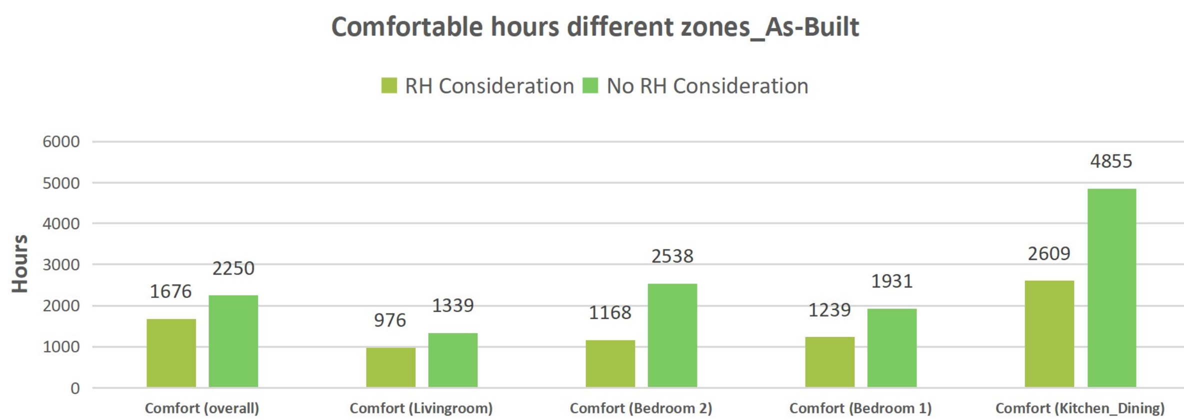

Figure 5: Comfortable hours of different zones

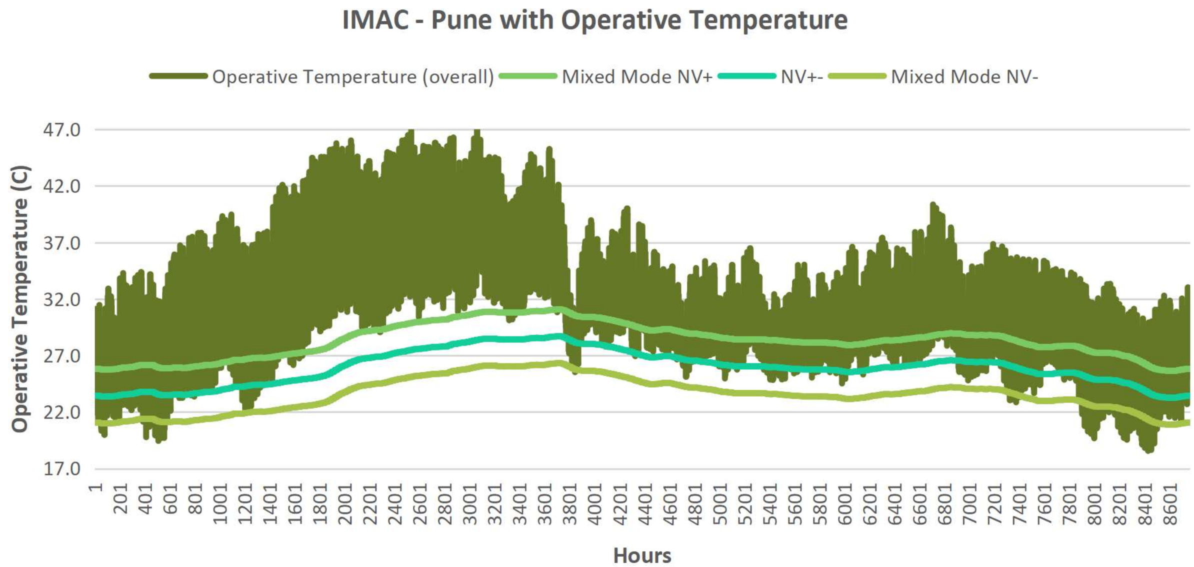

Figure 6: Comfort scenario for the building

2.4.2 Case 1 - Window sizing and Shading

2.4.2.1 First Floor

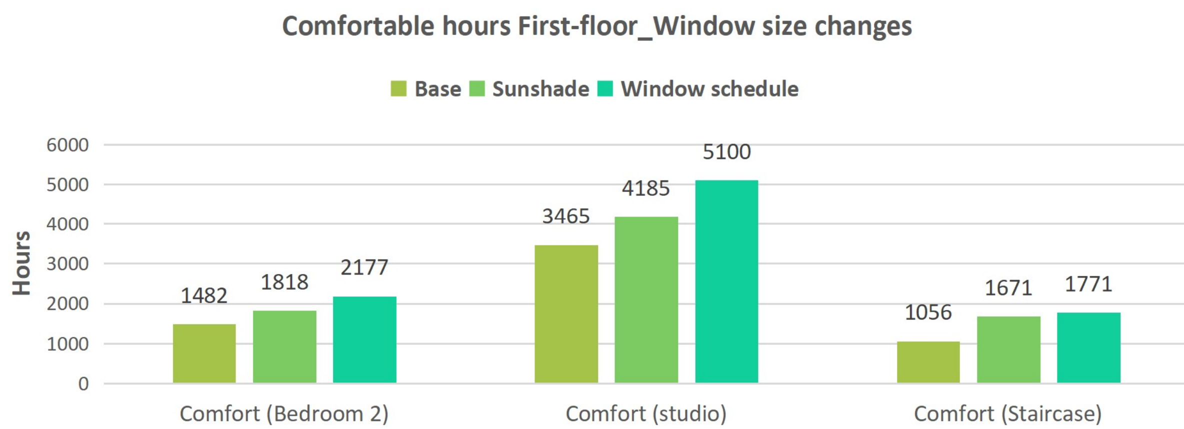

Figure 7: Comfortable hours-First floor

Figure 8: First floor sunshades

Sunshade dimensions:

