Energy Efficient Buildings:

A case study of Saleem Arcade

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Engr Fahim Ullah.

Contents

Acknowledgments 6

Abstract 7

1. History 7

2. Intoduction 8

3. Problem Statement 9

4. Objectives 10

5. Methodology 10

5.1. Literature Review: 10

5.2. Site Selection 10

5.3. Site visits 10

5.4. Acquiring Drawings and Specifications 11

5.5. Detailed study 11

5.6. Digitalization 11

5.7. Energy Efficiency 11

5.8. Comparative Analysis 12

6. Building Information 12

6.1. Technical Information 12

6.2. Building Drawings 13

6.2.1. Basement Plan 13

6.2.2. Ground Floor Plan 14

6.2.3. 1st 2nd and 3rd floor plans 14

6.2.4. North Elevation ... 15

6.2.5. South Elevation ... 15

6.2.6. East and West Elevations ... 16

6.2.7. 3D ... 17

7. Literature Review ... 18

7.1. Hempcrete ... 19

7.1.1. Overview of Hempcrete ... 20

9.1. Energy Efficient Buildings ... 23

9.2. Revit ... 24

9.2.1. Architectural ... 24

9.2.2. Structural ... 24

9.2.3. MEP ... 24

9.2.4. GBS ... 25

9.2.5. EUI ... 25

9.2.6. Life Cycle Energy Cost ... 25

9.2.7. Renewable Energy Potential ... 26

9.3. Annual Carbon Emission ... 27

9.4. Monthly Heating Load ... 27

9.5. Monthly Cooling Load ... 28

9.6. Monthly Gas Consumption ... 29

9.7. Annual Wind Rose (Speed Distribution) ... 30

9.8. Annual Wind Rose (Frequency Distribution) ... 31

9.9. Monthly Wind Roses 33

9.10. Annual Temperature Bins 34

9.11. Humidity 35

9.12. Diurnal Weather Averages 35

9.13. Billing Criteria(Gas) 36

9.14. Monthly Electricity Consumption 36

9.15. Billing Criteria (Electricity) 37

9.16. Monthly Peak Demand 38

9.17. Monthly Design Data 38

10. Energy analysis comparison 39

10.1. Annual Energy use Cost/Units 39

10.2. Monthly Energy Load 40

10.2.1. Heating Load 40

10.3. Cooling Load 42

10.4. Annual Carbon Foot Print 44

10.5. Shadow Analysis 44

10.5.1. Strategy 44

11. Figures 50

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We are also thankful to our department for providing us this opportunity to work on our project and providing all the necessary facilities to effectively accomplish the task at hand.

Finally we would like to thank our parents for their prayers, understanding and psychological support.

Abstract

Around 90% of our modern life is spent in buildings, including homes and offices. Energy used in buildings amount for a huge percentage of a country's total power generation. For a developing country like Pakistan it is very important to keep a good balance between energy needs of public and industrial sector.

An energy inefficient building has been studied and comparative analysis has been carried out, to find out the energy consumption and the amount of energy that could be saved using different energy efficient components in modern construction. These energy efficient components include Glass glazing, Energy efficient architectural designs and cheap insulating material i-e Hempcrete.

Architectural Drawings of an existing energy inefficient building were acquired. These hardcopies were redesigned on Revit. (incomplete)

1. History

Fossil fuel Crisis (Energy) in 1960s and 1970s gave rise to a new debate. It was that time when people started to think seriously about the future of fossil fuels and energy consumption in the long run. A few days of crisis was enough for people to chance their perspective about future. They started to think about new ways to replace the existing fossil fuel with new alternatives. It was quite evident that the natural fossil fuel will no longer be with us and people will have to develop new sustainable sources.

The book “silent spring” published in 1962 is considered to be the first official effort to start the concept of energy efficient and Green buildings. Late there was a movement in the U.S for the need and the desire of energy efficient buildings

2. *Intoduction*

Energy efficient building is one that has minimum water consumption, emphasizes on energy efficiency, low waste generation and provides healthier spaces for occupants as compared to other buildings. Energy efficiency plays a vital role in achieving sustainability in buildings and organizations. Sustainability is all about using the resources of today efficiently, in a manner that meets our own needs, but doesn’t compromise the ability of others to meet their own needs in the future.

Need for energy efficient buildings

More than 90% of our time is spent in buildings i.e. either in the office

or at home. Energy used in buildings (residential and commercial) accounts for

a significant percentage of a country’s total energy consumption. This percentage depends greatly on the degree of electrification, the level of urbanization,

the amount of building area per capita, the prevailing climate, as well as national

and local policies to promote efficiency. The following are estimated figures for

different regions:

European Union countries > 40%

Philippines 15-205

Brazil 42%

Florida/USA 47%

California 66%

In many countries, buildings consume more energy than transport and industry.

The International Energy Agency (IEA) statistics estimate that globally, the building sector is responsible for more electricity consumption than any other sector,42%

The building sector encompasses a diverse set of end use activities, which have different energy use implications. Space heating, space cooling and lighting, which together account for a majority of building energy use in industrialized countries, depend not only on the energy efficiency of temperature control and lighting systems, but also on the efficiency of the buildings in which they operate. Building designs and materials have a significant effect on the energy consumed for a select set of end uses

Ref: Michael Laar and Friedrich Wilhelm Grimme, 2002.

(Sustainable Buildings in the Tropics. Institute of Technology in the Tropics ITT, University of Applied Sciences Cologne)

3. Problem Statement

Comparative analysis of a building before and after making it an energy efficient building

4. Objectives

In the inception of project, it was discussed that our project will have the following objective and that we will work in accordance to achieve them.

Energy analysis of the existing building.

Digital modeling of the existing building via BIM (Revit + Naviswork)

Application of hempcrete.

Comparative energy analysis of the new building and the old one.

5. Methodology

5.1. Literature Review:

The project started off with an extensive literature review. Each and every group member read 5-10 research papers thoroughly. Multiple existing projects were studied and areas of common interest were outlined and studied.

5.2. Site Selection

One of our group member's father is a contractor who recently completed a plaza. We took this opportunity to work on a new infrastructure. The blue prints and structural details of this building were easily available. Hence it was an obvious choice for us. The building is located in Soan garden Islamabad.

5.3. Site visits

We regularly visited the project site during out digital modeling phase in which we digitalize that building suing BIM softwares. The contractors and the engineering staff were contacted and hence a comprehensive real life most accurate replica of the building was made in the softwares.

5.4. Acquiring Drawings and Specifications

That plaza was never digitalized. The structural drawings and the infrastructure details were obtained from thought our friends sources. These drawings so obtained were in raw form and these were studied and comprehended according to our needs. Month energy consumption bills were also obtained which will alter help in our subsequent energy studies and comparative analysis.

5.5. Detailed study

These obtained Drawings and bills were studied in the light of our literature review. This phase was the most important and took a lot of time. Many things were out of our project scope but frequent site visits and meet ups with our professor and lecturer made it simple and understandable.

5.6. Digitalization

The structural drawings so obtained were in hard copy. The first step was to digitalize those drawings using a BIM softwares. A working model was obtained and this building was then studied for energy analysis and energy efficiency. Commonly used software are

- Revit
- Naviswork
- Autodesk GBS
- AutoDesk Auto CAD
- Primavera p6
- Lumion

5.7. Energy Efficiency

The existing building was studied for energy efficiency. Electricity, water, gas etc bills were collected they were analyzed for energy efficiency. This building was then redesigned as an energy efficient building. The building was designed with the help of new renewable energy efficient material. That helped it become less energy consuming building.

5.8. Comparative Analysis

The two buildings, the energy efficient and the other existing Energy Inefficient building were compared for their energy efficiencies. Monthly bills were compared. Revit analysis was conducted. The compared results were than analysis.

6. Building Information

The building is located at Soan Garden, Rawalpindi, Pakistan. It has an aprox area of 5286km^2.Climatic conditions are very ideal for sustainable construction, on average the lowest temperature goes from 2.7 C to 40 C. On average the highest precipitation was 237mm recorded. Our analysis are based upon average climatic conditions and sun screen for that we have taken the essential data from the nearest weather station in Rawalpindi, its ID is (709049).

