IMPACTS OF CLIMATE CHANGE ON ENERGY DEMAND OF A MID RISE OFFICE BUILDING – A CASE OF NEW DELHI

ARN 702 – Dissertation

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25th, MAY-2018

CANDIDATE'S DECLARATION

I hereby declare that the report entitled "**IMPACT OF CLIMATE CHANGE ON BUILDING ENERGY DEMAND OF A MID SIZE OFFICE BUILDING- A CASE OF NEW DELHI**" submitted in partial fulfilment of the requirement for the award of the degree of Master in Architecture at the Department of Architecture and Planning, Indian Institute of Technology Roorkee, is the authentic record of my own work carried out during the period from **July 2018 to May 2019** under the guidance of **Dr. E. Rajasekar**, Department of Architecture and Planning, Indian Institute of Technology Roorkee, India.

Date: 25th June, 2019

Place: Roorkee **Mr. Chinmay Jha**

This is to certify that above statement made by the candidate Mr. Chinmay Jha is true to the best of my knowledge.

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Date: 25th May, 2019

Place: Roorkee

CERTIFICATE

Certified that the report entitled "**IMPACT OF CLIMATE CHANGE ON BUILDING ENERGY DEMAND OF A MID SIZE OFFICE BUILDING- A CASE OF NEW DELHI**" which has been submitted by Mr. Chinmay Jha, for partial fulfilment of the requirement for the award of the post graduate degree of Master of Architecture, in the Department of Architecture and planning, Indian Institute of Technology Roorkee, is the student's own work carried out by him under my supervision and guidance. The matter embodied in this dissertation has not been submitted for the award of any other degree of this or any other institute.

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ABSTRACT

Climate change is a most concerning issue in the last few decades. As per the IPCC (Emission Scenarios) [1] this phenomenon is expected to result in a global temperature increase of 1.5 °C. Apart from its impact on annual mean temperature, it has brought significant changes to the temporal weather events. Such a change is seen as a critical factor for building designers given its impact on building's thermal behaviour, occupant's thermal comfort and resultant energy use. Buildings which are designed to current day's cooling and heating design day scenarios may exhibit inferior performance in the above context. In this context, this study intends to decipher the climate change phenomena using a bottom-up approach and delineate strategies for climate change resilience. The study has the following objectives (a) to map the impact of climate change based on the magnitude and temporal variations of dry bulb temperature, relative humidity and global horizontal irradiance; (b) to establish the effect of climate change on the energy use of a mid-size office building; and (c) to delineate design strategies for climate change resilient building envelope. The scope of the study is limited to a mid-sized office building located in the composite climate of Delhi. For this purpose, a review of plan-form configurations is carried out. Based on this, five representative spatial layouts are prepared. The weather data made available by Indian Society of Heating Refrigeration and Air conditioning Engineers (ISHRAE) for the year 1990 is morphed for the years 2020 and 2050 using the climate change world weather file generator. This tool uses IPCC TAR model summary data of the HadCM3 A2 experiment ensemble. A statistical analysis of dry-bulb temperature (Ta), relative humidity (RH) and global horizontal irradiance (GHI) is carried out to map the magnitude and temporal variation between the years 1990 (base), 2020 and 2050. It is found that the climate variables exhibit a significant change in magnitude due to the impact of climate change. The analysis further reveals the presence of significant temporal variations. In order to assess the implication on the energy demand, a representative office building in the city of Delhi (Development Alternatives World Headquarters) is modelled using Design Builder software tool. The energy demand of the building is simulated for the years 1990, 2020 and 2050. A comparative assessment of energy demand and the impact of changes in climate variables is presented. Desirable changes to the building envelop are identified in order to cap the energy demand of the building to the base year's limits. Further the representative office building layouts are

modelled as per ECBC and Super-ECBC criteria and the impact of climate change on their energy demand is presented. The climate-change resilient building envelop interventions are discussed for these layouts.

INTRODUCTION:

Climatic change and global warming are two of the most concerning issues of ecosystem which are continuously becoming a threat to ecosystem in last few decades. The year 2016 was the hottest year recorded in history with an average of about 0.94°C temperature globally. Moreover, the Intergovernmental Panel on Climate Change (IPCC) have has shown concern for increasing concentration of global warming and greenhouse gases (GHGs) into its report of fifth assessment. Since 1850, the last few decades have the highest temperatures due to the continuous emission of carbon dioxide, methane, nitrous oxide etc. which has resulted in rise in global temperature.

Due to changing climatic conditions, the energy consumption of a building also gets adversely affected with different heating and cooling demands. It will also impact the consumption of fuels mixture by buildings with increased electricity consumption for cooling and reducing the usage of natural gas for heating. Due to such variations, the capitals invested by businesses and individuals to cool down the buildings also fluctuate, with the total energy consumption depends upon whether increased cooling demands outweighs decreased heating demands.

RELEVANCE:

Consumptions of energy sources and thermal comfort are highly dependent upon the weather conditions. Variation in climatic conditions has increased global temperature which imparts similar effect on the energy and space conditioning of buildings in upcoming time. Tropical areas will also experience a decrease in energy demand for space heating due to increasing temperature. Indoor thermal temperature of building is also rising due to the rise in temperature at the lands near the temperate zone due to which the energy demands for more cooling has been increased. Therefore, the importance of strategic building design has become important which will incorporate certain suitable equipped framework to minimize or reduce the impacts of increasing energy demand by buildings for heating and cooling loads. It is now required to design Building with adaptive strategies to mitigate the impact of increased demands for heating and cooling energy.

DISSERTATION TITLE:

IMPACTS OF CLIMATE CHANGE ON ENERGY DEMAND OF A MID RISE OFFICE BUILDING – A CASE OF NEW DELHI.

RESEARCH QUESTIONS:

1. How much impact does climate change is going to make on thermal severity and Building energy demands?
2. What thermal performance improvement strategies are required, and to what extent these strategies will address the issue?

AIM:

This study aims at investigating the impacts of climate changing scenario on heating & cooling energy demands in an office Building – A case of New Delhi.

OBJECTIVE:

- To Identify the impacts of Climate Severity on the basis of Dry Bulb Temperature (DBT), Relative Humidity (RH) and Global Horizontal Irradiance (GHI).
- To establish the effect of climate change on thermal performance and energy demand of an office building.
- To Identify strategies for the design of climate change resilient built envelope.

RESEARCH METHODOLOGY:

Stage 1:

Quantifying Impacts of thermal severity of climate change for current & future scenario.

- Climate analysis for the city of new Delhi on the basis of present-day Climate Data.
- Generating weather Data For future Scenario.
    - Emission Scenario Selection- from IPCC SRES Report.
    - Setting up Climate change world weather data Generation tool.
    - Generating weather Data files for 2030. 2050, 2070 using CC world File Generator.
- Climate thermal severity Analysis. For this analysis, 3 Parameters have been recognised to calculate the impact of thermal Severity.
    - Dry Bulb Temperature (° C)
    - Relative Humidity (%)
    - Global Horizontal Irradiance (kWh/sqm)

Stage 2:

Changes established in thermal performance & overall energy demand of a medium size office building in New Delhi, for current & future climates, on Building thermal & energy simulation program.

- **Preparing a Building software Model out of an existing Building, DA World Headquarters.**
- **- Preparing 5 Typical Office Model Based on studying various Parameters**
    - Building form/Layout
    - Area/Occupancy
    - Type of Building Materials
    - ECBC Standards for an Office Building.
    - HVAC & Occupancy.
- **Computer Simulations**
    - To Assess the thermal performance and Energy Performance Demand of the Building Model for the current and future climate types. Energy Plus Computer Simulation Program, Design Builder will be used. Weather Data Generated for Each Scenario using weather Data File in Energy Plus Weather (EPW) Format.
- **Comparative Analysis between Simulated and Actual model Energy Consumption Data.**
- **Validating the performance and authenticity of simulated model with Actual Energy Consumption Data**
- **Indoor thermal conditioning and building energy Performance Analysis of the mid-size office building.**
    - Indoor thermal comfort condition analysed on the basis of simulated results for each zone of the Building Model.

Stage 3:

Identification of climate Resilient Design Strategies on Built Envelope in order to account for thermal energy performance of office building for current & future climate change scenario.

- Identifying the Mitigation Strategies for Built envelope in Indian Context.
- Using these measures, Either Individually or in combination, to cap the future Building Energy Demands to present consumption scenarios

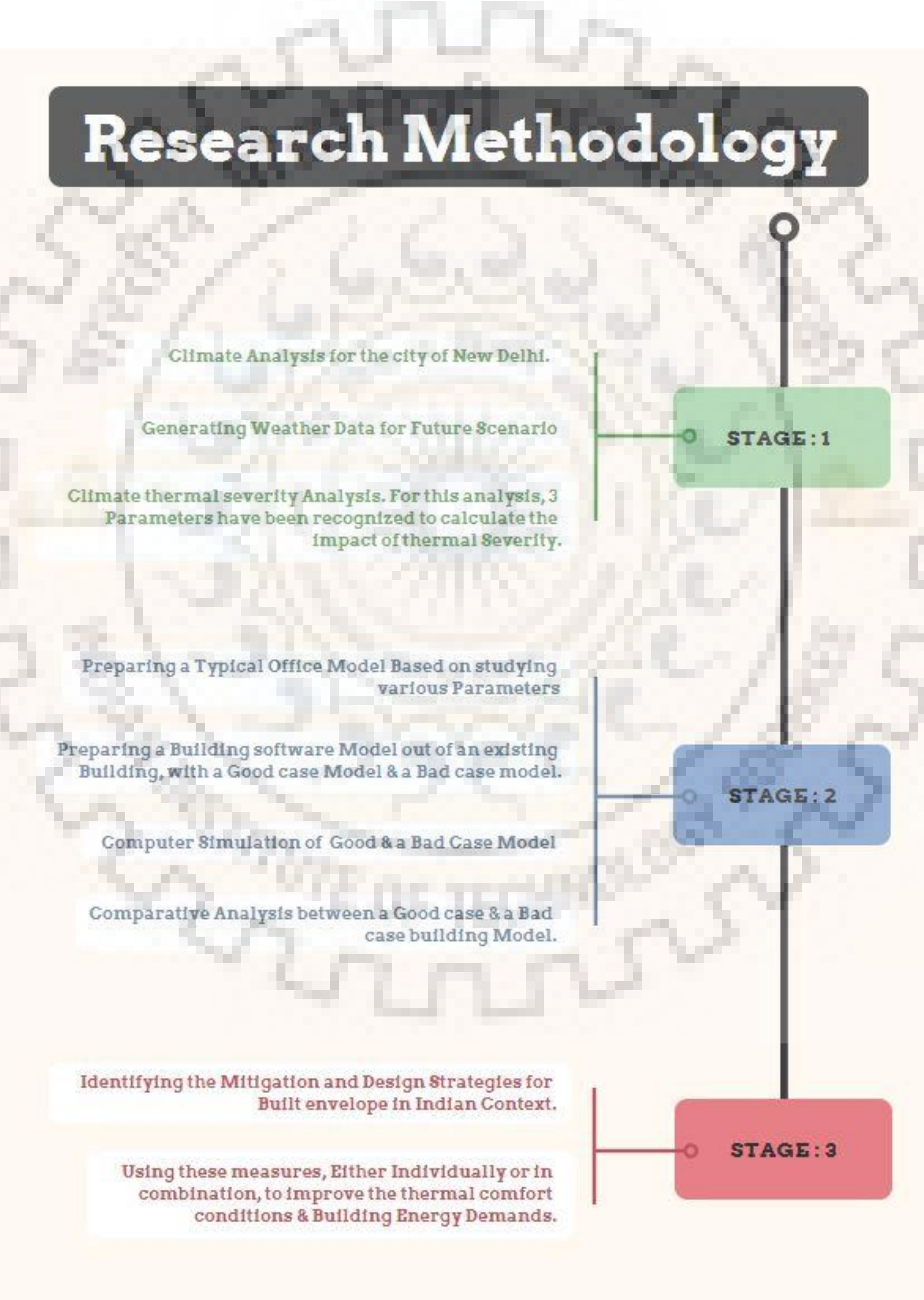


Figure 1 Research Methodology

SCOPE AND LIMITATIONS:

Some aspects which will not be covered by this thesis outcome

- Study is limited to a *typical mid-size office building.*
- Study is limited to the *city of New Delhi.*

LITERATURE REVIEW –

The impacts of climatic change on building energy expenditures throughout the globe need to be understood. Due to increasing electricity consumption for cooling purpose, the related expenditure has also raised. Studies have shown that there exists no special difference in the changes in net expenditure all over the globe. Net expenditure has been decreased in Canada, Russia and other areas where there is high heating demands and similarly it increases in the areas where there exists low demand for space heating and high demands of space cooling. All these results are explained depending upon the key drivers linking building energy with regional climate.

Approaches identified by existing literature studies

1. There are studies which incorporated the statistical and econometric relationship between energy and important primary climate variable, statistics of temperature and energy demand are most commonly used.
2. Another approach attempts to employ the implications of Building specific energy simulation models. This approach involves Building impacts at global level; & Building impacts using a detailed service-based building energy model.

Some of the studies carried out on climate change impact on Building.

Table 1 Summary on studies carried on climate Change

Author	Period	Type of Building	Country	Conclusion
L. Guan	2070	Commercial	Australia	Cooling demand increased from 28% to 59%
Wang et al.	2100	Residential	Australia	Variation in Total energy- 48% to 350%
Wan et al.	2100	Commercial	China	cooling energy increased by 11-20% & heating energy decreased by 13-55%.

Frank	2100	Commercial and residential	Swiss	Heating demand decreased by 36-58% & cooling demand increased by 223-1050%
Berger et al.	2050	Commercial	Austria	Heating demand decreased by 11-56% & cooling demand increased by 28-91%
Dodoo et al.	2050-2100	Residential	Sweden	Cooling demand increased by 33-49% & heating demand decreased by 13-22%.
Pilli-Sihvola et al.	Not-Mentioned	Commercial and residential	Finland, Holland, Germany, France & Spain	cooling demand increased & heating demand decreased.
Yilha et al.	2030-2050-2100	Residential	Finland	cooling demand increased by 40-80% & heating demand decreased by 20-40%.
Asimakopouloset al.	2100	Commercial and residential	Greece	heating demand decreased by 44-75% & cooling demand increased by 28-59%.
Amato et al.	Not-mentioned	Commercial and residential	United States	Electricity consumption increased by 1.2-2.1% & gas consumption decreased by 7-14%
Wang and Chan	2040-2080	Commercial, residential and public	United States	cooling demand increased & heating demand decreased.
Dirks et al.	2052-2089	Commercial, Residential	United states	total energy consumption varied by -31.4 to + 15.4%.

Radhi	2050-2100	Residential	UAE	cooling energy increased by 23.5%
Huang & Hwang	2020-2050-2080	Residential	Taiwan	Cooling energy demand increased by 31-82%
Casagrande & Alvarez	2020-2050-2080	Commercial	Brazil	cooling energy demand increased by 10.7-25.6%

CLIMATE SEVERITY ANALYSIS

The city Delhi Being located in the Northern plains of Indian Subcontinent, the Himalayas and Thar Desert highly influences the city's climatic condition. Such conditions cause to have both, hot and cold extremities, with 5 distinct seasons, i.e., summer, rainy, autumn, winter & spring. Distribution of the climate pattern in New Delhi can be understood by subdividing climate into summer, monsoon, short cold winters, & two pleasant transition seasons.

Summer season starts early in April and peaks in May, with and average temperatures near **32 °C**, sometimes occasional heat waves results in as high as **45 °C**.

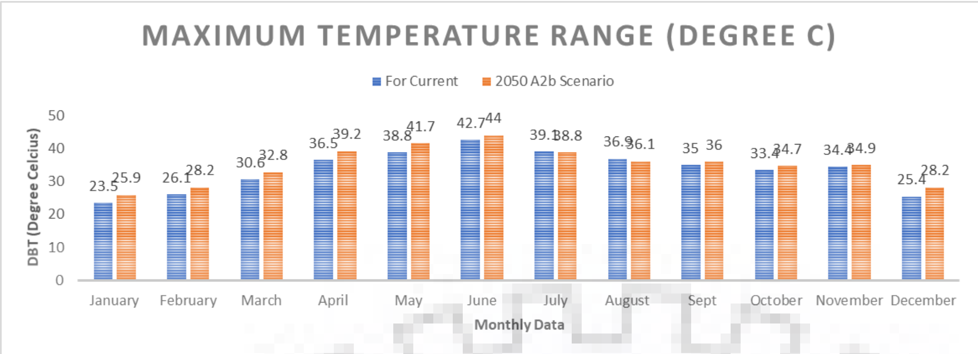
Winters season starts around late November or early December, which later peaks in January. Delhi's proximity to Himalayas is responsible for lower temperature due to chill winds, resulting in average temperature to be around **12-13 °C**.

Climate Data Analysis for current Scenario and Future Scenario-

Climate Data for Current and 2050 A2b Future Scenario done comparing on the basis of 3 Parameters.

- Dry Bulb Temperature (Degree C)
- Relative Humidity (%)
- Global Horizontal Irradiance (kWh/Sqm)
- Heating and cooling Degree Hours

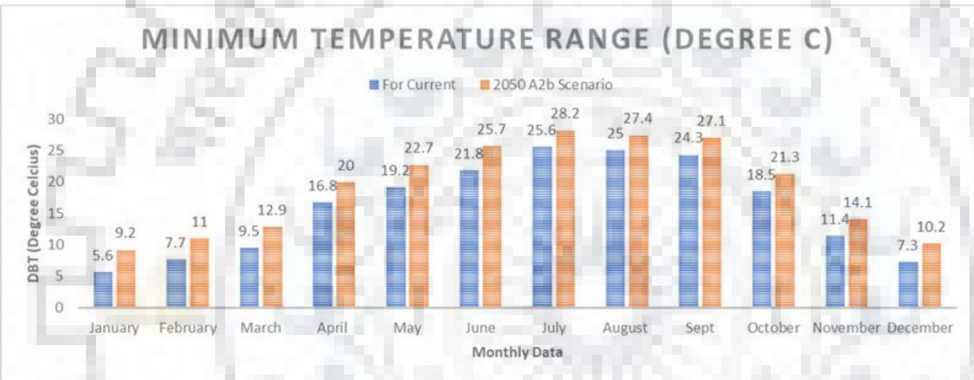
Temperature-



Difference	Percentage
2.4	10.2%
2.1	8.0%
2.2	7.2%
2.7	7.4%
2.9	7.5%
1.3	3.0%
-0.3	-0.8%
-0.8	-2.2%
1	2.9%
1.3	3.9%
0.5	1.5%
2.8	11.0%

Figure 2 Min Temperature Range for Both Climate Scenario

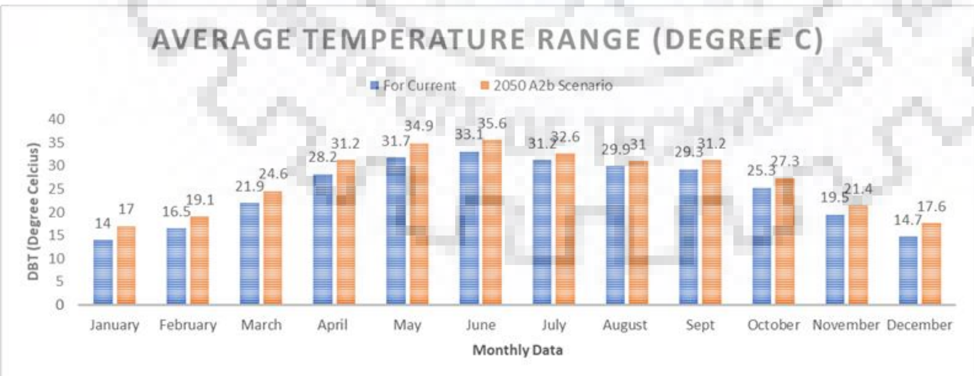
Maximum temperature for 2050 A2b scenario shows an 10-12% increase, 2.4 to 2.8 degrees increase in future temperature for the month of December to February.



Difference	Percentage
3.6	64.3%
3.3	42.9%
3.4	35.8%
3.2	19.0%
3.5	18.2%
3.9	17.9%
2.6	10.2%
2.4	9.6%
2.8	11.5%
2.8	15.1%
2.7	23.7%
2.9	39.7%

Figure 3 Min Temperature Range for Both Climate Scenario

Minimum temperature for both climate slices saw an increase of around 4 degrees in the month of June, showing a percentage increase of 18%.

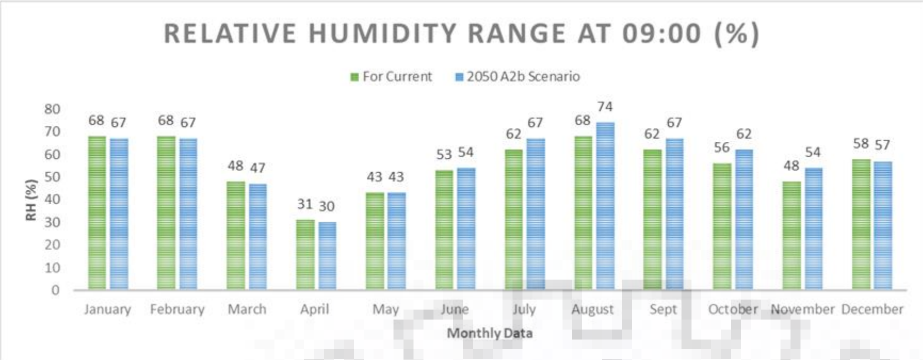


Difference	Percentage
3	21.4%
2.6	15.8%
2.7	12.3%
3	10.6%
3.2	10.1%
2.5	7.6%
1.4	4.5%
1.1	3.7%
1.9	6.5%
2	7.9%
1.9	9.7%
2.9	19.7%

Figure 4 Avg. Temperature Range for Both Climate Scenario

Average Temperature for shows a percentage increase in 2050 A2b scenario of around 21%, with an average increase of 3 degrees.

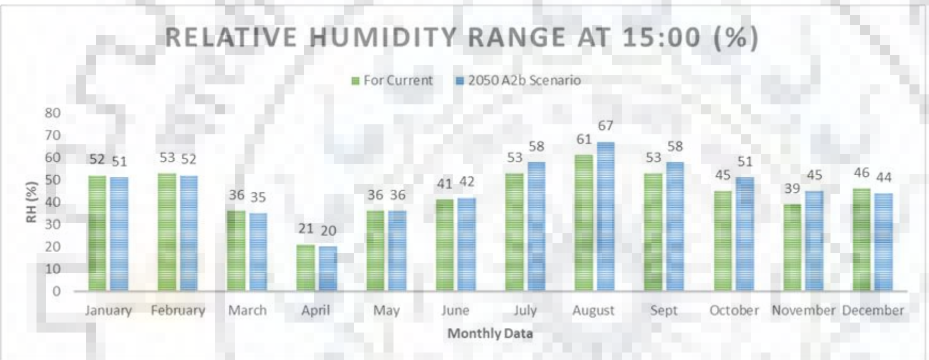
Relative Humidity-



Difference	Percentage
-1	-1.5%
-1	-1.5%
-1	-2.1%
-1	-3.2%
0	0.0%
1	1.9%
5	8.1%
6	8.8%
5	8.1%
6	10.7%
6	12.5%
-1	-1.7%

Figure 5 RH Range for Both Climate Type

RH Study for both current and future time scenario is compared at two times of the day. Simulated studies show that for winter months & Early months of summer, percentage of RH declined by **2-5 %.**

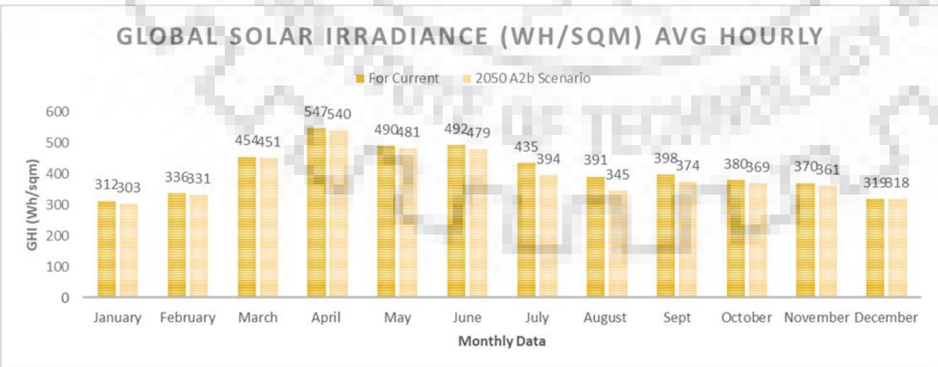


Difference	Percentage
-1	-1.9%
-1	-1.9%
-1	-2.8%
-1	-4.8%
0	0.0%
1	2.4%
5	9.4%
6	9.8%
5	9.4%
6	13.3%
6	15.4%
-2	-4.3%

Figure 6 RH range for both Climate Type.

Whereas for the months of late summer and early winter, RH has risen up from 2% to 15%.

Global Horizontal Irradiance-

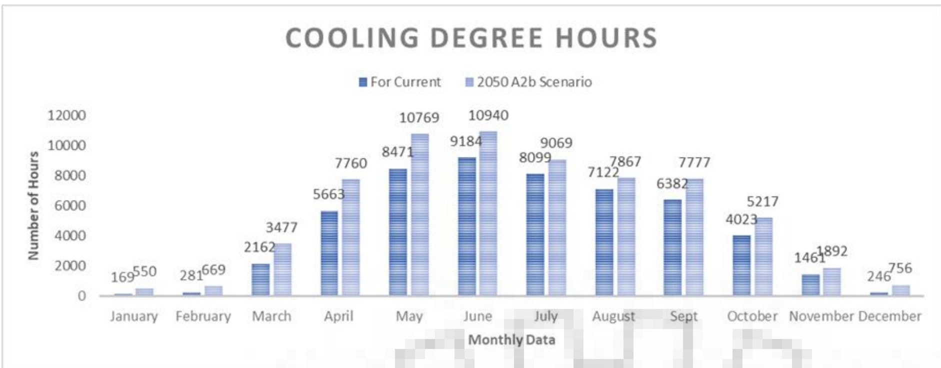


Difference	Percentage
-9	-2.9%
-5	-1.5%
-3	-0.7%
-7	-1.3%
-9	-1.8%
-13	-2.6%
-41	-9.4%
-46	-11.8%
-24	-6.0%
-11	-2.9%
-9	-2.4%
-1	-0.3%

Figure 7 GHI Range for Both Climate Scenario

GHI Values show a Reduction in the Magnitude for the weather data of A2b Scenario of 2050. This Impact varies between 1% to 12%, most in the months of July, August and September.

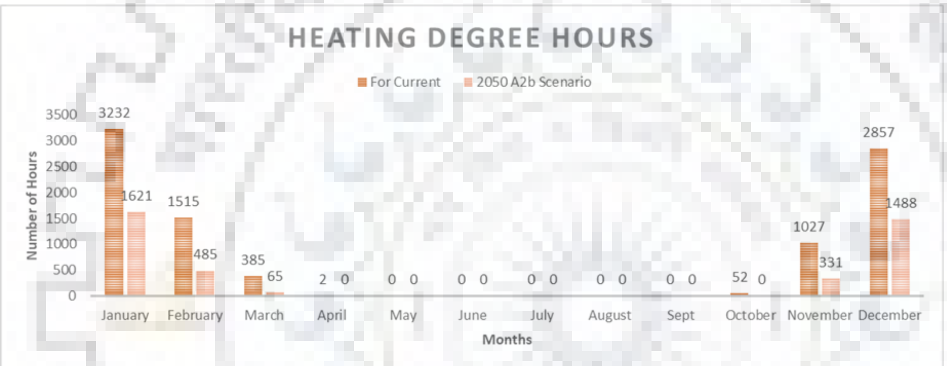
Heating and Cooling Degree Hours-



Difference	Percentage
381	225.4%
388	138.1%
1315	60.8%
2097	37.0%
2298	27.1%
1756	19.1%
970	12.0%
745	10.5%
1395	21.9%
1194	29.7%
431	29.5%
510	207.3%

Figure 8 CDD Range for Both Climate Scenario

Cooling Degree Hours show a significant increase for the weather data 2050 scenario, with most in the case of summer months and least in the winter months



Difference	Percentage
-1611	-49.8%
-1030	-68.0%
-320	-83.1%
-2	-100.0%
0	NA
0	NA
0	NA
0	NA
0	NA
-52	-100.0%
-696	-67.8%
-1369	-47.9%

Figure 9 HDD Range for Both Climate Scenario

Heating Degree Hours shows a Significant Reduction for the Future case scenario reducing the load on heating space appliances. The impact is reduced by mostly 50% for the total Heating load.

Dry Bulb Temperature Hourly Data Variation-

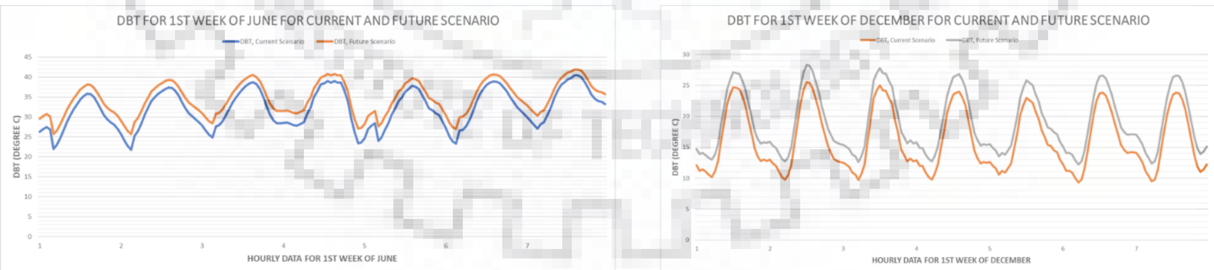


Figure 10 Hourly Reading for 1st week of June & Dec for both Climate type

Graph Comparison shows Temperature Readings on hourly basis for Both Climate Scenarios in the 1st Week of June and December. Hourly Data Comparison for both months shows a significant Increase in Average DBT, touching around 4-5 degree Celsius.