1. Horizontal - 2’6”

2. Vertical - 1’ on west wall window on the right side

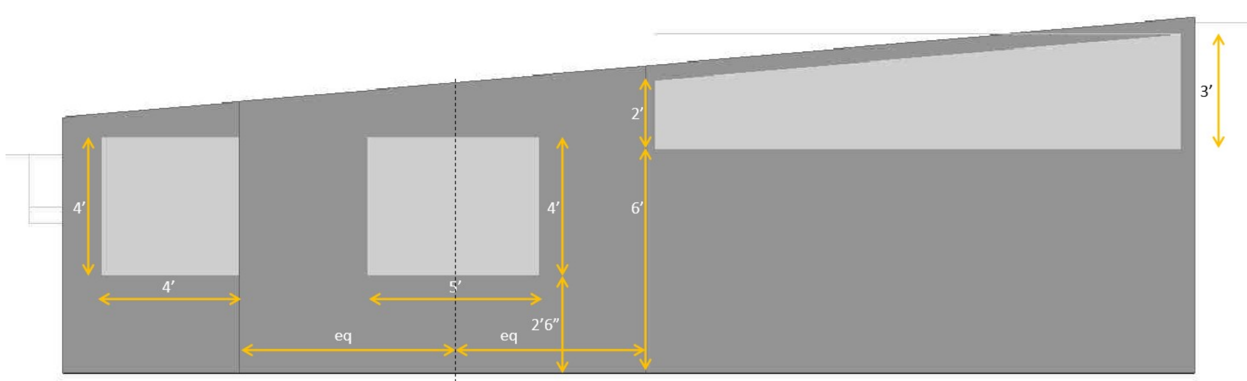

Figure 9: South elevation-First floor

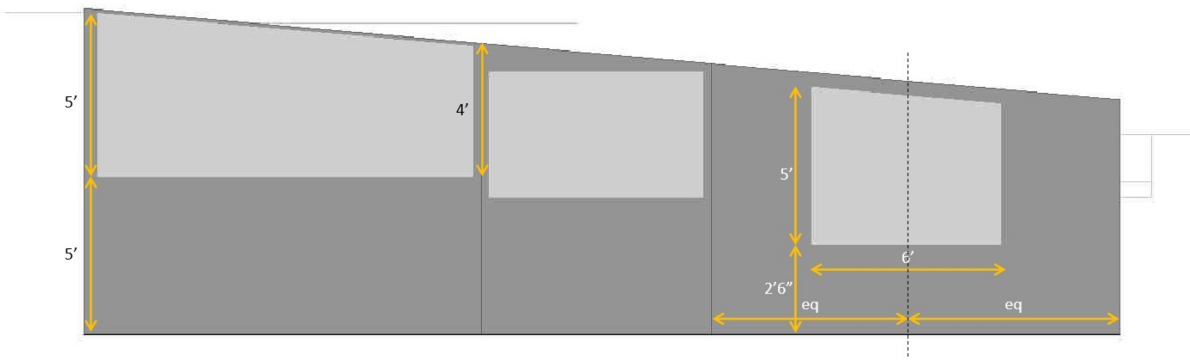

Figure 10: North elevation- First floor

***North - No sunshade**

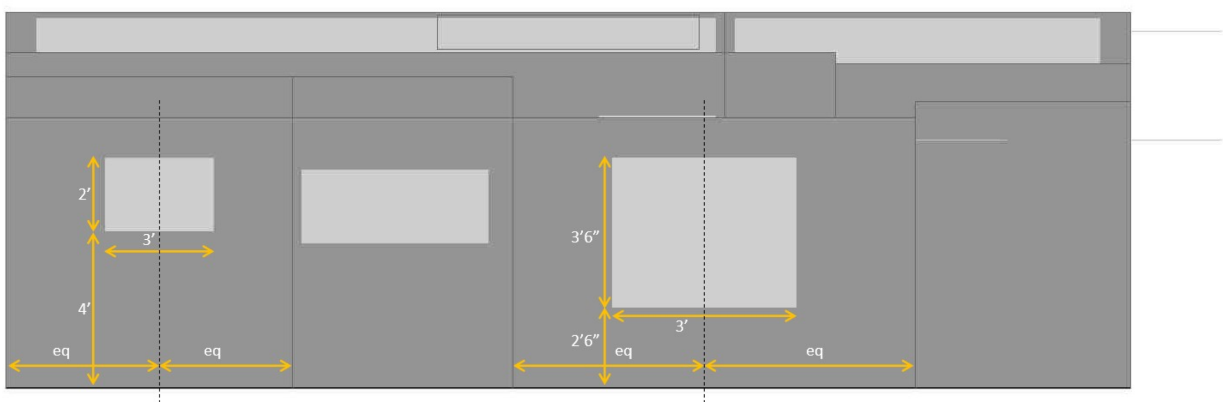

Figure 11: West elevation- First floor

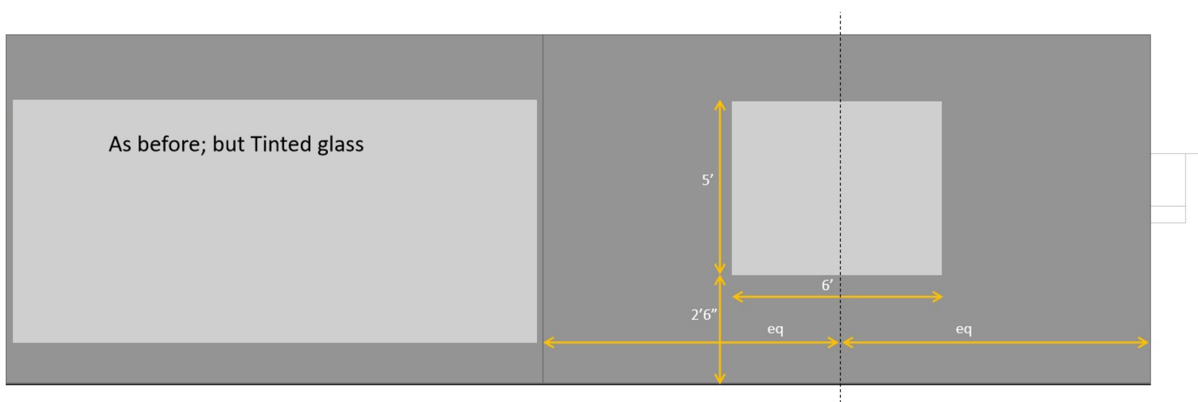

Figure 12: North elevation- Ground floor

2.4.2.2 Ground Floor

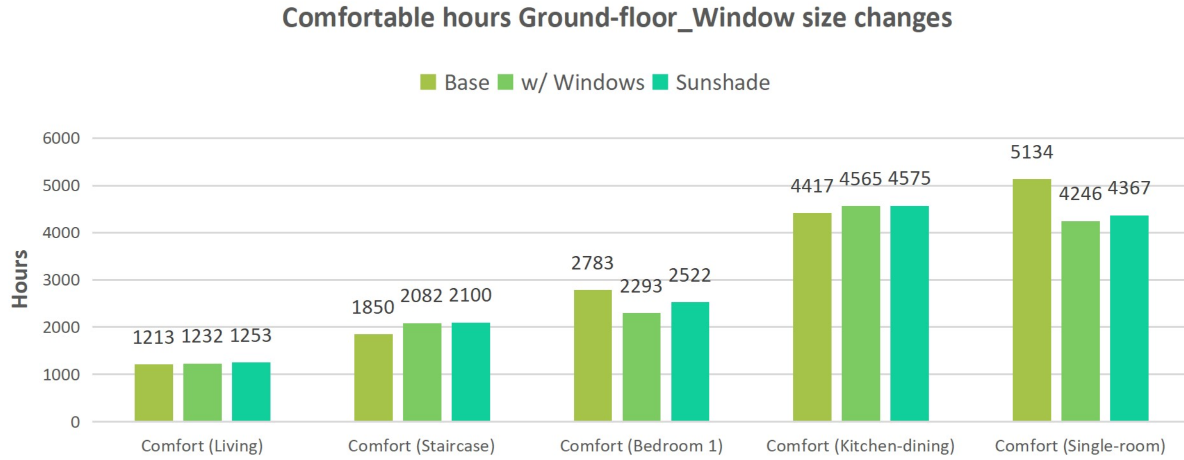

Figure 13: Comfortable hours ground floor

2.4.3 Case 2 - Walls

2.4.3.1 Walls - First Floor

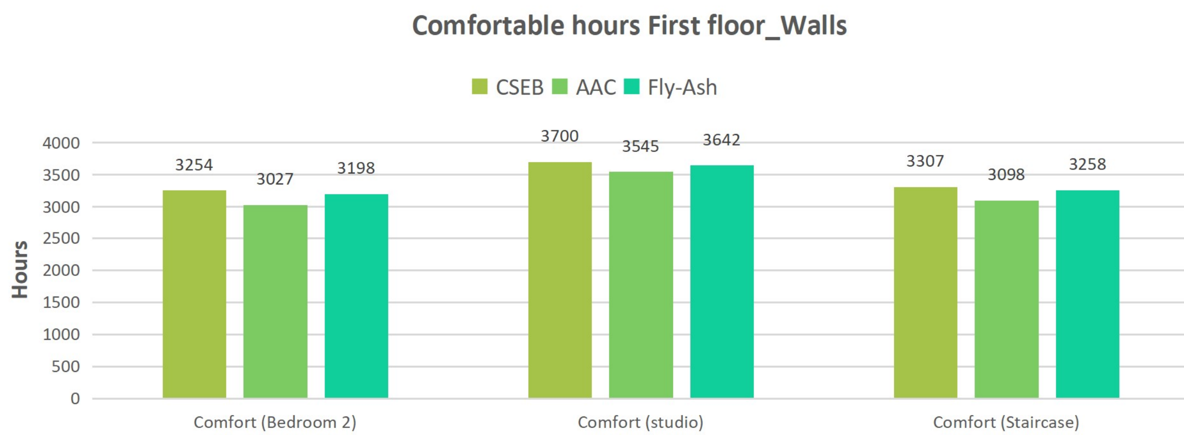

Figure 14: Wall changes-First floor

2.4.3.2 Walls - Ground Floor

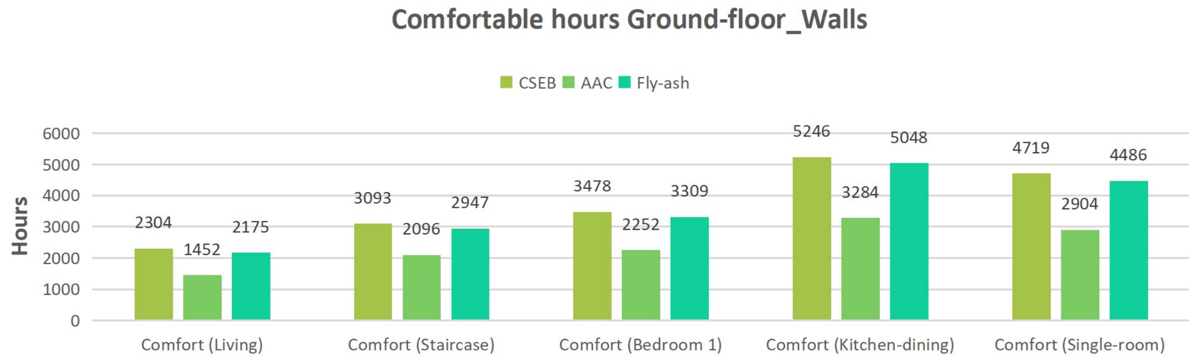

Figure 15: Wall changes-Ground floor

2.4.4 Case 3 - Roofs

2.4.4.1 Roof - First Floor

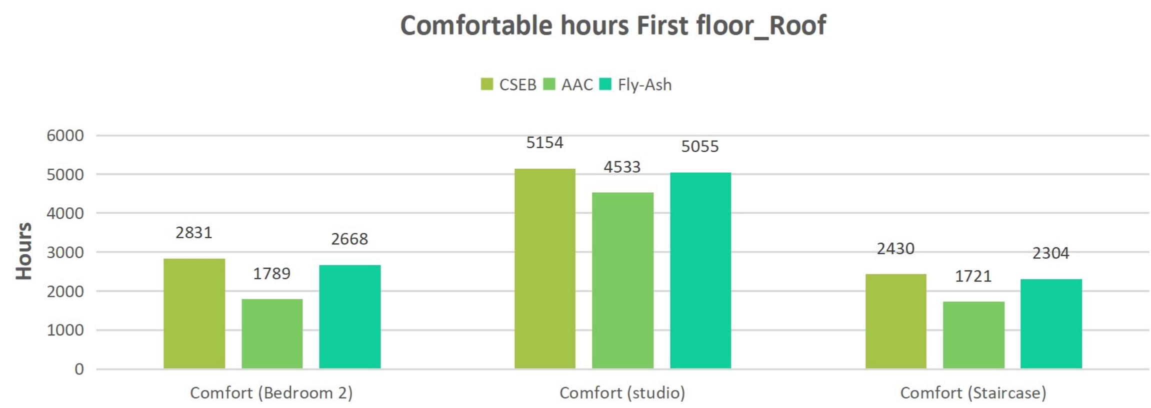

Figure 16: Roof changes-First floor

2.4.4.2 Roof - Ground Floor

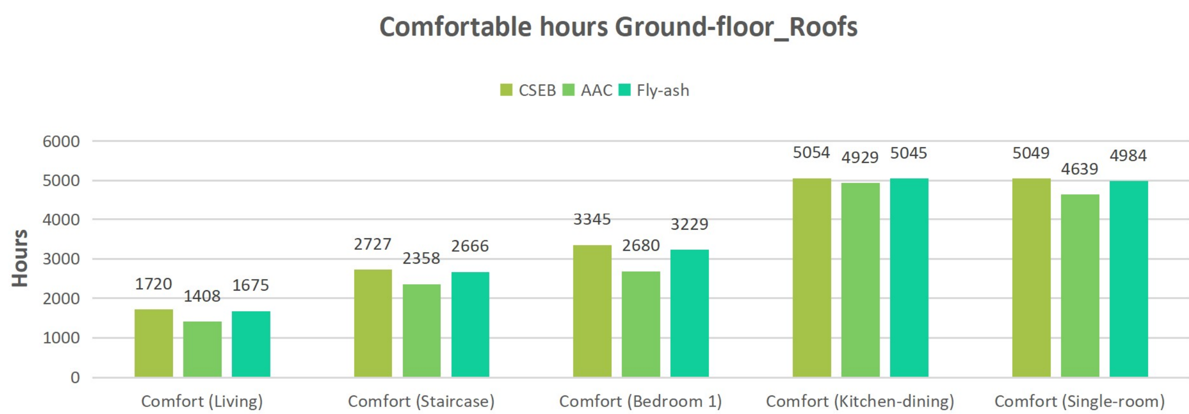

Figure 17: Roof changes-Ground floor

3 Daylight Analysis

3.1 Intent

To connect building occupants with the outdoors, reinforce circadian rhythms, and reduce the use of electrical lighting by introducing daylight into the space.

3.2 Requirements

Provide manual or automatic (with manual override) glare-control devices for all regularly occupied spaces.

3.3 Spatial Daylight Autonomy

Spatial Daylight Autonomy (sDA) is a measure used in building design to assess how much natural light a space receives throughout the year. It calculates the percentage of occupied hours when a space meets a specific light level target. Designers use sDA to optimize building layouts and window configurations for better natural lighting, which can enhance comfort and reduce energy use for artificial lighting.