6.1. Technical Information

Location	Rawalpindi, Pakistan
Weather Station	709049
Outdoor Temperature	Max 43^{o}C – Min 0.60^{o}C
Floor Area	30770 f^2
Exterior Wall Area	13848 f^2
Average Lightning Power	0.99W/f^2
People	320
Exterior Window Ratio	0.21
Electrical Cost	9.00 Rs/kWh
Gas Cost	78.0 Rs/kWh
Orientation	33^o NW

Table 1

6.2. Building Drawings

6.2.1. Basement Plan

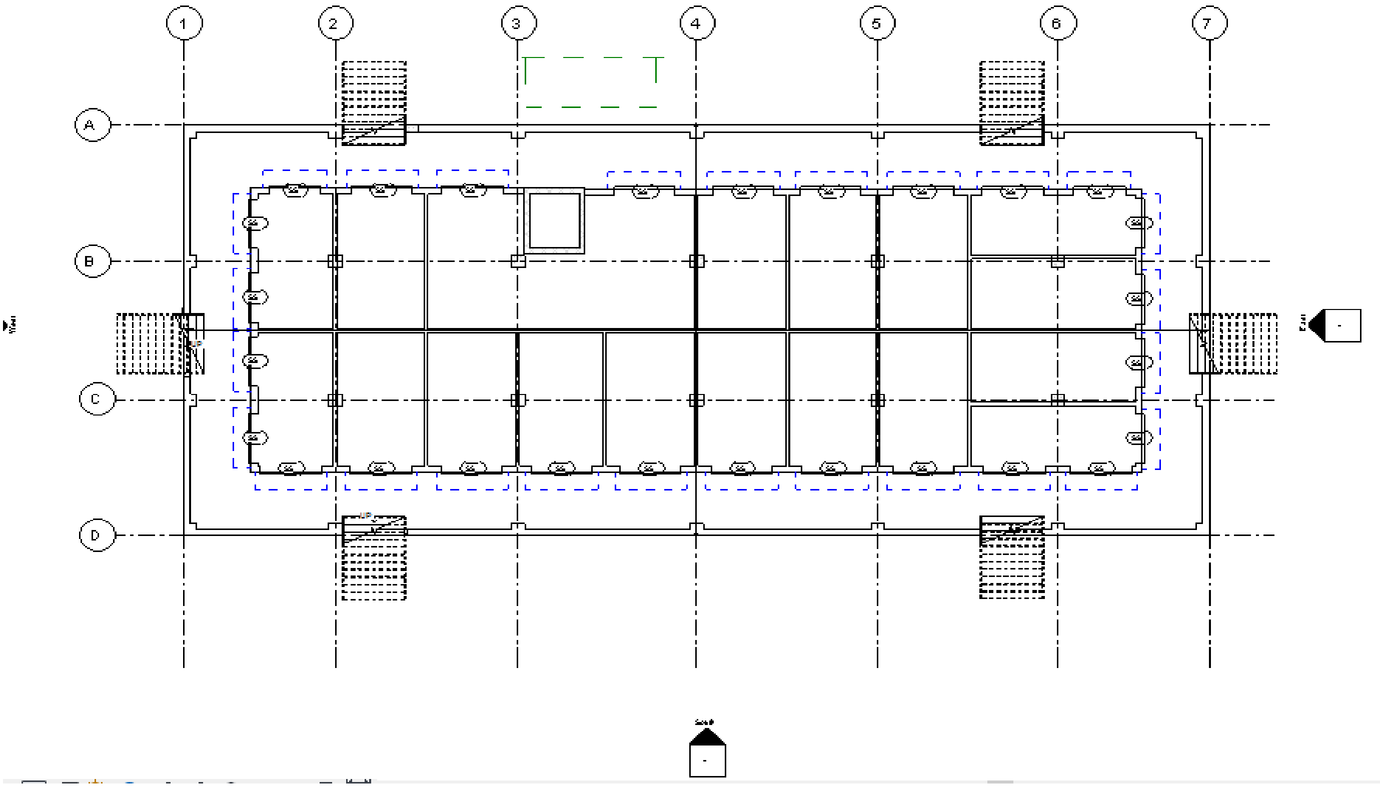


Figure 1

6.2.2. Ground Floor Plan

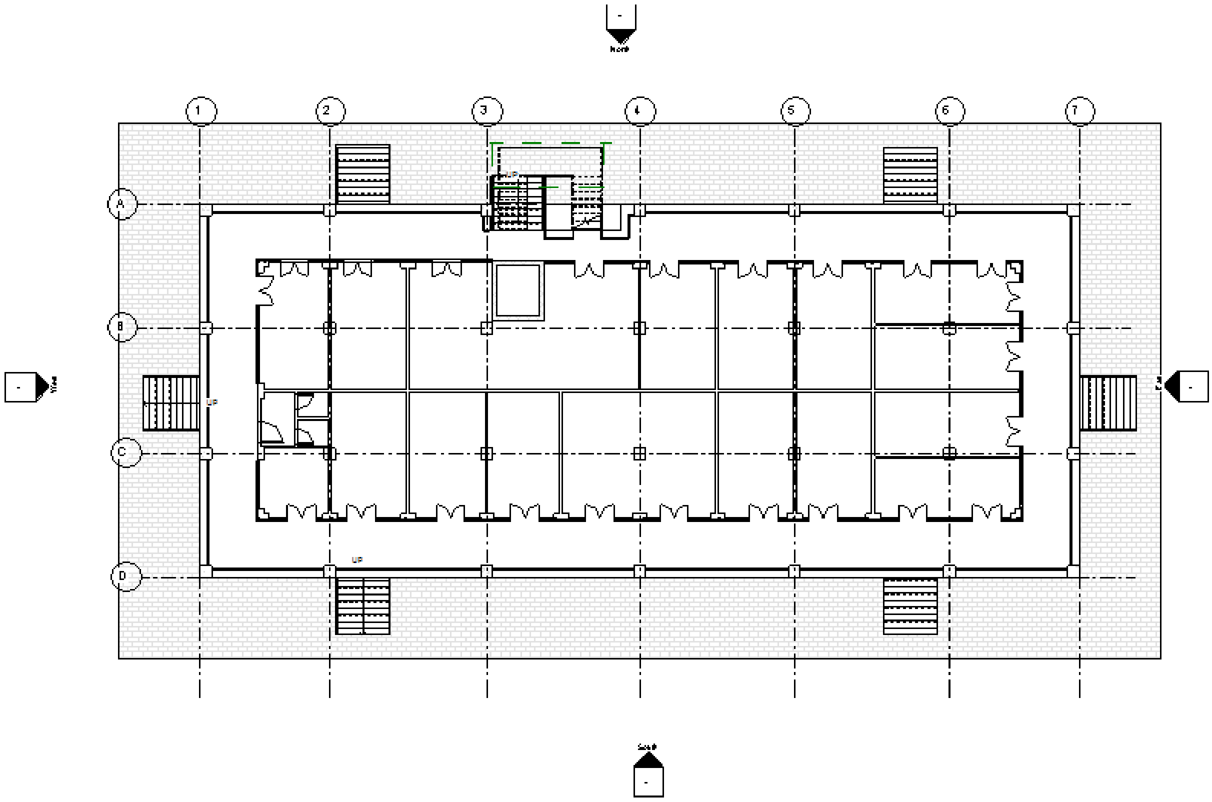


Figure 2

6.2.3. 1st 2nd and 3rd floor plans

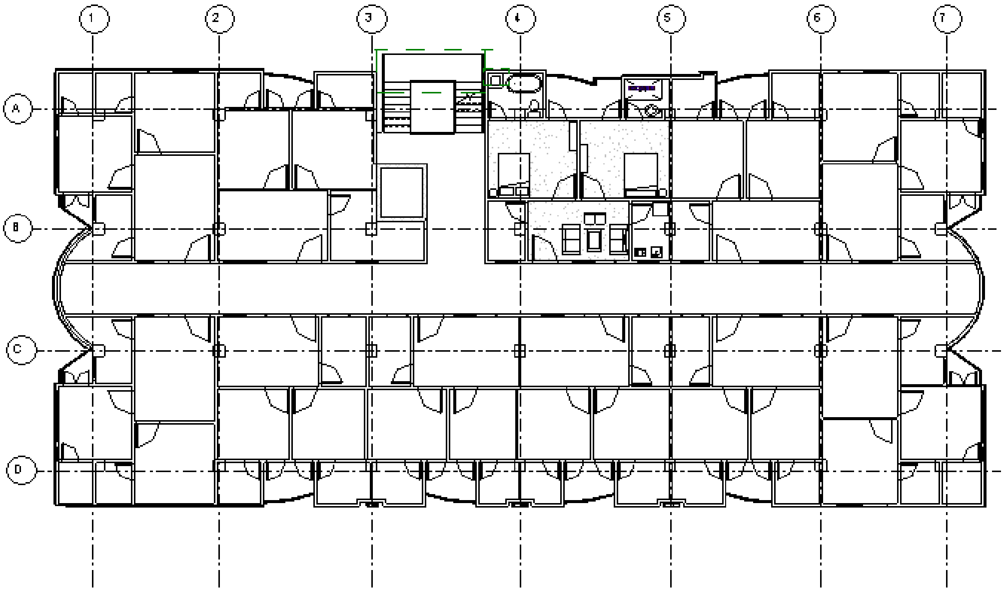


Figure 3

6.2.4. North Elevation

Figure 4

6.2.5. South Elevation

Figure 5

6.2.6. East and West Elevations

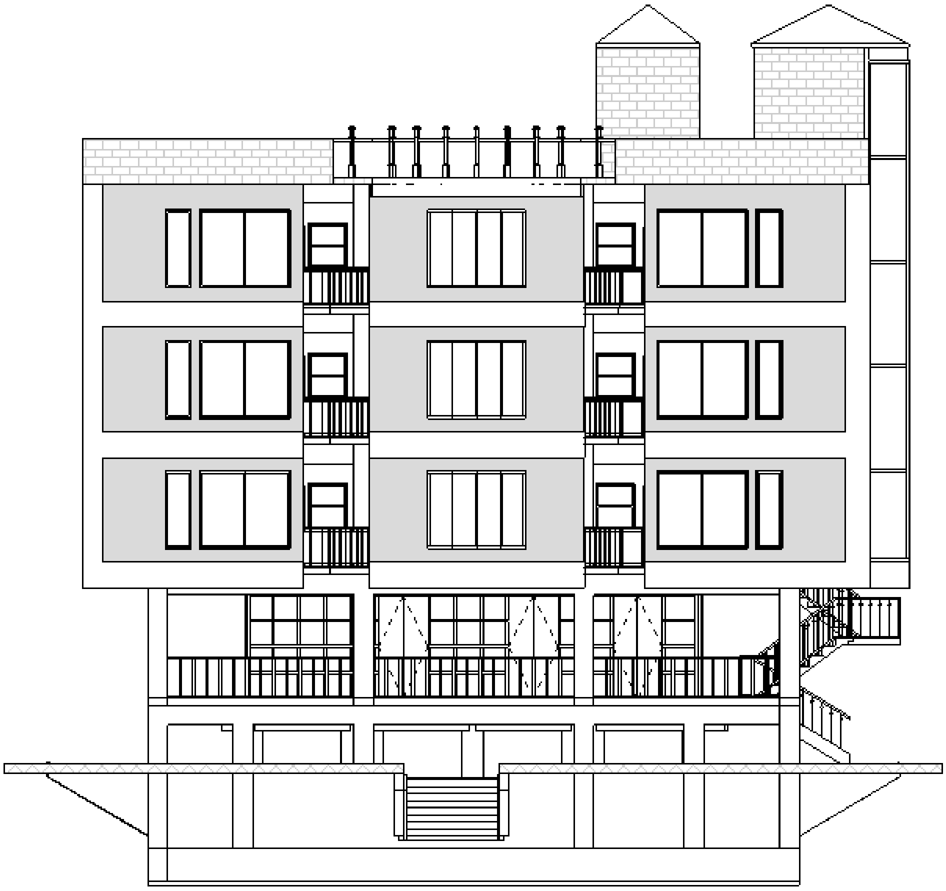


Figure 6

6.2.7. 3D

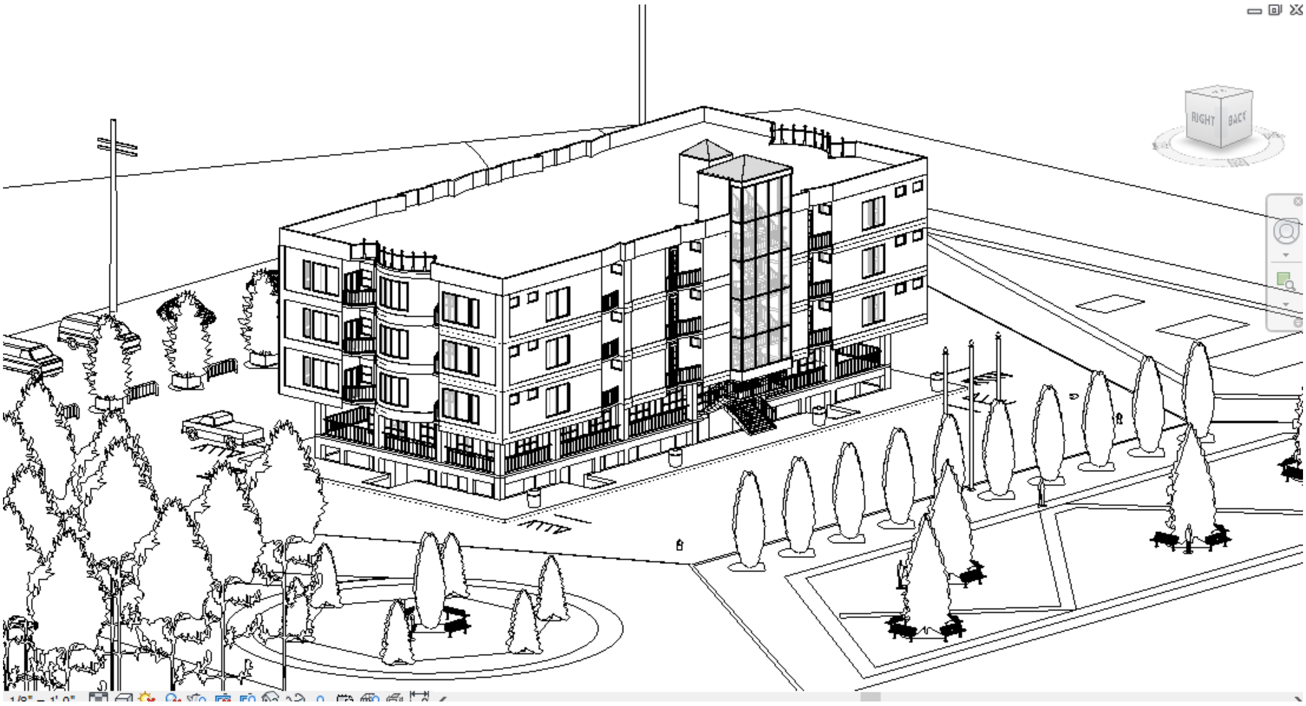


Figure 7

Figure 8

7. Literature Review

7.1. Hempcrete

1. Hempcrete (a hemp–lime composite construction material) is a relatively new material. Comprising of the chopped stalk of the industrial hemp plant mixed with a lime-based binder, HempCrete provides a natural, healthy, sustainable, local, low-embodied-energy building material that can truly claim to be better than zero carbon. Carbon dioxide taken up by the plant when it was growing is locked up in its woody fibers, and at the end of the building's life the HempCrete can be left to compost and be used as a soil additive rather than going into landfill. As a highly insulating material with significant thermal mass, HempCrete has excellent thermal performance within the structure of a building, and there is increasing evidence that it actually performs much better in real-life situations than is suggested by steady-state modelling.
2. Hempcrete is especially attractive to self-builders and community groups, because of the relatively low-tech nature of the construction method. Also, owing to the fact that it's a relatively labor-intensive construction method, big savings can be made by providing your own labor, HempCrete is also commercially viable as a construction material in a wide range of applications. Its cost is comparable to that of conventional construction methods, but if you factor in the true cost of the embodied carbon of conventional building materials, in terms of environmental damage, and consider the financial benefits of the energy savings that HempCrete delivers through the lifetime of the building, you could argue that it's actually a lot cheaper!