5 °C TEMPERATURE BINNING (Hours)

5 DEGREE BINS	1990	2020	2050	2080
T (5-10)	331	116	28	0
T (10-15)	1155	999	665	330
T (15-20)	1197	2431	1280	2397
T (20-25)	1365	1243	1272	1163
T (25-30)	2354	2211	1852	1381
T (30-35)	1887	2160	2478	2835
T (35-40)	638	690	902	1336
T (40-45)	99	153	279	443
T (45-50)	0	0	4	38

	DIFFRENCE AS TO 2020	DIFFRENCE AS TO 2050	DIFFRENCE AS TO 2080
T (5-10)	-215	-303	-331
T (10-15)	-156	-490	-825
T (15-20)	1234	83	1200
T (20-25)	-122	-93	-202
T (25-30)	-143	-502	-973
T (30-35)	273	591	948
T (35-40)	52	264	698
T (40-45)	54	180	344
T (45-50)	0	4	38

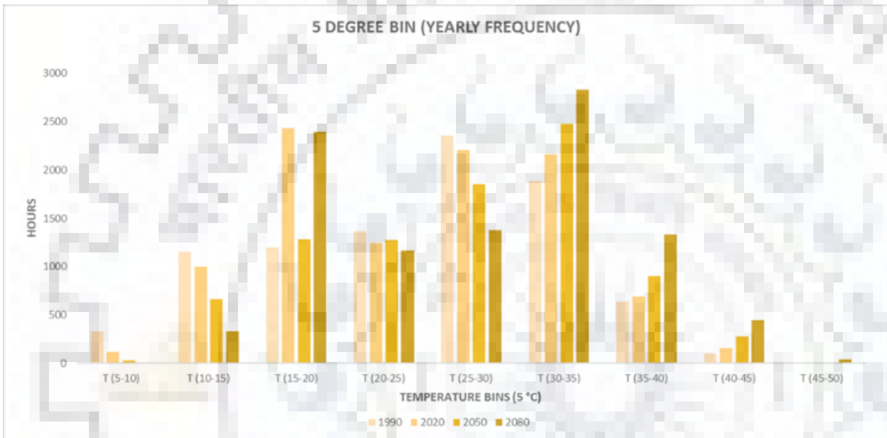


Figure 11 5 Degree Celsius Bins

Number of temperature hours reduced from lower temperature bins and increased to higher temperature bins. It states that the total number of hours are decreasing from cooler temperature bins and increasing into hotter temperature bins.

Hours have been clearly reducing from the lower temperature bins significantly for every year. These hourly number were increasing in higher temperature bins. Among Higher temperature bins, bin category 0f 30-35 registers higher number of hours increased up to 2080.

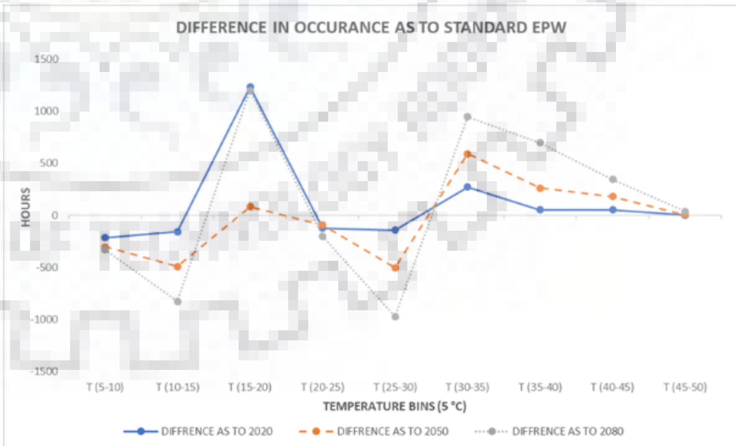


Figure 12 Difference in Frequency as to standard EPW

Result: 5 Degree Celsius binning shows a significant increase in the number of hours falling in higher temperature bins. Temperature hours falling in 30 °C to 45 °C binning has shown a strong increase, which states that future climate temperature occurrences are going to be on higher side.

2 °C TEMPERATURE BINNING SUMMER (Hours)

2 DEGREE BINS FOR SUMMER MONTHS (MAY-JUN)				
	1990	2009	2050	2080
T (18-20)	5	0	0	0
T (20-22)	17	1	0	0
T (22-24)	37	17	7	0
T (24-26)	69	45	17	4
T (26-28)	136	154	44	15
T (28-30)	255	211	77	37
T (30-32)	254	237	206	74
T (32-34)	226	205	260	207
T (34-36)	179	181	231	283
T (36-38)	164	179	205	256
T (38-40)	134	188	173	200
T (40-42)	79	123	141	192
T (42-44)	26	37	82	121
T (44-46)	2	1	21	64

	DIFFERENCE AS TO 2020	DIFFERENCE AS TO 2050	DIFFERENCE AS TO 2080
T (18-20)	-5	-5	-5
T (20-22)	-16	-17	-17
T (22-24)	-20	-30	-37
T (24-26)	-24	-52	-65
T (26-28)	18	-92	-121
T (28-30)	-44	-178	-218
T (30-32)	-17	-48	-180
T (32-34)	-21	34	-19
T (34-36)	2	52	104
T (36-38)	15	41	92
T (38-40)	54	39	66
T (40-42)	44	62	113
T (42-44)	11	56	95
T (44-46)	-1	19	62

Result: 2 Degree Celsius binning for summer months of May & June shows a Similar increase in the number of hours falling in higher temperature bins. Temperature hours falling in 32 °C to 46 °C binning

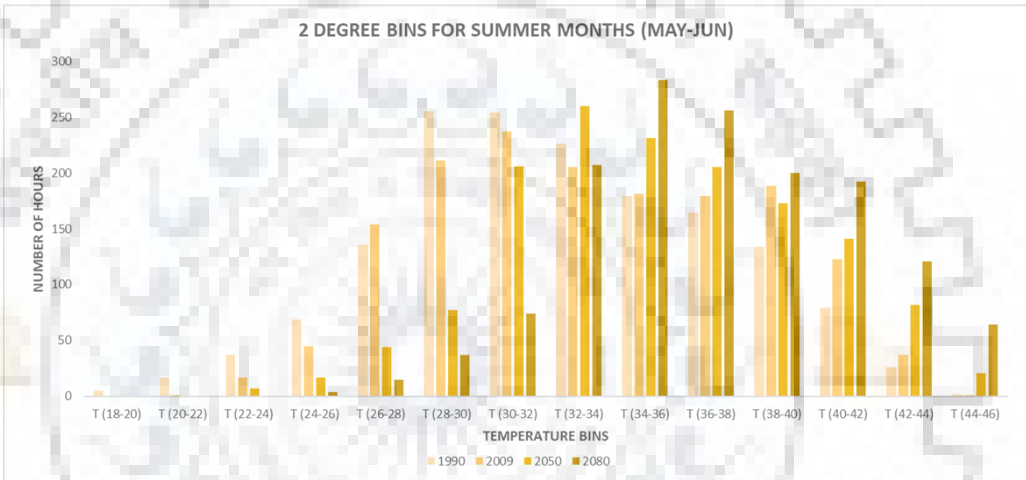


Figure 13 2 Degree Celsius Bins for Summer Months

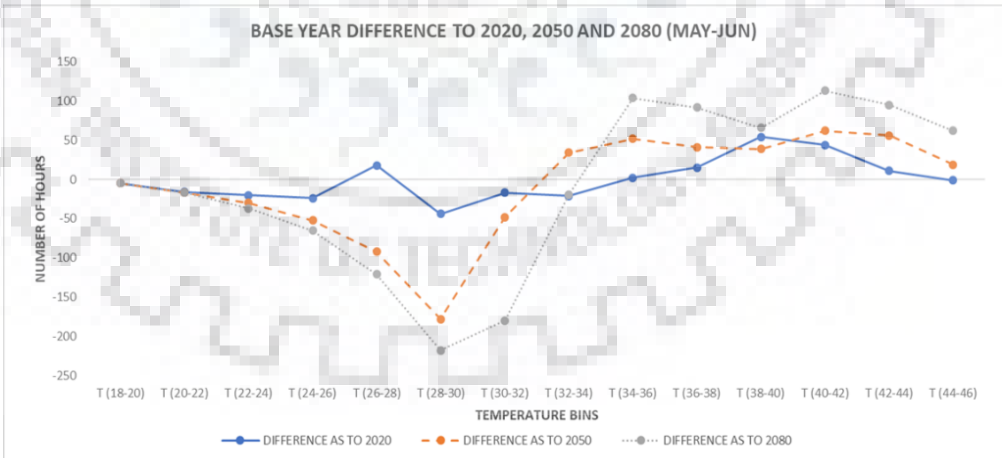


Figure 14 Difference in Frequency to 2020,2050,2080

has shown a strong increase, which states there is going to an increase in Higher temperature hours in future.

2 °C TEMPERATURE BINNING WINTER (Hours)

2 DEGREE BINS FOR WINTER MONTHS (DEC-JAN)				
	1990	2020	2050	2080
T (4-6)	9	11	0	0
T (6-8)	71	96	0	0
T (8-10)	231	182	26	0
T (10-12)	295	220	117	0
T (12-14)	250	248	279	137
T (14-16)	152	190	285	286
T (16-18)	127	157	186	296
T (18-20)	136	195	126	179
T (20-22)	171	171	118	125
T (22-24)	102	103	163	134
T (24-26)	22	29	133	174
T (26-28)	0	4	34	106
T (28-30)	0	0	2	19

	DIFFERENCE AS TO 2020	DIFFERENCE AS TO 2050	DIFFERENCE AS TO 2080
T (4-6)	2	-9	-9
T (6-8)	25	-71	-71
T (8-10)	-49	-205	-231
T (10-12)	-75	-178	-295
T (12-14)	-2	29	-113
T (14-16)	38	133	134
T (16-18)	30	59	169
T (18-20)	59	-10	43
T (20-22)	0	-53	-46
T (22-24)	1	61	32
T (24-26)	7	111	152
T (26-28)	4	34	106
T (28-30)	0	2	19

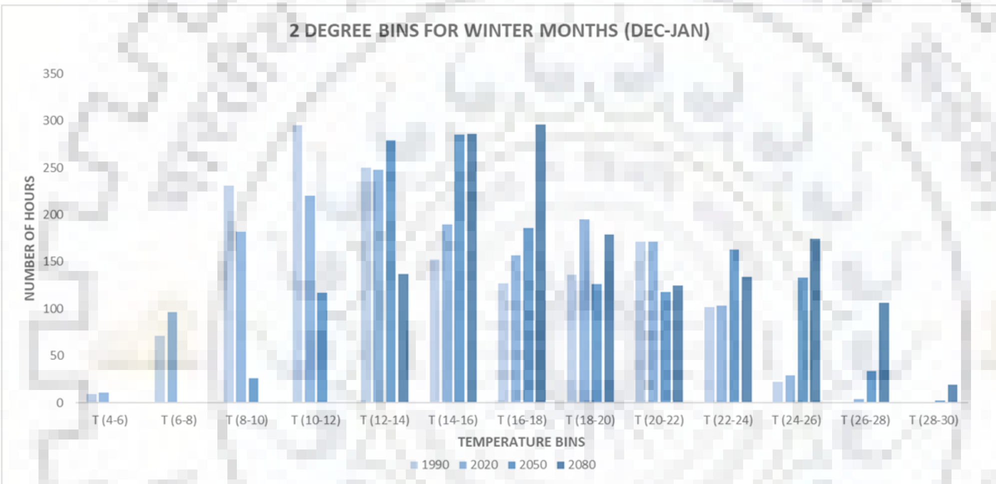


Figure 15 2 Degree Celsius Binning for winter months

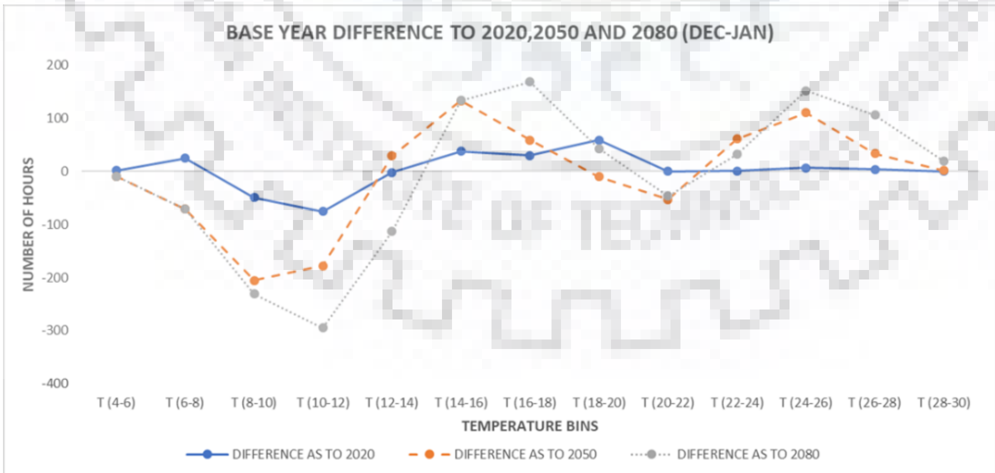


Figure 16 Difference in Frequency to 2020, 2050, 2080

Result: 2 Degree Celsius binning for winter months of May & June shows a Similar increase in the number of hours falling in higher temperature bins. Temperature hours falling in 14°C-18°C t& 22°C-30°C binning has shown a strong increase, which states there is going to an increase in Higher temperature hours in future.

DAILY TEMPERATURE DIFFERENCE BINNING (Days)

For T(max) BIN CATEGORY	TEMPERATURE BINS (1 DEGREE) '2020-1990	TEMPERATURE BINS (1 DEGREE) '2050-1990	TEMPERATURE BINS (1 DEGREE) '2080-1990
(-1)-0	61.0	22.0	13.0
0-1	136.0	48.0	21.0
1-2	166.0	107.0	39.0
2-3		176.0	85.0
3-4		9.0	41.0
4-5			123.0
5-6			38.0
6-7			
7-8			

For T(min) BIN CATEGORY	TEMPERATURE BINS (1 DEGREE) '2020-1990	TEMPERATURE BINS (1 DEGREE) '2050-1990	TEMPERATURE BINS (1 DEGREE) '2080-1990
(-1)-0			
0-1	36.0		
1-2	306.0	28.0	
2-3	21.0	184.0	
3-4		149.0	40.0
4-5			160.0
5-6			132.0
6-7			23.0
7-8			

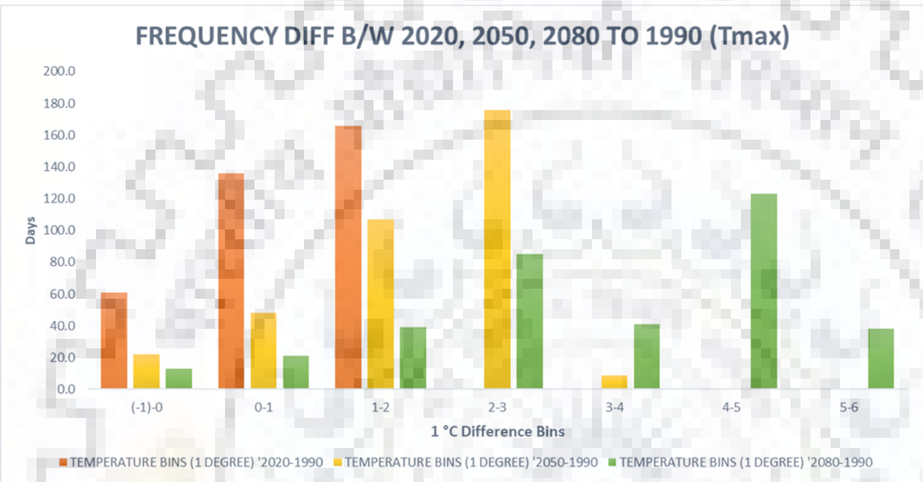


Figure 18 T(max) Frequency Difference b/w 2020,2050,2080

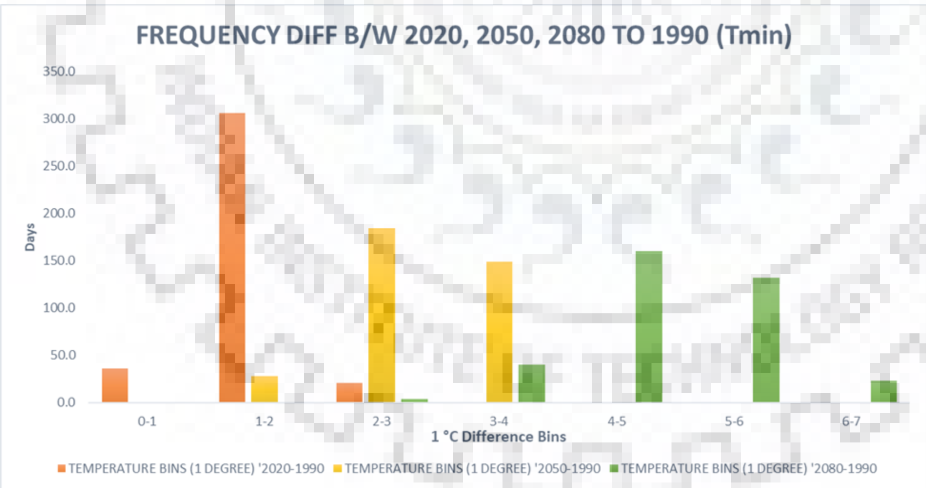


Figure 17 T(min) Frequency Difference b/w 2020,2050,2080

Result-

Number of hours in temperature difference categories has shown a larger spread into a higher number of temperature difference categories. Data for 2080 shows number of hours falling to a higher difference category. This explains the hourly temperature difference is going to be around 4-6°C for 2080, 2-4°C for 2050 & 1-2°C for 2020.

10% RELATIVE HUMIDITY BINNING (Hours)

10% RH BINS	1990	2009	2050	2080
RH (10-0)	0	0	0	1
RH (20-10)	83	80	79	144
RH (30-20)	536	421	434	389
RH (40-30)	972	841	844	765
RH (50-40)	1214	1016	1035	1030
RH (60-50)	1498	1230	1249	1152
RH (70-60)	1441	1274	1300	1271
RH (80-70)	1587	1382	1428	1324
RH (90-80)	1504	1503	1505	1514
RH (100-90)	784	1013	886	1170

	DIFFRENCE AS TO 2020	DIFFRENCE AS TO 2050	DIFFRENCE AS TO 2080
T (10-0)	0	0	1
T (20-10)	-3	-4	61
T (30-20)	-115	-102	-147
T (40-30)	-131	-128	-207
T (50-40)	-198	-179	-184
T (60-50)	-268	-249	-346
T (70-60)	-167	-141	-170
T (80-70)	-205	-159	-263
T (90-80)	-1	1	10
T (100-90)	229	102	386

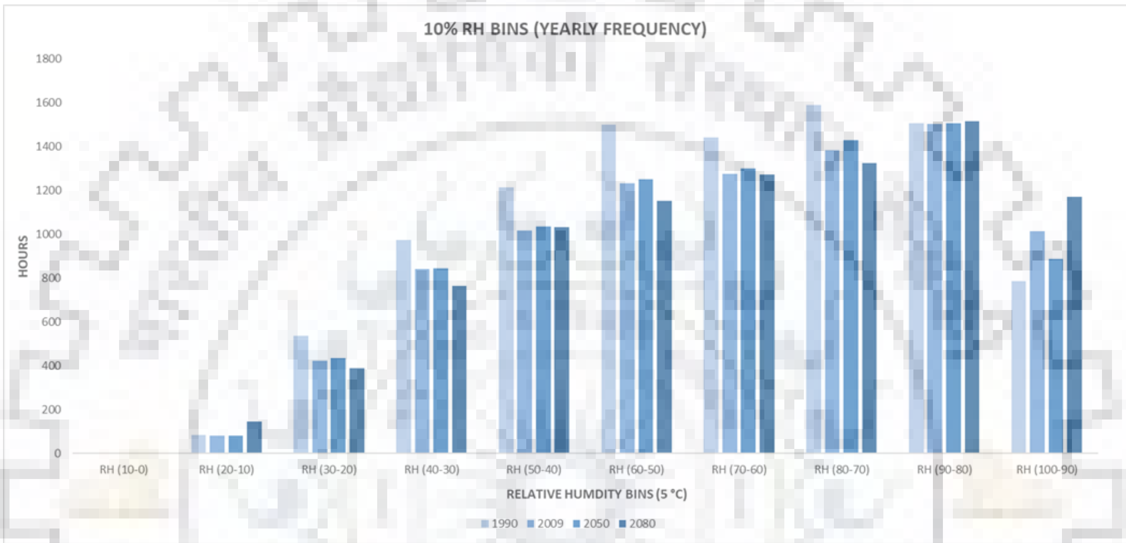


Figure 19 10% RH Bins

RH hours shows a slight reduce in the numbers consecutively from 1990 to 2080, for the categories from 20% to 80%. But these numbers increased in extreme category of 10%-20% & 90%-100%.

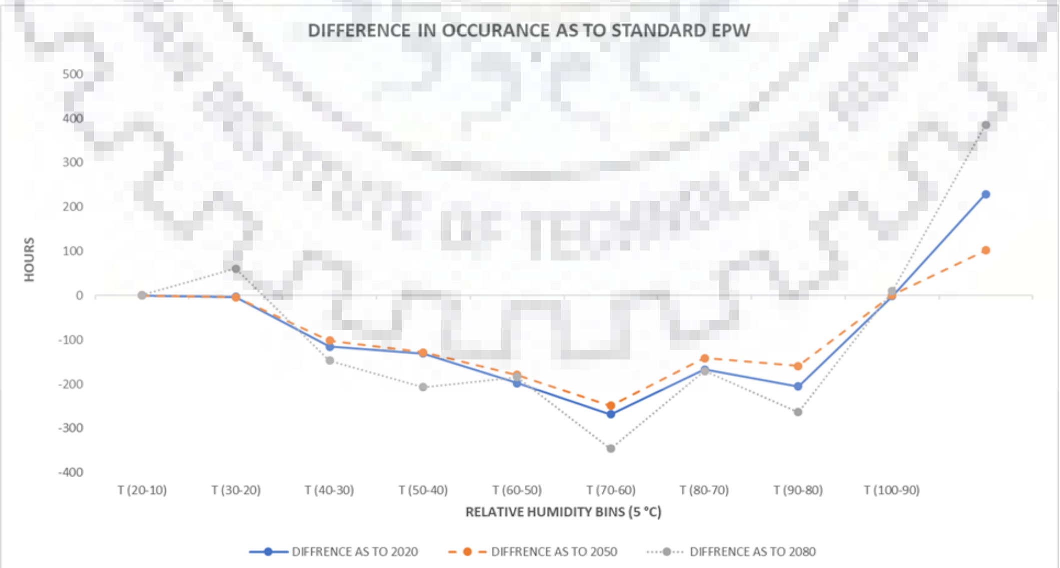


Figure 20 Difference in Frequency as to standard EPW

Graph above explains the aforementioned scenario how the hours been increasing in the extreme low and high category of relative humidity, while reducing slightly in all other categories.

100 W/m^2 GHI BINNING (Hours): Direct Normal Radiation GHI BINNING (Hours)

Direct Normal Radiation				
100 W/m2 BINS				
	1990	2020	2050	2080
GH (100-30)	475	480	519	556
GH (200-100)	622	600	623	648
GH (300-200)	572	529	529	527
GH (400-300)	300	423	421	392
GH (500-400)	310	362	356	332
GH (600-500)	329	317	296	282
GH (700-600)	312	277	258	254
GH (800-700)	266	226	230	235
GH (900-800)	210	201	180	178
GH (1000-900)	164	111	101	94
GH (1000 & Above)	238	50	38	32

	DIFFRENCE AS TO 2020	DIFFRENCE AS TO 2050	DIFFRENCE AS TO 2080
GH (100-30)	5	44	81
GH (200-100)	-22	1	26
GH (300-200)	-43	-43	-45
GH (400-300)	123	121	92
GH (500-400)	52	46	22
GH (600-500)	-12	-33	-47
GH (700-600)	-35	-54	-58
GH (800-700)	-40	-36	-31
GH (900-800)	-9	-30	-32
GH (1000-900)	-53	-63	-70
GH (1000 & Above)	-188	-200	-206

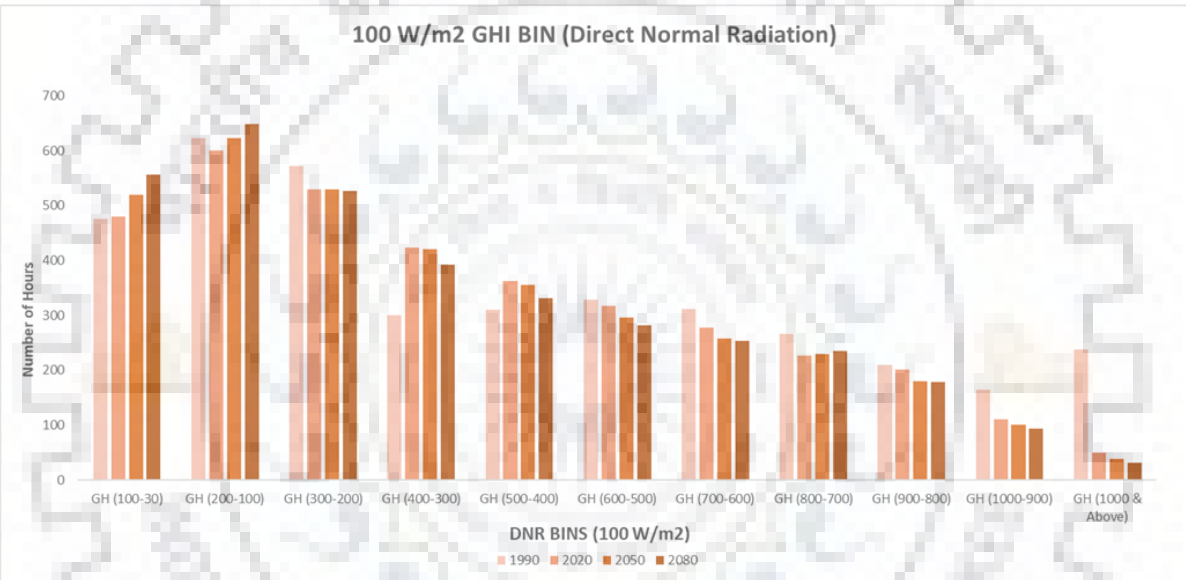


Figure 22 100W/m2 GHI BIN (DNR)

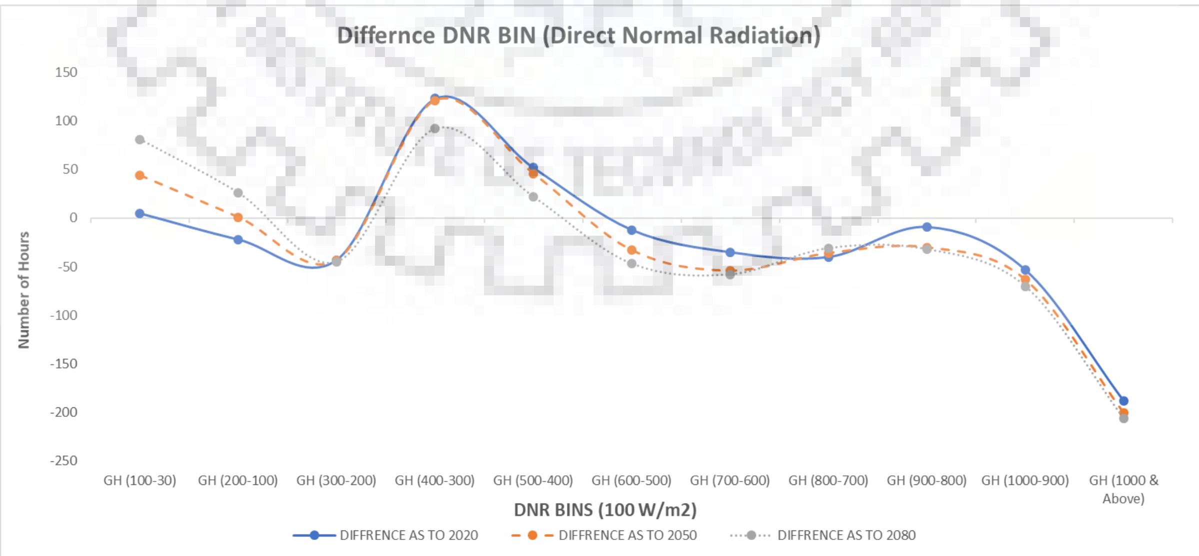


Figure 21 Difference in DNR Bin

100 W/m² GHI BINNING (Hours): Diffuse Horizontal Radiation GHI BINNING (Hours)

Diffuse Horizontal Radiation				
100 W/m2 BINS				
	1990	2020	2050	2080
GH (100-30)	1050	581	571	556
GH (200-100)	1265	1285	1277	1269
GH (300-200)	782	1035	1038	1035
GH (400-300)	425	641	630	628
GH (500-400)	289	303	327	348
GH (600-500)	11	4	5	9

	DIFFRENCE AS TO 2020	DIFFRENCE AS TO 2050	DIFFRENCE AS TO 2080
GH (100-30)	20	12	4
GH (200-100)	253	256	253
GH (300-200)	216	205	203
GH (400-300)	14	38	59
GH (500-400)	-7	-6	-2

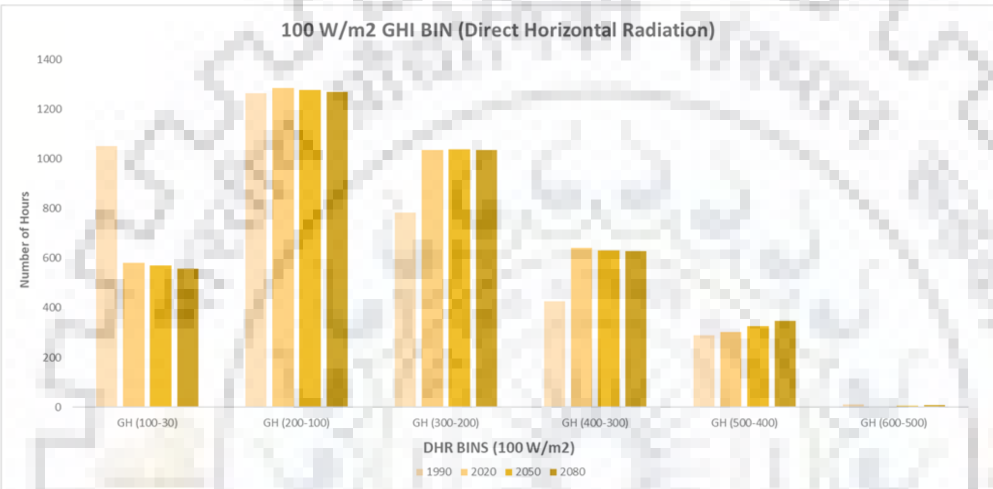


Figure 23 100 W/m2 GHI BIN (DHR)

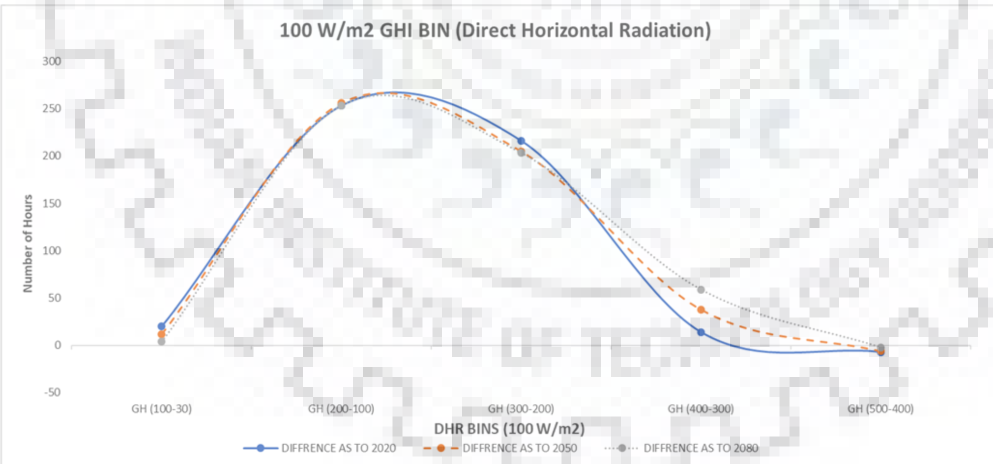


Figure 24 Difference in Frequency (DHR)

Result- Graph above explains that the Number of hours which falls in the category of 600 W/m2 GHI will reduce in numbers for the coming years. For 2020, the number will reduce, then increase for 2050 and then a steep reduction in 2080 again.