3.4 Annual Sunlight Exposure

Annual sunlight exposure refers to the total amount of sunlight an area receives over the course of a year. It can be measured in various units such as lux-hours or kilowatt-hours per square metre

3.5 Cases

3.5.1 As-is case

Table 1: Showing the percentage of area in range for sDA, ASE & UDI for the as-is case

Zone	Floor Area (m2)	sDA Area in Range (m2)	sDA Area in Range (%)	ASE Area in Range (m2)	ASE Area in Range (%)	UDI Area in Range (m2)	UDI Area in Range (%)
Dining_Kitchen	31.67	31.67	**100**	31.67	**100**	31.078	**98.13**
Single Bedroom	10.75	5.387	**50.112**	10.221	**95.078**	0	**0**
Living	28.099	27.619	**98.289**	11.177	**39.778**	1.923	**6.843**
Bedroom 1	15.295	7.061	**46.166**	13.715	**89.671**	0	**0**
Staircase & lift (GF)	10.34	10.34	**100**	9.844	**95.204**	0	**0**
Studio room	7.257	7.038	**96.98**	5.479	**75.503**	0	**0**

Staircase & Lift (FF)	12.94	12.94	**100**	6.556	**50.664**	0	**0**
Bedroom 2	30.601	20.457	**66.851**	26.316	**85.997**	0	**0**

1. **Overall Daylighting Performance:** Most zones have good daylighting potential, with sDA (usable sunlight area) exceeding 50% of the floor area. This suggests ample opportunity to incorporate natural light strategies in the design.

2. **Dining, Kitchen and Staircase & lift (Ground Floor):** These zones achieve excellent daylighting with sDA exceeding 98% of the floor area. Strategic window placement or skylights can further enhance natural light penetration.

3. **Living Room:** While the sDA is good (almost 98%), the ASE (potentially excessively bright sunlight area) is relatively low (around 40%). This indicates a balanced distribution of daylight with minimal glare concerns.