3. There is a great pleasure to be found in building with HempCrete, which comes not only from the extraordinary thermal performance achieved but also from the simplicity: both of the material itself and of the elements within a typical HempCrete construction. Hemp Crete's low-tech nature means that, with relative ease, highly energy-efficient

buildings can be constructed that contain virtually no synthetic, highly processed or high-embodied-carbon materials. With a good understanding of the material, and a little practice, HempCrete is a hugely rewarding material to work with, and can produce beautiful, healthy, 'future-proof' buildings.

4. The hemp plant, thanks to its many uses and in particular its most famous one, as a widely popular recreational drug, is one of the most instantly recognizable plants in the world. A great deal has been written about hemp's many uses throughout human history and about the politics of its prohibition during the twentieth century.

7.1.1. Overview of Hempcrete

Technical

1. Hempcrete aims to provide sustainable, environment friendly and cost effective insulation for retrofit/new construction. It takes inspiration from the fact that nature has given us an abundant natural building material that can be used with virtually zero carbon footprint and negligible energy consumption. For this purpose Hempcrete is utilized which is a combination of Hemp woody core, lime and water.
2. The idea is to make use of the synergistic relationship between lime and Hemp plant. Hemp's high silica content reacts with Calcium Hydroxide from lime to produce a material that's hard enough to be used as in-fill panels or walls and light enough to be less dense that water. Compare this with conventional masonry or Cement-based concrete which is 7-8 times denser (hence more dead load on the structure) and has a much higher carbon footprint. It capitalizes on the fact that lime powder requires much lesser temperature during sintering process at the plant than normal cement. Besides, hemp provides

additional insulation and breathability to the structure making Hempcrete an ideal material for low-rise construction.