(ΔT) DAILY DIFFERENCE IN TEMPERATURE

ΔT	1990	2020	2050	2080
	14.5	14.4	14.1	13.2
	15.7	15.7	15.6	14.7
	15.3	15.3	15.2	14.3
	14.2	14.2	14.1	13.3
	12.4	12.4	12.3	11.6
	14.5	14.5	14.4	13.5
	14.3	14.3	14.2	13.4
	14.8	14.8	14.7	13.8
	16.4	16.4	16.3	15.3
	14.0	14.0	13.9	13.1
	14.2	14.2	14.1	13.3
	14.6	14.6	14.5	13.6
	15.3	15.3	15.2	14.3
	12.7	12.7	12.6	11.9
	15.8	15.8	15.7	14.8
DEC	15.2	15.2	15.1	14.2
	14.5	14.5	14.4	13.5
	14.9	14.9	14.8	13.9
	12.2	12.2	12.1	11.4
	11.0	11.0	10.9	10.3
	12.5	12.5	12.4	11.7
	13.1	13.1	13.0	12.2
	11.9	11.9	11.8	11.1
	11.3	11.3	11.2	10.6
	7.3	7.3	7.3	6.8
	7.2	7.2	7.2	6.7
	12.1	12.1	12.0	11.3
	14.1	14.1	14.0	13.2
	13.9	13.9	13.8	13.0
	15.7	15.7	15.6	14.7
	19.3	20.8	22.1	23.4

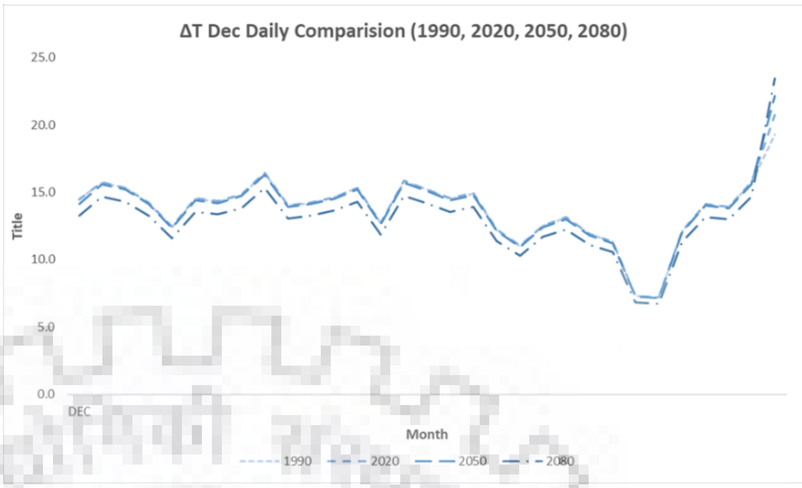


Figure 25 Delta T Daily (December)

ΔT is the difference between Maximum and the minimum temperature of the day. It has been observed that daily ΔT for **winter months** has been shrinking by a magnitude of **1.28 °C,** for the winter month of December.

ΔT	1990	2020	2050	2080
	13.8	12.9	12.4	11.4
	15.6	14.7	13.6	12.4
	13.8	13.0	12.1	11.0
	15.6	14.7	13.6	12.4
	13.8	13.0	12.1	11.0
	15.6	14.7	13.6	12.4
	13.3	12.5	11.6	10.6
	13.3	12.5	11.6	10.6
	15.4	14.5	13.5	12.2
	17.2	16.2	15.0	13.7
	13.7	12.9	12.0	10.9
	9.5	8.9	8.3	7.5
	10.2	9.6	8.9	8.1
	6.4	6.0	5.6	5.1
JUN	11.5	10.8	10.0	9.1
	10.9	10.3	9.5	8.7
	7.4	7.0	6.5	5.9
	10.2	9.6	8.9	8.1
	9.0	8.5	7.9	7.1
	7.0	6.6	6.1	5.6
	10.1	9.5	8.8	8.0
	8.2	7.7	7.2	6.5
	11.0	10.4	9.6	8.7
	4.0	3.8	3.5	3.2
	7.0	6.6	6.1	5.6
	6.0	5.7	5.2	4.8
	5.4	5.1	4.7	4.3
	7.8	7.3	6.8	6.2
	7.4	7.0	6.5	5.9
	8.4	7.7	7.0	6.1

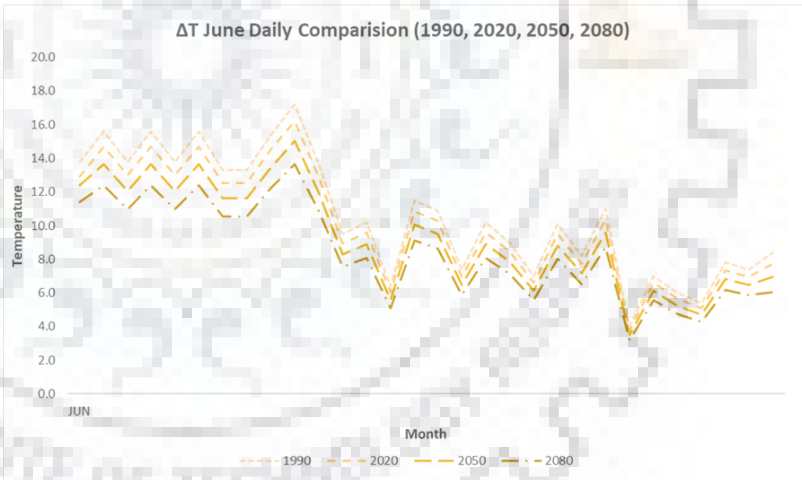


Figure 26 Delta T Daily (June)

Daily ΔT for the **summer month** of June for every consecutive year has been shrinking by a magnitude of **2.4 °C.**

CLIMATE CLUSTER ANALYSIS

Climate clusters have been prepared by considering 4 factors affecting change in climate severity, i.e., **T_max (Daily), T_min (Daily), Rh_avg (Daily) & GHI_avg (Daily).** Considering data values for all these parameters, all 1460 data points have been grouped into 9 clusters. each cluster has a total of 160 data points. following a similar pattern, 9 clusters for **1460** data points are prepared. every cluster has unique mean daily parameter values, different from each cluster. these clusters are later identified into three seasons (Summer, Monsoon & Rainy) based on parameter weight. clusters having highest **T_max (Daily) & T_min (Daily)** are classified into summer & winter months. cluster with clusters with **high RH_avg (Daily) & low GHI_avg (Daily)** classified into monsoon clusters. every season is assigned 3 clusters, divided into severe, moderate and low. clusters in summer, monsoon, and winter seasons have been categorized as pre-summer, summer, post-summer, pre-monsoon, monsoon, post-monsoon, pre-winter, winter & post-winter.

1990									
CLUSTER	**7**	**8**	**1**	**6**	**2**	**3**	**4**	**5**	**9**
SIZE (Days)	**76**	**70**	**68**	**45**	**37**	**25**	**24**	**19**	**1**
Tmax	22.61	29.26	34.83	31.85	38.56	40.45	33.32	18.23	31.6
Tmin	9.19	14.75	26.02	24.63	27.19	25.93	20.05	10.97	18
GHIavg	373.15	443.58	455.33	368.49	520.86	610	560.31	260.82	280
Rhavg	69.29	58.23	65.64	77.51	52.53	38.37	39.97	84.12	51.26

2050									
CLUSTER	**3**	**5**	**9**	**2**	**8**	**4**	**7**	**1**	**6**
SIZE (Days)	**84**	**63**	**56**	**41**	**41**	**32**	**31**	**16**	**1**
Tmax	35.33	30.91	25.24	40.22	23	36.87	32.65	43.54	33.7
Tmin	28	17.27	11.74	29.67	13.95	23.33	27.62	31.2	20.9
GHIavg	411.86	435.99	382.92	503.62	296.37	553.39	333.19	608.31	310
Rhavg	71.31	61.46	65.05	53.31	80.06	39.04	85.37	38.42	55.65

Figure 27 Climate Data Grouped into 9 clusters.

Seasonal clusters prepared for comparing how base year's (1990 ISHRAE) climate severity nodes are getting affected when compared with seasonal clusters of extrapolated climate data of 2050.

Through this analysis, we tried to find out

- By what magnitude the number of days will shift when seasonal clusters of 1990 compared with 2050.

- How Energy consumption is changing per cluster?

- How days shifting among cluster is impacting energy consumption among the clusters?

			SEVERE			MODERATE		LOW	
			1990	2050		1990	2050	1990	2050
SUMMER CLUSTER			3(25)	1(16)		2(37)	2(41)	4(24)	4(32)
	Tmax		40.45	43.54		38.56	40.22	33.32	36.87
	Tmin		25.93	31.2		27.19	29.67	20.05	23.33
	GHIavg		610	608.31		520.86	503.62	560.31	553.39
	Rhavg		38.37	38.42		52.53	53.31	39.97	39.04
			1990	2050		1990	2050	1990	2050
WINTER CLUSTER			7(76)	9(56)		5(19)	8(41)	8(70)	5(63)
	Tmax		22.61	25.25		18.23	23	29.26	30.91
	Tmin		9.19	11.67		10.97	13.95	14.75	17.27
	GHIavg		373.15	383.88		260.82	296.37	443.58	435.99
	Rhavg		69.29	64.99		84.12	80.06	58.23	61.46
			1990	2050		1990	2050	1990	2050
RAIN CLUSTER			6(45)	7(31)		9(1)	6(1)	1(68)	3(84)
	Tmax		31.85	32.65		31.6	33.7	34.83	35.33
	Tmin		24.63	27.62		18	20.9	26.02	28
	GHIavg		368.49	333.19		280	310	455.33	411.86
	Rhavg		77.51	85.37		51.26	55.65	65.64	71.31

Figure 28 Clusters Identified into Seasonal Clusters

Change in the number of days has been shifting from the 1990 seasonal cluster to the 2050 seasonal cluster.

following daily data clustering for the base year 1990 & 2050, it has been observed that there is a significant shift in the number of days among seasonal clusters. when clustered days among different seasons for the base year 1990 was compared with extrapolated weather data of 2050, it was found out that a slight decrease in the number of days from winter season clusters of 2050. This decrease in number from winter clusters are unequally compensated into summer & monsoon clusters. a total of 5 number of days from winter clusters of 2050 has shifted. unequal compensation of 3 days to summer clusters & 2 days to winter clusters.

further breaking down these seasonal clusters, each seasonal cluster is further categorized into severe, moderate & low impact subcategories. a similar pattern of change is noticed among subcategories of every season. when these impact categories of the 2050 year were compared with 1990, it is noticed that the number of days from a severe impact category of each cluster has reduced. this reduction of days from severe impact category is compensated into moderate & low impact categories. severe impact category, or also termed as severe summer cluster, (25 days), when compared with severe summer cluster (16 days) of 2050, a reduction of 9 days. similarly, severe impact clusters of winter & monsoon season show similar behavior, with a reduction in several days, 14 days for monsoon severe category & 20 days for severe winter category. another important behavior noticed is that where the number of days is reducing from severe impact category of each season, these difference in numbers are shifted into moderate & low impact categories of these seasons.

1990			2050			
Seasons	Clusters	Days	Seasons	Clusters	Days	Shifting Days
Summer Season	4 (Low)	24	Summer Season	4 (Low)	32	3
	3 (Severe)	25		1 (Severe)	16	
	2 (Moderate)	37		2 (Moderate)	41	
Monsoon Season	1 (Moderate)	68	Monsoon Season	3 (Moderate)	84	2
	6 (Severe)	45		7 (Severe)	31	
	9 (Low)	1		6 (Low)	1	
Winter Season	5 (Moderate)	19	Winter Season	8 (Moderate)	41	-5
	7 (Severe)	76		9 (Severe)	56	
	8 (Low)	70		5 (Low)	63	

Figure 29 Cluster days Comparison *Source: Author*

from the analysis above, it has become clear that

1) The number of days is shifting from winter clusters, and are compensated into summer & monsoon seasons.

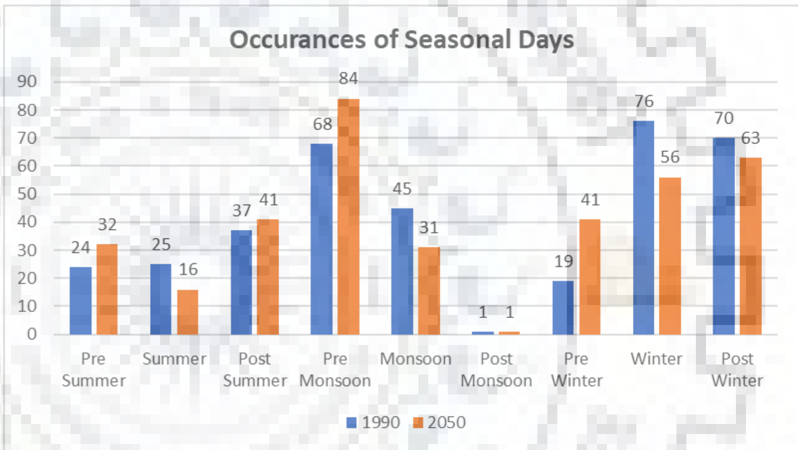


Figure 30 Clustered Days Comparison *Source: Author*

2) It is obvious that climate parameters extremes are rising in each cluster, total number of days experiencing these extremities for 2050, when compared with the data of 1990, shows that the days from severe impact category has reduced from every seasonal cluster, which implies that climate extremes will keep on rising, but with less number of severe impact days & more number of moderate to lower impact days.

Energy Consumption per Cluster

to understand how the energy consumption of an office building is changing when seasonal clusters of 2050 were compared to 1990, an ECBC prescribed base case modeled in the design-builder was simulated for the base year of 1990 & for 2050. Daily energy consumption values of the respective year were associated with seasonal clusters of the same year. The energy impact for each cluster was calculated by summing up the energy consumption values associated with perspective clusters, to find out the impact of the respective cluster on total energy consumption of the cluster.

Analysis of the seasonal impact on energy consumption was done in two ways.

1) Comparing total energy consumption of 1990 & 2050

2) Comparing average energy consumption for 1990 & 2050.

Comparison through Total Energy Consumption (TEC)

Simultaneous comparison between change in the number of days & change in energy consumption shows a similar pattern. energy consumption changes as the number of days shift among the cluster. energy consumption increases when the days' increase, it reduces as the number of days reduces.

Total Energy Consumption (TEC)			
Seasons	Clusters	1990 (kWh)	2050 (kWh)
Summer Season	Low (S)	14866	24772
	Severe (S)	25344	20222
	Moderate (S)	44035	54982
Monsoon Season	Low (M)	77342	109120
	Severe (M)	47557	40813
	Moderate (M)	580	726
Winter Season	Low (W)	3080	12428
	Severe (W)	17676	15405
	Moderate (W)	30932	34607

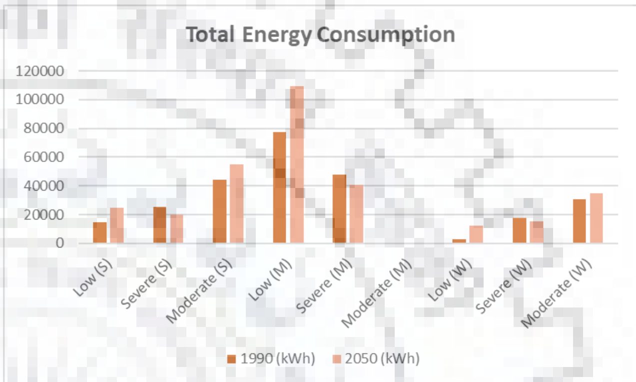


Figure 31 Total Energy Consumption Comparison (kWh) *Source: Author*

Comparison through Annual Energy consumption (AEC)

Average energy consumption explains the energy consumed per day in a seasonal cluster. The total energy consumption of each cluster of the respective year was distributed among the day's belonging to different clusters to find out the average energy consumed in a cluster per day. it is observed that clusters with higher energy consumption average are identified as summer, post-summer, pre-monsoon & monsoon, and clusters with lower average energy consumption for pre-summer, post-summer, post-monsoon, pre-winter, winter, post-winter.

Average Energy Consumption (AEC)			
Seasons	Clusters	1990 (kWh)	2050 (kWh)
Summer Season	Low (S)	619	774
	Severe (S)	1014	1264
	Moderate (S)	1190	1341
Monsoon Season	Low (M)	1137	1299
	Severe (M)	1057	1317
	Moderate (M)	580	726
Winter Season	Low (W)	162	303
	Severe (W)	233	275
	Moderate (W)	442	549

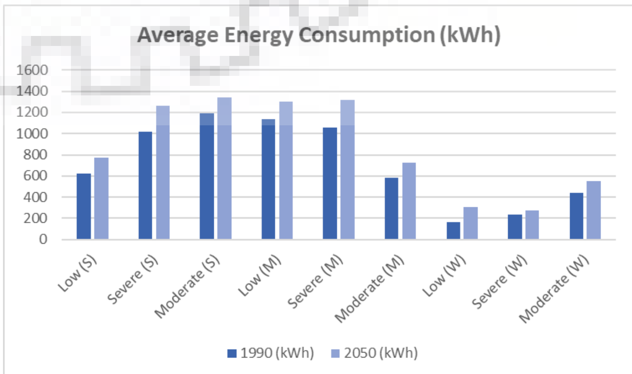


Figure 32 Average Energy Consumption Comparison (kWh)

Energy consumption affected by shifting days among seasonal clusters

On comparing the relationship of change in shifting days among seasonal clusters with total energy consumed by such cluster, it is found out that total energy consumed has a positive relationship with the change in numbers. As the number of days reduces in a cluster, the total energy consumption also reduced with it, & vice versa.

Days						Total Energy Consumption (TEC)		
Seasons	Clusters	Days (1990)	Days (2050)	Diffrence		TEC 1990 (kWh)	TEC 2050 (kWh)	Rise (kWh)
Summer Season	Low (S)	24	32	8		14866	24772	9906
	Severe (S)	25	16	-9		25344	20222	-5123
	Moderate (S)	37	41	4		44035	54982	10947
Monsoon Season	Low (M)	68	84	16		77342	109120	31779
	Severe (M)	45	31	-14		47557	40813	-6744
	Moderate (M)	1	1	0		580	726	146
Winter Season	Low (W)	19	41	22		3080	12428	9348
	Severe (W)	76	56	-20		17676	15405	-2271
	Moderate (W)	70	63	-7		30932	34607	3675

Figure 33 TEC Relationship with Shift in days

On the contrary, when average energy consumption was compared with the shifting days among the clusters, it shows close to no revelation with an increase or decrease in number. reduction & increase in the number of days doesn't have any impact on the change in average energy consumption. this comparison shows that actual energy consumption per cluster per day will keep on increasing year by year. However, change in the number of days among different clusters may impact the Actual energy consumption by increasing & decrease the magnitude, but can never bring it down below zero.

Days						Average Energy Consumption (AEC)		
Seasons	Clusters	1990	2050	Diffrence		AEC 1990 (kWh)	AEC 2050 (kWh)	Rise (kWh
Summer Season	Low (S)	24	32	8		619	774	155
	Severe (S)	25	16	-9		1014	1264	250
	Moderate (S)	37	41	4		1190	1341	151
Monsoon Season	Low (M)	68	84	16		1137	1299	162
	Severe (M)	45	31	-14		1057	1317	260
	Moderate (M)	1	1	0		580	726	146
Winter Season	Low (W)	19	41	22		162	303	141
	Severe (W)	76	56	-20		233	275	43
	Moderate (W	70	63	-7		442	549	107

Figure 34 AEC Relationship with shift in days

CASE STUDY - DEVELOPMENT ALTERNATIVES WORLD HEADQUARTERS

Architecture	Ashok B. Lall Architects, New Delhi
Site Location:	New Delhi, Qutab Institutional Area
Climate:	Tropical, composite
Construction Period:	November 2005 to November 2008 (est.)
Building type:	Institutional headquarters
Building volume:	Basement: 5,479m3; superstructure: 10,160m3
Maximum number of occupants:	Workplaces: 245; visitors: 210
Mechanical systems:	Hybrid cooling, evaporative and refrigerant modes

Figure 35 DA Headquarters Building, New Delhi

Development Alternatives World Headquarters, Qutub Institutional Area, New Delhi, has been construction of November 2005 to November 2008. It sits in a composite climate of tropical region, in an urban setting with forest bordering.

DA Headquarters falls into the category of institutional Headquarters/Office Building with 5 floors and 1 basement an occupancy of 250+ and a parking space of 18 cars and 30 motor cycles in basement garage 9 cars and 12 motor cycles on grade. Construction has been done with reinforced concrete frame, Masonry walls (cement stabilized compressed earth blocks, & cement stabilized fly ash lime gypsum blocks.

Figure 36Labrynth Floor Plan or original Building

The establishment is the nerve center of world Development Alternatives and is named on the basis of its primary objective which is to deliver the sustainable building alternatives for urban development.

DA stood in need of more capacious region by the year 2006 to occupy 150 to 200 occupants. Therefore, in order to form required space, DA was ordered either to undergo for its demolishment or to opt for an upward or lateral building expansion or to look for an additional office area to any other location.

Inclusive Design process

To obtain required objectives, suitable design briefs, related consents, the architects made a discussion with all the representatives and staff of DA. The future occupants were so much concern about the impact of building on environment and components of nature and other aspects of mankind. They were thinking of constructing the building in a way that it can deliver the experience of nature. They were to be embracing the elements of flora and fauna. Unfinished and more environmental centric surfaces were chosen. The building plan should be convenient for both the urban and rural visitors.

New building in the same spirit

The architect along with the team reached to a conclusion of building new establishment prevailing the essence and memory of authentic property. All its components and designs, the old domed lobby, vaulted ceilings and courtyard in center reflects the essence of old building. The presence of a tree at the main entrance has clearly reflected the essence of old building in the new one.

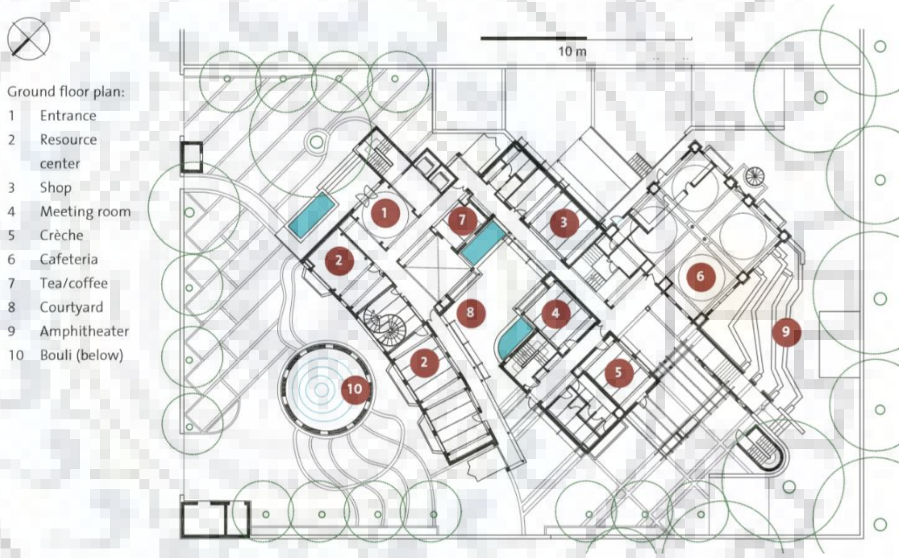


Figure 38 Ground Floor Plan

Figure 37 First Floor Plan

Space & Materials used

On the contradiction to the accepted and established industrial architecture of glass and metal, DA world headquarter demonstrated the importance of low embodied energy materials in constructing more advantageous urban buildings.

Reduced gray energy

Despite of the fact that there are no suitable requirements lay down by building codes for the conservation of gray energy, the architects have focused upon the energy consumption in construction methods. Recycled and renewable substances followed by natural materials were opted. Highly embodied energy materials were used productively where it was crucially required.

Most of the inner and outer walls are constructed by cement stabilized compressed earth or fly- ash lime gypsum block. The curtain wall is primarily constructed by strengthened thick sheet of glass which is said to be an elementary building material of modern architecture. For constructing windows of DA building, Lall opt to use small panes of five- millimeter glass similar to the structural glazing. The lesser the use of reused glass, the lesser will be the thickness of glass.

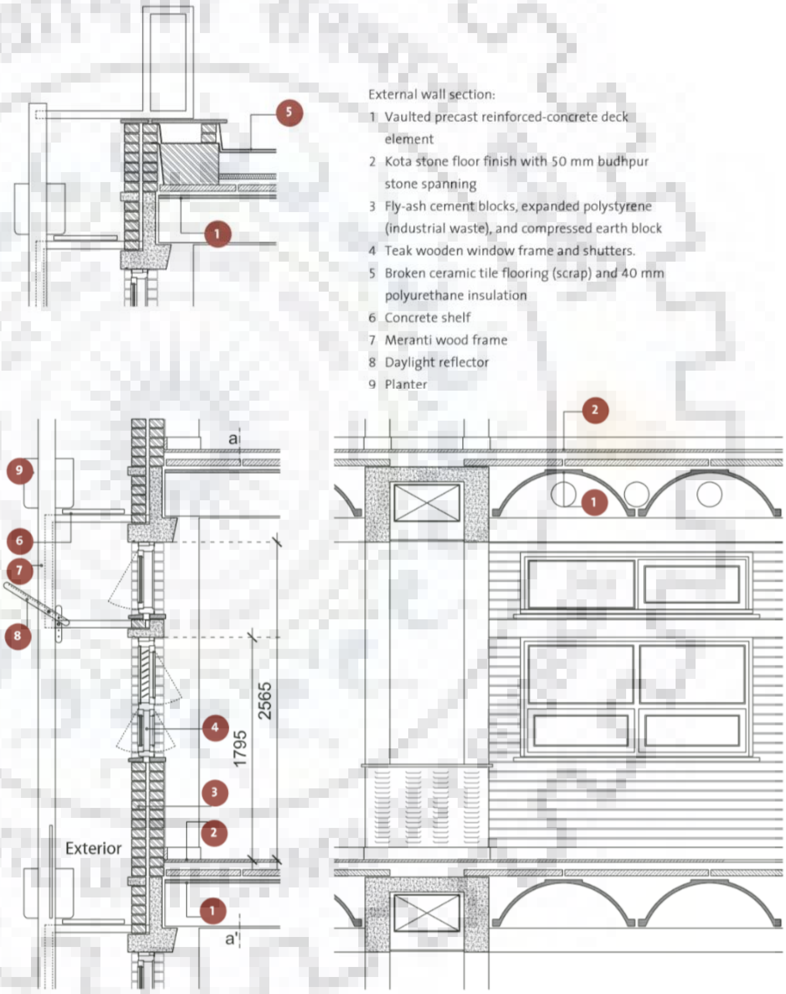


Figure 39 External Wall Section

Low energy through Passive cooling

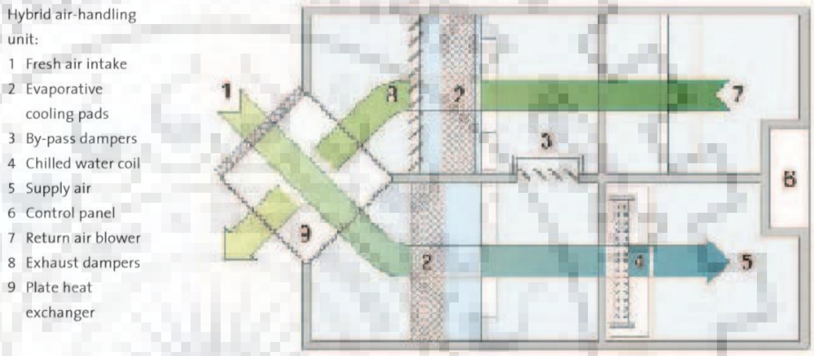
The application of Lal tends to regulate the thermal gain abstracted from the vernacular architecture. Initially the establishment is considered to be opaque, then he located light, ventilation and view openings. Glaring is used at an area of about twenty or less percentage of the envelope. Shading of windows is done during warm climatic conditions. The windows facing towards east and west direction are constructed with a small size and shades are placed to block intense sunrays.

Following types of glazing are used in building

(1) fixed insulating glass panels with a 16 mm air space,
(2) operable windows with insulating glass with a 16 mm airspace, and
(3) windows consisting of a fixed single-pane outer panel and an operable inner sash, with an adjustable venetian blind in between

Heating, Ventilation & Air Conditioning (HVAC)

Direct and indirect evaporation cooling systems would be utilized to control dryness in an extreme hot weather. Similarly, in an extreme humid climate, refrigerant cooling would be used. There is an



unavailability of such systems in Indian markets which gave Lal an option to develop its first model by

Figure 41 Prototype Air- Handling unit

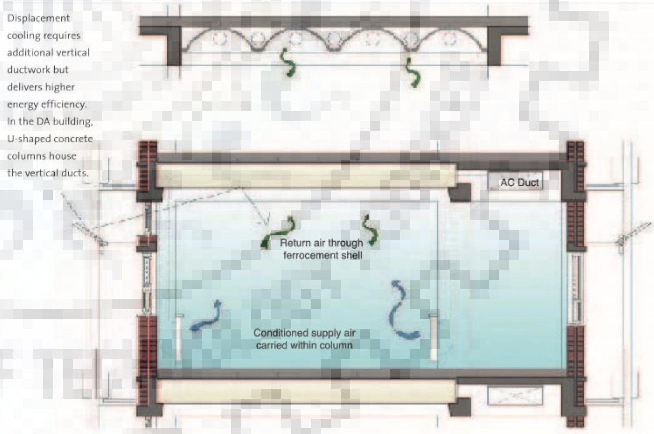


Figure 41 Displacement Cooling Techniques installed

working with conditioning specialists. The consultants arranged the whole cooling system as per Lal's office and converted the whole system into a single packed unit which could be better suited with the architecture.