4. **Bedrooms:** Daylighting performance varies in bedrooms. Bedroom 1 has a lower sDA (around 46%) and no usable daylight area (UDI). This suggests limited natural light penetration and might require additional artificial lighting strategies. Bedroom 2 fares better with a higher sDA (around 67%) but still lacks UDI.

5. **Studio Room and Staircase & Lift (FF):** Similar to Bedroom 1, these zones have good sDA but no UDI. Strategic window placement or light shelves could improve the usability of daylight.

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3.5.1.1 Spatial Daylight Autonomy

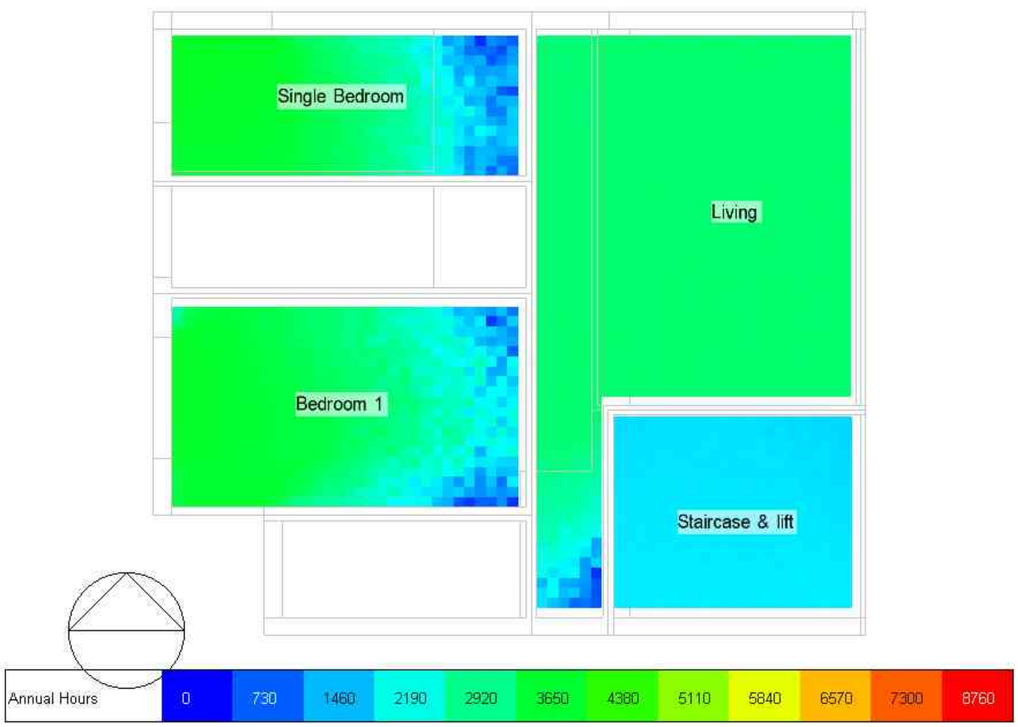

Figure 18: sDA of Ground Floor rooms for the as-is case

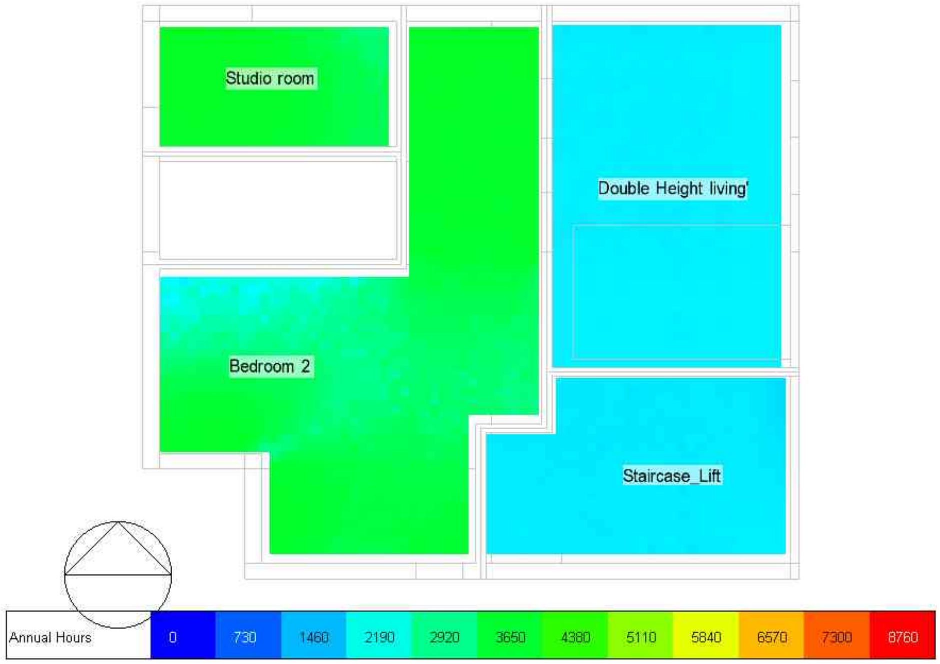

Figure 19: sDA for First floor rooms for the as-is case

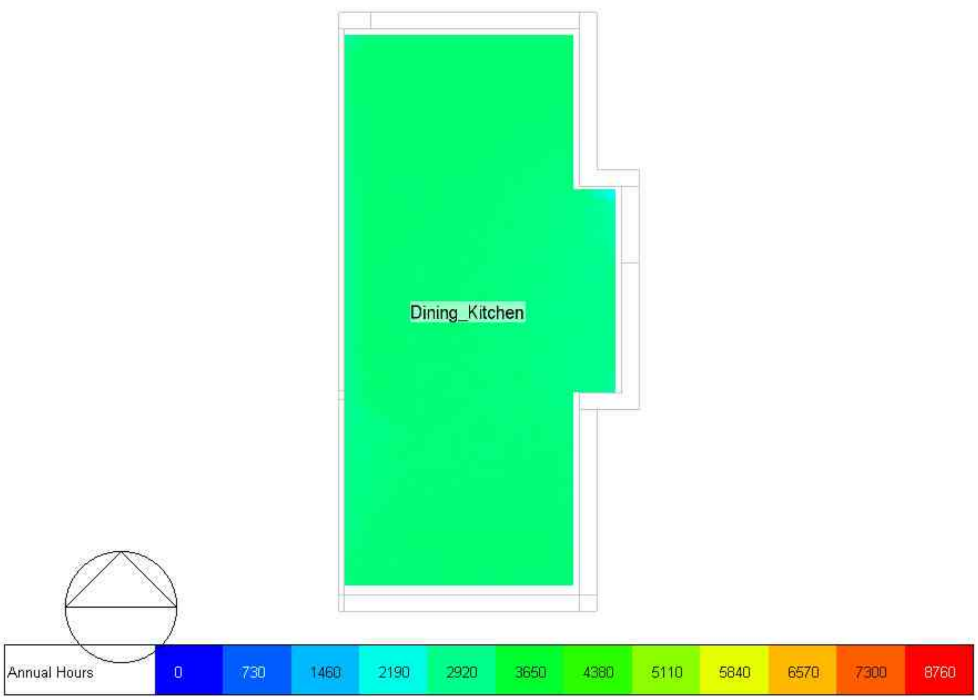

Figure 20: sDA for Dining and kitchen area for the as-is case

3.5.1.2 Uniform Daylight Autonomy (UDI)

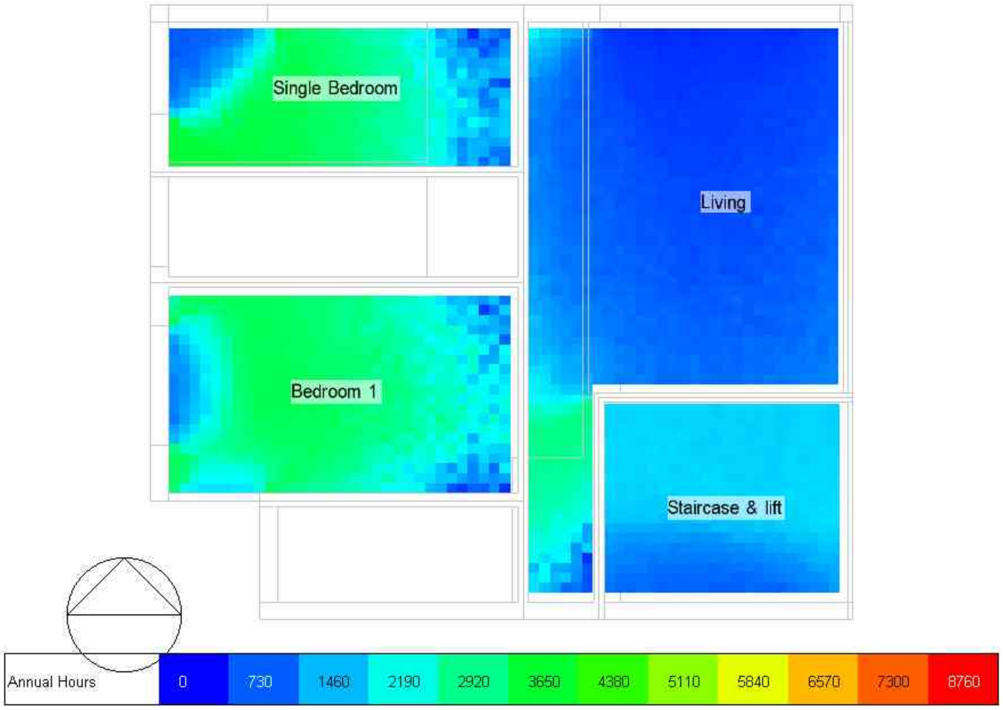

Figure 21: UDI for Ground floor rooms for the as-is case

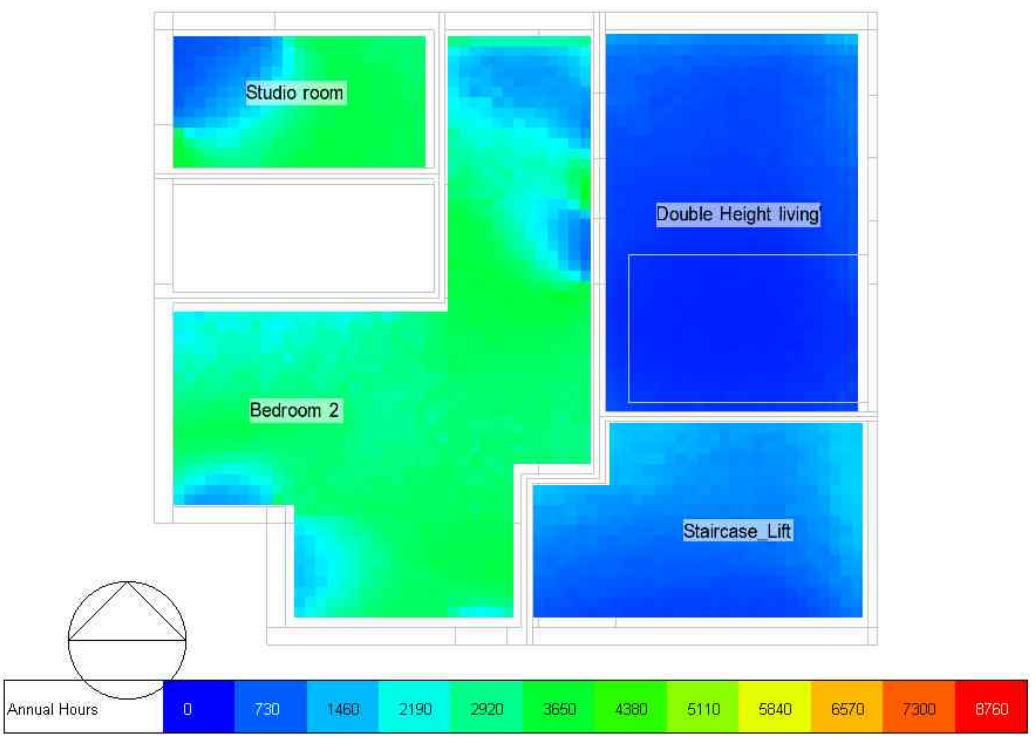

Figure 22: UDI for First floor rooms for the as-is case

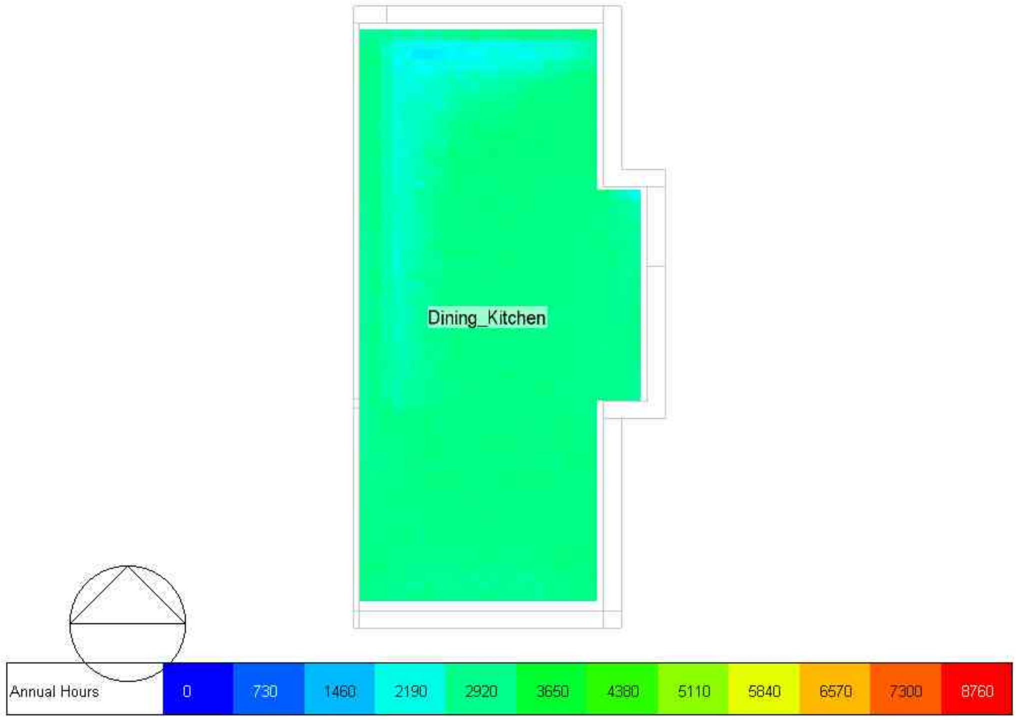

Figure 23: UDI for Dining and kitchen area for the as-is case

3.5.2 Case 1 - Window sizing

Table 2: Showing the percentage of area in range for sDA, ASE & UDI for the Resized window case

Zone	Floor Area (m2)	sDA Area in Range (m2)	sDA Area in Range (%)	ASE Area in Range (m2)	ASE Area in Range (%)	UDI Area in Range (m2)	UDI Area in Range (%)
Dining_Kitchen	32.175	31.393	**97.572**	32.175	**100**	31.346	**97.425**
Single Bedroom	10.964	9.909	**90.38**	10.964	**100**	8.83	**80.537**
Living	28.261	26.822	**94.908**	11.913	**42.154**	7.997	**28.297**
Bedroom 1	15.432	3.912	**25.352**	14.828	**96.088**	2.439	**15.806**
Staircase & lift (GF)	10.443	10.443	**100**	10.443	**100**	10.443	**100**
Studio room	7.426	7.426	**100**	7.426	**100**	5.382	**72.483**
Staircase & Lift (FF)	13.106	13.106	**100**	10.52	**80.266**	7.635	**58.254**

Bedroom 2	30.949	30.449	**98.387**	27.835	**89.939**	25.22	**81.49**

Overall Daylighting Improvement:

There's a general improvement in sDA (usable daylight area) in most zones, indicating greater access to natural light. Dining_Kitchen, Staircase & lift (GF), Studio room, and Staircase & Lift (FF) achieved 100% sDA, signifying excellent daylight penetration.

Zone-Specific Observations:

1. **Dining and Kitchen:** Increased window size preserved excellent sDA (97.57%) and achieved 100% ASE (potentially excessively bright sunlight area), suggesting potential glare concerns. Consider adding diffusers or blinds to manage excessive brightness.

2. **Single Bedroom:** Daylight availability improved significantly, with sDA reaching 90.38%. However, ASE also reached 100%, indicating a risk of glare. Similar to the Dining_Kitchen, explore glare control strategies.

3. **Living Room:** The sDA increased to 94.91%, while ASE remained moderate at 42.15%. This suggests a balanced distribution of daylight with some areas potentially experiencing glare. Strategically placed light shelves or diffusers could further optimize light distribution.

4. **Bedroom 1:** While the sDA improved to 25.35%, it remains the lowest compared to other zones. The ASE is also high (96.09%), indicating limited deep daylight penetration and potential glare. Consider additional window enlargement or explore incorporating skylights to improve both sDA and ASE distribution.

5. **Bedroom 2:** Daylight performance improved considerably with a sDA of 98.38%. However, ASE is also high at 89.94%, suggesting potential glare. Implement diffusers or blinds for better glare control.