3. Conventional Insulation in the market is based on artificial polymers that are not only flammable but also pose significant threat of Global Warming on account of their CFC emission during manufacture. Hempcrete on the other hand has no emissions, is fire resistant and much more sustainable and profitable to grow and use as insulation. The typical Jumbolon boards that are available in the market are not suited for use on exterior walls since at high temperatures; they tend to degrade over time. Also they have no breathability which poses problems of humidity control inside the rooms. Hempcrete walls on the other hand allow cross-moisture ventilation and absorption. They also resist molds and termite attack. A fact sheet for a typical Hempcrete wall is listed as below (limecrete)

Density	275kg/m3
Flexural Strength	0.3-0.4 N/mm2
Thermal conductivity	λ=0.06W/m.K
Heat Capacity	1500-1700 J/kg
Mean Acoustic Absorption Coefficient	0.69 NRC
Air Permeability	0.75 gm/m2/mm hg
Vapour permeability	24.2 gm/m2/mm hg
μ Vapour Diffusion Resistance	4.84
Carbon capture	130kg CO2/m3
Airtightness	<2m3/m2.hr@50pa
Fire Rating	1 hr BS EN 1365-1:1999

Typical Insulation Values				
Wall Thickness(mm)	**Wall Thickness(inches)**	**U-value ($K.m^2/W$)**	**R-Value ($Ft^2.F.h/Btu$) USA**	**RSI-value 0.176 International**
300	12	0.23	25	4.35
400	16	0.18	33	5.56
500	20	0.14	50	7.14

8. R-Value (US) = RSI x 5.67826
9. RSI (SI) = R-value x 0.17611

CAST-IN-SITU CONSTRUCTION OVERVIEW:

Cast-in-situ hempcrete Cast-in-situ hempcrete refers to mixing hempcrete on-site and casting it into moulds constructed from shuttering, or formwork, to form the walls, floor or roof in the exact position that they will remain within a building. The shuttering may be temporary or permanent. Because hempcrete is a non-load-bearing material, it is always cast around a structural frame, which provides the main load-bearing element of the building. This is usually, but not always, built of timber. This applies whether it is being used in a new build or a restoration context. In new builds the usual method is to construct a simple studwork frame from softwood, and bury this within the centre of the hempcrete wall, but alterations can be made to the frame to accommodate different design details, both of the wall itself and of internal and external finishes. Mixing the hemp shiv and binder together with water can be done with a variety of types of mechanical mixer, depending on the quantity needed, the speed at which it is required, the method of application and access to the site. The freshly mixed hempcrete is either placed (rather than ‘poured’, since it isn’t a liquid consistency), or sprayed into the void created by the shuttering. It is left for a short time to take an initial set (i.e. set hard enough to bear its own weight), after which the shuttering, if it is temporary, is removed and the hempcrete is allowed to dry out gradually over the next few weeks, until it is dry enough for finishes to be applied.

Hand-placing The hand-placing of cast-in-situ hempcrete refers to the use of manual labour to place the hempcrete into the void created by the shuttering, as well as to ferry it from the mixer to the place where it is needed. The placing process needs to be carried out carefully to ensure both the quality and certain desirable characteristics of the finished material. The manual transport of the hempcrete is done using large tubs or buckets, since it is a relatively lightweight material.

The hempcrete is cast in shuttering, usually temporary, around the structural frame, which is usually placed centrally within the wall. Hand-placing is the 'standard' method of building with hempcrete, although, since it is quite a labour-intensive process, mechanical delivery systems (spray-applying – see below) have been developed. These are particularly suitable for very largescale commercial applications. The placing of the hempcrete material by hand allows a high level of control over the quality of the finished product, although there is a need to carefully monitor consistency of workmanship if lots of people are involved in the placing. The low-tech, hands-on nature of hand-placed cast-in-situ hempcrete appeals to self-builders, whether individuals or groups, who have the time to devote their own labour to the build process in order to reduce costs.

9.1. Energy Efficient Buildings

Energy efficient building is one that has minimum water consumption, emphasizes on energy efficiency, low waste generation and provides healthier spaces for occupants as compared to other buildings. Energy efficiency plays a vital role in achieving sustainability in buildings and organizations. Sustainability is all about using the resources of today efficiently, in a manner that meets our own needs, but doesn’t compromise the ability of others to meet their own needs in the future.

It is the development of a balance between two most important parameters which includes home building and sustainable infrastructure. This new concept future expands the orthodox methodology of building construction and usage. The advent of new technologies has given rise new ways of constructions, each one emphasis on a certain specific goals and objectives. Fortunately, most of the time the common objective is to reduce the usage of energy and to reduce the social economic and adverse socio environmental consequences

9.2. Revit

Revit is a very powerful tool for architecture, structural and HVAC designing of a building. We have used its architectural and HVAC capabilities for our energy analysis and design.

9.2.1. Architectural

This phase of Revit is used to construct only architectural design, model designed over it is not capable for structural analysis. The architectural components are doors, walls, architectural columns, windows, openings, stairs/ramps and floors , energy analysis can be runed over architectural design etc.

9.2.2. Structural

This type of mode is capable to design structural analytical model and this type of model is capable for structural analysis.Things like beams/girders, columns, footings and reinforcement comes in structural mode.

9.2.3. MEP

MEP stands for Mechanical Electrical Plumbing. This is a very powerful tool. It includes Ducts, Fans, HVAC, heating and all other things related to cooling and heating of the building.

9.2.4. GBS

Green Building Studio is a web app solely used for energy analysis.

Following are the different energy analysis that GBS can do.

9.2.5. EUI

Energy Use Intensity, Because Energy Use Intensity (EUI) is 1/m2, It is a very effective method to find energy usage when buildings have different sizes.

Parameter	**Explanation**	**Unit**
Electrical	Annual Electricity/floor area	KWh/area
Gas	Annual Fuel/area	KWh/area
Total	Combined measure of total energy Fuel + Electricity	KWh/area

Table 2

9.2.6. Life Cycle Energy Cost

It tells us that after saving that much amount of energy after how long the installed equipment will return its cost. Default rate of return is 30yrs @6.1% discount.

Parameter	**Explanation**
LC Electricity	This tells us that how much analyses model will use electricity in 30 years.
LC Fuel	This tells us that how much designed model will use gas in 30 years.
Total	How much total resource the analyzed model will use.

Table 3

9.2.7. Renewable Energy Potential

Revit analyzes all roof surfaces for their estimated potential to generate electricity using photovoltaic panels. The 3 different levels of efficiency, reflecting the PV system's ability to convert sunlight into electricity.

Wind energy potential is estimated based on the annual amount of electricity that can be generated from one 15ft dia wind turbine. The estimate uses cut-in and cut-out winds of 6 and 45 miles per hour (mph) respectively, located at the coordinates of the weather data.

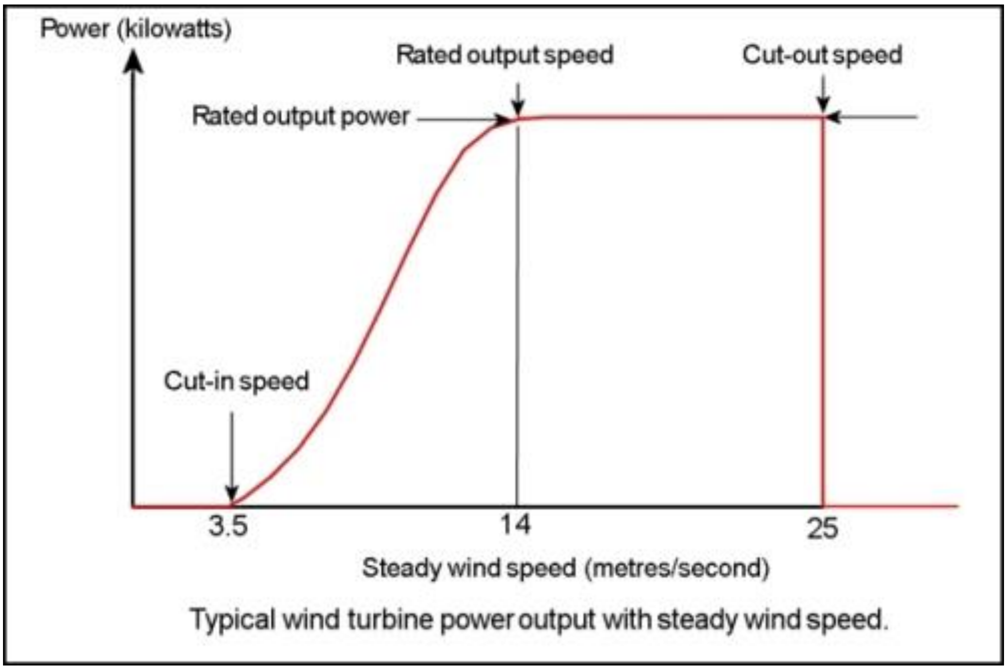


Figure 9

Cut-in speed

At very low wind speeds, there is insufficient torque wind is producing over the blades of turbine. However. The speed at which the turbine first starts to rotate and the power produce at this moment is called cut in speed power and it is between 3 and 4 m/s.

Cut-out speed

As the speed increases above the maximum operational rate, at some point, there is a risk of damage to the rotor. This is called the cut-out speed and is usually around 25 m/s.