Design Process Research & Development

It is the most feasible alternative for accomplishing the project and to assess its loopholes. Required alterations can be done on the

Figure 42 Hybrid Air-Handling Unit

basis of certain technical, suitable procedures which deliver estimated results to take the rest of the process in an appropriate direction.

All the lights, casements, Venetian blinds, fans are controlled by the employees of DA as per the climatic conditions. Therefore, it is necessary for the employees to identify the functioning and importance of windows and shades in controlling building's environmental temperature

Water conservation

All the estimations related to water conservation in the establishment of DA had to be done at low price. Provision of drinking water is conducted by municipality network which is not unreliable. Therefore, an onsite well was considered as an alternative.

All cost-effective methods such as sand, biomimetic multilayer water purification procedures are utilized for rural areas by DA for rural areas.

Along with it, the waste water treatment is completed with the help of onsite biological digesters that are being timely charged by particular pathogens. The biologically treated water is reused after filtration in flush away toilets and watering plants. The plants are watered by the means of drip watering system which irrigate root of the plants through small volume of water.

Economic value

The economic value has always been the most critical element of the whole project. It needs to be started earlier than the completion of funding process. The value of designs was reduced with an inclusion of simpler techniques of experimenting in the replacement of a detailed and complicated study. The price of constructing building was cut down by defining the most reasonable materials with a simpler method of construction was used. Yet they declined the construction of a cut price building.

Elevation & Sectional Details

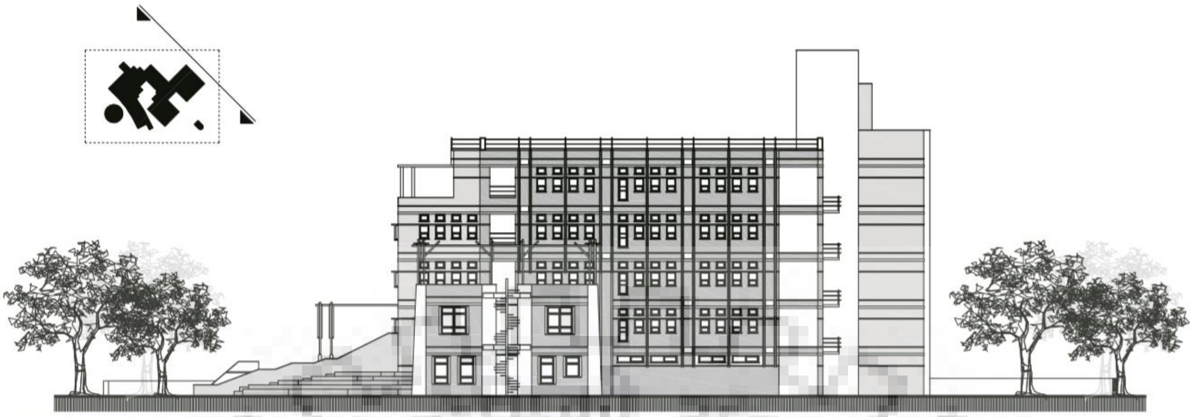


Figure 43 Elevation of DA Headquarters

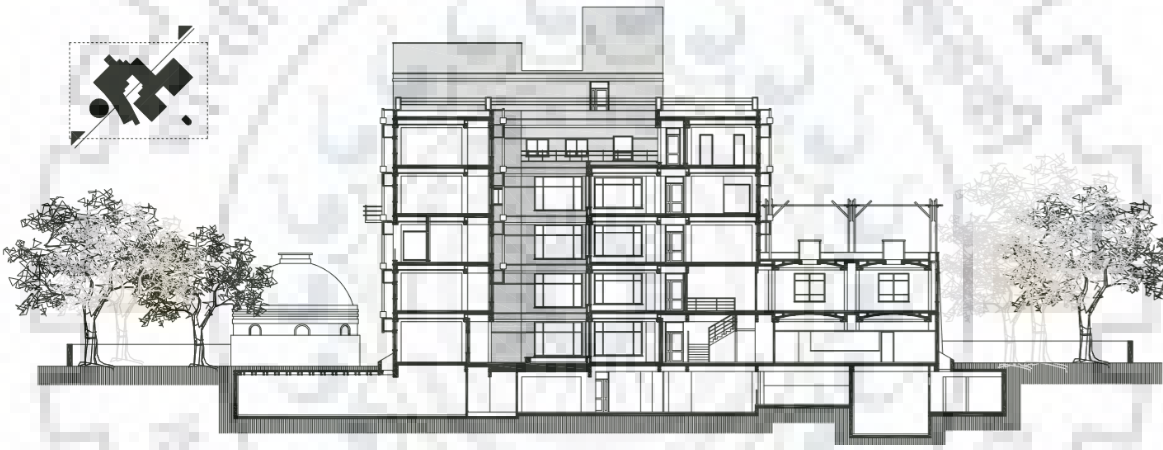


Figure 44 Section 1 of DA Headquarters

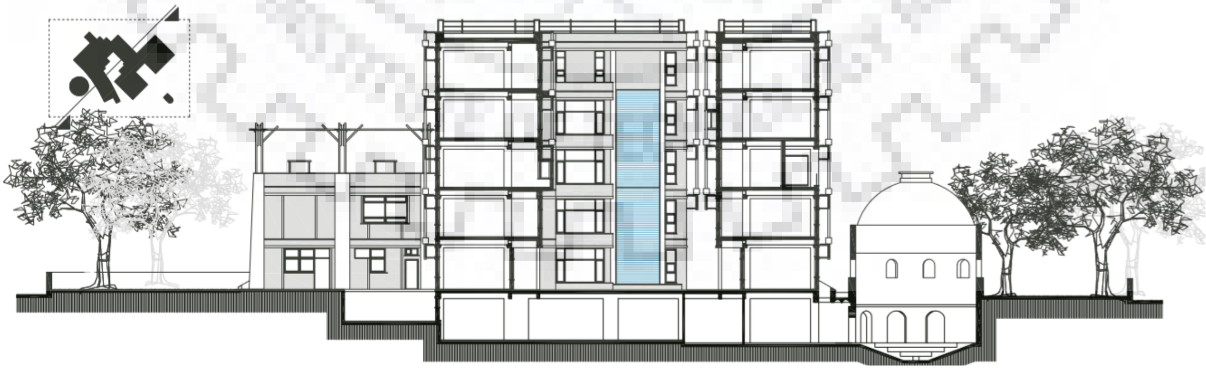


Figure 45 Section 2 of DA Headquarters

SITE STUDY OBSERVATIONS

Materials used -

Materials used are ferro cement concrete, Mud bricks, Red brick, fly ash bricks, terracotta cladding tiles, kota stone for the flooring, broken sanitary tiles for roof, Reused wood from the old project lowering the embodied energy of the structure. Certified plantation wood from Nagpur. Glass partitions made up of embedded steel wires for fire safety purposes.

Figure 46 Kota stone Floor

Figure 47 Sanitary tiles on Roof

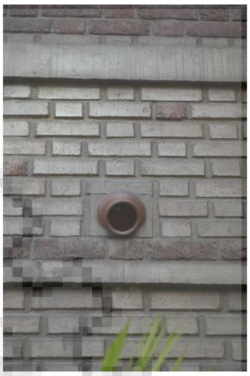


Figure 48 Fly ash & Red Mud Brick

Design Observations –

- Building is constructed of 5 levels, starting from Ground floor giving access to Basement & first floor, second floor and third floor.
- Circular stepped unit is for the purpose of Reading along the future basement library. Currently, basement is used for storage and parking purposes.
- All three upper floors have been superimposed with similar floor pattern (with difference in furniture layout on all three floors).
- Hybrid Air conditioners have been installed on roof to take care of the floor conditioning. Use of water as a refrigerant during winters, and coolant during scarcity of water during summers.

Figure 49 First floor Workspace

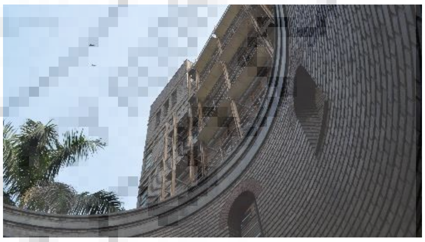


Figure 50 Reading space beside library

Figure 51 Ground floor Cafeteria

- Each floor has a floor specific HVAC control room unit which takes care of the HVAC cooling specific of each floor.

Figure 53 Conference room 3rd floor

Figure 52 Hybrid AC Split unit

Figure 54 Roof without Solar panels

- No solar panels installed on the roof of the building as stated earlier in the description.
- Light wells on the roof of the conference above the ground cafeteria to reduce day light energy consumption.
- Occupants have been asked to acclimatize according to increase thermal comfort temperature to further reduce down the energy consumption of the building.

Figure 56 Cafeteria & conference area

Figure 55 Facade installation for plants

- Each floor has a small balcony area attached to its workspace that is incorporated to make occupant feel the transition between the outside temperature with inside workspace.
- Installation on the external façade of every window is built for the purpose of catering plants and creepers. Now they are solely used for the purpose of maintenance.
- Ceiling reflectors have been installed outside the windows to reflect outside light inside the ceiling.

Figure 58 Ceiling light reflectors

Figure 57Balcony attached to each floor

- Inner courtyard has a wall which is used for water to flow down on it to the ground floor tank, creating a waterfall effect which lowers down the courtyard temperature by increasing humidity. Mostly rain water is used for this purpose.
- Sanitary tiles pieces have been used as flooring material on roof to reflect most of the heat & light.
- Masons have been given the freedom to creates aesthetic patterns on the brick cladding & the mud plaster.

Figure 59 Light wells on roof

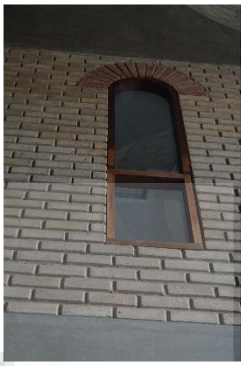


Figure 60 Reused wooden frame

U-Value Calculation for External wall (Development Alternative World Headquarters)

U-Value of Fly Ash Brick Block (**R1**)

U-Value of Extended Polystyrene (**R2**)

U-Value of Brick Blocks (**R3**)

Thermal Resistance of Outer Surface (**Ho**)

Thermal Resistance of Inner Surface (**Hi**)

R= Thermal Resistance of material

k= Thermal Conductivity of material

U= Thermal transmittance of material

k1	0.856	**W/m.K**	**t1**	0.113 **m** (where t = thickness of the wall)	
k2	0.0321	**W/m.K**	**t2**	0.0275 **m**	
k3	0.771	**W/m.K**	**t3**	0.113 **m**	
R1	0. 132009346	**m2.k/W**		**(where R = t/k)**	
R2	1. 246106	**m2.k/W**			
R3	0. 146562905	**m2.k/W**			
Ho	19.86	**W/m.K**			
Hi	9.36	**W/m.K**			
Rt	1. 681868	**m2.k/W**		(where Rt = R1+R2+R3+1/Ho+1/Hi)	
Ut	0.594577	**W/m2. K**			(where Ut = 1/Rt)

So, U-Factor of External wall is **0.5945 W/m2.K**

BUILDING MODEL & SIMULATIONS FOR DA HQ BUILDING

Various existing buildings in the region of National Capital region were considered to be taken as a live case stud. among these examples, Development Alternatives world Headquarters was finalised because if its recognition for the use of many green passive and active strategies to bring down the overall energy consumption of the building, which the building claims to be 25-30% less than any similar typical building.

About the Building

Development alternatives World HQ, designed by Architect Ashok B. Lal is famous for its energy saving climate resilient design strategies. This building has been selected as a case study for this dissertation as a representative office building in the city of new Delhi.

Constructed in 2008, has a total built-up area of 4500 sqm., is a G+5 floor construction. Materials used are fly ash cement blocks for most of the external façade, with double glazed 6mm glass window. Uses a hybrid HVAC system, mix of Evaporative cooling and refrigerant cooling.

Thermal Properties

U-factor of external wall, roof and window glazing has been taken into consideration according to the material and requirements used on the actual building.

U- Value for External wall- **0.594 W/m2.K**

U- Value for Roof- **2.930 W/m2.K**

U- Factor window-

SHGC- **0.697**

VLT- **0.78**

U- Value- **2.708 W/m2.K**

3-D Modelling of Development Alternatives World Headquarters, New Delhi.

Model for this building has been designed energy plus tool, Design Builder to Quantify the impact of energy consumption for 1990, 2020 & 2050. This building thermal properties, shading installed and wall profile has been incorporated in detail to get accurate energy consumption Data.

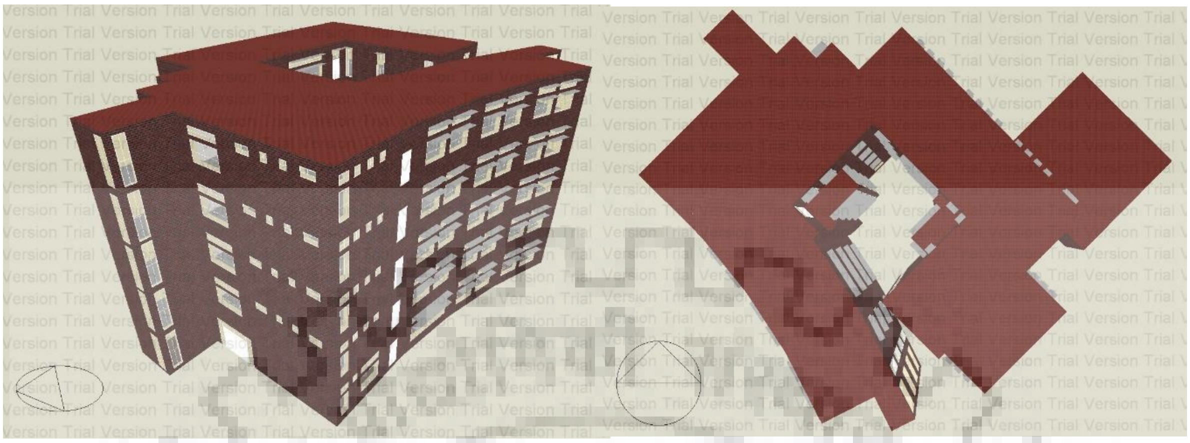


Figure 62 Design Builder model of DA world Headquarters, New Delhi

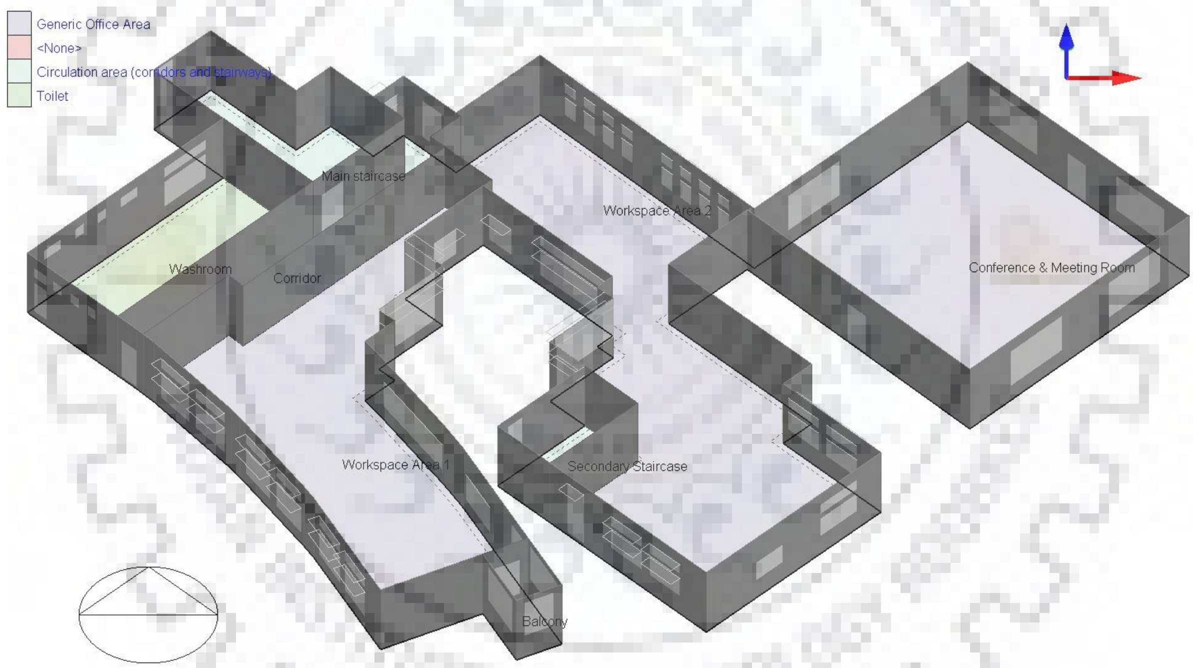


Figure 61 Typical Floor plan of DA Building, New Delhi

Energy consumption Data Analysis for Base year (1990) with Morphed future years (2020 & 2050) has been done in the later chapter of Analysis and Discussion. energy consumption of Energy plus tool simulated model of DA headquarters done on the basis of comparing Heating energy demand, cooling energy demand & Total HVAC energy.

Development Alternatives Building Model Energy Consumption Validation

To validate the Energy performance of the Design Builder Generated model of DA Building, New Delhi, Last three years of Actual Energy Consumption Data has been provided by the DA building Administration. Collective Mean Monthly Energy consumption for 2016, 2017, 2018 has been taken derive out Average of actual energy consumption for all three years. This monthly mean and annual average data used to validate the Simulated DA Building Model Energy Consumption Data for year of 2020, extrapolated from the 1990 ASHRAE weather file.

Months	Consumption in 2016-17 (kWh)	Consumption in 2017-18 (kWh)	Consumption in 2018-19 (kWh)
April	35802	33132	25074
May	40212	41994	35328
June	41556	40434	38976
July	38496	41874	39184
August	36402	37008	36284
Sept	33996	35584	25694
October	24180	23154	18988
November	15480	13716	10626
December	19956	20010	26998
January	31228	28609	25502
February	17970	20435	21132
March	23562	10968	17770
Total	**358840**	**346918**	**321556**

Table 2 Actual Energy Consumption Data, DA Building. *Source: DA Building Administration*

	Actual monthly Mean (kWh)	Simulated energy in 2020 (kWh)	Difference in Units (kWh)
JAN	28446	28004	-443
FEB	19846	7558	-12287
MAR	17433	12475	-4958
APR	31336	21157	-10179
MAY	39178	36356	-2822
JUN	40322	38900	-1422
JUL	39851	38271	-1581
AUG	36565	42333	5768
SEP	31758	35972	4214
OCT	22107	22801	694
NOV	13274	10026	-3248
DEC	22321	19027	-3295
TOTAL	**342438**	**312879**	**-29559**

Table 3 Simulated Energy Data in 2020 validation with Actual monthly Mean Data (2016, 2017, 2018)

Comparison between simulated vs Actual energy consumption Data shows **91.37%** similarity with the performance of simulated Design Builder Generated Energy Model. Monthly Data comparison shows Simulated Model is working strikingly similar with the summer and monsoon months (May to Oct) with **102.31%** similarity, while winter months (Nov to Apr) works in cohesion with **74.06%** efficiency.

MODELLING 5 TYPICAL MID SIZE OFFICE BUILDING LAYOUTS

To identify Typical office Layout used in Indian context, a set of 50 existing Plan forms for Office buildings referred. These Building plan forms were selected on the basis of different shape forms, and Different Service Cores. For example, Square, Rectangle, circular etc., in shape forms; & single service core and multiple service core system, in differential service cores.

Plan forms Referred for Deriving out Typical Office layouts are Given Below.

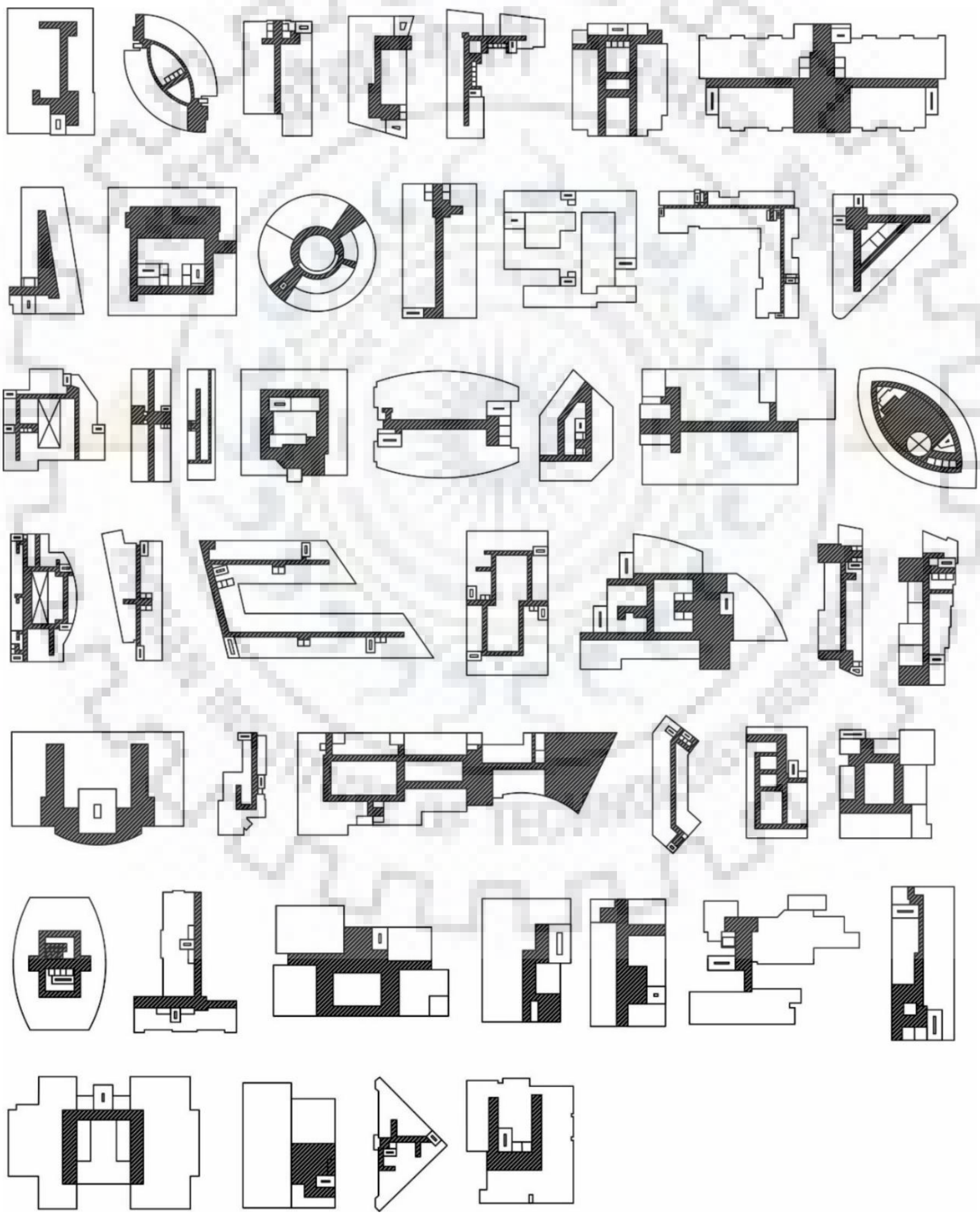


Figure 63 Plan Forms studied to Derive Typical Floor Layout *Source: Author*

Identification of 5 typical office layouts

1. Square Layout

Figure 64 Typical Square Layout

2. Rectangle Layout

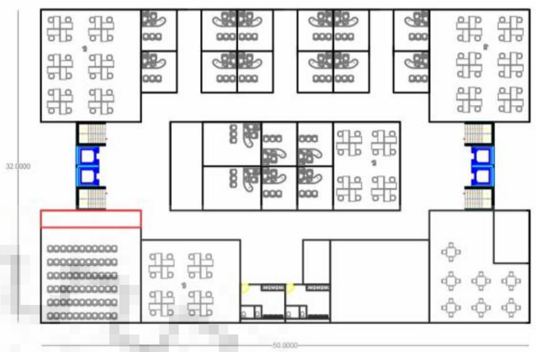


Figure 65 Typical Rectangle layout *Source:Author*

3. Curve Layout

Figure 67 Typical Curve layout

4. U Shaped Layout

Figure 66 Typical U Shape Layout *Source:Author*

5. Triangle Layout

Figure 68 Typical Triangle Layout *Source:Author*

Modelling 5 base cases layout

Various Existing plan forms have been studied and 5 typical layouts for a small sized office building. To study the effects of climate type on the energy performance of every typical building layout, a model for has been prepared in Energy Plus's Design Builder for each Building layout type. Every Base model have been equipped with ECBC prescribed values for a small size office building.

Square Layout Building Model -

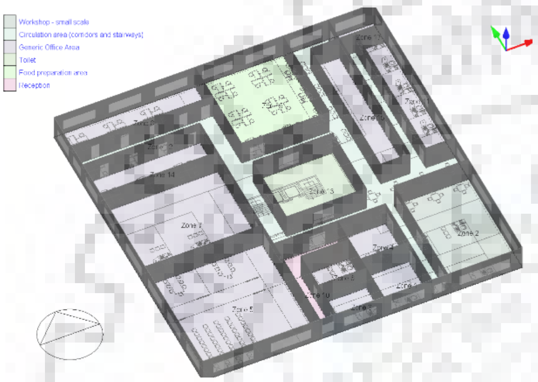


Figure 70 Square Typical Floor Model

Rectangular layout Building Model -

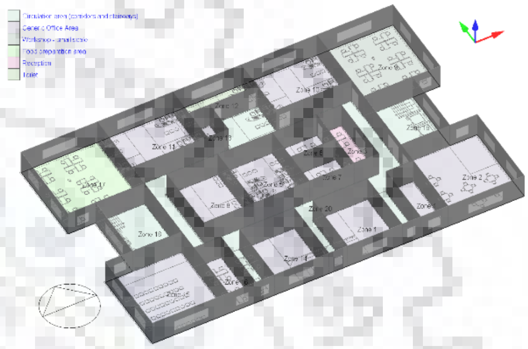


Figure 69 Rectangle Typical floor Model

Curve Layout Building Model -

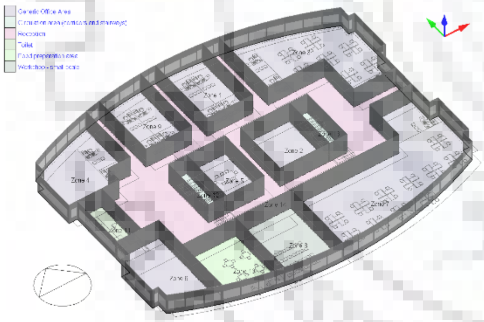


Figure 72 Curve Typical floor Model

Triangle Layout Building Model -

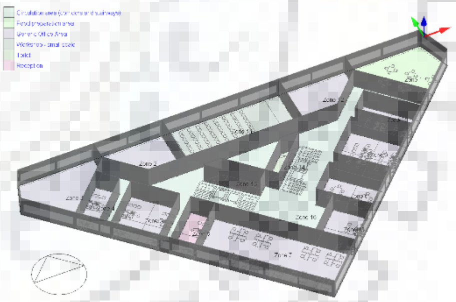


Figure 71 Triangle Typical floor model

U Shape layout Building Model -

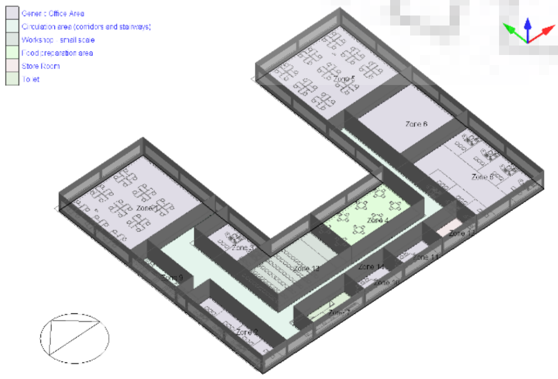


Figure 73 U Shape Typical Floor Model

Area & occupancy

Area of the Derived typical Office Layout has been limited to 1600 sq.m Most of the Existing Office Building has been constructed in the range of 1600 sq.m Another reason to set this limit to 1600 sq.m is that it makes it feasible to carry Energy and Heat Gains analysis on the Typical floor Layouts. Occupancy of a small size office building according to NBC is prescribed to be 1 per 10 sq.m So, occupancy of the office space is limited between 130 and 150.

ENVELOPE SERVICES PRESCRIBED IN ECBC FOR BASE CASE OFFICE BUILDING

The main provision of energy building code inhibits minimum consumption of energy for designing and construction purpose. In addition to this, it also includes developmental requirements for attaining high level of energy efficiency for buildings.

All the Typical Office Layouts has complied with the mandatory provisions for a base case small sized office building in ECBC

Base Case Values Mentioned for a small Size office layout are discussed below;

ECBC Prescriptive values for Base Case Standard

Daylighting:

For a small size office Building Case, ECBC prescribes minimum 40% of daylighting to enter into the envelope.

Window to Wall Ratio:

Prescribed WWR for a base case should not be more than 40%.

Visual Light Transmittance:

Minimum 0.27 of the Light Transmittance is allowed in ECBC base case office type.

U- Values:

Roof- for a composite Climate type, U-Value Should not be more than 0.33

External Walls- for a composite Climate type, U-Value Should not be more than 0.63.