3.5.2.1 Spatial Daylight Autonomy

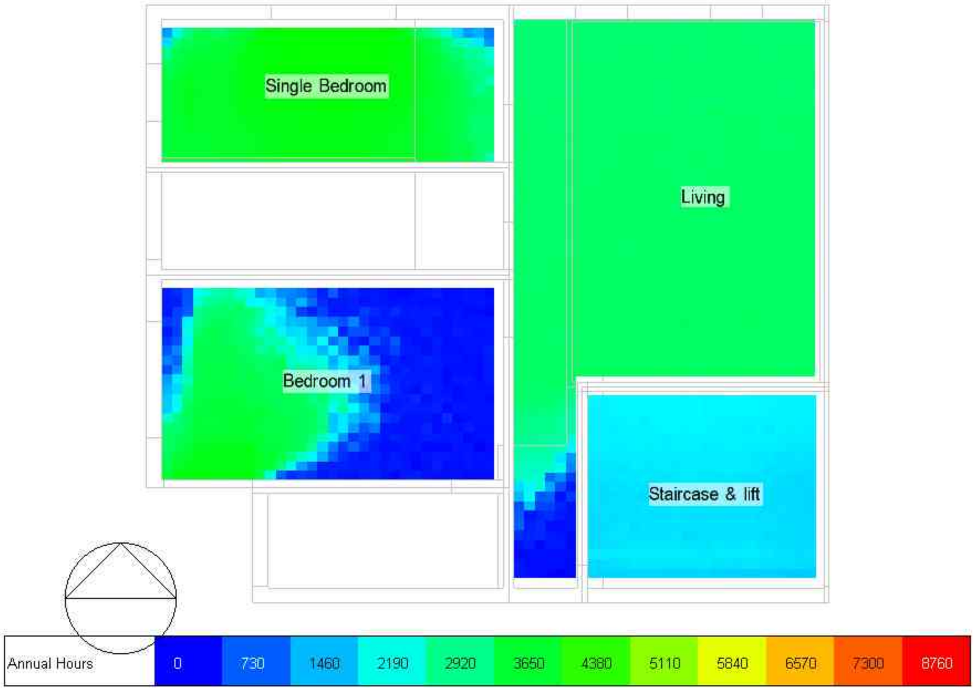

Figure 24: sDA for Ground floor rooms for the Resized window case

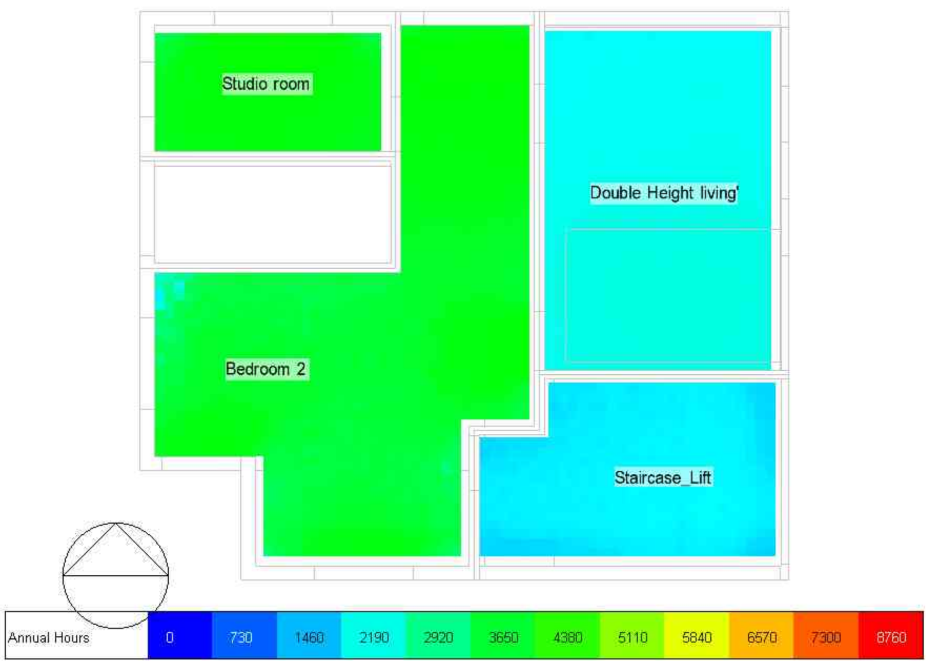

Figure 25: sDA for First floor rooms for the Resized window case

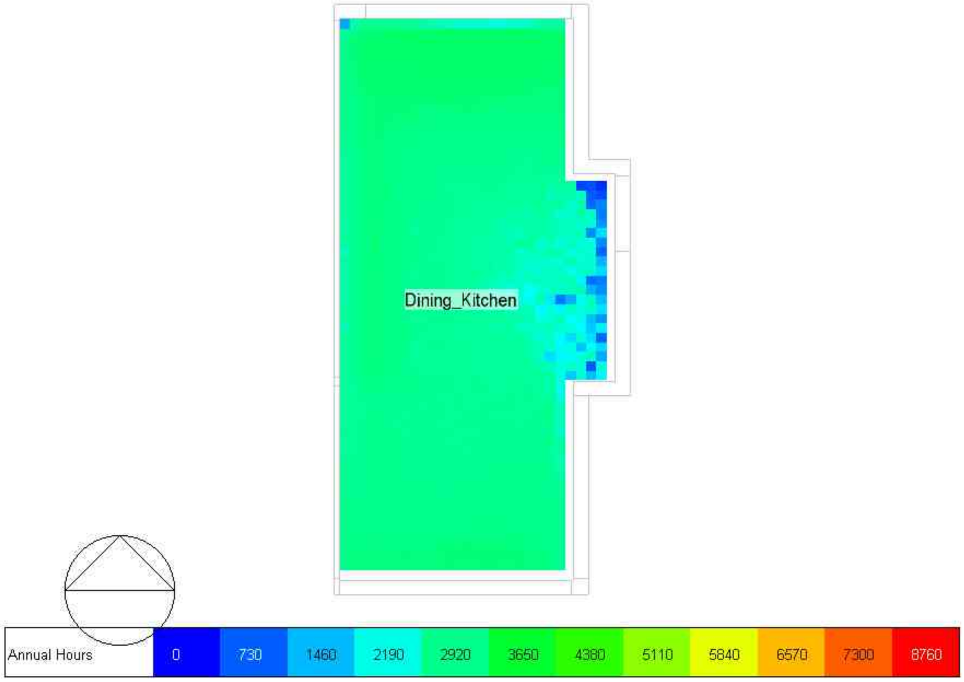

Figure 26: sDA for Dining and kitchen area for the Resized window case

3.5.2.2 Uniform Daylight Autonomy (UDI)

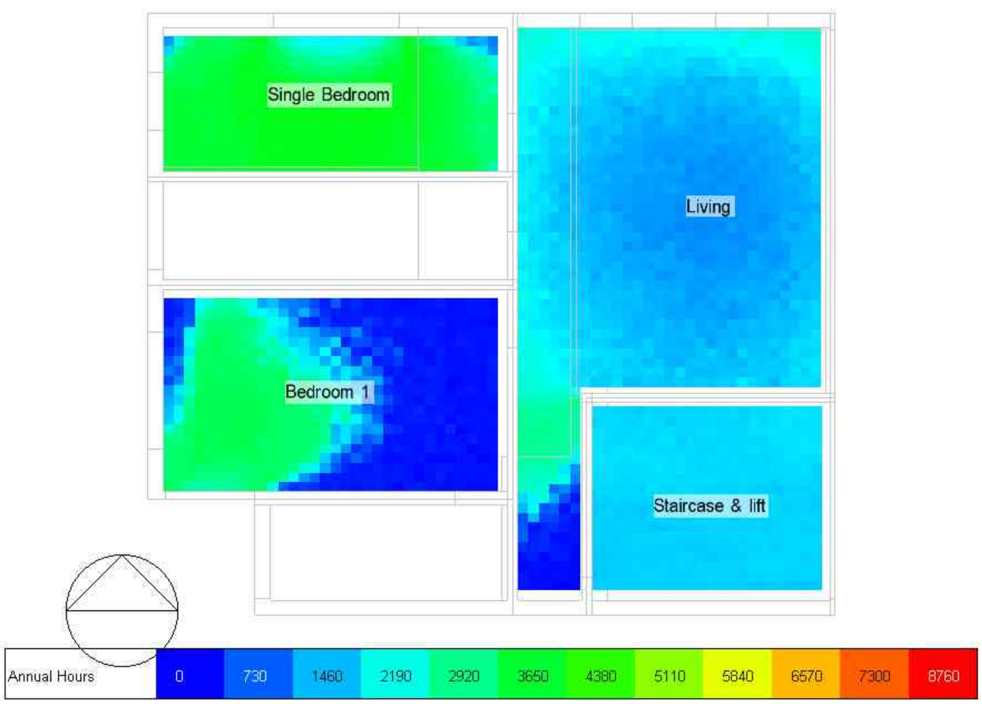

Figure 27: UDI for Ground floor rooms for the Resized window case

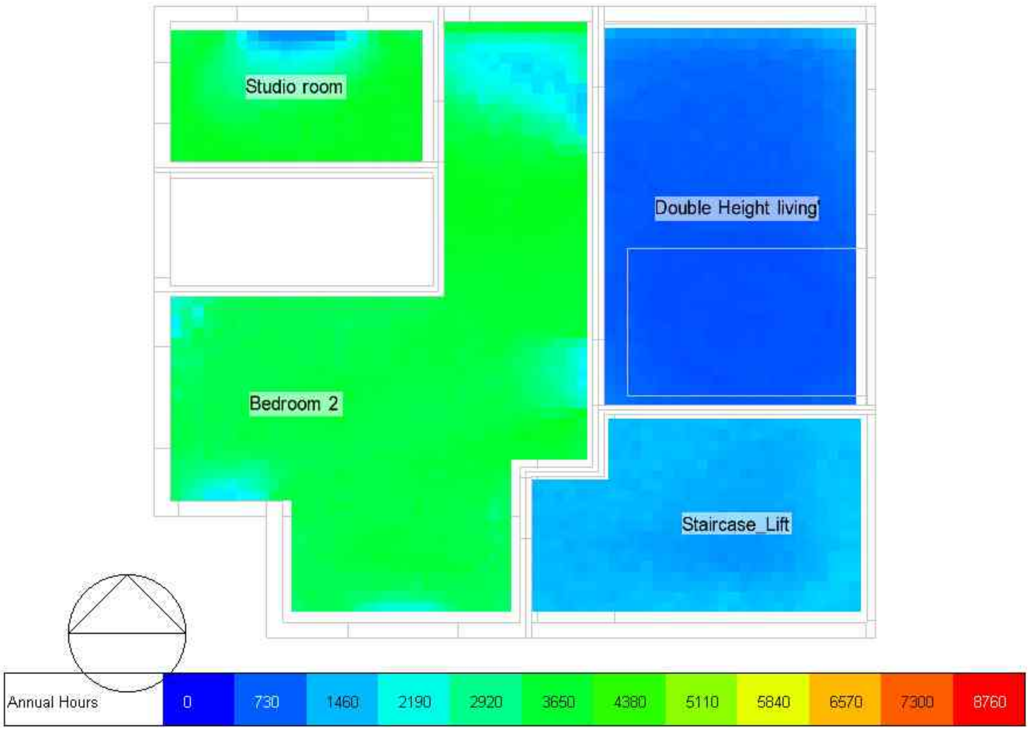

Figure 28: UDI for First floor rooms for the Resized window case

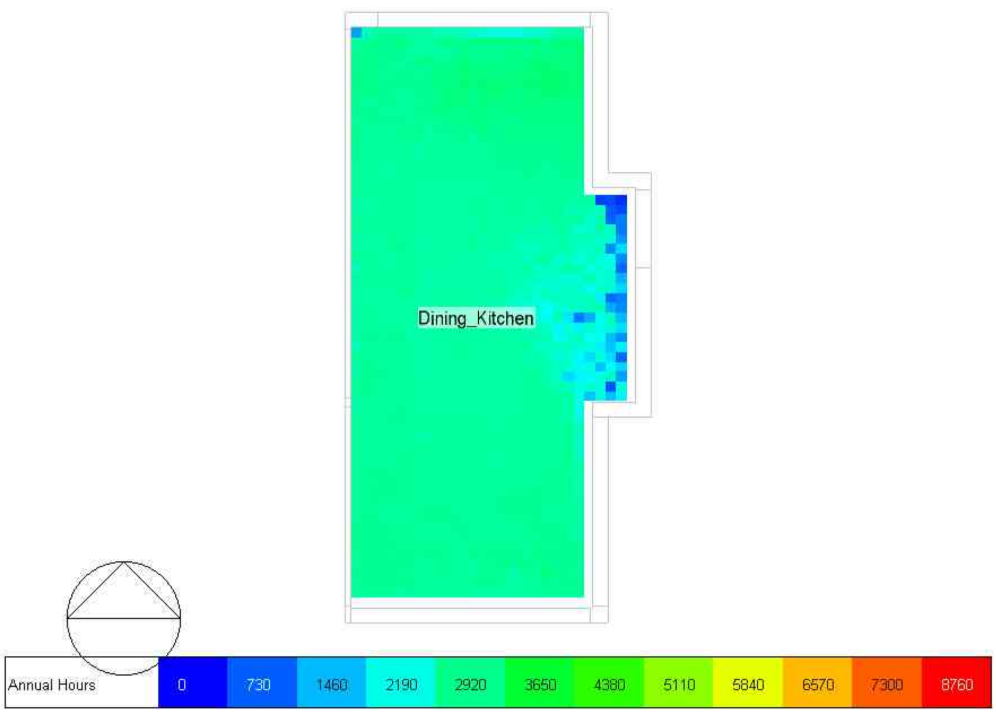

Figure 29: UDI for Dining and kitchen for the Resized window case

3.6 Daylighting Insights with Increased Window Sizes

The optimized window sizes resulted in significant improvements in daylighting for most zones. Here are some key insights:

Positive Impact:

1. Overall Improvement: Most zones witnessed a rise in sDA (usable daylight area), signifying a successful strategy to enhance natural light penetration.

2. Excellent Daylighting: Dining_Kitchen, Staircase & lift (on both floors), and Studio Room achieved 100% sDA, indicating excellent access to natural light. These areas likely feel bright and airy.

Areas for Adjustment:

1. Glare Potential: While achieving high sDA is desirable, some zones also show a significant increase in ASE (potentially excessively bright sunlight area). This suggests potential glare concerns in:

   a. Staircase and Lift area

   b. Living Room (to a larger extent)

   c. Bedroom 2

3.6.1 Case 2 - Window sizing with shading (Proposed)

Table 3: Showing the percentage of area in range for sDA, ASE & UDI for the Resized window with shading case (Proposed changes)

Zone	Floor Area (m2)	sDA Area in Range (m2)	sDA Area in Range (%)	ASE Area in Range (m2)	ASE Area in Range (%)	UDI Area in Range (m2)	UDI Area in Range (%)
Dining_Kitchen	32.1	31.6	**98.3**	32.1	**100**	31.5	**98.1**
Single Bedroom	10.9	9.738	**88.8**	10.964	**100**	8.757	**79.8**
Living	28.2	26.7	**94.7**	12.1	**42.8**	7.714	**27.2**
Bedroom 1	15.4	14.159	**91.7**	14.263	**92.4**	13.1	**85**
Staircase & lift	10.4	10.443	**100**	10.443	**100**	10.443	**100**
Studio room	7.4	7.426	**100**	7.426	**100**	5.955	**80.2**
Staircase_Lift	13.1	13.106	**100**	13.106	**100**	13.106	**100**
Bedroom 2	30.9	27.93	**90.2**	29.404	**95.0**	23.746	**76.7**

This case showcases the impact of adding window shading (750mm horizontal on south and west sides, 300mm vertical on west side) on daylighting performance after increasing window sizes.

Positive Impact Maintained:

1. **Overall Improvement:** Similar to the previous analysis, most zones maintained a significant increase in sDA (usable daylight area) compared to the baseline scenario without window size adjustments. This indicates successful implementation of strategies to enhance natural light penetration.

2. **Excellent Daylighting:** Zones like Dining_Kitchen, Staircase & lift (both floors), and Studio Room continue to achieve close to 100% sDA, signifying excellent access to natural light.

Impact of Shading:

Glare Control: The inclusion of shading seems effective in addressing the previously observed glare potential. Most zones, particularly those with south and west facing windows (Living Room, Bedroom 2), show a decrease in glare (potentially excessively bright sunlight area) compared to the findings with only optimised window size.

Zone-Specific Observations:

1. **Dining and Kitchen:** The sDA remains high at 98.3%, the ASE in the space is maintained to reduce glare.

2. **Living Room:** The sDA remains around 94.7%, with a slight betterment in glare metrics compared to the previous analysis. This might indicate a need for further refinement of shading elements, particularly for south-facing windows.

3. **Single Bedroom and Bedroom 2:** Due to the shading, both zones have full coverage for ASE.