The available power in a wind to rotate the blade is calculated by the formula below.

$$\frac{1}{2}\rho U^3 \frac{\pi d^2}{4}$$

Equation 1

9.3. Annual Carbon Emission

Unit= tons/yr

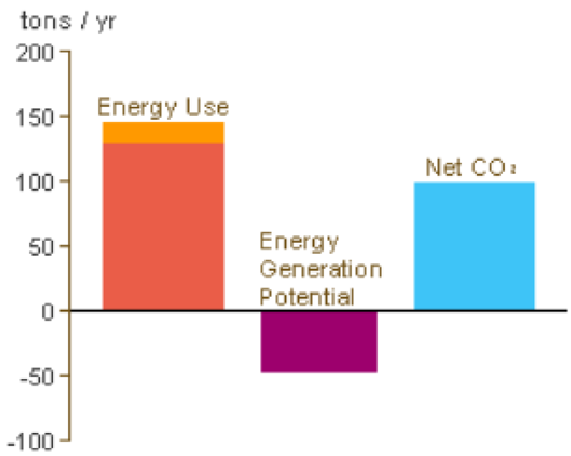


Figure 10

It is actually amount of Greenhouse gases that a building is producing during its function. In our project we have calculated it for a year span hence our unit is tons/yr

9.4. Monthly Heating Load

Unit= mBtu

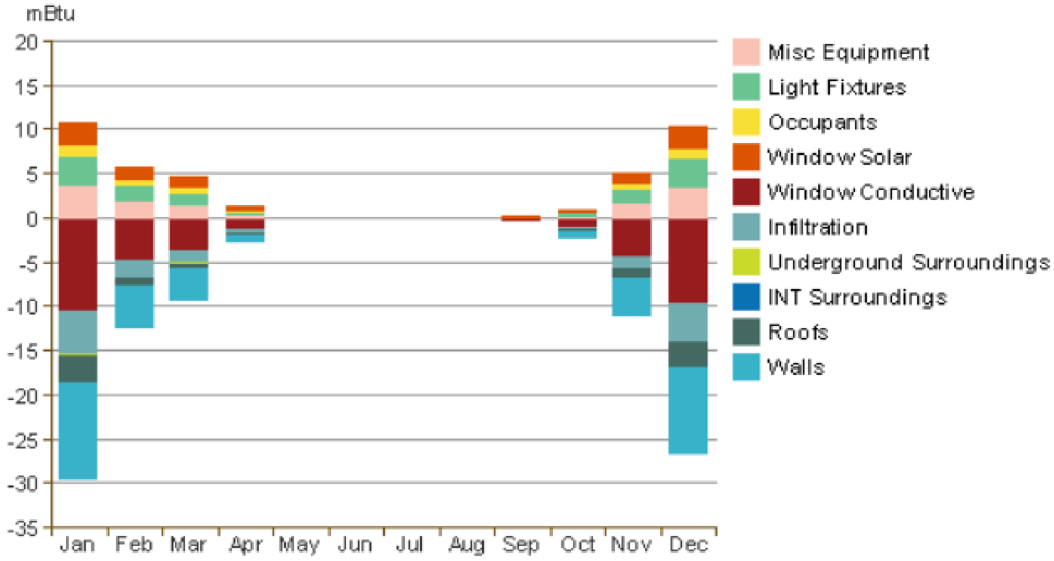


Figure 11

It is the load that heating system has to bear to maintain the desired temperature in the building.

Building fixtures and even building itself is composed of many different materials hence it also causes materials or fixtures to emit or absorb heat, things that emit heat energy like lamps, bulbs, heaters etc contributes in heating the building hence reducing the load over boiler to expense much energy to maintain the indoor temperature while some buildings components like roof, walls and windows etc emits energy out of the building causing boiler to expanse more energy to maintain the indoor temperature. Values that contribute are taken as positive while all others are negative.

9.5. Monthly Cooling Load

Unit= mBtu

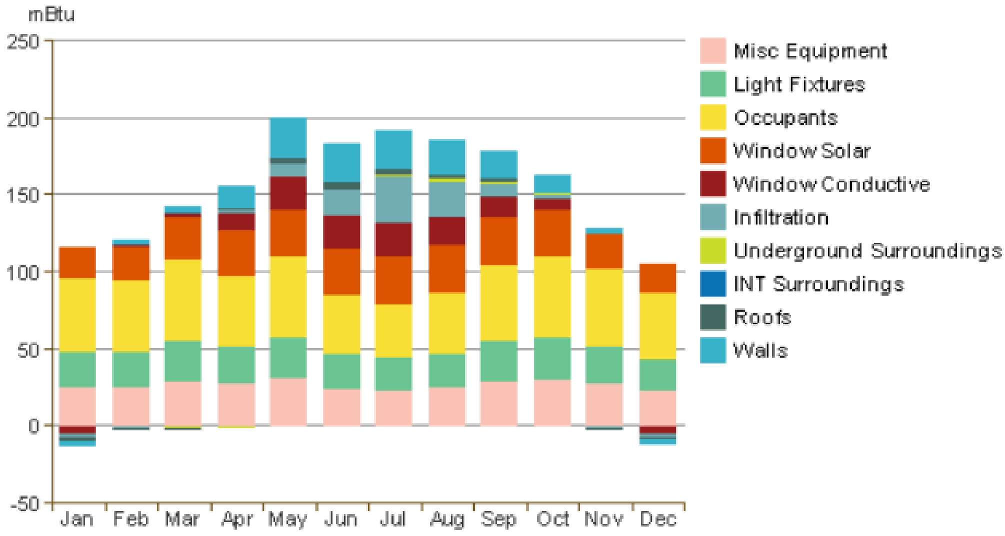


Figure 12

It is the load that air-conditioning system has to bear to maintain the desired temperature in the building.

This is the same concept as Heating Load but has an opposite effect. Things emits thermal energy like lamps, bulb, computer etc causes air-conditioning system to expense more energy i.e Electrical energy to maintain indoor temperature, while ventilation system prevents excessive external heat to enter the building causing air conditioning to expense less energy to maintain the temperature.

9.6. Monthly Gas Consumption

Units= Therms

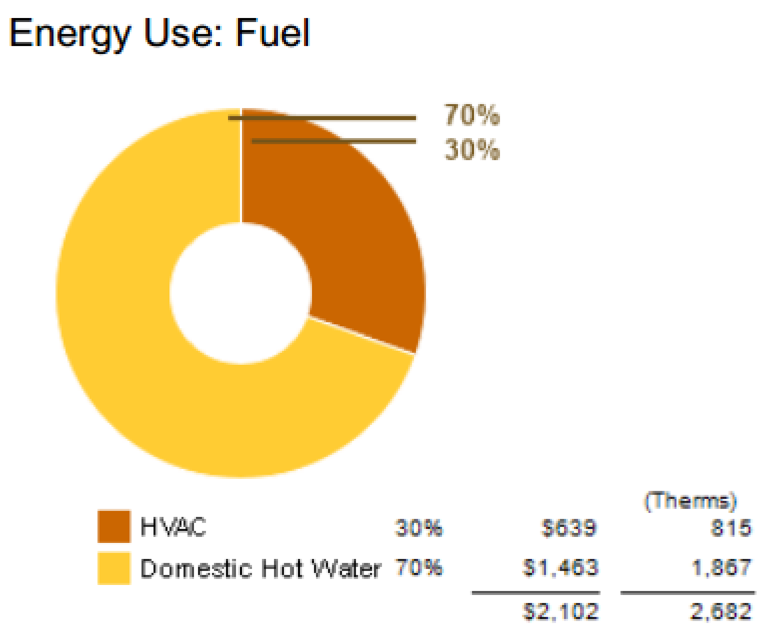


Figure 13

In Pakistan SNGPL uses Hm^3 or MMBtu for gas billing calculation but as REVIT follows American standards, hence it uses Therms.

9.7. Annual Wind Rose (Speed Distribution)

This chart shows the frequency and speed of wind blowing from each course.

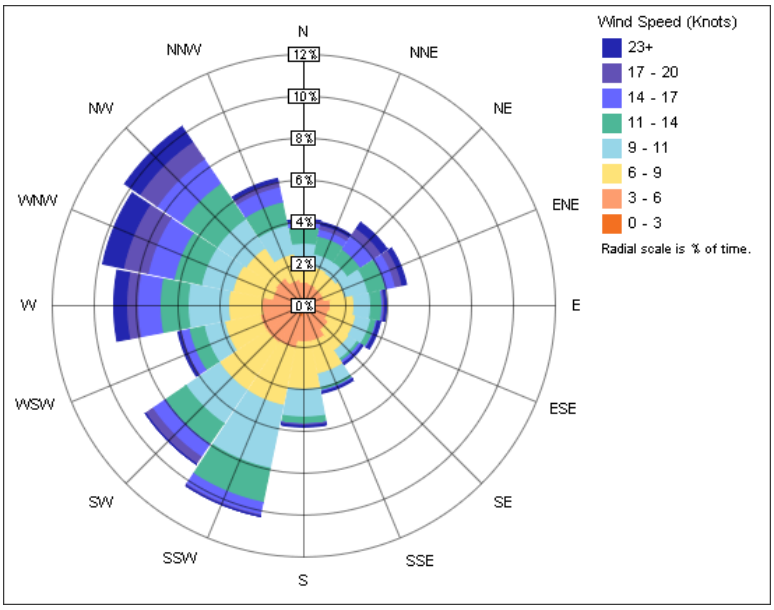


Figure 14

As you move out of the radial scale the colour associated numeric value can be obtained from the legend, wind coming from that course increases. Each spoke is divided by color code for respective wind speed range. The radial length of each spoke around the circle is the percentage of time that the wind blows from that course.