Window- U-Factor – 3.0 w/m2k

SHGC – Non-North – 0.27

North > 15 Degrees – 0.5

North < 15 Degrees – 0.27

HVAC System for a Base Case Design

Building with less than or equal to 12,500 sqm of conditioned area

System B-

System type - VRF (Variable Refringent flow)

Fan Control – Constant Volume

Cooling type – Direct Expansion with air cooled condenser

Heating type – Heat pump

Scheduling for Lighting & HVAC

Table 4 HVAC & Lighting Schedule

Business - Office		
Time Period	HVAC Fan Schedule (On/Off) Daytime Business	External Lighting Schedule
00:00 – 01:00	0	0.80
01:00 – 02:00	0	0.80
02:00 – 03:00	0	0.80
03:00 – 04:00	0	0.80
04:00 – 05:00	0	0.80
05:00 – 06:00	0	0.80
06:00 – 07:00	0	0.00
07:00 – 08:00	1	0.00
08:00 – 09:00	1	0.00
09:00 – 10:00	1	0.00
10:00 – 11:00	1	0.00
11:00 – 12:00	1	0.00
12:00 – 13:00	1	0.00
13:00 – 14:00	1	0.00
14:00 – 15:00	1	0.00
15:00 – 16:00	1	0.00
16:00 – 17:00	1	0.00
17:00 – 18:00	1	0.00
18:00 – 19:00	1	0.80
19:00 – 20:00	1	0.80
20:00 – 21:00	1	0.80
21:00 – 22:00	1	0.80
22:00 – 23:00	0	0.80
23:00 – 24:00	0	0.80

BASE CASES ENERGY CONSUMPTION SIMULATION ANALYSIS

After creating models for each typical office floor plan, every Design builder model is equipped with the prescribed values from ECBC 2016 for making a standard design Office building following basic requirements. Every model after fulfilling the basic requirement is simulated against the New Delhi climate, and simulation results for cooling load, heating load, system loads and space gains in Kilo Watt Hours (kWh) measured monthly for the period of one year.

Energy benchmark of commercial buildings (BEE)

Data has been accumulated from 1160 commercial establishments through random sampling across all climatic zones which included offices, hotels, hospitals, BPOs and malls. As a part of analysis, it has been observed that centralised air-cooling chiller systems have been used by small- sized buildings which inhibits comparatively higher EPIs.

Moreover, additional research and studies need to be conducted to analyse the co- relation between EPI and other components affecting or influencing energy performance of a building.

However, further studies would be required to establish the co-relation between EPI and various factors impacting the energy performance of a building.

ENERGY PERFORMANCE INDEX OF BASE CASE

Energy performance Index Benchmarking has been formulated by Building Energy Efficiency, India. It recommends the acceptable limits on the energy consumption in commercial buildings. For office building, domain has been set between 86 to 179 kWh/m2/yr, for composite climates.

EPI benchmarks for Office Buildings

Climate Zone	Less than 50% AC	More than 50% AC
	EPI (kWh/m²/yr)	
Warm & Humid	101	182
Composite	86	179
Hot & Dry	90	173
Moderate	94	179

Figure 74 EPI BEE Benchmarking for Commercial Building

CASES		Energy Consumption Annually	
		kWh/yr	kWh/m2/yr
			(Area: 1600 sq.m.)
SQUARE		200750.20	125.47
RECTANGLE		196996.24	123.12
CURVE		220292.29	137.68
TRIANGLE		182389.49	113.99
U-SHAPED		201195.34	125.75

Table 5 Base Case Models Energy Performance Index

All 5 Building layouts, when Base 1990 ASHRAE weather file energy Consumption Data Compared with BEE Issued Energy performance index Bench-marking, EPIs for all 5 building layouts satisfied the domain of 86 to 179 kWh/m2/yr.

IMPROVEMENT STRATEGIES

Various Parameters play important part in affecting the HDD and CDD of a building envelope. Throughout the world, there are various factors identified which affects the energy and thermal comfort of buildings; for ex – Aspect ratio, Window to Wall Ratio, Shading Devices, Orientation and Glazing. Out of given 5 factors, this study is taking 3 most important factors as building energy performance improvement strategies, they are-

1. U-Value (External Wall)

   Optimization carried on by estimating the best U-Value, which in turn can bring down the energy consumption of year 2020 & 2050 at same level with the energy consumption of the Base Year (1990). This Process of achieving the desired U-Value which brings down the energy consumption of the base case model is by Trial & error Method.

2. SHGC

   Optimization carried on by estimating the best range of SHGC value, which in turn can bring down the energy consumption of year 2020 & 2050 at same level with the energy consumption of the Base Year (1990). This Process of achieving the desired SHGC which brings down the energy consumption of the base case model is by Trial & error Method.

3. U-Value (Window)

   Optimization carried on by estimating the best range of SHGC value, which in turn can bring down the energy consumption of year 2020 & 2050 at same level with the energy consumption of the Base Year (1990). This Process of achieving the desired SHGC which brings down the energy consumption of the base case model is by Trial & error Method.

ANALYSIS & DISCUSSIONS

Energy Consumption by all three Building design models have been simulated to check how Base year's Energy Consumption is Changing for Future year Simulations (i.e. 2020 &2050). Energy Data has been analysed by simulating the Building Model and extracting Heating energy Demand, Cooling Energy Demand & Total HVAC load. These individual load types are then compared with respective Base (1990) and Future years loads (2020 &2050).

Design Builder Models of DA Building and Five Base cases with different building profiles have been simulated in a composite climate type; & energy consumption for each is analysed.

1. **Development Alternative World Headquarters, New Delhi**

Plan profile for this model has been taken from 5 typical plan forms (Square, Rectangle, Triangle, Curve & U-Shaped). This plan form later extruded to a 3D Office Space with a standard occupancy for Office building According to NBC (10 m2/person). This model has been designed in compliance with all the prescriptive values recommended for an ECBC Base case.

DA Building Heating Loads (kWh)

DA HEAQUARTERS			
	HEATING LOAD (kWh) 1990	HEATING LOAD (kWh) 2020	HEATING LOAD (kWh) 2050
JAN	26158.9	16743.4	9743.1
FEB	7596.9	4630.6	2312.4
MAR	1087.6	894.1	383.7
APR	0.0	0.0	0.0
MAY	0.0	0.0	0.0
JUN	0.0	0.0	0.0
JUL	0.0	0.0	0.0
AUG	0.0	0.0	0.0
SEP	0.0	0.0	0.0
OCT	125.9	49.1	6.6
NOV	3448.0	3548.3	1986.3
DEC	16417.7	12860.2	7994.7
Total	54835.0	38725.6	22426.8

	(kWh) Diff. of 2020 to 1990	PERCENTAGE (%) Diff. of 2020 to 1990	(kWh) Diff. of 2050 to 2020	PERCENTAGE (%) Diff. of 2050 to 2020
JAN	-9415.6	-35.99371228	-7000.3	-41.80923662
FEB	-2966.3	-39.04672896	-2318.2	-50.06314576
MAR	-193.5	-17.78814114	-510.4	-57.08294413
APR	0.0	0	0	0
MAY	0.0	0	0	0
JUN	0.0	0	0	0
JUL	0.0	0	0	0
AUG	0.0	0	0	0
SEP	0.0	0	0	0
OCT	0.0	0	0	0
NOV	100.3	2.909642583	-1562.0	-44.02173071
DEC	-3557.6	-21.66912133	-4865.4	-37.83338621
Total	-16032.6	-29.23792621	-16256.3	-41.97826512

Table 6 DA Building Heating Loads comparison between 1990, 2020 & 2050 *Source: Author*

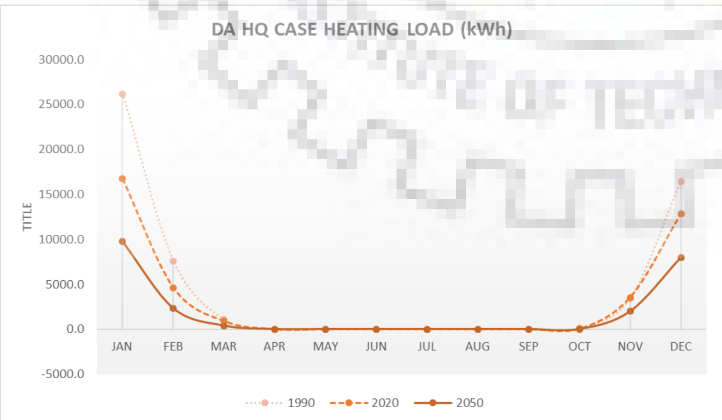


Figure 75 DA Building Heating Loads

Heating Energy Demands:

for 2020
Units: -16032 kWh
Percentage: -29.93%

for 2050
Units: -16256 kWh
Percentage: -41.97%

DA Building Cooling Loads (kWh)

DA HEAQUARTERS			
	COOLING LOAD (kWh)	COOLING LOAD (kWh)	COOLING LOAD (kWh)
	1990	2020	2050
JAN	2061	3153	4500
FEB	3656	5190	7135
MAR	14248	16642	19790
APR	23489	26239	28726
MAY	40122	44155	48503
JUN	42461	45465	48914
JUL	39846	42432	44967
AUG	40460	43587	45942
SEP	33740	37402	40523
OCT	23846	27258	30721
NOV	9128	9865	12148
DEC	2573	3515	4906
Total	275631	304902	336775

	(kWh)	PERCENTAGE (%)	(kWh)	PERCENTAGE (%)
	Diff. of 2020 to 1990	Diff. of 2020 to 1990	Diff. of 2050 to 2020	Diff. of 2050 to 2020
JAN	1092	53	1347	43
FEB	1534	42	1946	37
MAR	2394	17	3147	19
APR	2749	12	2487	9
MAY	4033	10	4348	10
JUN	3004	7	3449	8
JUL	2586	6	2536	6
AUG	3127	8	2355	5
SEP	3662	11	3121	8
OCT	3412	14	3463	13
NOV	737	8	2283	23
DEC	942	37	1391	40
Total	29271	11	31873	10

Table 7 DA Building cooling Loads comparison between 1990, 2020 & 2050 *Source: Author*

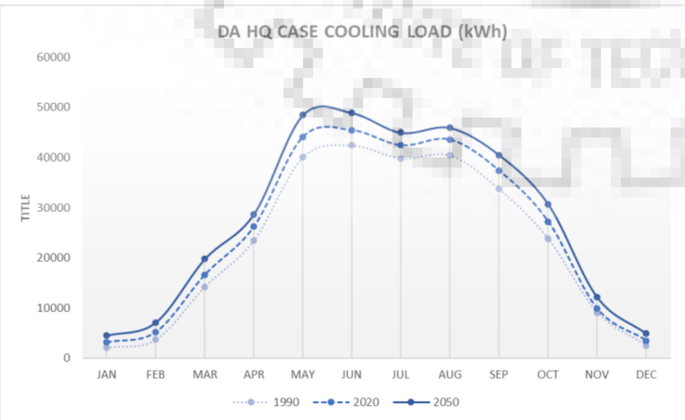


Figure 76 DA Building Cooling Loads

Cooling Energy Demands:

for 2020
Units: 29271 kWh
Percentage: 11 %

for 2050
Units: 31873 kWh
Percentage: 10 %

DA Total HVAC (kWh)

DA HEAQUARTERS			
	TOTAL HVAC (kWh)	TOTAL HVAC (kWh)	TOTAL HVAC (kWh)
	1990	2020	2050
JAN	28220	19897	14243
FEB	11253	9820	9448
MAR	15336	17536	20173
APR	23489	26239	28726
MAY	40122	44155	48503
JUN	42461	45465	48914
JUL	39846	42432	44967
AUG	40460	43587	45942
SEP	33740	37402	40523
OCT	23972	27307	30728
NOV	12576	13413	14134
DEC	18991	16375	12901
Total	330466	343628	359202

	(kWh)	PERCENTAGE (%)	(kWh)	PERCENTAGE (%)
	Diff. of 2020 to 1990	Diff. of 2020 to 1990	Diff. of 2050 to 2020	Diff. of 2050 to 2020
JAN	-8323	-29	-5653	-28
FEB	-1433	-13	-372	-4
MAR	2200	14	2637	15
APR	2749	12	2487	9
MAY	4033	10	4348	10
JUN	3004	7	3449	8
JUL	2586	6	2536	6
AUG	3127	8	2355	5
SEP	3662	11	3121	8
OCT	3335	14	3420	13
NOV	837	7	721	5
DEC	-2616	-14	-3474	-21
Total	13162	4	15574	5

Table 8 DA Building HVAC Loads comparison between 1990, 2020 & 2050 *Source: Author*

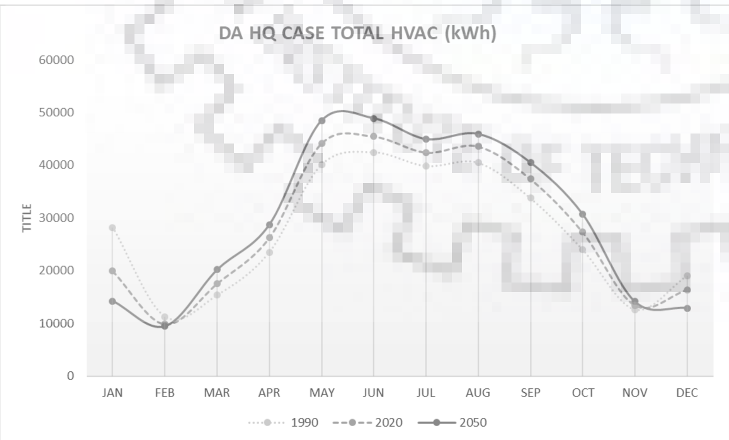


Figure 77 DA Building Total HVAC Loads

Total HVAC Energy Demands:

for 2020
Units: 13162 kWh
Percentage: 4 %

for 2050
Units: 15574 kWh
Percentage: 5 %

2. Square ECBC Base Case

Square Base Heating (kWh)

SQUARE BASE CASE			
	HEATING LOAD (kWh)	HEATING LOAD (kWh)	HEATING LOAD (kWh)
	1990	2020	2050
JAN	2492	1773	1117
FEB	897	593	328
MAR	262	262	262
APR	0	0	0
MAY	0	0	0
JUN	0	0	0
JUL	0	0	0
AUG	0	0	0
SEP	0	0	0
OCT	6	0	0
NOV	511	458	235
DEC	1763	1436	960
Total	5931.0	4521.8	2902.4

	(kWh) Diff. of 2020 to 1990	PERCENTAGE (%) Diff. of 2020 to 1990	(kWh) Diff. of 2050 to 2020	PERCENTAGE (%) Diff. of 2050 to 2020
JAN	-719	-29	-656	-37
FEB	-304	-34	-265	-45
MAR	0	0	0	0
APR	0	0	0	0
MAY	0	0	0	0
JUN	0	0	0	0
JUL	0	0	0	0
AUG	0	0	0	0
SEP	0	0	0	0
OCT	0	0	0	0
NOV	-53	-10	-223	-49
DEC	-327	-19	-476	-33
Total	-1403.2	-23.65858956	-1619.5	-35.81440344

Table 9 Square Base Heating Loads comparison between 1990, 2020 & 2050 *Source: Author*

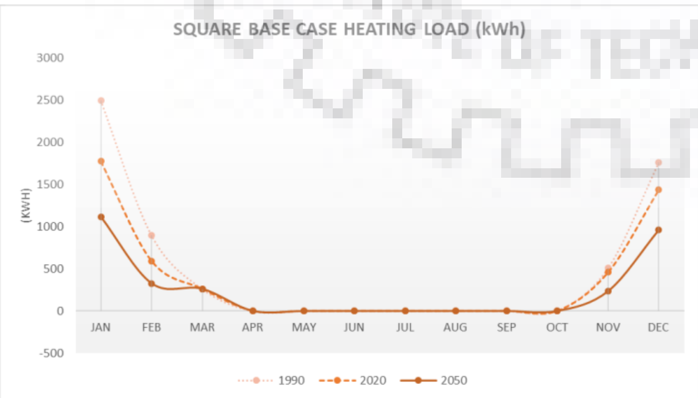


Figure 78 Square base Heating Loads

Heating Energy Demands:

for 2020
Units: -1403 kWh
Percentage: -23 %

for 2050
Units: -1619 kWh
Percentage: -35 %

Square Base Cooling (kWh)

SQUARE BASE CASE			
	COOLING LOAD (kWh)	COOLING LOAD (kWh)	COOLING LOAD (kWh)
	1990	2020	2050
JAN	3017	3970	5041
FEB	4228	5254	6551
MAR	10895	12264	14137
APR	14982	16518	17988
MAY	26131	28795	31413
JUN	28217	30105	32203
JUL	27133	28883	30510
AUG	28333	30533	32108
SEP	23327	25950	27925
OCT	17133	19467	21747
NOV	7900	8316	9791
DEC	3524	4187	5154
Total	194818.5	214241.7	234569.8

	(kWh) Diff. of 2020 to 1990	PERCENTAGE (%) Diff. of 2020 to 1990	(kWh) Diff. of 2050 to 2020	PERCENTAGE (%) Diff. of 2050 to 2020
JAN	953	32	1071	27
FEB	1026	24	1297	25
MAR	1369	13	1873	15
APR	1536	10	1471	9
MAY	2664	10	2618	9
JUN	1889	7	2098	7
JUL	1750	6	1627	6
AUG	2200	8	1575	5
SEP	2623	11	1975	8
OCT	2334	14	2280	12
NOV	416	5	1476	18
DEC	663	19	967	23
Total	19423.2	9.969880785	20328.1	9.488397969

Table 10 Square base Cooling Loads comparison between 1990, 2020 & 2050 *Source: Author*

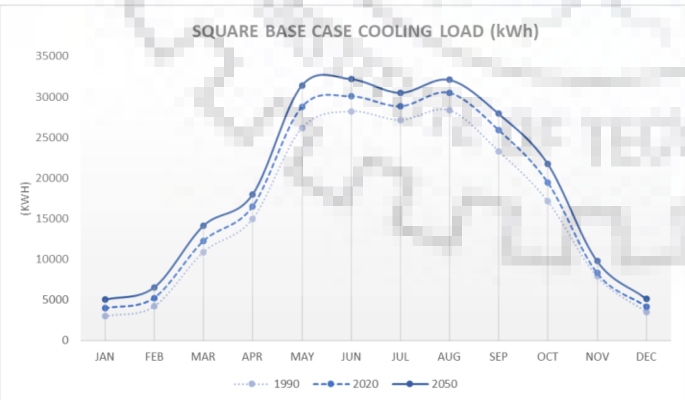


Figure 79 Square base Cooling Loads

Cooling Energy Demands:

for 2020
Units: 19423 kWh
Percentage: 9.96 %

for 2050
Units: 20328 kWh
Percentage: 9.48 %

Square Base Total HVAC (kWh)

SQUARE BASE CASE			
	TOTAL HVAC (kWh)	TOTAL HVAC (kWh)	TOTAL HVAC (kWh)
	1990	2020	2050
JAN	5509	5742	6158
FEB	5125	5847	6879
MAR	11157	12526	14399
APR	14982	16518	17988
MAY	26131	28795	31413
JUN	28217	30105	32203
JUL	27133	28883	30510
AUG	28333	30533	32108
SEP	23327	25950	27925
OCT	17140	19467	21747
NOV	8410	8774	10027
DEC	5287	5623	6114
Total	200750.0	218763.5	237472.1

	(kWh)	PERCENTAGE (%)	(kWh)	PERCENTAGE (%)
	Diff. of 2020 to 1990	Diff. of 2020 to 1990	Diff. of 2050 to 2020	Diff. of 2050 to 2020
JAN	233	4	416	7
FEB	722	14	1032	18
MAR	1369	12	1873	15
APR	1536	10	1471	9
MAY	2664	10	2618	9
JUN	1889	7	2098	7
JUL	1750	6	1627	6
AUG	2200	8	1575	5
SEP	2623	11	1975	8
OCT	2327	14	2280	12
NOV	364	4	1253	14
DEC	336	6	491	9
Total	18013.5	8.97307512	18708.6	8.551995739

Table 11 Square Base HVAC Loads comparison between 1990, 2020 & 2050 *Source: Author*

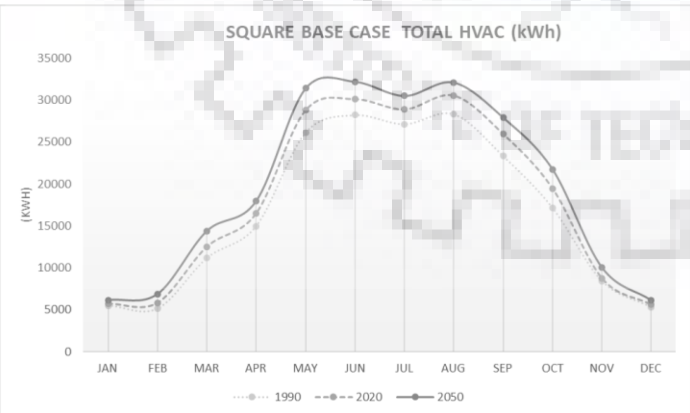


Figure 80 Square Base Total HVAC Loads

Total HVAC Energy Demands:

for 2020
Units: 18013 kWh
Percentage: 8.97 %

for 2050
Units: 18708 kWh
Percentage: 8.55 %

3. Rectangle ECBC Base Case

Rectangle Base Heating (kWh)

RECTANGLE BASE CASE			
	HEATING LOAD (kWh)	HEATING LOAD (kWh)	HEATING LOAD (kWh)
	1990	2020	2050
JAN	2489.0	1806.8	1144.9
FEB	918.0	614.4	332.5
MAR	262.0	262.4	262.4
APR	0.0	0.0	0.0
MAY	0.0	0.0	0.0
JUN	0.0	0.0	0.0
JUL	0.0	0.0	0.0
AUG	0.0	0.0	0.0
SEP	0.0	0.0	0.0
OCT	5.0	0.0	0.0
NOV	507.0	458.3	229.9
DEC	1767.0	1462.7	978.4
Total	5948.0	4604.6	2948.1

	(kWh)	PERCENTAGE (%)	(kWh)	PERCENTAGE (%)
	Diff. of 2020 to 1990	Diff. of 2020 to 1990	Diff. of 2050 to 2020	Diff. of 2050 to 2020
JAN	-682.2	-27.4082945	-661.9	-36.63220967
FEB	-303.6	-33.06719826	-281.9	-45.88580453
MAR	0.4	0.152671756	0.0	0
APR	0.0	0	0	0
MAY	0.0	0	0	0
JUN	0.0	0	0	0
JUL	0.0	0	0	0
AUG	0.0	0	0	0
SEP	0.0	0	0	0
OCT	0.0	0	0	0
NOV	-48.7	-9.610941617	-228.4	-49.84101098
DEC	-304.3	-17.2203056	-484.4	-33.11373313
Total	-1338.4	-22.50100208	-1656.6	-35.97639526

Table 12 Rectangle Base Heating Loads comparison between 1990, 2020 & 2050 *Source: Author*

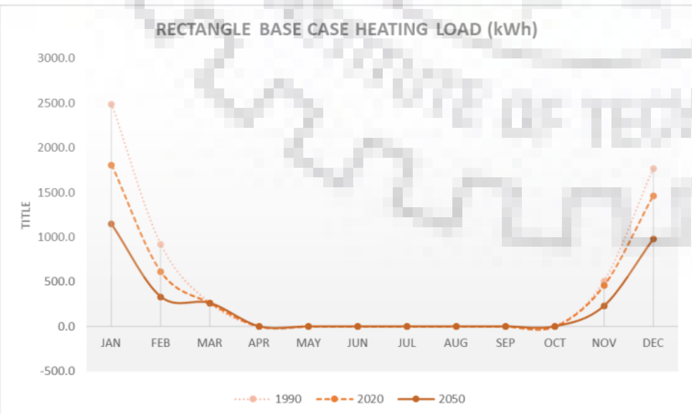


Figure 81 Rectangle Base heating Loads

Heating Energy Demands:

for 2020
Units: -1338 kWh
Percentage: -22.5 %

for 2050
Units: -1656 kWh
Percentage: -35.97 %

Rectangle Base Cooling (kWh)

RECTANGLE BASE CASE			
	COOLING LOAD (kWh)	COOLING LOAD (kWh)	COOLING LOAD (kWh)
	1990	2020	2050
JAN	3208.8	4145.9	5215.1
FEB	4345.1	5362.6	6650.1
MAR	10813.8	12157.3	13973.7
APR	14578.1	16082.9	17517.0
MAY	25367.2	27969.6	30513.9
JUN	27359.0	29179.7	31210.1
JUL	26315.7	28031.1	29592.1
AUG	27532.6	29659.6	31180.2
SEP	22777.8	25322.4	27215.7
OCT	16922.4	19168.6	21363.2
NOV	8077.6	8481.0	9930.8
DEC	3749.0	4402.8	5354.4
Total	191047.0	209963.5	229716.2

	(kWh)	PERCENTAGE (%)	(kWh)	PERCENTAGE (%)
	Diff. of 2020 to 1990	Diff. of 2020 to 1990	Diff. of 2050 to 2020	Diff. of 2050 to 2020
JAN	937.0	29.20189221	1069.3	25.79125787
FEB	1017.5	23.41843126	1287.5	24.00820829
MAR	1343.5	12.42416339	1816.4	14.94091719
APR	1504.8	10.32266801	1434.0	8.91655889
MAY	2602.4	10.25887604	2544.2	9.096399135
JUN	1820.8	6.65510653	2030.4	6.958272299
JUL	1715.4	6.518490123	1561.0	5.568808289
AUG	2127.0	7.725363634	1520.6	5.126891072
SEP	2544.6	11.17142541	1893.3	7.476831252
OCT	2246.2	13.27329293	2194.6	11.4490078
NOV	403.4	4.994139601	1449.7	17.09393827
DEC	653.8	17.44060644	951.6	21.61332888
Total	18916.5	9.901494189	19752.7	9.407681988

Table 13 Rectangle Cooling Loads comparison between 1990, 2020 & 2050 *Source: Author*

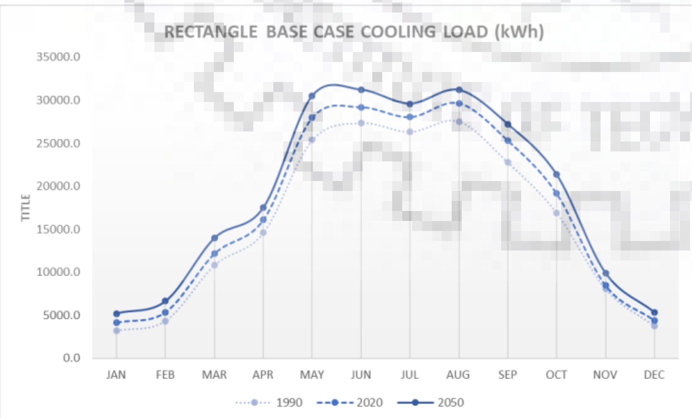


Figure 82 Rectangle Base Cooling Load

Cooling Energy Demands:

for 2020
Units: 18916 kWh
Percentage: 9.90 %

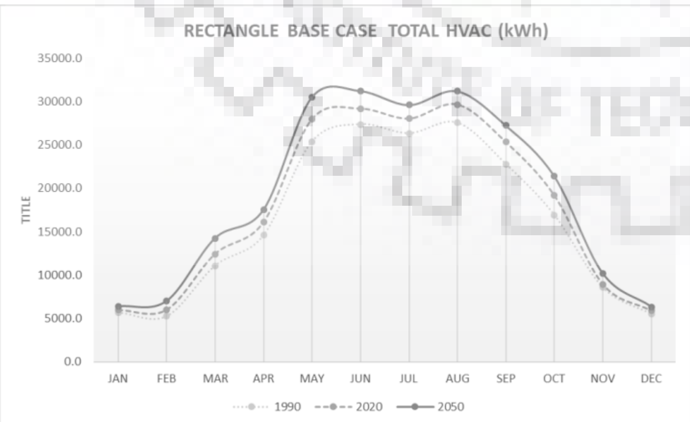
for 2050
Units: 19752 kWh
Percentage: 9.40 %

Rectangle Base Total HVAC (kWh)

RECTANGLE BASE CASE			
	TOTAL HVAC (kWh)	TOTAL HVAC (kWh)	TOTAL HVAC (kWh)
	1990	2020	2050
JAN	5698.0	5952.7	6360.1
FEB	5263.4	5977.1	6982.6
MAR	11076.2	12419.7	14236.1
APR	14578.1	16082.9	17517.0
MAY	25367.2	27969.6	30513.9
JUN	27359.0	29179.7	31210.1
JUL	26315.7	28031.1	29592.1
AUG	27532.6	29659.6	31180.2
SEP	22777.8	25322.4	27215.7
OCT	16927.6	19168.6	21363.2
NOV	8584.8	8939.3	10160.6
DEC	5516.2	5865.6	6332.8
Total	196996.3	214568.2	232664.3

	(kWh)	PERCENTAGE (%)	(kWh)	PERCENTAGE (%)
	Diff. of 2020 to 1990	Diff. of 2020 to 1990	Diff. of 2050 to 2020	Diff. of 2050 to 2020
JAN	254.7	4.469517726	407.4	6.843939551
FEB	713.7	13.56008138	1005.5	16.82309833
MAR	1343.5	12.12982842	1816.4	14.62524901
APR	1504.8	10.32266801	1434.0	8.91655889
MAY	2602.4	10.25887604	2544.2	9.096399135
JUN	1820.8	6.65510653	2030.4	6.958272299
JUL	1715.4	6.518490123	1561.0	5.568808289
AUG	2127.0	7.725363634	1520.6	5.126891072
SEP	2544.6	11.17142541	1893.3	7.476831252
OCT	2241.0	13.23870721	2194.6	11.4490078
NOV	354.5	4.129778277	1221.3	13.66251831
DEC	349.4	6.334131907	467.2	7.965822487
Total	17571.8	8.91987088	18096.1	8.433738048

Table 14 Rectangle HVAC Loads comparison between 1990, 2020 & 2050 *Source: Author*



Total HVAC Energy Demands:

for 2020
Units: **17571 kWh**
Percentage: **8.91 %**

for 2050
Units: **18096 kWh**
Percentage: **8.43 %**

Figure 83 Rectangle Base HVAC laods

4. Curve ECBC Base Case

Curve Base Heating (kWh)

CURVE BASE CASE			
	HEATING LOAD (kWh)	HEATING LOAD (kWh)	HEATING LOAD (kWh)
	1990	2020	2050
JAN	3126.0	2228.4	1381.1
FEB	1110.0	710.3	365.4
MAR	262.0	262.4	262.4
APR	0.0	0.0	0.0
MAY	0.0	0.0	0.0
JUN	0.0	0.0	0.0
JUL	0.0	0.0	0.0
AUG	0.0	0.0	0.0
SEP	0.0	0.0	0.0
OCT	8.0	0.0	0.0
NOV	575.0	508.1	250.0
DEC	2206.0	1804.4	1174.4
Total	7287.0	5513.6	3433.2