3.6.1.1 Spatial Daylight Autonomy

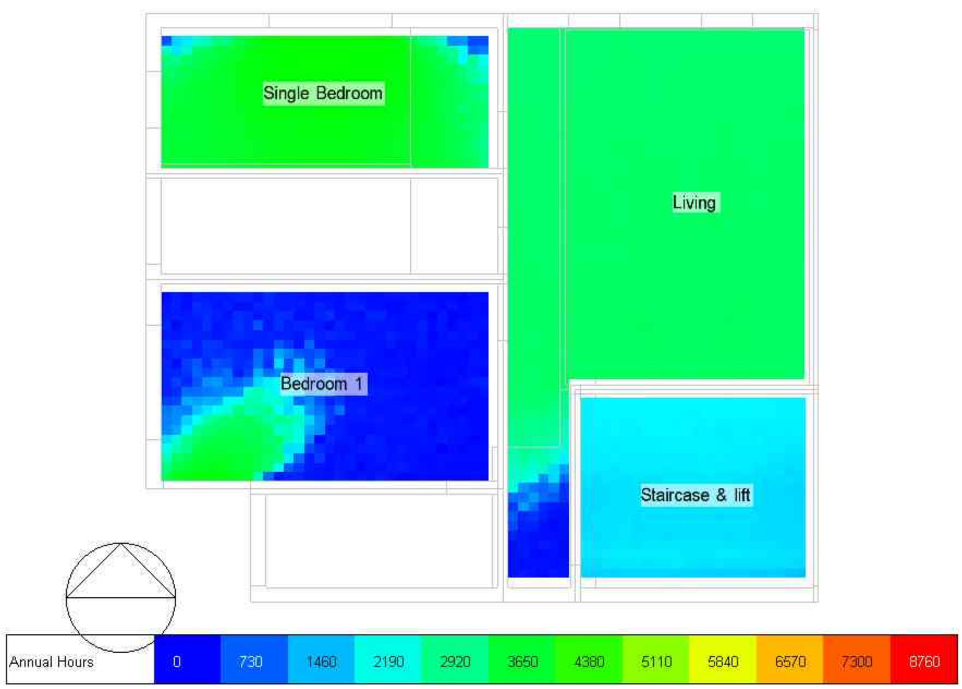

Figure 30: sDA for Ground floor rooms for the Resized window with shading case

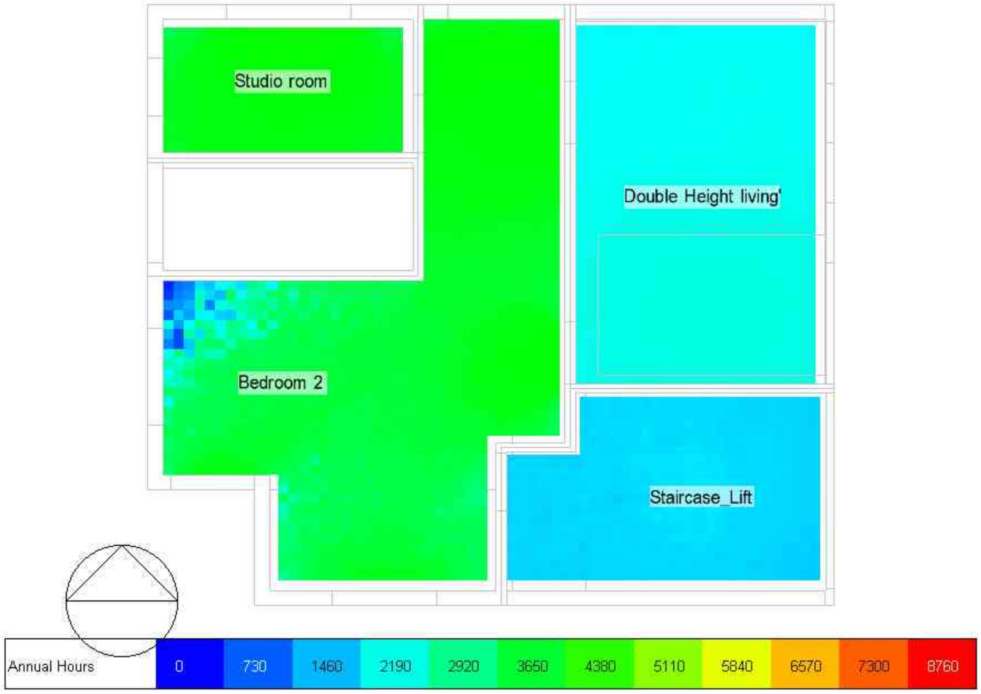

Figure 31: sDA for First floor rooms for the Resized window with shading case

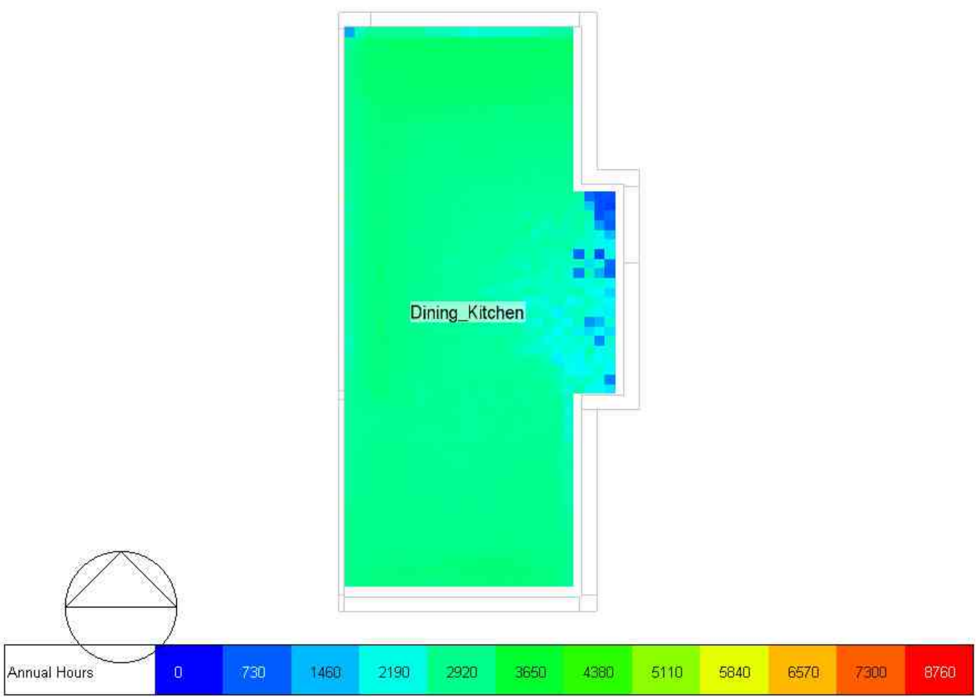

Figure 32: sDA for Dining and kitchen area for the Resized window with shading case

3.6.1.2 Uniform Daylight Autonomy (UDI)

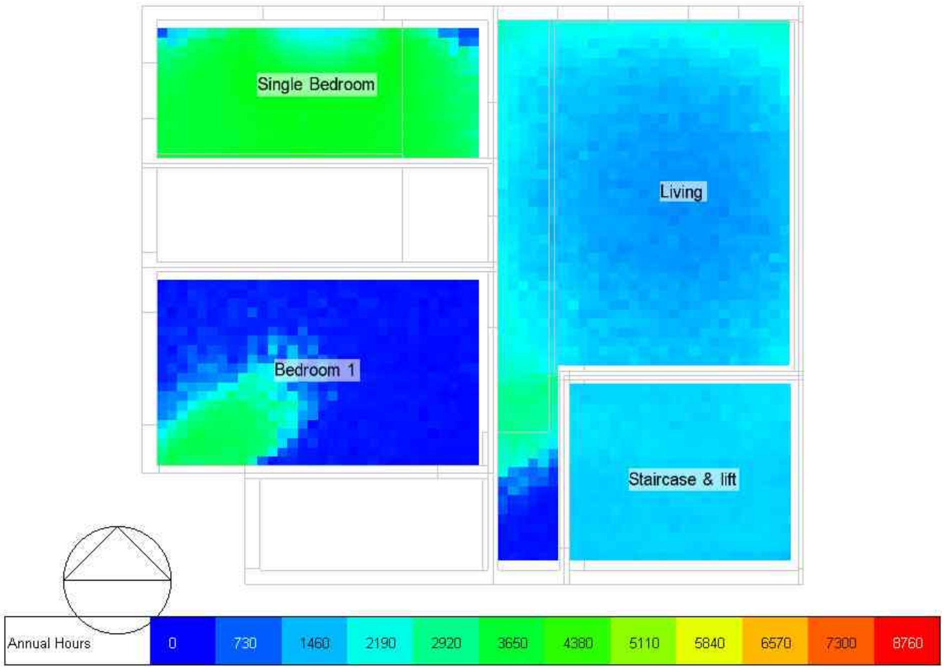

Figure 33: UDI for Ground floor rooms for the Resized window with shading case

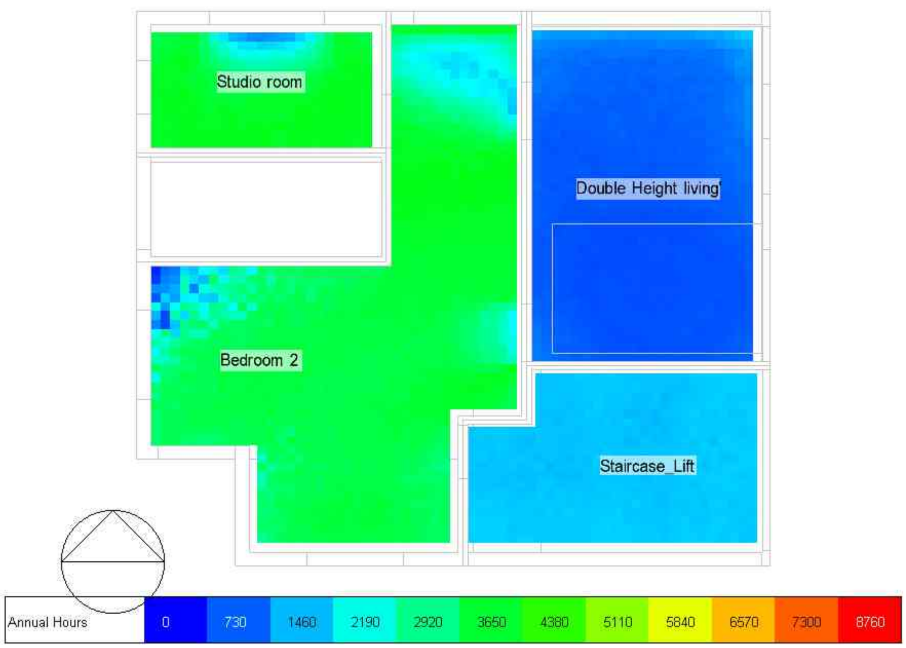

Figure 34: UDI for First floor rooms for the Resized window with shading case

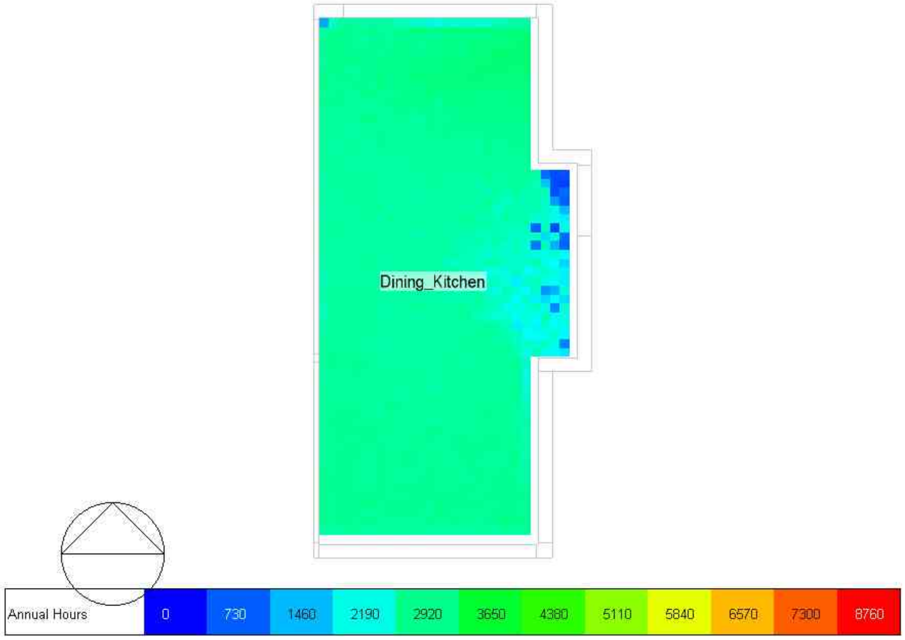

Figure 35: UDI for Dining and kitchen for the Resized window with shading case

4 Wind Analysis

4.1 Cases

4.1.1 As-is case

4.1.1.1 Outdoor and surroundings

Wind and external CFD analysis was performed to study the wind velocity and the pockets created for wind flow. The prevalent wind direction of Pune is from West. It is observed that the voids between the blocks create a high pressure zone hence increasing the air velocity between the context blocks. However, the same reduces the air-flow to the site. It is important to note here that the wind flows from the southern and northern sides of the site, making it viable for bigger openings that could provide comfort.