9.8. Annual Wind Rose (Frequency Distribution)

This wind rose shows the same data as the WR Speed distribution represents wind speed rather than percent of time. Also, the colour code represents wind speed hours than wind speed.

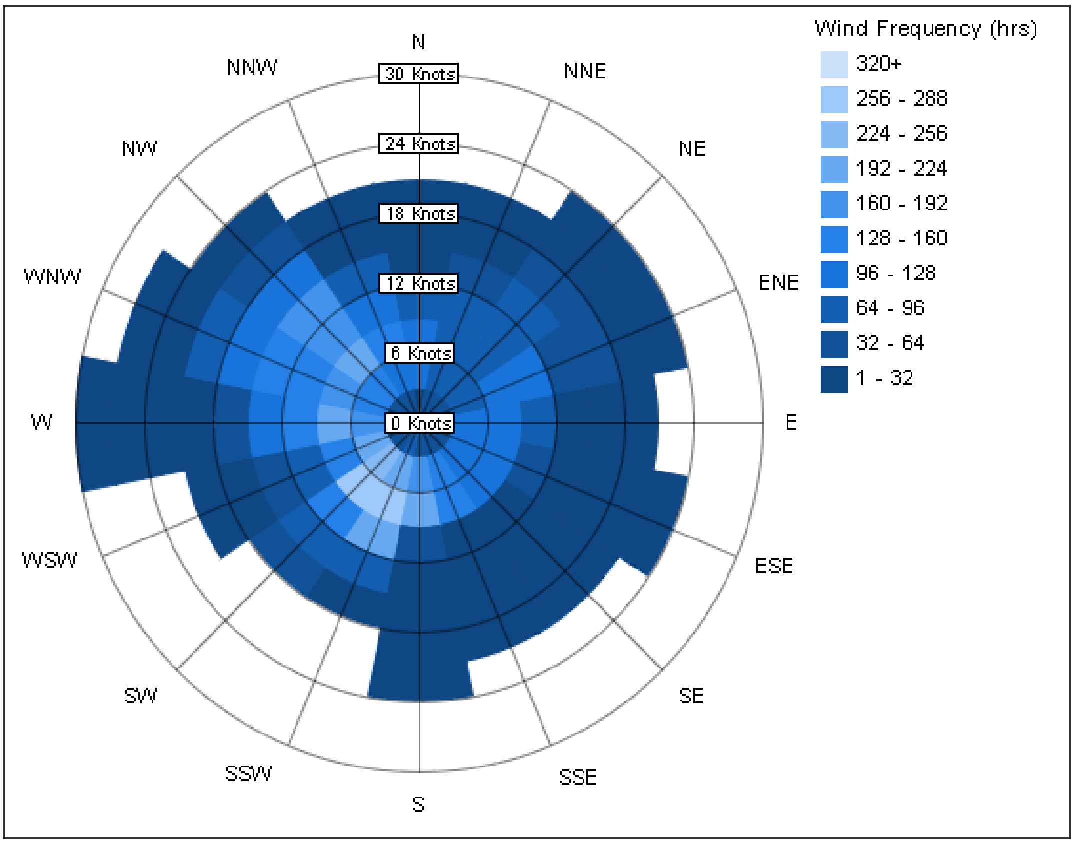

Wind Frequency (hrs)
320+
256 - 288
224 - 256
192 - 224
160 - 192
128 - 160
96 - 128
64 - 96
32 - 64
1 - 32
N
NNE
NE
ENE
E
ESE
SE
SSE
S
SSW
SW
WSW
W
WNW
NW
NNW
30 Knots
24 Knots
18 Knots
12 Knots
6 Knots
0 Knots

Figure 15

9.9. Monthly Wind Roses

These wind roses show frequency distribution for each month of the year.