	(kWh)	PERCENTAGE (%)	(kWh)	PERCENTAGE (%)
	Diff. of 2020 to 1990	Diff. of 2020 to 1990	Diff. of 2050 to 2020	Diff. of 2050 to 2020
JAN	-897.6	-28.71244754	-847.4	-38.02613799
FEB	-399.7	-36.00849694	-344.9	-48.55393752
MAR	0.4	0.152671756	0.0	0
APR	0.0	0	0	0
MAY	0.0	0	0	0
JUN	0.0	0	0	0
JUL	0.0	0	0	0
AUG	0.0	0	0	0
SEP	0.0	0	0	0
OCT	0.0	0	0	0
NOV	-66.9	-11.63333426	-258.1	-50.79919532
DEC	-401.6	-18.20642022	-630.0	-34.91532931
Total	-1765.4	-24.22630339	-2080.4	-37.73176845

Table 15 Curve Base Heating Loads comparison between 1990, 2020 & 2050 *Source: Author*

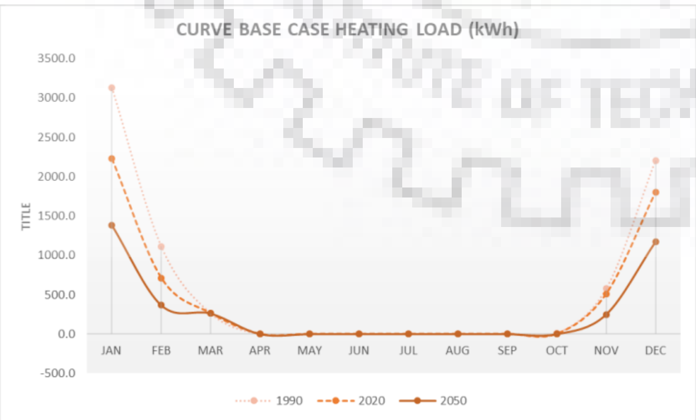


Figure 84 Curve Base Heating Loads

Heating Energy Demands:

for 2020
Units: -1765 kWh
Percentage: -24.22 %

for 2050
Units: -2080 kWh
Percentage: -37.73 %

Curve Base Cooling (kWh)

CURVE BASE CASE			
	COOLING LOAD (kWh)	COOLING LOAD (kWh)	COOLING LOAD (kWh)
	1990	**2020**	**2050**
JAN	3078.8	4100.0	5253.2
FEB	4296.9	5425.8	6858.4
MAR	11607.5	13149.5	15270.6
APR	16184.2	17915.7	19556.2
MAY	28757.5	31794.8	34761.2
JUN	31126.6	33246.8	35620.1
JUL	30021.4	32018.2	33778.0
AUG	31398.5	33892.7	35658.9
SEP	25799.9	28806.7	31030.9
OCT	18716.7	21415.8	24007.0
NOV	8383.3	8862.8	10495.6
DEC	3633.0	4368.7	5421.9
Total	**213004.4**	**234997.5**	**257712.0**

	(kWh)	PERCENTAGE (%)	(kWh)	PERCENTAGE (%)
	Diff. of 2020 to 1990	Diff. of 2020 to 1990	Diff. of 2050 to 2020	Diff. of 2050 to 2020
JAN	1021.2	33.16989721	1153.1	28.12552045
FEB	1128.9	26.27159413	1432.6	26.40419343
MAR	1541.9	13.28405203	2121.1	16.13103965
APR	1731.5	10.69867183	1640.5	9.156742028
MAY	3037.2	10.5615757	2966.4	9.329973957
JUN	2120.2	6.811498339	2373.3	7.138279689
JUL	1996.8	6.65136445	1759.8	5.496138461
AUG	2494.2	7.943644861	1766.2	5.211120929
SEP	3006.8	11.65447753	2224.2	7.721142308
OCT	2699.1	14.42085877	2591.2	12.09940975
NOV	479.4	5.718835286	1632.8	18.42358419
DEC	735.7	20.25063465	1053.2	24.1086252
Total	**21993.1**	**10.325177**	**22714.5**	**9.665865094**

Table 16 Curve Base Cooling Loads comparison between 1990, 2020 & 2050 *Source: Author*

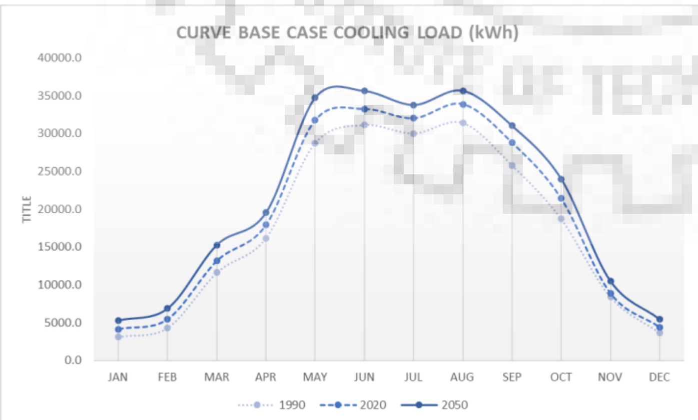


Figure 85 Curve Base Cooling Loads

Cooling Energy Demands:

for 2020
Units: 21993 kWh
Percentage: 10.32 %

for 2050
Units: 22714 kWh
Percentage: 9.66 %

Curve Base Total (kWh)

CURVE BASE CASE			
	TOTAL HVAC (kWh)	TOTAL HVAC (kWh)	TOTAL HVAC (kWh)
	1990	2020	2050
JAN	6205.0	6328.5	6634.2
FEB	5406.6	6136.1	7223.8
MAR	11869.9	13411.9	15533.0
APR	16184.2	17915.7	19556.2
MAY	28757.5	31794.8	34761.2
JUN	31126.6	33246.8	35620.1
JUL	30021.4	32018.2	33778.0
AUG	31398.5	33892.7	35658.9
SEP	25799.9	28806.7	31030.9
OCT	18725.1	21415.8	24007.0
NOV	8958.0	9370.9	10745.6
DEC	5839.3	6173.0	6596.3
Total	**220292.1**	**240511.1**	**261145.3**

	(kWh)	PERCENTAGE (%)	(kWh)	PERCENTAGE (%)
	Diff. of 2020 to 1990	Diff. of 2020 to 1990	Diff. of 2050 to 2020	Diff. of 2050 to 2020
JAN	123.5	1.989629976	305.8	4.831437777
FEB	729.5	13.49184671	1087.8	17.72714343
MAR	1541.9	12.99039098	2121.1	15.81543991
APR	1731.5	10.69867183	1640.5	9.156742028
MAY	3037.2	10.5615757	2966.4	9.329973957
JUN	2120.2	6.811498339	2373.3	7.138279689
JUL	1996.8	6.65136445	1759.8	5.496138461
AUG	2494.2	7.943644861	1766.2	5.211120929
SEP	3006.8	11.65447753	2224.2	7.721142308
OCT	2690.7	14.36961502	2591.2	12.09940975
NOV	412.9	4.609055631	1374.7	14.67017923
DEC	333.8	5.715982508	423.2	6.856043904
Total	**20219.0**	**9.178283459**	**20634.1**	**8.579291672**

Table 17 Curve Base HVAC Loads comparison between 1990, 2020 & 2050 *Source: Author*

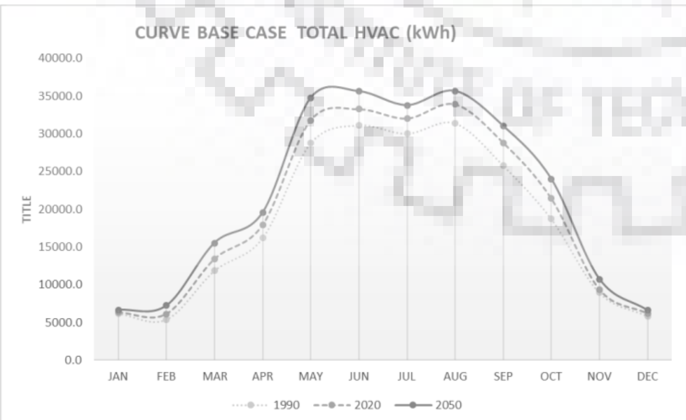


Figure 86 Curve base HVAC Loads

Total HVAC Energy Demands:

for 2020
Units: 20219 kWh
Percentage: 9.17 %

for 2050
Units: 20634 kWh
Percentage: 8.58 %

5. Triangle ECBC Base Case

Triangle Base Heating (kWh)

TRIANGLE BASE CASE			
	HEATING LOAD (kWh)	HEATING LOAD (kWh)	HEATING LOAD (kWh)
	1990	2020	2050
JAN	3577.9	2189.8	1300.5
FEB	963.6	633.9	337.2
MAR	262.4	262.4	262.4
APR	25.8	34.4	41.4
MAY	35.1	54.6	67.5
JUN	51.3	41.4	47.8
JUL	14.6	25.4	27.0
AUG	15.8	12.7	13.7
SEP	14.0	9.0	13.6
OCT	16.9	9.2	13.5
NOV	411.1	297.4	135.3
DEC	2557.5	1839.6	1206.0
Total	7945.9	5409.8	3465.9

	(kWh)	PERCENTAGE (%)	(kWh)	PERCENTAGE (%)
	Diff. of 2020 to 1990	Diff. of 2020 to 1990	Diff. of 2050 to 2020	Diff. of 2050 to 2020
JAN	-1388.1	-38.79755216	-889.2	-40.60927845
FEB	-329.7	-34.21121576	-296.7	-46.8085778
MAR	0.0	0	0.0	0
APR	0.0	0	0	0
MAY	0.0	0	0	0
JUN	0.0	0	0	0
JUL	0.0	0	0	0
AUG	0.0	0	0	0
SEP	0.0	0	0	0
OCT	0.0	0	0	0
NOV	-113.7	-27.66056281	-162.1	-54.49791666
DEC	-717.9	-28.06933557	-633.7	-34.44507051
Total	-2549.4	-32.08406094	-1981.7	-36.63170941

Table 18 Triangle Base Heating Loads comparison between 1990, 2020 & 2050 *Source: Author*

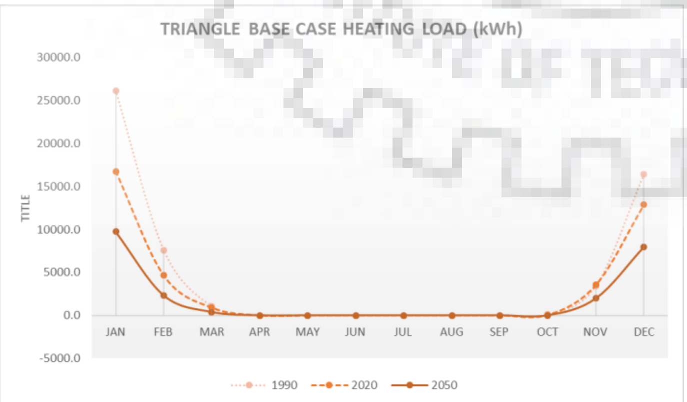


Figure 87 Triangle Base Heating Loads.

Heating Energy Demands:

for 2020
Units: -2549 kWh
Percentage: -32.08 %

for 2050
Units: -1981 kWh
Percentage: -36.63 %

Triangle Base Cooling (kWh)

TRIANGLE BASE CASE			
	COOLING LOAD (kWh)	COOLING LOAD (kWh)	COOLING LOAD (kWh)
	1990	2020	2050
JAN	8190.0	9775.7	11836.0
FEB	14041.4	17468.7	20940.2
MAR	31354.5	36869.1	41738.8
APR	54666.4	61122.8	65444.9
MAY	71469.5	77982.5	84384.5
JUN	71827.1	76623.2	81127.9
JUL	61236.1	64868.3	66138.7
AUG	58754.3	62499.0	63382.7
SEP	55747.5	60455.5	62444.5
OCT	43622.4	48346.5	52082.7
NOV	23560.2	26207.7	29560.7
DEC	11712.7	14698.3	17931.8
Total	**506182.1**	**556917.3**	**597013.5**

	(kWh)	PERCENTAGE (%)	(kWh)	PERCENTAGE (%)
	Diff. of 2020 to 1990	Diff. of 2020 to 1990	Diff. of 2050 to 2020	Diff. of 2050 to 2020
JAN	1585.7	19.36100576	2060.3	21.07583392
FEB	3427.3	24.40855352	3471.6	19.87327929
MAR	5514.6	17.58795137	4869.7	13.20815716
APR	6456.3	11.81038087	4322.1	7.071189656
MAY	6513.1	9.11310904	6402.0	8.209465862
JUN	4796.1	6.677251616	4504.7	5.878977601
JUL	3632.3	5.931558331	1270.4	1.958362636
AUG	3744.7	6.373446092	883.8	1.414045862
SEP	4708.0	8.445239649	1989.0	3.290016319
OCT	4724.1	10.82952077	3736.2	7.72791505
NOV	2647.5	11.23729729	3352.9	12.7937093
DEC	2985.6	25.4902501	3233.6	21.99957
Total	**50735.2**	**10.0231164**	**40096.2**	**7.199659086**

Table 19 Triangle Base Cooling Loads comparison between 1990, 2020 & 2050 *Source: Author*

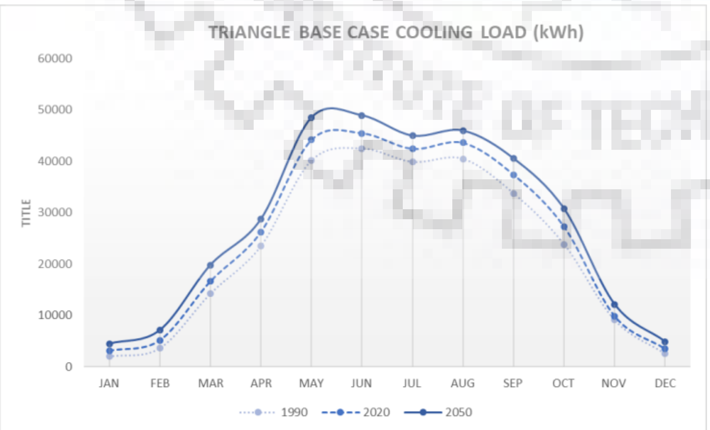


Figure 88 Triangle Base Cooling Loads.

Cooling Energy Demands:

for 2020
Units: 50735 kWh
Percentage: 10 %

for 2050
Units: 40096 kWh
Percentage: 7.19 %

Triangle Base Total HVAC (kWh)

TRIANGLE BASE CASE			
	TOTAL HVAC (kWh)	TOTAL HVAC (kWh)	TOTAL HVAC (kWh)
	1990	2020	2050
JAN	11767.9	11965.5	13136.5
FEB	15004.9	18102.6	21277.4
MAR	31616.9	37131.5	42001.2
APR	54692.2	61157.2	65486.3
MAY	71504.6	78037.1	84452.0
JUN	71878.4	76664.7	81175.7
JUL	61250.6	64893.7	66165.7
AUG	58770.1	62511.7	63396.4
SEP	55761.5	60464.5	62458.1
OCT	43639.3	48355.7	52096.3
NOV	23971.3	26505.1	29696.0
DEC	14270.2	16537.9	19137.8
Total	514128.0	562327.1	600479.4

	(kWh)	PERCENTAGE (%)	(kWh)	PERCENTAGE (%)
	Diff. of 2020 to 1990	Diff. of 2020 to 1990	Diff. of 2050 to 2020	Diff. of 2050 to 2020
JAN	197.5	1.67860749	1171.1	9.787051518
FEB	3097.6	20.64412079	3174.9	17.53816135
MAR	5514.6	17.44198257	4869.7	13.11481805
APR	6465.0	11.82066901	4329.1	7.078591653
MAY	6532.5	9.135835347	6414.9	8.220304089
JUN	4786.2	6.658766912	4511.0	5.884075247
JUL	3643.1	5.9478178	1272.0	1.960117326
AUG	3741.5	6.366408894	884.8	1.415373903
SEP	4703.0	8.434216452	1993.6	3.297137087
OCT	4716.4	10.80758861	3740.5	7.735470344
NOV	2533.8	10.57027423	3190.9	12.0387685
DEC	2267.7	15.89141245	2599.9	15.72091002
Total	48199.1	9.374925375	38152.3	6.784719484

Table 20 Triangle Base HVAC Loads comparison between 1990, 2020 & 2050 *Source: Author*

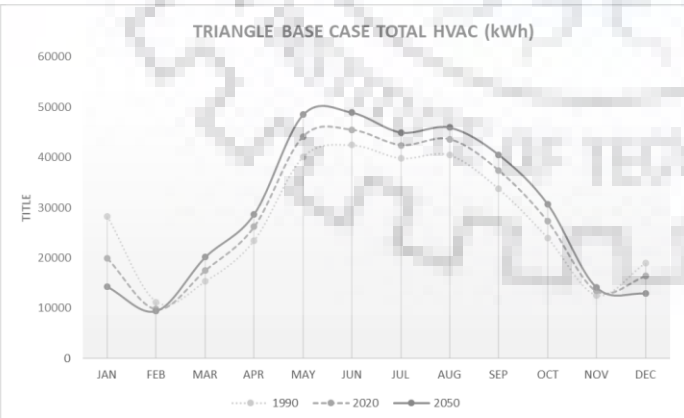


Figure 89 Triangle Total HVAC loads

Total HVAC Energy Demands:

for 2020
Units: 48199 kWh
Percentage: 9.37 %

for 2050
Units: 38152 kWh
Percentage: 6.78 %

6. U-Shaped ECBC Base Case

U-Shaped Base Heating (kWh)

U-SHAPED BASE CASE			
	HEATING LOAD (kWh)	HEATING LOAD (kWh)	HEATING LOAD (kWh)
	1990	2020	2050
JAN	3578	2190	1301
FEB	964	634	337
MAR	262	262	262
APR	26	34	41
MAY	35	55	68
JUN	51	41	48
JUL	15	25	27
AUG	16	13	14
SEP	14	9	14
OCT	17	9	14
NOV	411	297	135
DEC	2557	1840	1206
Total	7946	5410	3466

	(kWh) Diff. of 2020 to 1990	PERCENTAGE (%) Diff. of 2020 to 1990	(kWh) Diff. of 2050 to 2020	PERCENTAGE (%) Diff. of 2050 to 2020
JAN	-1388	-39	-889	-41
FEB	-330	-34	-297	-47
MAR	0	0	0	0
APR	0	0	0	0
MAY	0	0	0	0
JUN	0	0	0	0
JUL	0	0	0	0
AUG	0	0	0	0
SEP	0	0	0	0
OCT	0	0	0	0
NOV	-114	-28	-162	-54
DEC	-718	-28	-634	-34
Total	-2549	-32	-1982	-37

Table 21 U-Shaped Base Heating Loads comparison between 1990, 2020 & 2050 *Source: Author*

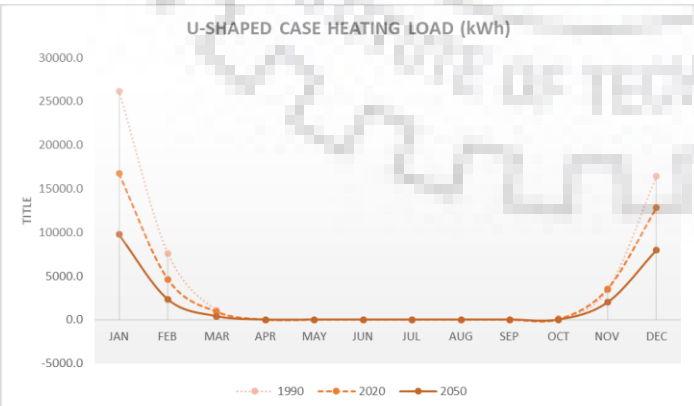


Figure 90 U-shaped Heating Loads

Heating Energy Demands:

for 2020
Units: -2549 kWh
Percentage: -32 %

for 2050
Units: -1982 kWh
Percentage: -37 %

U-Shaped Base Cooling (kWh)

U-SHAPED BASE CASE			
	COOLING LOAD (kWh)	COOLING LOAD (kWh)	COOLING LOAD (kWh)
	1990	2020	2050
JAN	8190	9776	11836
FEB	14041	17469	20940
MAR	31354	36869	41739
APR	54666	61123	65445
MAY	71469	77983	84384
JUN	71827	76623	81128
JUL	61236	64868	66139
AUG	58754	62499	63383
SEP	55748	60456	62445
OCT	43622	48347	52083
NOV	23560	26208	29561
DEC	11713	14698	17932
Total	506182	556917	597013

	(kWh)	PERCENTAGE (%)	(kWh)	PERCENTAGE (%)
	Diff. of 2020 to 1990	Diff. of 2020 to 1990	Diff. of 2050 to 2020	Diff. of 2050 to 2020
JAN	1586	19	2060	21
FEB	3427	24	3472	20
MAR	5515	18	4870	13
APR	6456	12	4322	7
MAY	6513	9	6402	8
JUN	4796	7	4505	6
JUL	3632	6	1270	2
AUG	3745	6	884	1
SEP	4708	8	1989	3
OCT	4724	11	3736	8
NOV	2648	11	3353	13
DEC	2986	25	3234	22
Total	50735	10	40096	7

Table 22 U-Shaped Base Cooling Loads comparison between 1990, 2020 & 2050 *Source: Author*

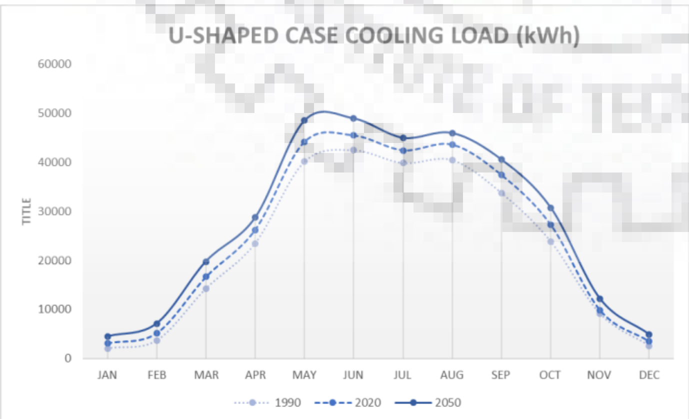


Figure 91 U-shaped cooling loads

Cooling Energy Demands:

for 2020
Units: 50735 kWh
Percentage: 10 %

for 2050
Units: 40096 kWh
Percentage: 7 %

U-Shaped Base Total HVAC (kWh)

U-SHAPED BASE CASE			
	TOTAL HVAC (kWh)	TOTAL HVAC (kWh)	TOTAL HVAC (kWh)
	1990	2020	2050
JAN	11768	11965	13137
FEB	15005	18103	21277
MAR	31617	37131	42001
APR	54692	61157	65486
MAY	71505	78037	84452
JUN	71878	76665	81176
JUL	61251	64894	66166
AUG	58770	62512	63396
SEP	55761	60465	62458
OCT	43639	48356	52096
NOV	23971	26505	29696
DEC	14270	16538	19138
Total	514128	562327	600479

	(kWh)	PERCENTAGE (%)	(kWh)	PERCENTAGE (%)
	Diff. of 2020 to 1990	Diff. of 2020 to 1990	Diff. of 2050 to 2020	Diff. of 2050 to 2020
JAN	198	2	1171	10
FEB	3098	21	3175	18
MAR	5515	17	4870	13
APR	6465	12	4329	7
MAY	6533	9	6415	8
JUN	4786	7	4511	6
JUL	3643	6	1272	2
AUG	3742	6	885	1
SEP	4703	8	1994	3
OCT	4716	11	3741	8
NOV	2534	11	3191	12
DEC	2268	16	2600	16
Total	48199	9	38152	7

Table 23 U-Shaped case HVAC Loads comparison between 1990, 2020 & 2050 *Source: Author*

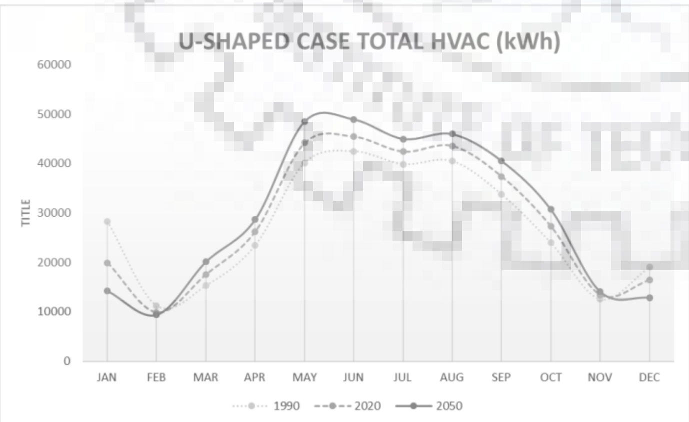


Figure 92 U-Shaped total HVAC

Total HVAC Energy Demands:

for 2020
Units: **48199 kWh**
Percentage: **9 %**

for 2050
Units: **38152 kWh**
Percentage: **7 %**

Mitigative strategies used to Cap Energy Consumption to Base Year 1990

1. Development Alternative World Headquarters, New Delhi

   A) U-Value (External Wall)

HEATING LOAD

0.14 U-VALUE DA HEAQUARTERS 2050

	HEATING LOAD (kWh) 1990	HEATING LOAD (kWh) 2050	(kWh) Diff. of 2050 to 1990	PERCENTAGE (%) Diff. of 2050 to 1990
JAN	26158.9	7702.5	-18456.4	-70.55482009
FEB	7596.9	1861.8	-5735.1	-75.49286913
MAR	1087.6	361.1	-726.5	-66.79710774
APR	0.0	0.0	0.0	0
MAY	0.0	0.0	0.0	0
JUN	0.0	0.0	0.0	0
JUL	0.0	0.0	0.0	0
AUG	0.0	0.0	0.0	0
SEP	0.0	0.0	0.0	0
OCT	125.9	9.0	-116.9	0
NOV	3448.0	1789.8	-1658.3	-48.0930204
DEC	16417.7	6468.9	-9948.9	-60.59826139
Total	**54835.0**	**18193.1**	**-36642.0**	**-66.82216437**

COOLING LOAD

0.14 U-VALUE DA HEAQUARTERS 2050

	COOLING LOAD (kWh) 1990	COOLING LOAD (kWh) 2050	(kWh) Diff. of 2050 to 1990	PERCENTAGE (%) Diff. of 2050 to 1990
JAN	2061.1	4844.8	2783.7	135.1
FEB	3656.0	7315.1	3659.2	100.1
MAR	14248.4	18751.3	4502.9	31.6
APR	23489.3	26073.6	2584.4	11.0
MAY	40122.5	43760.1	3637.6	9.1
JUN	42460.6	44264.1	1803.5	4.2
JUL	39846.2	40848.6	1002.4	2.5
AUG	40459.9	41931.9	1472.0	3.6
SEP	33740.3	36839.2	3098.9	9.2
OCT	23846.4	28415.9	4569.6	19.2
NOV	9127.6	11823.0	2695.4	29.5
DEC	2573.1	5213.7	2640.6	102.6
Total	**275631.3**	**310081.4**	**34450.1**	**12.49860674**

TOTAL HVAC

0.14 U-VALUE DA HEAQUARTERS 2050

	TOTAL HVAC (kWh) 1990	TOTAL HVAC (kWh) 2050	(kWh) Diff. of 2050 to 1990	PERCENTAGE (%) Diff. of 2050 to 1990
JAN	28220.0	12547.3	-15672.7	-55.5
FEB	11252.8	9176.9	-2075.9	-18.4
MAR	15336.0	19112.4	3776.5	24.6
APR	23489.3	26073.6	2584.4	11.0
MAY	40122.5	43760.1	3637.6	9.1
JUN	42460.6	44264.1	1803.5	4.2
JUL	39846.2	40848.6	1002.4	2.5
AUG	40459.9	41931.9	1472.0	3.6
SEP	33740.3	36839.2	3098.9	9.2
OCT	23972.2	28424.9	4452.7	18.6
NOV	12575.6	13612.8	1037.1	8.2
DEC	18990.9	11682.6	-7308.3	-38.5
Total	**330466.4**	**328274.5**	**-2191.9**	**-0.663267983**

Table 24 DA Building Energy Consumption at 0.14 U-Value *Source: Author*

B) SHGC (Window)

HEATING LOAD					
0.1 SHGC DA HEAQUARTERS 2050					
	HEATING LOAD (kWh)	HEATING LOAD (kWh)		(kWh)	PERCENTAGE (%)
	1990	2050		Diff. of 2050 to 1990	Diff. of 2050 to 1990
JAN	26158.9	13500.8		-12658.1	-48.38924987
FEB	7596.9	3294.7		-4302.2	-56.63061027
MAR	1087.6	528.3		-559.3	-51.42876189
APR	0.0	0.0		0.0	0
MAY	0.0	0.0		0.0	0
JUN	0.0	0.0		0.0	0
JUL	0.0	0.0		0.0	0
AUG	0.0	0.0		0.0	0
SEP	0.0	0.0		0.0	0
OCT	125.9	24.3		-101.5	0
NOV	3448.0	2579.2		-868.9	-25.19873736
DEC	16417.7	10624.5		-5793.2	-35.28646452
Total	54835.0	30551.8		-24283.2	-44.28416489

COOLING LOAD					
0.1 SHGC DA HEAQUARTERS 2050					
	COOLING LOAD (kWh)	COOLING LOAD (kWh)		(kWh)	PERCENTAGE (%)
	1990	2050		Diff. of 2050 to 1990	Diff. of 2050 to 1990
JAN	2061.1	3040.6		979.5	47.5
FEB	3656.0	5247.0		1591.1	43.5
MAR	14248.4	16466.5		2218.1	15.6
APR	23489.3	24984.3		1495.0	6.4
MAY	40122.5	44269.9		4147.4	10.3
JUN	42460.6	44695.8		2235.1	5.3
JUL	39846.2	41324.7		1478.5	3.7
AUG	40459.9	42567.8		2107.9	5.2
SEP	33740.3	37419.3		3679.0	10.9
OCT	23846.4	27550.6		3704.2	15.5
NOV	9127.6	9574.2		446.6	4.9
DEC	2573.1	3352.0		778.9	30.3
Total	275631.3	300492.6		24861.3	9.019754596

TOTAL HVAC					
0.1 SHGC DA HEAQUARTERS 2050					
	TOTAL HVAC (kWh)	TOTAL HVAC (kWh)		(kWh)	PERCENTAGE (%)
	1990	2050		Diff. of 2050 to 1990	Diff. of 2050 to 1990
JAN	28220.0	16541.4		-11678.6	-41.4
FEB	11252.8	8541.7		-2711.1	-24.1
MAR	15336.0	16994.7		1658.7	10.8
APR	23489.3	24984.3		1495.0	6.4
MAY	40122.5	44269.9		4147.4	10.3
JUN	42460.6	44695.8		2235.1	5.3
JUL	39846.2	41324.7		1478.5	3.7
AUG	40459.9	42567.8		2107.9	5.2
SEP	33740.3	37419.3		3679.0	10.9
OCT	23972.2	27574.9		3602.7	15.0
NOV	12575.6	12153.4		-422.3	-3.4
DEC	18990.9	13976.5		-5014.3	-26.4
Total	330466.4	331044.4		578.0	0.174914829