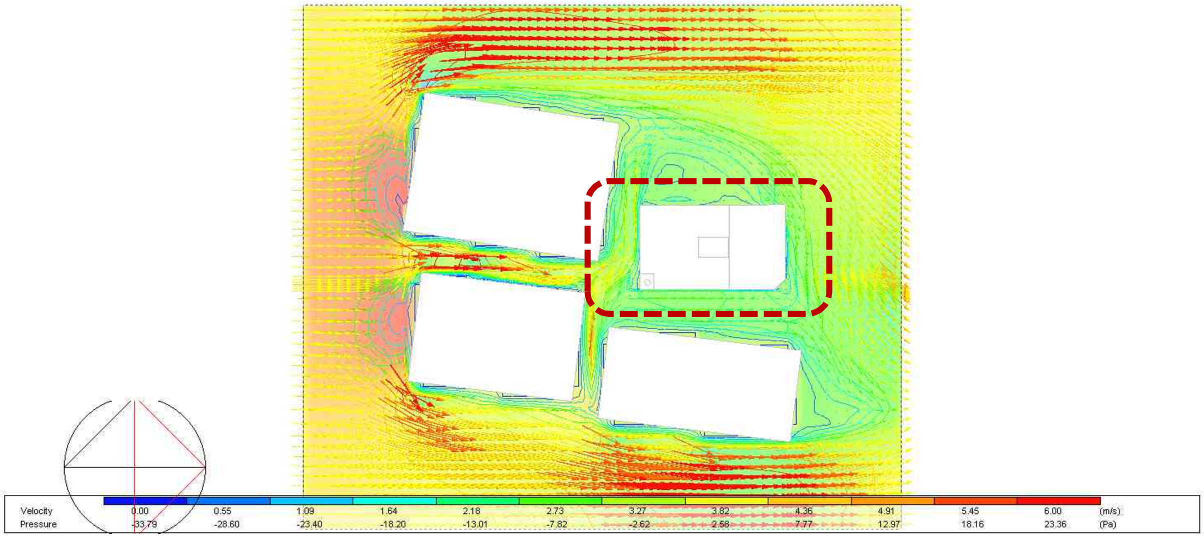

Figure 36: Outdoor surrounding wind velocity @5'

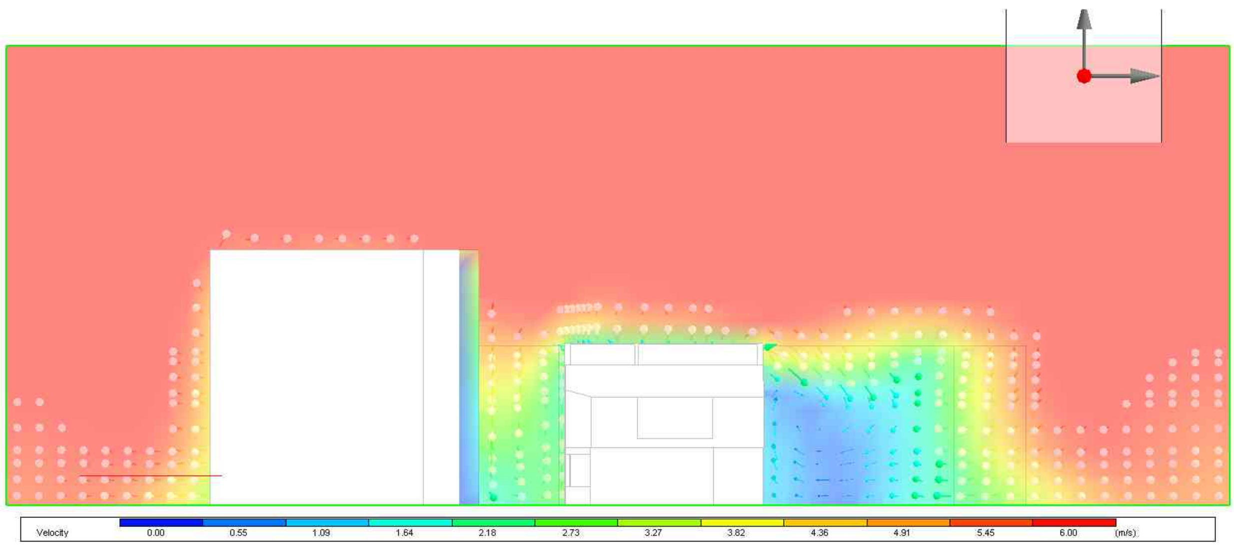

Figure 37: Outdoor surrounding wind velocity cut in section

4.1.1.2 Indoor spaces

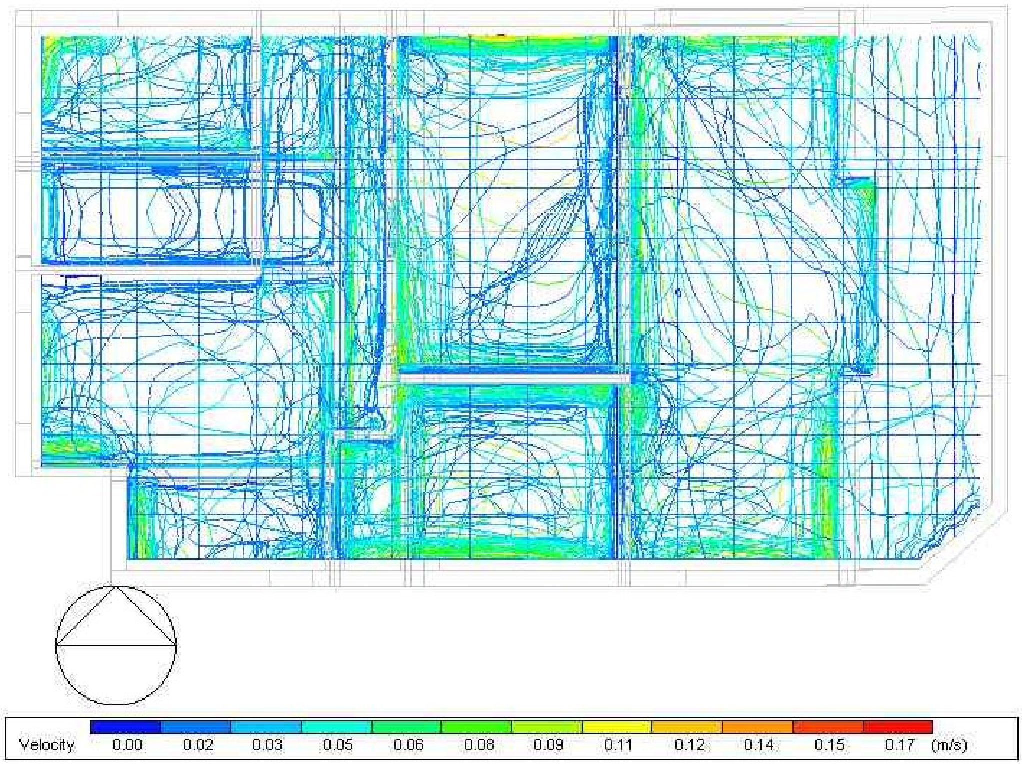

Figure 38: As-is case indoor air speed-Plan (Overall)