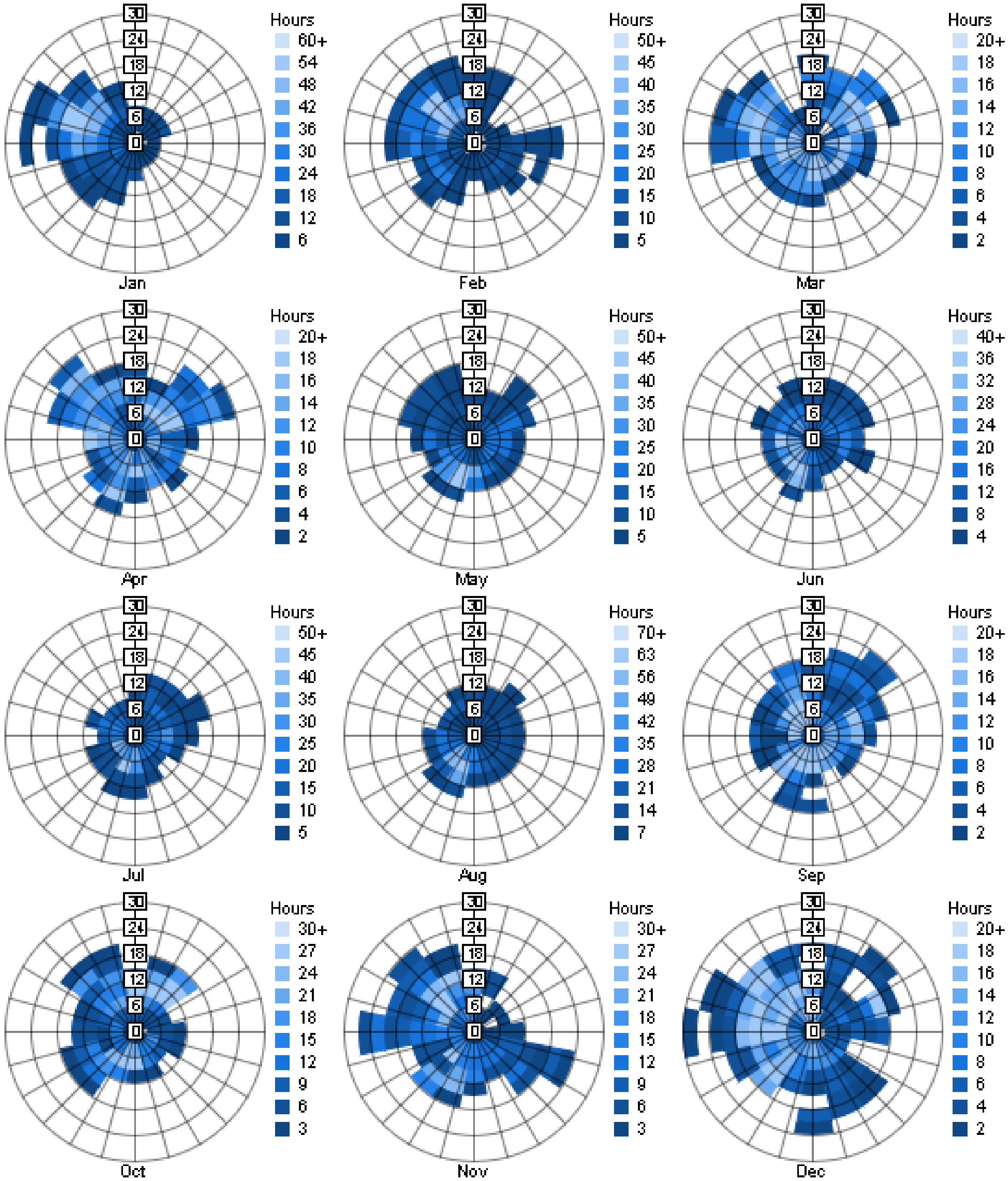


Figure 16

9.10. Annual Temperature Bins

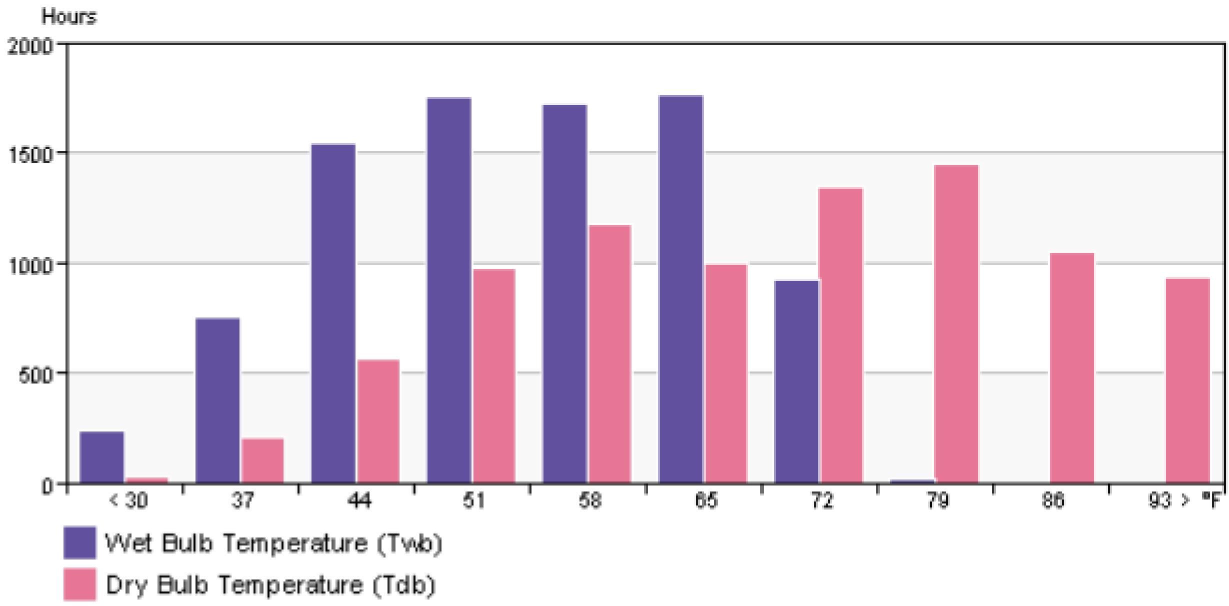


Figure 17

Using outdoor dry and wet bulb temperatures it can be deduced that how much humidity make difference between internal and external environment of the building. The cooling system that uses evaporation system is good in dry weather while in wet weather this system is no so feasible.

In summers night time ventilation is preferred while it is no suitable for day time cooling.

9.11. Humidity

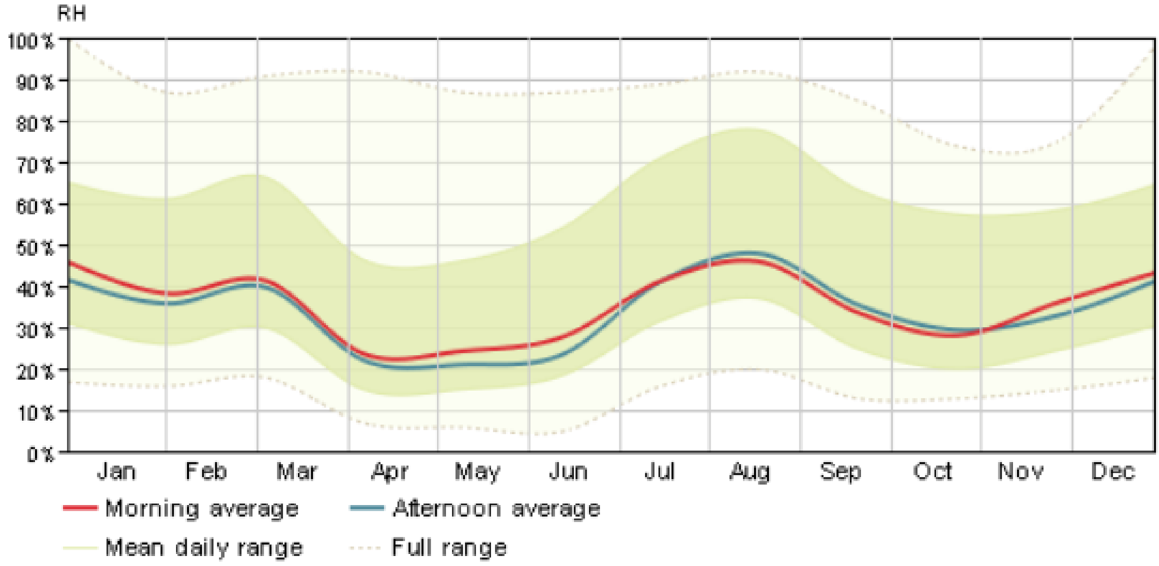


Figure 18

Humidity for each month is procured from the weather station .the red line shows the humidity in morning while blue one shows the afternoon reading. Mean daily and full range are also shown.

9.12. Diurnal Weather Averages

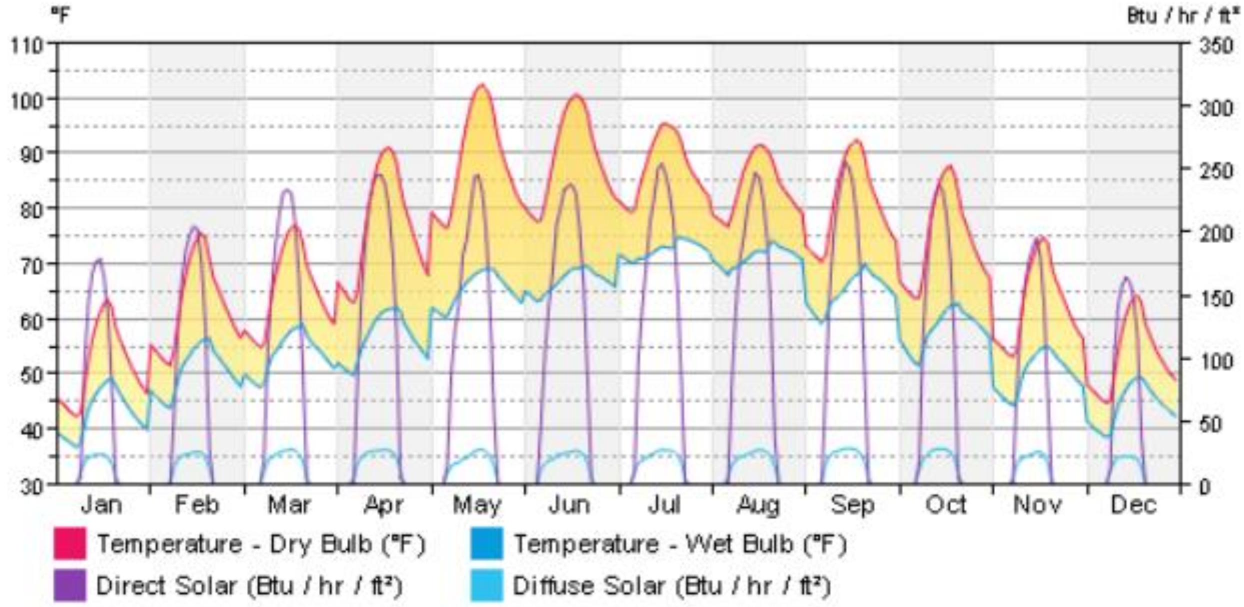


Figure 19

Parameter	Explanation
Dry Bulb Temp	Temperature measured directly from exposed thermometer bulb to the environment
Wet Bulb Temp	Temperature measured with a thermpmeter having a wet swap rolled over its bulb
Diffused Solar	Solar energy in a condition when light is scattered over the sky
Direct Solar	Solar energy approaching earth directly in a ray form

Table 4

9.13. Billing Criteria(Gas)

Following is the gas billing criteria issued by SNGPL w.e.f 01-01-2013

Sr#	Usage in Hm^3 (x)	Rs/MMBtu
1	≤ 1.00	106.14
2	$1.00 < x \leq 3.00$	212.28
3	≥ 3.00	530.69

Table 5

Column two represents the volume of gas used while third column shows the charges if as per column two criteria.

1 Therm=10^5 Btu.

1 Hm^3= 3.80 Btu (As per SNGPL conversion)

9.14. Monthly Electricity Consumption

Unit=KWh

Revit also analyze monthly electrical consumption.The electric consumption depends upon the type of building.

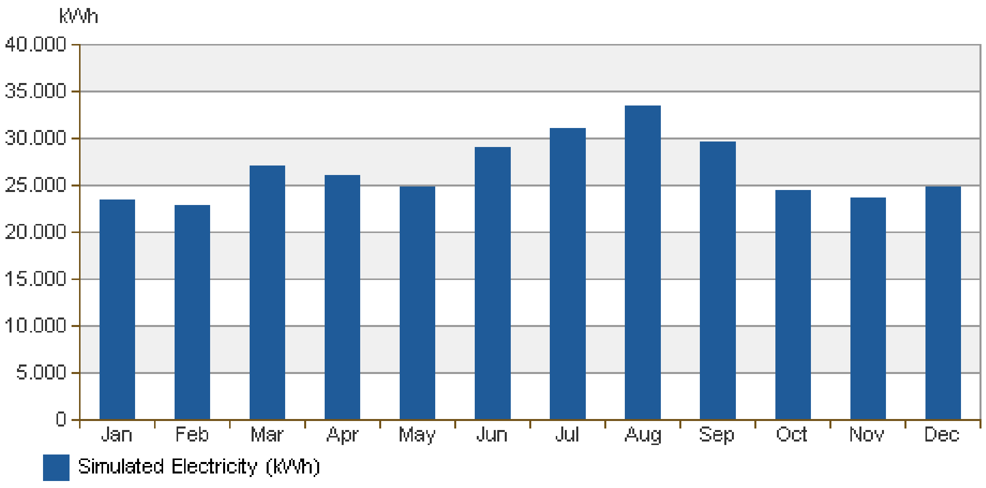


Figure 20

9.15. Billing Criteria (Electricity)

It is the monthly consumption of electricity. In Pakistan 1 KWh is taken as 1 Unit.