Table 25 DA Building Energy Consumption at 0.1 SHGC *Source: Author*

C) U-Value (Window)

HEATING LOAD				
0.1 U-VALUE (WINDOW) DA HEAQUARTERS 2050				
	HEATING LOAD (kWh)	HEATING LOAD (kWh)	(kWh)	PERCENTAGE (%)
	1990	2050	Diff. of 2050 to 1990	Diff. of 2050 to 1990
JAN	26158.9	7013.6	-19145.3	-73.18834142
FEB	7596.9	1602.1	-5994.8	-78.9111999
MAR	1087.6	261.1	-826.5	-75.99504226
APR	0.0	0.0	0.0	0
MAY	0.0	0.0	0.0	0
JUN	0.0	0.0	0.0	0
JUL	0.0	0.0	0.0	0
AUG	0.0	0.0	0.0	0
SEP	0.0	0.0	0.0	0
OCT	125.9	0.5	-125.3	0
NOV	3448.0	1426.8	-2021.3	-58.62069166
DEC	16417.7	5763.1	-10654.7	-64.89736712
Total	54835.0	16067.2	-38767.8	-70.69905276

COOLING LOAD				
0.1 U-VALUE (WINDOW) DA HEAQUARTERS 2050				
	COOLING LOAD (kWh)	COOLING LOAD (kWh)	(kWh)	PERCENTAGE (%)
	1990	2050	Diff. of 2050 to 1990	Diff. of 2050 to 1990
JAN	2061.1	5149.0	3087.9	149.8
FEB	3656.0	7819.2	4163.3	113.9
MAR	14248.4	20053.3	5805.0	40.7
APR	23489.3	28022.4	4533.2	19.3
MAY	40122.5	46874.9	6752.4	16.8
JUN	42460.6	47178.6	4718.0	11.1
JUL	39846.2	43683.2	3836.9	9.6
AUG	40459.9	44960.1	4500.2	11.1
SEP	33740.3	39638.0	5897.7	17.5
OCT	23846.4	30564.1	6717.8	28.2
NOV	9127.6	12689.3	3561.6	39.0
DEC	2573.1	5527.7	2954.6	114.8
Total	275631.3	332159.9	56528.6	20.50875919

TOTAL HVAC				
0.1 U-VALUE (WINDOW) DA HEAQUARTERS 2050				
	TOTAL HVAC (kWh)	TOTAL HVAC (kWh)	(kWh)	PERCENTAGE (%)
	1990	2050	Diff. of 2050 to 1990	Diff. of 2050 to 1990
JAN	28220.0	12162.7	-16057.3	-56.9
FEB	11252.8	9421.3	-1831.5	-16.3
MAR	15336.0	20314.4	4978.4	32.5
APR	23489.3	28022.4	4533.2	19.3
MAY	40122.5	46874.9	6752.4	16.8
JUN	42460.6	47178.6	4718.0	11.1
JUL	39846.2	43683.2	3836.9	9.6
AUG	40459.9	44960.1	4500.2	11.1
SEP	33740.3	39638.0	5897.7	17.5
OCT	23972.2	30564.7	6592.4	27.5
NOV	12575.6	14116.0	1540.4	12.2
DEC	18990.9	11290.8	-7700.1	-40.5
Total	330466.4	348227.1	17760.7	5.374440925

Table 26 DA Building Energy Consumption at 0.1 U-Value window *Source: Author*

2. Square ECBC Base case Layout

A) U-Value (Wall)

0.023 U-VALUE (WALL) SQUARE ECBC BASE 2050				
	HEATING LOAD (kWh)	HEATING LOAD (kWh)	(kWh)	PERCENTAGE (%)
	1990	2050	Diff. of 2050 to 1990	Diff. of 2050 to 1990
JAN	2492.0	925.1	-1566.9	-62.87732905
FEB	897.0	254.1	-642.9	-71.67493701
MAR	262.0	262.4	0.4	0.152671756
APR	0.0	0.0	0.0	0
MAY	0.0	0.0	0.0	0
JUN	0.0	0.0	0.0	0
JUL	0.0	0.0	0.0	0
AUG	0.0	0.0	0.0	0
SEP	0.0	0.0	0.0	0
OCT	6.0	0.0	-6.0	0
NOV	511.0	181.9	-329.1	-64.39441781
DEC	1763.0	777.6	-985.4	-55.89397221
Total	5931.0	2401.1	-3529.9	-59.51599106

COOLING LOAD

0.023 U-VALUE (WALL) SQUARE ECBC BASE 2050				
	COOLING LOAD (kWh)	COOLING LOAD (kWh)	(kWh)	PERCENTAGE (%)
	1990	2050	Diff. of 2050 to 1990	Diff. of 2050 to 1990
JAN	3016.9	4083.4	1066.5	35.4
FEB	4227.7	5405.9	1178.2	27.9
MAR	10894.5	11917.2	1022.7	9.4
APR	14981.5	15264.1	282.6	1.9
MAY	26130.7	26651.5	520.8	2.0
JUN	28216.6	27389.8	-826.9	-2.9
JUL	27133.0	25869.1	-1264.0	-4.7
AUG	28333.1	27137.1	-1196.0	-4.2
SEP	23327.1	23560.9	233.8	1.0
OCT	17133.4	18291.4	1158.0	6.8
NOV	7899.6	8150.0	250.4	3.2
DEC	3524.3	4207.6	683.3	19.4
Total	194818.5	197928.0	3109.5	1.59609121

TOTAL HVAC

0.023 U-VALUE (WALL) SQUARE ECBC BASE 2050				
	TOTAL HVAC (kWh)	TOTAL HVAC (kWh)	(kWh)	PERCENTAGE (%)
	1990	2050	Diff. of 2050 to 1990	Diff. of 2050 to 1990
JAN	5509.0	5008.5	-500.5	-9.1
FEB	5124.7	5660.0	535.2	10.4
MAR	11156.9	12179.6	1022.7	9.2
APR	14981.5	15264.1	282.6	1.9
MAY	26130.7	26651.5	520.8	2.0
JUN	28216.6	27389.8	-826.9	-2.9
JUL	27133.0	25869.1	-1264.0	-4.7
AUG	28333.1	27137.1	-1196.0	-4.2
SEP	23327.1	23560.9	233.8	1.0
OCT	17139.8	18291.4	1151.5	6.7
NOV	8410.4	8331.9	-78.5	-0.9
DEC	5287.1	4985.2	-301.9	-5.7
Total	200750.0	200329.1	-420.9	-0.209684978

Table 27 Square Base Energy consumption at 0.023 U-Value *Source: Author*

B) SHGC (Window)

0.01 SHGC SQUARE ECBC BASE 2050				
	HEATING LOAD (kWh)	HEATING LOAD (kWh)	(kWh)	PERCENTAGE (%)
	1990	2050	Diff. of 2050 to 1990	Diff. of 2050 to 1990
JAN	2492.0	1610.3	-881.7	-35.38063644
FEB	897.0	515.3	-381.7	-42.55694314
MAR	262.0	262.4	0.4	0.152671756
APR	0.0	0.0	0.0	0
MAY	0.0	0.0	0.0	0
JUN	0.0	0.0	0.0	0
JUL	0.0	0.0	0.0	0
AUG	0.0	0.0	0.0	0
SEP	0.0	0.0	0.0	0
OCT	6.0	0.0	-6.0	0
NOV	511.0	421.3	-89.7	-17.56320626
DEC	1763.0	1303.6	-459.4	-26.05658593
Total	5931.0	4112.9	-1818.1	-30.6549795

COOLING LOAD

0.01 SHGC SQUARE ECBC BASE 2050				
	COOLING LOAD (kWh)	COOLING LOAD (kWh)	(kWh)	PERCENTAGE (%)
	1990	2050	Diff. of 2050 to 1990	Diff. of 2050 to 1990
JAN	3016.9	3422.8	405.9	13.5
FEB	4227.7	4786.7	559.0	13.2
MAR	10894.5	11522.6	628.1	5.8
APR	14981.5	15397.5	416.0	2.8
MAY	26130.7	28472.4	2341.7	9.0
JUN	28216.6	29268.4	1051.8	3.7
JUL	27133.0	27820.9	687.9	2.5
AUG	28333.1	29507.5	1174.4	4.1
SEP	23327.1	25494.3	2167.2	9.3
OCT	17133.4	19173.0	2039.7	11.9
NOV	7899.6	7527.8	-371.8	-4.7
DEC	3524.3	3519.1	-5.1	-0.1
Total	194818.5	205913.2	11094.7	5.694879514

TOTAL HVAC

0.01 SHGC SQUARE ECBC BASE 2050				
	TOTAL HVAC (kWh)	TOTAL HVAC (kWh)	(kWh)	PERCENTAGE (%)
	1990	2050	Diff. of 2050 to 1990	Diff. of 2050 to 1990
JAN	5509.0	5033.1	-475.9	-8.6
FEB	5124.7	5302.0	177.2	3.5
MAR	11156.9	11785.0	628.1	5.6
APR	14981.5	15397.5	416.0	2.8
MAY	26130.7	28472.4	2341.7	9.0
JUN	28216.6	29268.4	1051.8	3.7
JUL	27133.0	27820.9	687.9	2.5
AUG	28333.1	29507.5	1174.4	4.1
SEP	23327.1	25494.3	2167.2	9.3
OCT	17139.8	19173.0	2033.2	11.9
NOV	8410.4	7949.1	-461.3	-5.5
DEC	5287.1	4822.8	-464.3	-8.8
Total	200750.0	210026.0	9276.0	4.620672672

Table 28 Square Base Energy consumption at 0.01 SHGC *Source: Author*

C) U-Value (Window)

HEATING LOAD				
0.1 U-VALUE (WINDOW) SQUARE ECBC BASE 2050				
	HEATING LOAD (kWh)	HEATING LOAD (kWh)	(kWh)	PERCENTAGE (%)
	1990	2050	Diff. of 2050 to 1990	Diff. of 2050 to 1990
JAN	2492.0	925.1	-1566.9	-62.87732905
FEB	897.0	254.1	-642.9	-71.67493701
MAR	262.0	262.4	0.4	0.152671756
APR	0.0	0.0	0.0	0
MAY	0.0	0.0	0.0	0
JUN	0.0	0.0	0.0	0
JUL	0.0	0.0	0.0	0
AUG	0.0	0.0	0.0	0
SEP	0.0	0.0	0.0	0
OCT	6.0	0.0	-6.0	0
NOV	511.0	181.9	-329.1	-64.39441781
DEC	1763.0	777.6	-985.4	-55.89397221
Total	5931.0	1506.1	-4424.9	-74.6059855

COOLING LOAD				
0.1 U-VALUE (WINDOW) SQUARE ECBC BASE 2050				
	COOLING LOAD (kWh)	COOLING LOAD (kWh)	(kWh)	PERCENTAGE (%)
	1990	2050	Diff. of 2050 to 1990	Diff. of 2050 to 1990
JAN	3016.9	4083.4	1066.5	35.4
FEB	4227.7	5405.9	1178.2	27.9
MAR	10894.5	11917.2	1022.7	9.4
APR	14981.5	15264.1	282.6	1.9
MAY	26130.7	26651.5	520.8	2.0
JUN	28216.6	27389.8	-826.9	-2.9
JUL	27133.0	25869.1	-1264.0	-4.7
AUG	28333.1	27137.1	-1196.0	-4.2
SEP	23327.1	23560.9	233.8	1.0
OCT	17133.4	18291.4	1158.0	6.8
NOV	7899.6	8150.0	250.4	3.2
DEC	3524.3	4207.6	683.3	19.4
Total	194818.5	232910.3	38091.8	19.55245166

TOTAL HVAC				
0.1 U-VALUE (WINDOW) SQUARE ECBC BASE 2050				
	TOTAL HVAC (kWh)	TOTAL HVAC (kWh)	(kWh)	PERCENTAGE (%)
	1990	2050	Diff. of 2050 to 1990	Diff. of 2050 to 1990
JAN	5509.0	5008.5	-500.5	-9.1
FEB	5124.7	5660.0	535.2	10.4
MAR	11156.9	12179.6	1022.7	9.2
APR	14981.5	15264.1	282.6	1.9
MAY	26130.7	26651.5	520.8	2.0
JUN	28216.6	27389.8	-826.9	-2.9
JUL	27133.0	25869.1	-1264.0	-4.7
AUG	28333.1	27137.1	-1196.0	-4.2
SEP	23327.1	23560.9	233.8	1.0
OCT	17139.8	18291.4	1151.5	6.7
NOV	8410.4	8331.9	-78.5	-0.9
DEC	5287.1	4985.2	-301.9	-5.7
Total	200750.0	234416.4	33666.4	16.77029979

Table 29 Square Base Energy consumption at 0.1 U-Value Window *Source: Author*

3. Rectangle ECBC Base case Layout

A) U-Value (Wall)

HEATING LOAD				
0.028 U-VALUE (WALL) RECTANGLE ECBC BASE 2050				
	HEATING LOAD (kWh)	HEATING LOAD (kWh)	(kWh)	PERCENTAGE (%)
	1990	2050	Diff. of 2050 to 1990	Diff. of 2050 to 1990
JAN	2489.0	949.1	-1539.9	-61.86874528
FEB	918.0	256.4	-661.6	-72.06587375
MAR	262.0	262.4	0.4	0.152671756
APR	0.0	0.0	0.0	0
MAY	0.0	0.0	0.0	0
JUN	0.0	0.0	0.0	0
JUL	0.0	0.0	0.0	0
AUG	0.0	0.0	0.0	0
SEP	0.0	0.0	0.0	0
OCT	5.0	0.0	-5.0	0
NOV	507.0	175.9	-331.1	-65.30770888
DEC	1767.0	792.1	-974.9	-55.17455291
Total	5948.0	2435.9	-3512.1	-59.04711205

COOLING LOAD				
0.028 U-VALUE (WALL) RECTANGLE ECBC BASE 2050				
	COOLING LOAD (kWh)	COOLING LOAD (kWh)	(kWh)	PERCENTAGE (%)
	1990	2050	Diff. of 2050 to 1990	Diff. of 2050 to 1990
JAN	3208.8	4303.2	1094.4	34.1
FEB	4345.1	5554.7	1209.7	27.8
MAR	10813.8	11837.9	1024.1	9.5
APR	14578.1	14883.8	305.8	2.1
MAY	25367.2	25930.0	562.7	2.2
JUN	27359.0	26596.3	-762.7	-2.8
JUL	26315.7	25146.9	-1168.9	-4.4
AUG	27532.6	26436.1	-1096.5	-4.0
SEP	22777.8	23033.9	256.1	1.1
OCT	16922.4	18062.9	1140.5	6.7
NOV	8077.6	8343.7	266.1	3.3
DEC	3749.0	4445.5	696.5	18.6
Total	191047.0	194574.8	3527.8	1.846538297

TOTAL HVAC				
0.028 U-VALUE (WALL) RECTANGLE ECBC BASE 2050				
	TOTAL HVAC (kWh)	TOTAL HVAC (kWh)	(kWh)	PERCENTAGE (%)
	1990	2050	Diff. of 2050 to 1990	Diff. of 2050 to 1990
JAN	5698.0	5252.3	-445.7	-7.8
FEB	5263.4	5811.2	547.8	10.4
MAR	11076.2	12100.3	1024.1	9.2
APR	14578.1	14883.8	305.8	2.1
MAY	25367.2	25930.0	562.7	2.2
JUN	27359.0	26596.3	-762.7	-2.8
JUL	26315.7	25146.9	-1168.9	-4.4
AUG	27532.6	26436.1	-1096.5	-4.0
SEP	22777.8	23033.9	256.1	1.1
OCT	16927.6	18062.9	1135.4	6.7
NOV	8584.8	8519.6	-65.2	-0.8
DEC	5516.2	5237.5	-278.6	-5.1
Total	196996.3	197010.6	14.3	0.007261108

Table 30 Rectangle Base Energy consumption at 0.028 U-Value *Source: Author*

B) SHGC (Wall)

HEATING LOAD				
0.028 SHGC RECTANGLE ECBC BASE 2050				
	HEATING LOAD (kWh)	HEATING LOAD (kWh)	(kWh)	PERCENTAGE (%)
	1990	2050	Diff. of 2050 to 1990	Diff. of 2050 to 1990
JAN	2489.0	1691.5	-797.5	-32.0391362
FEB	918.0	543.7	-374.3	-40.76977331
MAR	262.0	262.4	0.4	0.152671756
APR	0.0	0.0	0.0	0
MAY	0.0	0.0	0.0	0
JUN	0.0	0.0	0.0	0
JUL	0.0	0.0	0.0	0
AUG	0.0	0.0	0.0	0
SEP	0.0	0.0	0.0	0
OCT	5.0	0.0	-5.0	0
NOV	507.0	439.7	-67.3	-13.26775878
DEC	1767.0	1382.2	-384.8	-21.77624505
Total	5948.0	4319.6	-1628.4	-27.37683937

COOLING LOAD				
0.028 SHGC RECTANGLE ECBC BASE 2050				
	COOLING LOAD (kWh)	COOLING LOAD (kWh)	(kWh)	PERCENTAGE (%)
	1990	2050	Diff. of 2050 to 1990	Diff. of 2050 to 1990
JAN	3208.8	3414.8	206.0	6.4
FEB	4345.1	4748.5	403.4	9.3
MAR	10813.8	11294.3	480.6	4.4
APR	14578.1	15035.9	457.8	3.1
MAY	25367.2	27746.3	2379.0	9.4
JUN	27359.0	28497.7	1138.7	4.2
JUL	26315.7	27042.4	726.6	2.8
AUG	27532.6	28623.8	1091.2	4.0
SEP	22777.8	24790.1	2012.3	8.8
OCT	16922.4	18668.7	1746.3	10.3
NOV	8077.6	7417.4	-660.2	-8.2
DEC	3749.0	3500.3	-248.7	-6.6
Total	191047.0	200780.2	9733.2	5.094639818

TOTAL HVAC				
0.028 SHGC RECTANGLE ECBC BASE 2050				
	TOTAL HVAC (kWh)	TOTAL HVAC (kWh)	(kWh)	PERCENTAGE (%)
	1990	2050	Diff. of 2050 to 1990	Diff. of 2050 to 1990
JAN	5698.0	5106.4	-591.6	-10.4
FEB	5263.4	5292.2	28.9	0.5
MAR	11076.2	11556.7	480.6	4.3
APR	14578.1	15035.9	457.8	3.1
MAY	25367.2	27746.3	2379.0	9.4
JUN	27359.0	28497.7	1138.7	4.2
JUL	26315.7	27042.4	726.6	2.8
AUG	27532.6	28623.8	1091.2	4.0
SEP	22777.8	24790.1	2012.3	8.8
OCT	16927.6	18668.7	1741.1	10.3
NOV	8584.8	7857.1	-727.6	-8.5
DEC	5516.2	4882.5	-633.6	-11.5
Total	196996.3	205099.8	8103.5	4.113504243

Table 31 Rectangle Base Energy consumption at 0.028 SHGC *Source: Author*

C) U-Value (Wall)

HEATING LOAD				
0.1 U-VALUE (WINDOW) RECTANGLE ECBC BASE 2050				
	HEATING LOAD (kWh)	HEATING LOAD (kWh)	(kWh)	PERCENTAGE (%)
	1990	2050	Diff. of 2050 to 1990	Diff. of 2050 to 1990
JAN	2489.0	949.1	-1539.9	-61.86874528
FEB	918.0	256.4	-661.6	-72.06587375
MAR	262.0	262.4	0.4	0.152671756
APR	0.0	0.0	0.0	0
MAY	0.0	0.0	0.0	0
JUN	0.0	0.0	0.0	0
JUL	0.0	0.0	0.0	0
AUG	0.0	0.0	0.0	0
SEP	0.0	0.0	0.0	0
OCT	5.0	0.0	-5.0	0
NOV	507.0	175.9	-331.1	-65.30770888
DEC	1767.0	792.1	-974.9	-55.17455291
Total	5948.0	1420.5	-4527.5	-76.11768662

COOLING LOAD				
0.1 U-VALUE (WINDOW) RECTANGLE ECBC BASE 2050				
	COOLING LOAD (kWh)	COOLING LOAD (kWh)	(kWh)	PERCENTAGE (%)
	1990	2050	Diff. of 2050 to 1990	Diff. of 2050 to 1990
JAN	3208.8	4303.2	1094.4	34.1
FEB	4345.1	5554.7	1209.7	27.8
MAR	10813.8	11837.9	1024.1	9.5
APR	14578.1	14883.8	305.8	2.1
MAY	25367.2	25930.0	562.7	2.2
JUN	27359.0	26596.3	-762.7	-2.8
JUL	26315.7	25146.9	-1168.9	-4.4
AUG	27532.6	26436.1	-1096.5	-4.0
SEP	22777.8	23033.9	256.1	1.1
OCT	16922.4	18062.9	1140.5	6.7
NOV	8077.6	8343.7	266.1	3.3
DEC	3749.0	4445.5	696.5	18.6
Total	191047.0	228240.2	37193.2	19.46808445

TOTAL HVAC				
0.1 U-VALUE (WINDOW) RECTANGLE ECBC BASE 2050				
	TOTAL HVAC (kWh)	TOTAL HVAC (kWh)	(kWh)	PERCENTAGE (%)
	1990	2050	Diff. of 2050 to 1990	Diff. of 2050 to 1990
JAN	5698.0	5252.3	-445.7	-7.8
FEB	5263.4	5811.2	547.8	10.4
MAR	11076.2	12100.3	1024.1	9.2
APR	14578.1	14883.8	305.8	2.1
MAY	25367.2	25930.0	562.7	2.2
JUN	27359.0	26596.3	-762.7	-2.8
JUL	26315.7	25146.9	-1168.9	-4.4
AUG	27532.6	26436.1	-1096.5	-4.0
SEP	22777.8	23033.9	256.1	1.1
OCT	16927.6	18062.9	1135.4	6.7
NOV	8584.8	8519.6	-65.2	-0.8
DEC	5516.2	5237.5	-278.6	-5.1
Total	196996.3	229660.7	32664.4	16.58121333

Table 32 Rectangle Base Energy consumption at 0.1 U-Value window *Source: Author*

4. Curve ECBC Base case Layout

A) U-Value (Wall)

HEATING LOAD					
0.025 U-VALUE CURVE BASE CASE 2050					
	HEATING LOAD (kWh)	HEATING LOAD (kWh)		(kWh)	PERCENTAGE (%)
	1990	2050		Diff. of 2050 to 1990	Diff. of 2050 to 1990
JAN	3126.0	1156.4		-1969.6	-63.00782956
FEB	1110.0	278.8		-831.2	-74.88684054
MAR	262.0	262.4		0.4	0.152671756
APR	0.0	0.0		0.0	0
MAY	0.0	0.0		0.0	0
JUN	0.0	0.0		0.0	0
JUL	0.0	0.0		0.0	0
AUG	0.0	0.0		0.0	0
SEP	0.0	0.0		0.0	0
OCT	8.0	0.0		-8.0	0
NOV	575.0	185.0		-390.0	-67.81897026
DEC	2206.0	956.4		-1249.6	-56.64434995
Total	7287.0	2839.0		-4448.0	-61.0402377

COOLING LOAD					
0.025 U-VALUE CURVE BASE CASE 2050					
	COOLING LOAD (kWh)	COOLING LOAD (kWh)		(kWh)	PERCENTAGE (%)
	1990	2050		Diff. of 2050 to 1990	Diff. of 2050 to 1990
JAN	3078.8	4239.6		1160.8	37.7
FEB	4296.9	5638.3		1341.3	31.2
MAR	11607.5	12875.1		1267.6	10.9
APR	16184.2	16585.2		401.0	2.5
MAY	28757.5	29665.0		907.5	3.2
JUN	31126.6	30489.1		-637.5	-2.0
JUL	30021.4	28855.2		-1166.2	-3.9
AUG	31398.5	30415.5		-983.0	-3.1
SEP	25799.9	26420.3		620.5	2.4
OCT	18716.7	20371.3		1654.6	8.8
NOV	8383.3	8747.7		364.4	4.3
DEC	3633.0	4419.3		786.3	21.6
Total	213004.4	218721.8		5717.4	2.684158925

TOTAL HVAC					
0.025 U-VALUE CURVE BASE CASE 2050					
	TOTAL HVAC (kWh)	TOTAL HVAC (kWh)		(kWh)	PERCENTAGE (%)
	1990	2050		Diff. of 2050 to 1990	Diff. of 2050 to 1990
JAN	6205.0	5396.0		-809.0	-13.0
FEB	5406.6	5917.0		510.4	9.4
MAR	11869.9	13137.5		1267.6	10.7
APR	16184.2	16585.2		401.0	2.5
MAY	28757.5	29665.0		907.5	3.2
JUN	31126.6	30489.1		-637.5	-2.0
JUL	30021.4	28855.2		-1166.2	-3.9
AUG	31398.5	30415.5		-983.0	-3.1
SEP	25799.9	26420.3		620.5	2.4
OCT	18725.1	20371.3		1646.2	8.8
NOV	8958.0	8932.8		-25.2	-0.3
DEC	5839.3	5375.7		-463.6	-7.9
Total	220292.1	221560.8		1268.7	0.575915107

Table 33 Curve Base Energy consumption at 0.025 U-Value *Source: Author*

B) SHGC (Window)

HEATING LOAD				
0.01 SHGC CURVE BASE CASE 2050				
	HEATING LOAD (kWh)	HEATING LOAD (kWh)	(kWh)	PERCENTAGE (%)
	1990	2050	Diff. of 2050 to 1990	Diff. of 2050 to 1990
JAN	3126.0	1913.8	-1212.2	-38.77835125
FEB	1110.0	574.3	-535.7	-48.26288964
MAR	262.0	262.4	0.4	0.152671756
APR	0.0	0.0	0.0	0
MAY	0.0	0.0	0.0	0
JUN	0.0	0.0	0.0	0
JUL	0.0	0.0	0.0	0
AUG	0.0	0.0	0.0	0
SEP	0.0	0.0	0.0	0
OCT	8.0	0.0	-8.0	0
NOV	575.0	445.7	-129.3	-22.49210452
DEC	2206.0	1561.8	-644.2	-29.20372076
Total	7287.0	4757.9	-2529.1	-34.70691665

COOLING LOAD				
0.01 SHGC CURVE BASE CASE 2050				
	COOLING LOAD (kWh)	COOLING LOAD (kWh)	(kWh)	PERCENTAGE (%)
	1990	2050	Diff. of 2050 to 1990	Diff. of 2050 to 1990
JAN	3078.8	3604.1	525.3	17.1
FEB	4296.9	5092.5	795.6	18.5
MAR	11607.5	12719.5	1112.0	9.6
APR	16184.2	17154.3	970.1	6.0
MAY	28757.5	32091.5	3334.0	11.6
JUN	31126.6	33014.7	1888.1	6.1
JUL	30021.4	31406.5	1385.1	4.6
AUG	31398.5	33209.4	1810.9	5.8
SEP	25799.9	28696.3	2896.4	11.2
OCT	18716.7	21456.4	2739.7	14.6
NOV	8383.3	8185.1	-198.3	-2.4
DEC	3633.0	3729.4	96.5	2.7
Total	213004.4	230359.8	17355.4	8.147886844

TOTAL HVAC				
0.01 SHGC CURVE BASE CASE 2050				
	TOTAL HVAC (kWh)	TOTAL HVAC (kWh)	(kWh)	PERCENTAGE (%)
	1990	2050	Diff. of 2050 to 1990	Diff. of 2050 to 1990
JAN	6205.0	5517.9	-687.1	-11.1
FEB	5406.6	5666.8	260.2	4.8
MAR	11869.9	12981.9	1112.0	9.4
APR	16184.2	17154.3	970.1	6.0
MAY	28757.5	32091.5	3334.0	11.6
JUN	31126.6	33014.7	1888.1	6.1
JUL	30021.4	31406.5	1385.1	4.6
AUG	31398.5	33209.4	1810.9	5.8
SEP	25799.9	28696.3	2896.4	11.2
OCT	18725.1	21456.4	2731.3	14.6
NOV	8958.0	8630.7	-327.3	-3.7
DEC	5839.3	5291.2	-548.1	-9.4
Total	220292.1	235117.7	14825.6	6.729967506

Table 34 Curve Base Energy consumption at 0.01 SHGC *Source: Author*

C) U-Value (Window)

HEATING LOAD				
0.1 U-VALUE (WINDOW) DA HEAQUARTERS 2050				
	HEATING LOAD (kWh)	HEATING LOAD (kWh)	(kWh)	PERCENTAGE (%)
	1990	2050	Diff. of 2050 to 1990	Diff. of 2050 to 1990
JAN	3126.0	907.9	-2218.1	-70.9552382
FEB	1110.0	172.7	-937.3	-84.43719739
MAR	262.0	262.4	0.4	0.152671756
APR	0.0	0.0	0.0	0
MAY	0.0	0.0	0.0	0
JUN	0.0	0.0	0.0	0
JUL	0.0	0.0	0.0	0
AUG	0.0	0.0	0.0	0
SEP	0.0	0.0	0.0	0
OCT	8.0	0.0	-8.0	0
NOV	575.0	97.1	-477.9	-83.11551183
DEC	2206.0	717.8	-1488.2	-67.46226337
Total	7287.0	2158.0	-5129.0	-70.3862407

COOLING LOAD				
0.1 U-VALUE (WINDOW) DA HEAQUARTERS 2050				
	COOLING LOAD (kWh)	COOLING LOAD (kWh)	(kWh)	PERCENTAGE (%)
	1990	2050	Diff. of 2050 to 1990	Diff. of 2050 to 1990
JAN	3078.8	5804.4	2725.7	88.5
FEB	4296.9	7328.3	3031.3	70.5
MAR	11607.5	15433.0	3825.5	33.0
APR	16184.2	19190.3	3006.1	18.6
MAY	28757.5	33965.4	5207.9	18.1
JUN	31126.6	34775.6	3649.0	11.7
JUL	30021.4	33099.5	3078.2	10.3
AUG	31398.5	35064.5	3665.9	11.7
SEP	25799.9	30510.8	4710.9	18.3
OCT	18716.7	23951.7	5235.0	28.0
NOV	8383.3	10899.7	2516.4	30.0
DEC	3633.0	5931.4	2298.4	63.3
Total	213004.4	255954.7	42950.3	20.16403717