Figure 39: As-is case indoor air speed-North elevation

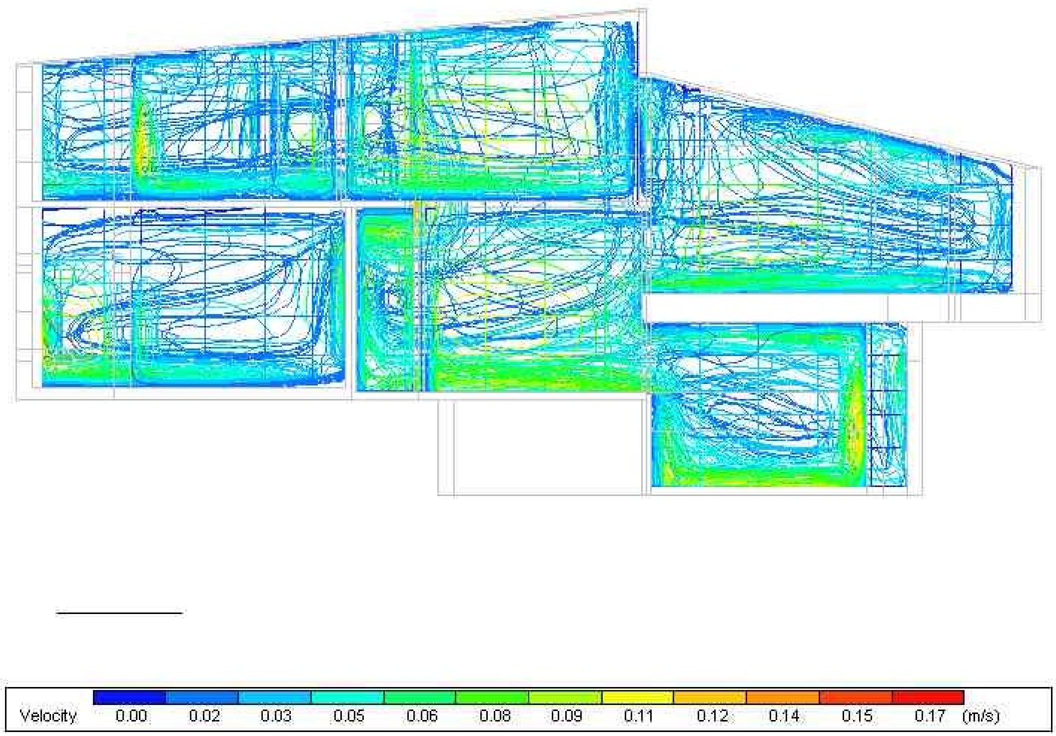

Figure 40: As is case indoor air speed-South elevation

4.1.2 Proposed Case

4.1.2.1 Outdoor and surroundings

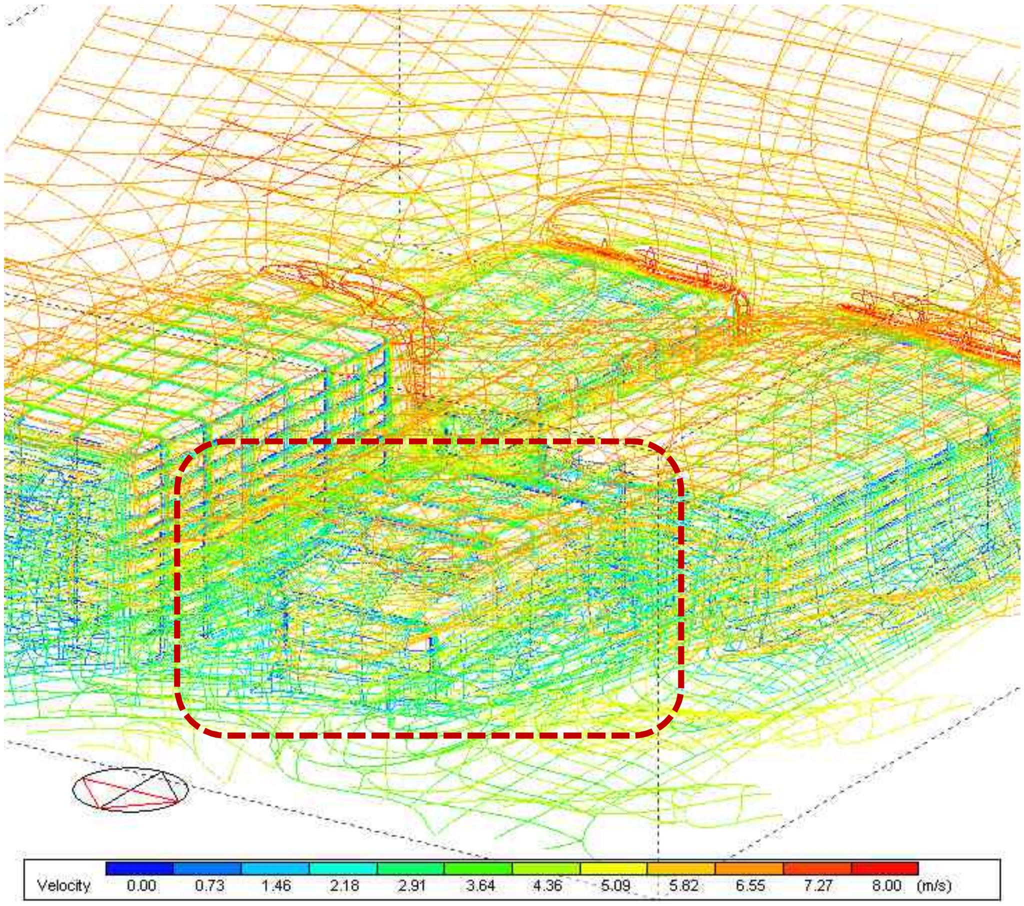

Figure 41: Proposed Outdoor air speed-3D

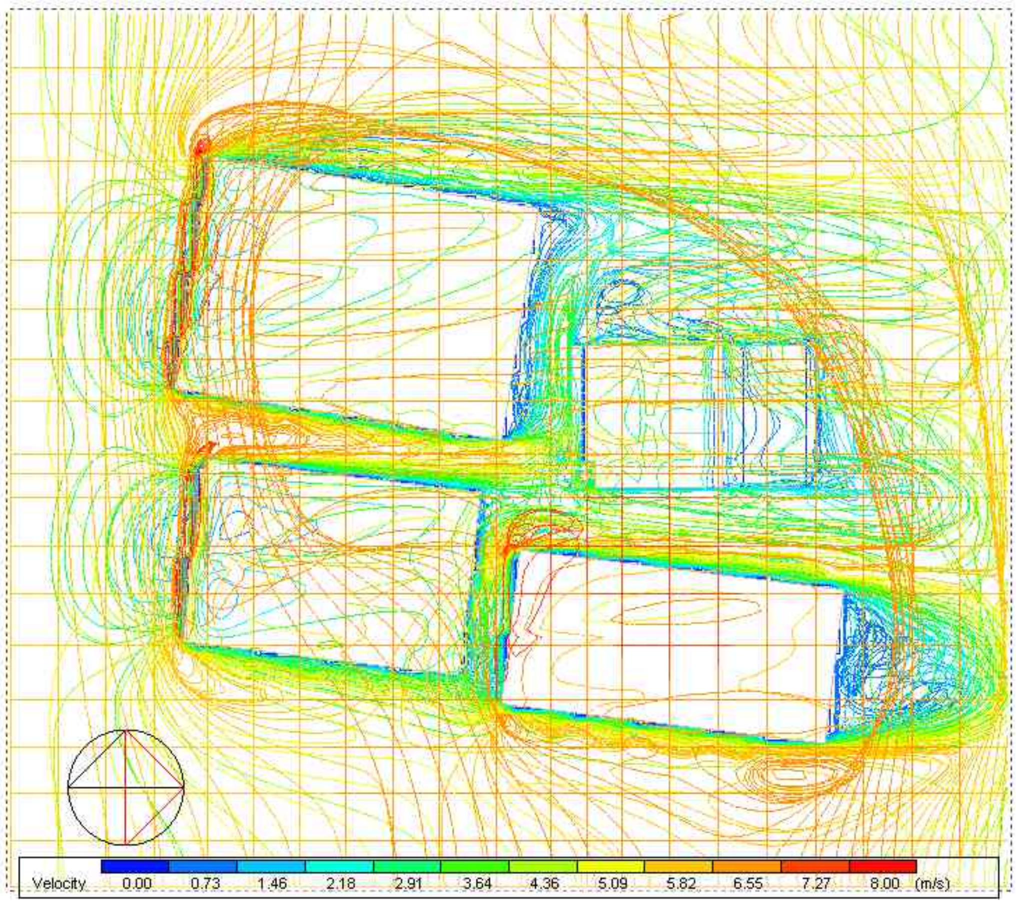

Figure 42: Proposed Outdoor air speed-Plan (Outdoor)

4.1.2.2 Indoor spaces

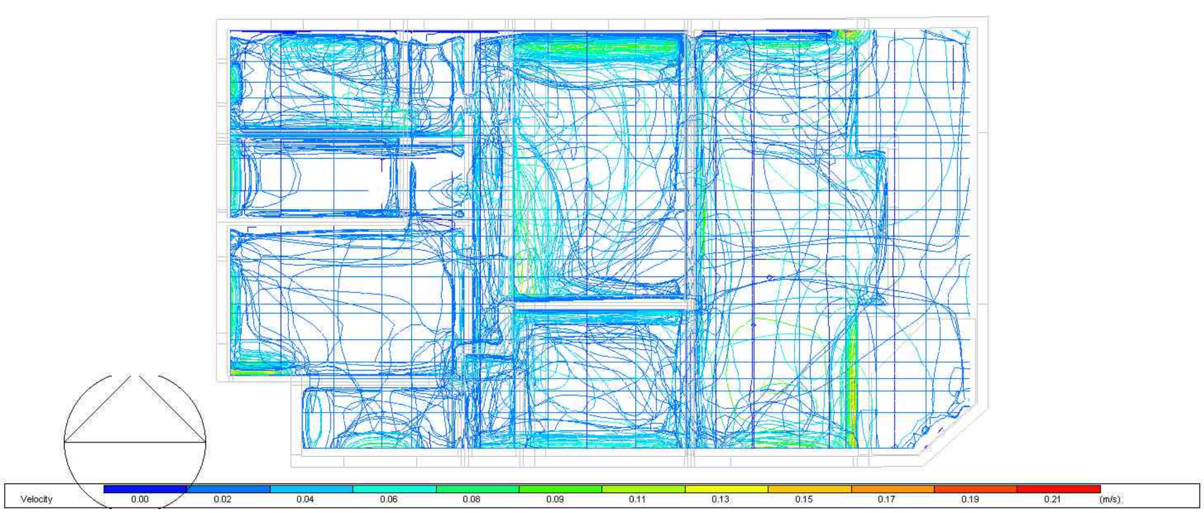

Figure 43: Proposed design indoor air speed-Plan (Overall)

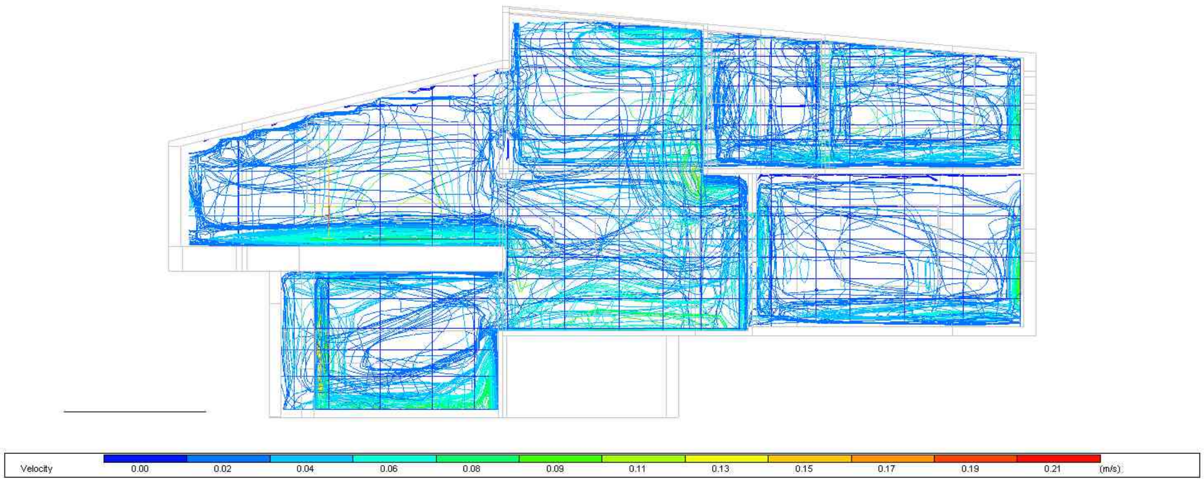

Figure 44: Proposed design indoor air speed-North elevation

Figure 45: Proposed design indoor air speed-South elevation

5 Recommendations

From all the above analysis it is observed that the as-is case has a considerably low occupant thermal comfort for all the major habitable spaces. These can be the reasons:

1. The humidity is above 70% threshold of comfort band of IMAC Mixed-Mode for a majority of 4600 hours of the 8760 hours in a year. This accounts for more than 50% of the total hours.

2. Second reason is due to consideration of brick and tile as building materials for the residence.

3. Third is due to inadequate number of openings for ventilation.

It is recommended that the above points are addressed in the design through alterations for a better occupant thermal comfort inside the spaces.

Given the constraints of no additional shading or increased window size as there can be compromise in occupant comfort, alternative solutions shall be explored to manage glare and optimize daylighting within the building. Here are some recommendations:

5.1.1 Tinted Glass

1. Utilize tinted glass for south and west-facing windows with high glare (potentially excessively bright sunlight area) to reduce glare. Consider the following:
2. **Glass Tinting Levels:** Select a tinting level that balances glare control with maintaining sufficient daylight transmission. Opt for a lower level (lighter tint) for north-facing windows to maximize natural light.
3. **Glass Color:** Explore options like bronze or grey tints, which offer good glare reduction while minimizing color distortion compared to green tints.

5.1.2 Optimize Light Distribution

1. **Light Shelves and Diffusers:** Utilize light shelves or diffusers strategically placed near windows to redirect sunlight deeper into the space, particularly in zones with deep floor plans (Living Room, Bedroom 1).
2. **Reflective Materials:** Employ light-colored, highly reflective materials for ceilings, walls, and furniture to enhance natural light distribution within the space.

5.1.3 Wind-velocity indoor

1. Air velocity indoor ranges between 0.1-0.3 m/s. Addition of ceiling and mechanical fans shall increase air circulation and better comfort at times. Ensure Natural ventilation through opening of doors and windows during required hours.
2. Addition of dehumidifiers will also help in keeping the high humidity inside the spaces in check. This is optional, however, shall help in enhancing indoor comfort and also reduce direct AC use which in turn has a humidifier/dehumidifier.