TOTAL HVAC				
0.1 U-VALUE (WINDOW) DA HEAQUARTERS 2050				
	TOTAL HVAC (kWh)	TOTAL HVAC (kWh)	(kWh)	PERCENTAGE (%)
	1990	2050	Diff. of 2050 to 1990	Diff. of 2050 to 1990
JAN	6205.0	6712.4	507.4	8.2
FEB	5406.6	7501.0	2094.4	38.7
MAR	11869.9	15695.4	3825.5	32.2
APR	16184.2	19190.3	3006.1	18.6
MAY	28757.5	33965.4	5207.9	18.1
JUN	31126.6	34775.6	3649.0	11.7
JUL	30021.4	33099.5	3078.2	10.3
AUG	31398.5	35064.5	3665.9	11.7
SEP	25799.9	30510.8	4710.9	18.3
OCT	18725.1	23951.7	5226.6	27.9
NOV	8958.0	10996.8	2038.8	22.8
DEC	5839.3	6649.2	809.9	13.9
Total	220292.1	258112.6	37820.6	17.16837121

Table 35 Curve Base Energy consumption at 0.1 U-Value window *Source: Author*

5. Triangle ECBC Base case Layout

A) U-Value (Wall)

HEATING LOAD				
0.027 U-VALUE TRIANGLE BASE CASE 2050				
	HEATING LOAD (kWh)	HEATING LOAD (kWh)	(kWh)	PERCENTAGE (%)
	1990	2050	Diff. of 2050 to 1990	Diff. of 2050 to 1990
JAN	2464.0	870.7	-1593.3	-64.66301238
FEB	843.0	211.1	-631.9	-74.95477817
MAR	262.0	262.4	0.4	0.152671756
APR	0.0	0.0	0.0	0
MAY	0.0	0.0	0.0	0
JUN	0.0	0.0	0.0	0
JUL	0.0	0.0	0.0	0
AUG	0.0	0.0	0.0	0
SEP	0.0	0.0	0.0	0
OCT	5.0	0.0	-5.0	0
NOV	439.0	143.5	-295.5	-67.32067335
DEC	1712.0	720.1	-991.9	-57.93562208
Total	5725.0	2207.8	-3517.2	-61.43512683

COOLING LOAD				
0.027 U-VALUE TRIANGLE BASE CASE 2050				
	COOLING LOAD (kWh)	COOLING LOAD (kWh)	(kWh)	PERCENTAGE (%)
	1990	2050	Diff. of 2050 to 1990	Diff. of 2050 to 1990
JAN	2615.4	3547.6	932.3	35.6
FEB	3648.7	4729.3	1080.6	29.6
MAR	9832.6	10838.4	1005.8	10.2
APR	13721.3	14032.9	311.6	2.3
MAY	23757.8	24271.9	514.1	2.2
JUN	25575.5	24821.8	-753.8	-2.9
JUL	24636.9	23495.6	-1141.3	-4.6
AUG	25779.3	24680.6	-1098.7	-4.3
SEP	21327.2	21505.6	178.4	0.8
OCT	15595.0	16676.1	1081.1	6.9
NOV	7087.7	7328.3	240.6	3.4
DEC	3087.7	3713.5	625.9	20.3
Total	176665.0	179641.7	2976.7	1.684934543

TOTAL HVAC				
0.027 U-VALUE TRIANGLE BASE CASE 2050				
	TOTAL HVAC (kWh)	TOTAL HVAC (kWh)	(kWh)	PERCENTAGE (%)
	1990	2050	Diff. of 2050 to 1990	Diff. of 2050 to 1990
JAN	5079.0	4418.3	-660.7	-13.0
FEB	4491.5	4940.4	449.0	10.0
MAR	10095.0	11100.8	1005.8	10.0
APR	13721.3	14032.9	311.6	2.3
MAY	23757.8	24271.9	514.1	2.2
JUN	25575.5	24821.8	-753.8	-2.9
JUL	24636.9	23495.6	-1141.3	-4.6
AUG	25779.3	24680.6	-1098.7	-4.3
SEP	21327.2	21505.6	178.4	0.8
OCT	15599.8	16676.1	1076.3	6.9
NOV	7527.1	7471.8	-55.3	-0.7
DEC	4799.3	4433.7	-365.6	-7.6
Total	182389.6	181849.5	-540.1	-0.296103479

Table 36 Triangle Base Energy consumption at 0.027 U-Value *Source: Author*

B) SHGC (Window)

HEATING LOAD				
0.01 SHGC TRIANGLE BASE CASE 2050				
	HEATING LOAD (kWh)	HEATING LOAD (kWh)	(kWh)	PERCENTAGE (%)
	1990	2050	Diff. of 2050 to 1990	Diff. of 2050 to 1990
JAN	2464.0	1637.1	-826.9	-33.56126907
FEB	843.0	489.1	-353.9	-41.98436785
MAR	262.0	262.4	0.4	0.152671756
APR	0.0	0.0	0.0	0
MAY	0.0	0.0	0.0	0
JUN	0.0	0.0	0.0	0
JUL	0.0	0.0	0.0	0
AUG	0.0	0.0	0.0	0
SEP	0.0	0.0	0.0	0
OCT	5.0	0.0	-5.0	0
NOV	439.0	389.8	-49.2	-11.20354305
DEC	1712.0	1321.9	-390.1	-22.78800292
Total	5725.0	4100.2	-1624.8	-28.38064725

COOLING LOAD				
0.01 SHGC TRIANGLE BASE CASE 2050				
	COOLING LOAD (kWh)	COOLING LOAD (kWh)	(kWh)	PERCENTAGE (%)
	1990	2050	Diff. of 2050 to 1990	Diff. of 2050 to 1990
JAN	2615.4	2659.5	44.2	1.7
FEB	3648.7	3868.9	220.3	6.0
MAR	9832.6	10037.4	204.7	2.1
APR	13721.3	13803.7	82.4	0.6
MAY	23757.8	25893.8	2136.0	9.0
JUN	25575.5	26612.7	1037.2	4.1
JUL	24636.9	25265.6	628.7	2.6
AUG	25779.3	26684.6	905.3	3.5
SEP	21327.2	23038.0	1710.8	8.0
OCT	15595.0	17084.7	1489.7	9.6
NOV	7087.7	6349.5	-738.2	-10.4
DEC	3087.7	2778.0	-309.7	-10.0
Total	176665.0	184076.4	7411.4	4.19517999

TOTAL HVAC				
0.01 SHGC TRIANGLE BASE CASE 2050				
	TOTAL HVAC (kWh)	TOTAL HVAC (kWh)	(kWh)	PERCENTAGE (%)
	1990	2050	Diff. of 2050 to 1990	Diff. of 2050 to 1990
JAN	5079.0	4296.6	-782.4	-15.4
FEB	4491.5	4358.0	-133.4	-3.0
MAR	10095.0	10299.8	204.7	2.0
APR	13721.3	13803.7	82.4	0.6
MAY	23757.8	25893.8	2136.0	9.0
JUN	25575.5	26612.7	1037.2	4.1
JUL	24636.9	25265.6	628.7	2.6
AUG	25779.3	26684.6	905.3	3.5
SEP	21327.2	23038.0	1710.8	8.0
OCT	15599.8	17084.7	1484.9	9.5
NOV	7527.1	6739.3	-787.8	-10.5
DEC	4799.3	4099.9	-699.4	-14.6
Total	182389.6	188176.6	5787.0	3.172895983

Table 37 Triangle Base Energy consumption at 0.01 SHGC *Source: Author*

C) U-Value (Window)

HEATING LOAD					
0.1 U-VALUE (WINDOW) TRIANGLE BASE CASE 2050					
	HEATING LOAD (kWh)	HEATING LOAD (kWh)		(kWh)	PERCENTAGE (%)
	1990	2050		Diff. of 2050 to 1990	Diff. of 2050 to 1990
JAN	2464.0	558.7		-1905.3	-77.32429099
FEB	843.0	100.6		-742.4	-88.06146311
MAR	262.0	262.4		0.4	0.152671756
APR	0.0	0.0		0.0	0
MAY	0.0	0.0		0.0	0
JUN	0.0	0.0		0.0	0
JUL	0.0	0.0		0.0	0
AUG	0.0	0.0		0.0	0
SEP	0.0	0.0		0.0	0
OCT	5.0	0.0		-5.0	0
NOV	439.0	46.3		-392.7	-89.44994579
DEC	1712.0	440.7		-1271.3	-74.26080794
Total	5725.0	1408.7		-4316.3	-75.39316957

COOLING LOAD					
0.1 U-VALUE (WINDOW) TRIANGLE BASE CASE 2050					
	COOLING LOAD (kWh)	COOLING LOAD (kWh)		(kWh)	PERCENTAGE (%)
	1990	2050		Diff. of 2050 to 1990	Diff. of 2050 to 1990
JAN	2615.4	4956.7		2341.3	89.5
FEB	3648.7	6266.1		2617.4	71.7
MAR	9832.6	13093.1		3260.5	33.2
APR	13721.3	16180.7		2459.3	17.9
MAY	23757.8	27710.8		3953.0	16.6
JUN	25575.5	28201.9		2626.4	10.3
JUL	24636.9	26906.9		2270.1	9.2
AUG	25779.3	28501.6		2722.3	10.6
SEP	21327.2	24939.5		3612.3	16.9
OCT	15595.0	19809.6		4214.6	27.0
NOV	7087.7	9234.3		2146.6	30.3
DEC	3087.7	5071.8		1984.1	64.3
Total	176665.0	210873.0		34208.0	19.36319753

TOTAL HVAC					
0.1 U-VALUE (WINDOW) TRIANGLE BASE CASE 2050					
	TOTAL HVAC (kWh)	TOTAL HVAC (kWh)		(kWh)	PERCENTAGE (%)
	1990	2050		Diff. of 2050 to 1990	Diff. of 2050 to 1990
JAN	5079.0	5515.4		436.4	8.6
FEB	4491.5	6366.8		1875.3	41.8
MAR	10095.0	13355.5		3260.5	32.3
APR	13721.3	16180.7		2459.3	17.9
MAY	23757.8	27710.8		3953.0	16.6
JUN	25575.5	28201.9		2626.4	10.3
JUL	24636.9	26906.9		2270.1	9.2
AUG	25779.3	28501.6		2722.3	10.6
SEP	21327.2	24939.5		3612.3	16.9
OCT	15599.8	19809.6		4209.8	27.0
NOV	7527.1	9280.7		1753.6	23.3
DEC	4799.3	5512.4		713.1	14.9
Total	182389.6	212281.8		29892.1	16.38917191

Table 38 Triangle Base Energy consumption at 0.01 U-Value window *Source: Author*

6. U-Shaped ECBC Base case Layout

A) U-Value (Wall)

HEATING LOAD				
0.035 U-VALUE U-SHAPED BASE CASE 2050				
	HEATING LOAD (kWh)	HEATING LOAD (kWh)	(kWh)	PERCENTAGE (%)
	1990	2050	Diff. of 2050 to 1990	Diff. of 2050 to 1990
JAN	2720.0	977.8	-1742.2	-64.05024816
FEB	962.0	251.3	-710.7	-73.88012921
MAR	262.0	262.4	0.4	0.152671756
APR	0.0	0.0	0.0	0
MAY	0.0	0.0	0.0	0
JUN	0.0	0.0	0.0	0
JUL	0.0	0.0	0.0	0
AUG	0.0	0.0	0.0	0
SEP	0.0	0.0	0.0	0
OCT	4.0	0.0	-4.0	0
NOV	511.0	171.6	-339.4	-66.42734344
DEC	1938.0	839.3	-1098.7	-56.69431011
Total	6397.0	2502.3	-3894.7	-60.88280519

COOLING LOAD				
0.035 U-VALUE U-SHAPED BASE CASE 2050				
	COOLING LOAD (kWh)	COOLING LOAD (kWh)	(kWh)	PERCENTAGE (%)
	1990	2050	Diff. of 2050 to 1990	Diff. of 2050 to 1990
JAN	2955.6	4131.9	1176.3	39.8
FEB	4180.6	5491.3	1310.7	31.4
MAR	11046.7	12187.2	1140.5	10.3
APR	15436.0	15778.9	342.8	2.2
MAY	26319.1	26865.4	546.3	2.1
JUN	28366.1	27610.9	-755.2	-2.7
JUL	27023.9	25820.5	-1203.4	-4.5
AUG	28002.0	26799.1	-1202.9	-4.3
SEP	23090.8	23314.1	223.3	1.0
OCT	17034.5	18155.2	1120.6	6.6
NOV	7892.8	8255.9	363.1	4.6
DEC	3451.3	4259.2	807.9	23.4
Total	194799.4	198669.5	3870.1	1.986728327

TOTAL HVAC				
0.035 U-VALUE U-SHAPED BASE CASE 2050				
	TOTAL HVAC (kWh)	TOTAL HVAC (kWh)	(kWh)	PERCENTAGE (%)
	1990	2050	Diff. of 2050 to 1990	Diff. of 2050 to 1990
JAN	5675.0	5109.8	-565.2	-10.0
FEB	5142.3	5742.6	600.3	11.7
MAR	11309.1	12449.6	1140.5	10.1
APR	15436.0	15778.9	342.8	2.2
MAY	26319.1	26865.4	546.3	2.1
JUN	28366.1	27610.9	-755.2	-2.7
JUL	27023.9	25820.5	-1203.4	-4.5
AUG	28002.0	26799.1	-1202.9	-4.3
SEP	23090.8	23314.1	223.3	1.0
OCT	17038.3	18155.2	1116.9	6.6
NOV	8403.7	8427.4	23.8	0.3
DEC	5388.9	5098.5	-290.4	-5.4
Total	201195.1	201171.9	-23.2	-0.011536577

Table 39 U-Shaped Base Energy consumption at 0.035 U-Value *Source: Author*

B) SHGC (Window)

HEATING LOAD				
0.03 SHGC U-SHAPED BASE CASE 2050				
	HEATING LOAD (kWh)	HEATING LOAD (kWh)	(kWh)	PERCENTAGE (%)
	1990	2050	Diff. of 2050 to 1990	Diff. of 2050 to 1990
JAN	2720.0	1876.3	-843.7	-31.01742132
FEB	962.0	591.7	-370.3	-38.48917058
MAR	262.0	262.4	0.4	0.152671756
APR	0.0	0.0	0.0	0
MAY	0.0	0.0	0.0	0
JUN	0.0	0.0	0.0	0
JUL	0.0	0.0	0.0	0
AUG	0.0	0.0	0.0	0
SEP	0.0	0.0	0.0	0
OCT	4.0	0.0	-4.0	0
NOV	511.0	468.9	-42.1	-8.236359883
DEC	1938.0	1544.1	-393.9	-20.32677296
Total	6397.0	4743.4	-1653.6	-25.84899703

COOLING LOAD				
0.03 SHGC U-SHAPED BASE CASE 2050				
	COOLING LOAD (kWh)	COOLING LOAD (kWh)	(kWh)	PERCENTAGE (%)
	1990	2050	Diff. of 2050 to 1990	Diff. of 2050 to 1990
JAN	2955.6	2897.8	-57.8	-2.0
FEB	4180.6	4211.7	31.1	0.7
MAR	11046.7	10768.1	-278.6	-2.5
APR	15436.0	14837.7	-598.4	-3.9
MAY	26319.1	27471.6	1152.6	4.4
JUN	28366.1	28227.2	-138.9	-0.5
JUL	27023.9	26725.8	-298.1	-1.1
AUG	28002.0	28123.6	121.6	0.4
SEP	23090.8	24322.4	1231.6	5.3
OCT	17034.5	18093.4	1058.8	6.2
NOV	7892.8	6837.1	-1055.8	-13.4
DEC	3451.3	3022.4	-428.8	-12.4
Total	194799.4	195538.8	739.4	0.379558585

TOTAL HVAC				
0.03 SHGC U-SHAPED BASE CASE 2050				
	TOTAL HVAC (kWh)	TOTAL HVAC (kWh)	(kWh)	PERCENTAGE (%)
	1990	2050	Diff. of 2050 to 1990	Diff. of 2050 to 1990
JAN	5675.0	4774.1	-900.9	-15.9
FEB	5142.3	4803.4	-338.9	-6.6
MAR	11309.1	11030.5	-278.6	-2.5
APR	15436.0	14837.7	-598.4	-3.9
MAY	26319.1	27471.6	1152.6	4.4
JUN	28366.1	28227.2	-138.9	-0.5
JUL	27023.9	26725.8	-298.1	-1.1
AUG	28002.0	28123.6	121.6	0.4
SEP	23090.8	24322.4	1231.6	5.3
OCT	17038.3	18093.4	1055.1	6.2
NOV	8403.7	7306.0	-1097.7	-13.1
DEC	5388.9	4566.5	-822.4	-15.3
Total	201195.1	200282.2	-912.9	-0.453716528

Table 40 U-Shaped Base Energy consumption at 0.03 SHGC *Source: Author*

C) U-Value (Window)

HEATING LOAD				
0.1 U-VALUE (WINDOW) U-SHAPED BASE CASE 2050				
	HEATING LOAD (kWh)	HEATING LOAD (kWh)	(kWh)	PERCENTAGE (%)
	1990	2050	Diff. of 2050 to 1990	Diff. of 2050 to 1990
JAN	2720.0	553.0	-2167.0	-79.67092588
FEB	962.0	95.7	-866.3	-90.04684366
MAR	262.0	262.4	0.4	0.152671756
APR	0.0	0.0	0.0	0
MAY	0.0	0.0	0.0	0
JUN	0.0	0.0	0.0	0
JUL	0.0	0.0	0.0	0
AUG	0.0	0.0	0.0	0
SEP	0.0	0.0	0.0	0
OCT	4.0	0.0	-4.0	0
NOV	511.0	50.8	-460.2	-90.06144579
DEC	1938.0	447.2	-1490.8	-76.92241073
Total	6397.0	1409.1	-4987.9	-77.97202013

COOLING LOAD				
0.1 U-VALUE (WINDOW) U-SHAPED BASE CASE 2050				
	COOLING LOAD (kWh)	COOLING LOAD (kWh)	(kWh)	PERCENTAGE (%)
	1990	2050	Diff. of 2050 to 1990	Diff. of 2050 to 1990
JAN	2955.6	5737.6	2782.1	94.1
FEB	4180.6	7202.0	3021.4	72.3
MAR	11046.7	14577.1	3530.3	32.0
APR	15436.0	18007.8	2571.8	16.7
MAY	26319.1	30480.0	4160.9	15.8
JUN	28366.1	31206.7	2840.6	10.0
JUL	27023.9	29472.0	2448.1	9.1
AUG	28002.0	30909.0	2907.0	10.4
SEP	23090.8	26900.7	3809.9	16.5
OCT	17034.5	21443.8	4409.2	25.9
NOV	7892.8	10357.5	2464.7	31.2
DEC	3451.3	5803.9	2352.7	68.2
Total	194799.4	232098.0	37298.6	19.14720111

TOTAL HVAC				
0.1 U-VALUE (WINDOW) U-SHAPED BASE CASE 2050				
	TOTAL HVAC (kWh)	TOTAL HVAC (kWh)	(kWh)	PERCENTAGE (%)
	1990	2050	Diff. of 2050 to 1990	Diff. of 2050 to 1990
JAN	5675.0	6290.6	615.6	10.8
FEB	5142.3	7297.8	2155.5	41.9
MAR	11309.1	14839.5	3530.3	31.2
APR	15436.0	18007.8	2571.8	16.7
MAY	26319.1	30480.0	4160.9	15.8
JUN	28366.1	31206.7	2840.6	10.0
JUL	27023.9	29472.0	2448.1	9.1
AUG	28002.0	30909.0	2907.0	10.4
SEP	23090.8	26900.7	3809.9	16.5
OCT	17038.3	21443.8	4405.5	25.9
NOV	8403.7	10408.3	2004.6	23.9
DEC	5388.9	6251.2	862.3	16.0
Total	201195.1	233507.2	32312.1	16.06008012

Table 41 U-Shaped Base Energy consumption at 0.1 U-Value Window *Source: Author*

RESEARCH FINDINGS

Simulations results analysis explains how different building models are operating and preforming in relationship with each other. This relationship has been explained in terms of percentage.

CASE TYPE	LOADS TYPE	1990	2020	2050	Average Increase
DA BUILDING	Heating Loads	-	-29.23%	-41.97%	-35.600%
	Cooling laods	-	11%	10%	10.500%
	Total HVAC	-	4%	5%	4.500%
SQAURE BASE	Heating Loads	-	-23.65%	-35.81%	-29.730%
	Cooling laods	-	9.96%	9.48%	9.720%
	Total HVAC	-	8.97%	8.55%	8.760%
RECTANGLE BASE	Heating Loads	-	-22.50%	-35.97%	-29.235%
	Cooling laods	-	9.90%	9.40%	9.650%
	Total HVAC	-	8.91%	8.43%	8.670%
CURVE BASE	Heating Loads	-	-24.22%	-37.73%	-30.975%
	Cooling laods	-	10.32%	9.66%	9.990%
	Total HVAC	-	9.17%	8.58%	8.875%
TRIANGLE BASE	Heating Loads	-	-32.08%	-36.63%	-34.355%
	Cooling laods	-	10%	7.19%	8.595%
	Total HVAC	-	9.37%	6.78%	8.075%
U-SHAPED BASE	Heating Loads	-	-32%	-37%	-34.500%
	Cooling laods	-	10%	7%	8.500%
	Total HVAC	-	9%	7%	8.000%

Table 42 AVERAGE ENERGY CHANGE FOR EACH CASE TYPE (2020, 2050)

Energy simulations for **DA Building** indicates a decrease in heating energy demands by **35.6%** on average, cooling energy demand by **10.5%,** and overall energy demand by **4.5%.**

Energy simulations for **Square Base Case** indicates a decrease in heating energy demands by **29.73%** on average, cooling energy demand by **9.72%,** and overall energy demand by **8.76%.**

Energy simulations for **Rectangle Base Case** results indicated a decrease in heating energy demands by **29.23%** on average, cooling energy demand by **9.65%,** and overall energy demand by **8.67%.**

Energy simulations for **Curve Base Case** results indicated a decrease in heating energy demands by **30.97%** on average, cooling energy demand by **9.99%,** and overall energy demand by **8.87%.**

Energy simulations for **Triangle Base Case** results indicated a decrease in heating energy demands by **34.35%** on average, cooling energy demand by **8.59%,** and overall energy demand by **8.07%.**

Energy simulations for **U-Shaped Base Case** results indicated a decrease in heating energy demands by **34.5%** on average, cooling energy demand by **8.5%,** and overall energy demand by **8.0%.**

ENERGY CONSUMPTION IN VARIOUS PROFILES			
	1990 (%)	2020 (%)	2050 (%)
SQUARE	BASE	8.97%	8.55%
RECTANGLE	-1.87	8.91%	8.43%
CURVE	9.73	9.17%	8.58%
TRIANGLE	-9.15	9.37%	6.78%
U-SHAPED	0.22	9%	7%

Table 43 Variations in Energy Consumption in Various Profile

Comparison between the energy consumption between various profiles show a significant difference in the energy consumed in various profiles. In this analysis, to carry out the comparative analysis, energy consumption of square base case has been considered as reference case.

Percentage variation the first column of the above table shows values in terms of percentage. This percentage is the energy consumed by various profiles as compared to Square profile. **Triangle Profile** when show **least energy** consumed among these profiles. Where are **Curve Profile** Layout Consumed **maximum energy** as compared to Square Profile.

CONCLUSIONS

Mitigative strategies used here just to find out that at what value, a single mitigative factor can be able to Limit the energy consumption of future scenario to the present scenario.

Mitigation factors selected for this study are

1. U-Value (External Wall)
2. SHGC (Window0
3. U-Value (Window)

Mitigative Capping Value & Efficiency for DA Building

CASE TYPE	MITIGATION TYPE	CAPPING VALUE	LOADS TYPE	1990 (Base)	2050 (reduced to)	Efficiency
DA BUILDING	U-VALUE (WALL)	0.14	Heating Loads	-	-66.82%	-
			Cooling laods	-	12.49%	-
			Total HVAC	-	-0.66%	100.6600%
	SHGC (WINDOW)	0.1	Heating Loads	-	-44.28%	-
			Cooling laods	-	9.01%	-
			Total HVAC	-	0.17%	99.8300%
	U-VALUE (WINDOW)	0.1	Heating Loads	-	-70.69%	-
			Cooling laods	-	20.50%	-
			Total HVAC	-	5.37%	94.6300%

Table 44 DA Building Mitigative Capping Values and Efficiency.

For DA Building New Delhi, Simulation suggested a Final U-Value (Wall) of **0.14 with 100% efficiency**. SHGC (Window) **at 0.1 with 99.8% efficiency**, & U-Value (window) at **0.1 with 94.63% efficiency.**

Mitigative Capping Value & Efficiency for Square Base Layout.

CASE TYPE	MITIGATION TYPE		LOADS TYPE	1990 (Base)	2050 (reduced to)	Efficiency
SQAURE BASE	U-VALUE (WALL)	0.023	Heating Loads	-	-59.51%	-
			Cooling laods	-	1.50%	-
			Total HVAC	-	-0.20%	100.2000%
	SHGC (WINDOW)	0.01	Heating Loads	-	-30.65%	-
			Cooling laods	-	5.69%	-
			Total HVAC	-	4.62%	95.3800%
	U-VALUE (WINDOW)	0.1	Heating Loads	-	-74.60%	-
			Cooling laods	-	19.55%	-
			Total HVAC	-	16.77%	83.2300%

Table 45 Square Case Mitigative Capping Values and Efficiency.

For Square Base layout, Simulation suggested a Final U-Value (Wall) of **0.023 with 100% efficiency**. SHGC (Window) **at 0.01 with 95.38% efficiency**, & U-Value (window) at **0.1 with 83.23% efficiency.**

Mitigative Capping Value & Efficiency for Rectangle Base Layout

CASE TYPE	MITIGATION TYPE		LOADS TYPE	1990 (Base)	2050 (reduced to)	Efficiency
RECTANGLE BASE	U-VALUE (WALL)	0.028	Heating Loads	-	-59.04%	-
			Cooling laods	-	1.84%	-
			Total HVAC	-	0.01%	99.9930%
	SHGC (WINDOW)	0.028	Heating Loads	-	-27.37%	-
			Cooling laods	-	5.09%	-
			Total HVAC	-	4.11%	95.8900%
	U-VALUE (WINDOW)	0.1	Heating Loads	-	-76.11%	-
			Cooling laods	-	19.46%	-
			Total HVAC	-	16.58%	83.4200%

Table 46 Rectangle Case Mitigative Capping Values and Efficiency.

For Rectangle Base layout, Simulation suggested a Final U-Value (Wall) of **0.028 with 99.99% efficiency**. SHGC (Window) **at 0.028 with 95.89% efficiency**, & U-Value (window) at **0.1 with 83.42% efficiency.**

Mitigative Capping Value & Efficiency for Curve Base Layout

CASE TYPE	MITIGATION TYPE		LOADS TYPE	1990 (Base)	2050 (reduced to)	Efficiency
CURVE BASE	U-VALUE (WALL)	0.025	Heating Loads	-	-61.04%	-
			Cooling laods	-	2.68%	-
			Total HVAC	-	0.57%	99.4300%
	SHGC (WINDOW)	0.01	Heating Loads	-	-34.70%	-
			Cooling laods	-	8.14%	-
			Total HVAC	-	6.72%	93.2800%
	U-VALUE (WINDOW)	0.1	Heating Loads	-	-70.38%	-
			Cooling laods	-	20.16%	-
			Total HVAC	-	17.16%	82.8400%

Table 47 Curve Case Mitigative Capping Values and Efficiency.

For Curve Base layout, Simulation suggested a Final U-Value (Wall) of **0.025 with 99.43% efficiency**. SHGC (Window) **at 0.01 with 93.28% efficiency**, & U-Value (window) at **0.1 with 82.84% efficiency.**

Mitigative Capping Value & Efficiency for Triangle Base Layout

CASE TYPE	MITIGATION TYPE		LOADS TYPE	1990 (Base)	2050 (reduced to)	Efficiency
TRIANGLE BASE	U-VALUE (WALL)	0.027	Heating Loads	-	-61.43%	-
			Cooling laods	-	1.68%	-
			Total HVAC	-	-0.29%	100.2900%
	SHGC (WINDOW)	0.01	Heating Loads	-	-28.38%	-
			Cooling laods	-	4.19%	-
			Total HVAC	-	3.17%	96.8300%
	U-VALUE (WINDOW)	0.1	Heating Loads	-	-75.39%	-
			Cooling laods	-	19.36%	-
			Total HVAC	-	16.38%	83.6200%

Table 48 Triangle Base Mitigative Capping Values and Efficiency.

For Triangle Base layout, Simulation suggested a Final U-Value (Wall) of **0.027 with 100% efficiency**. SHGC (Window) **at 0.01 with 96.83% efficiency**, & U-Value (window) at **0.1 with 83.62% efficiency.**

Mitigative Capping Value & Efficiency for Triangle Base Layout

CASE TYPE	MITIGATION TYPE		LOADS TYPE	1990 (Base)	2050 (reduced to)	Efficiency
U-SHAPED BASE	U-VALUE (WALL)		Heating Loads	-	-60.88%	-
		0.035	Cooling laods	-	1.98%	-
			Total HVAC	-	-0.01%	100.0110%
	SHGC (WINDOW)		Heating Loads	-	-25.84%	-
		0.03	Cooling laods	-	0.37%	-
			Total HVAC	-	-0.45%	100.4500%
	U-VALUE (WINDOW)		Heating Loads	-	-77.97%	-
		0.1	Cooling laods	-	19.14%	-
			Total HVAC	-	16.06%	83.9400%

Table 49 U-Shaped Mitigative Capping Values and Efficiency.

For U-Shaped Base layout, Simulation suggested a Final U-Value (Wall) of **0.035 with 100% efficiency**. SHGC (Window) **at 0.03 with 100% efficiency**, & U-Value (window) at **0.1 with 83.94% efficiency.**

Concluding Mitigative values:

Final Mitigative Value required for U-Value (External Wall), SHGC & U-Value (Window) have been finalized through various iterative runs in the simulations. A table of these value are shown Below.

Mitigative Strategies	DA Building	Sqaure	Rectangle	Curve	Triangle	U-Shaped
U-Value (Wall)	0.14	0.023	0.028	0.025	0.027	0.035
SHGC	0.1	0.01	0.028	0.01	0.01	0.03
U-Value (Window)	0.1	0.1	0.1	0.1	0.1	0.1

Table 50 Table of Final Mitigative values.

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