Month	Timings	Rs/unit
June-Aug	7pm-11pm	15
Sept-Nov	6pm-10pm	15
Dec-Feb	5pm-9pm	15
Mar-May	6pm-10pm	15

Table 6

Charges at all timings except the above are 9Rs/unit.

PTV,NJ and other charges are exempted from the results.

However REVIT has used 9Rs/unit as default rate.

9.16. *Monthly Peak Demand*

Unit=KW

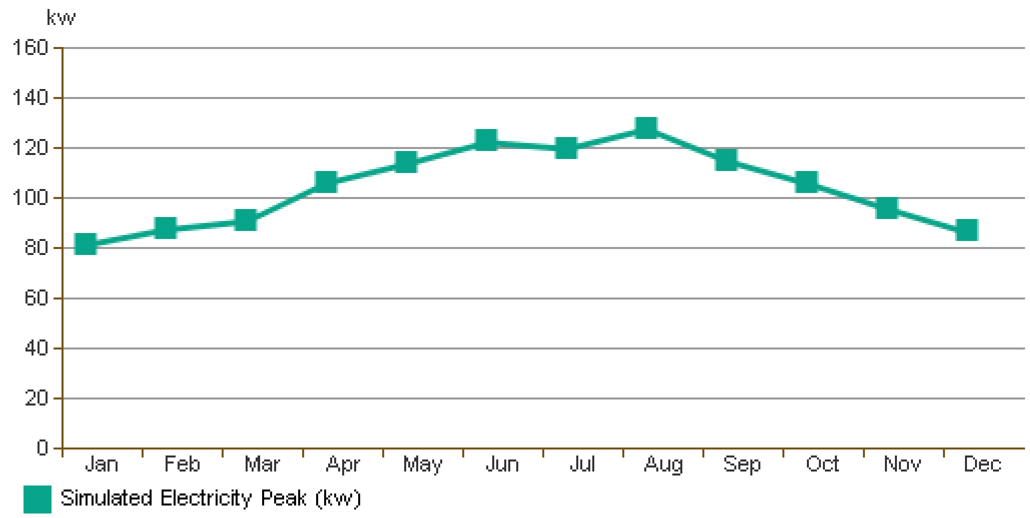


Figure 21

It refers to the instantaneous amount of energy required by a machine to start its operation.

In Pakistan WAPDA has set different criteria to charge for these demands. Usually this factor is used in industrial appliances.

9.17. *Monthly Design Data*

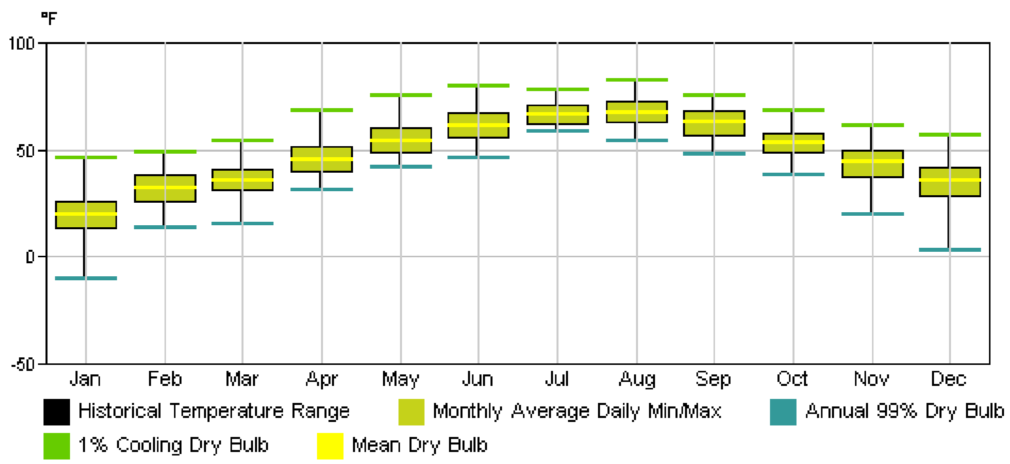


Figure 22

Use this data to understand the conditions that governs the size equipment used for heating and cooling.

Parameter	Explanation
Cooling Dry Bulb	This is used to measure cooling loading.
Monthly Average Daily Min/Max	It is the average of Max and Min daily dry bulb temperatures.
Mean Dry Bulb	This represents average hourly temperature.
Annual Dry Bulb	It is used to calculate heating loading.

Table 7

10. *Energy analysis comparison*

10.1. *Annual Energy use Cost/Units*

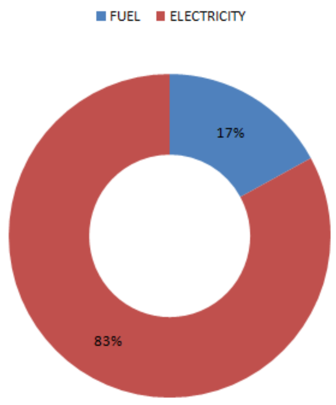
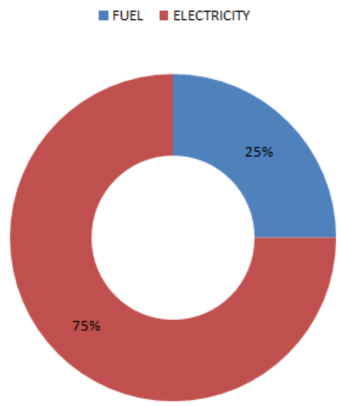
EFFICIENT	INEFFICIENT
	
Electricity=387,955 KWh	Electricity=438,005 KWh
Fuel=268,3 Therms	Fuel=483,7 Therms

Figure 23

From above graph following analysis were deducted

Efficient

Electricity Cost= 364,2900 Rs/yr

Fuel Cost=210,300 Rs/yr

Total=385,320,0 Rs/yr

Inefficient

Electricity Cost=4112900 Rs/yr

Fuel Cost=381,900 Rs/yr

Total=449,480,0 Rs/yr

Comparative analysis

Cost Saved=449,4800-385,3200=641,600 Rs/yr

Almost 17% of total cost is saved per year.

10.2. Monthly Energy Load

10.2.1. Heating Load

Inefficient

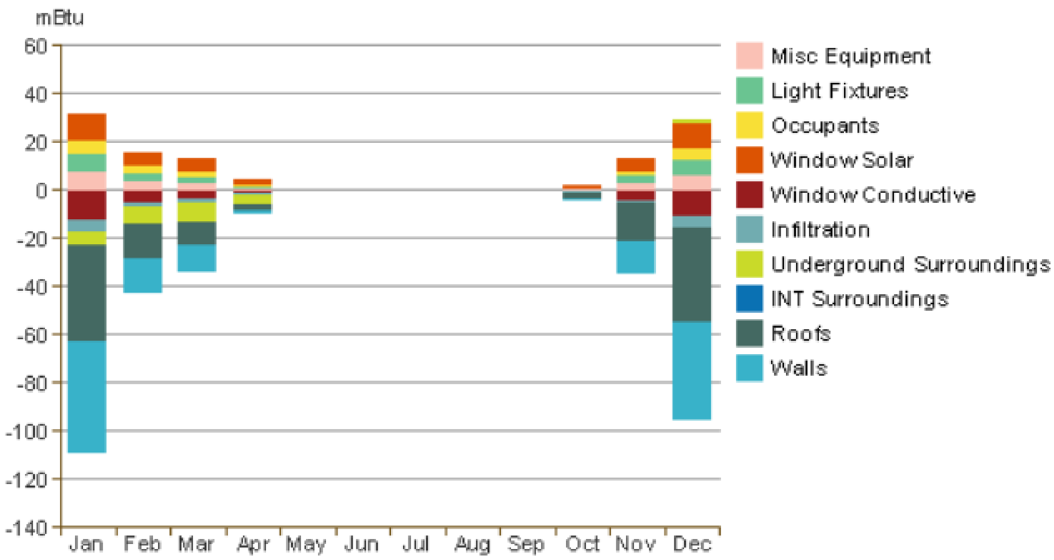


Figure 24

Maximum Negative load=125 mBtu

Maximum Positive load=30 mBtu

Maximum load difference=125-30=95 mBtu

Extra Heating required is of 95 mBtu

Efficient

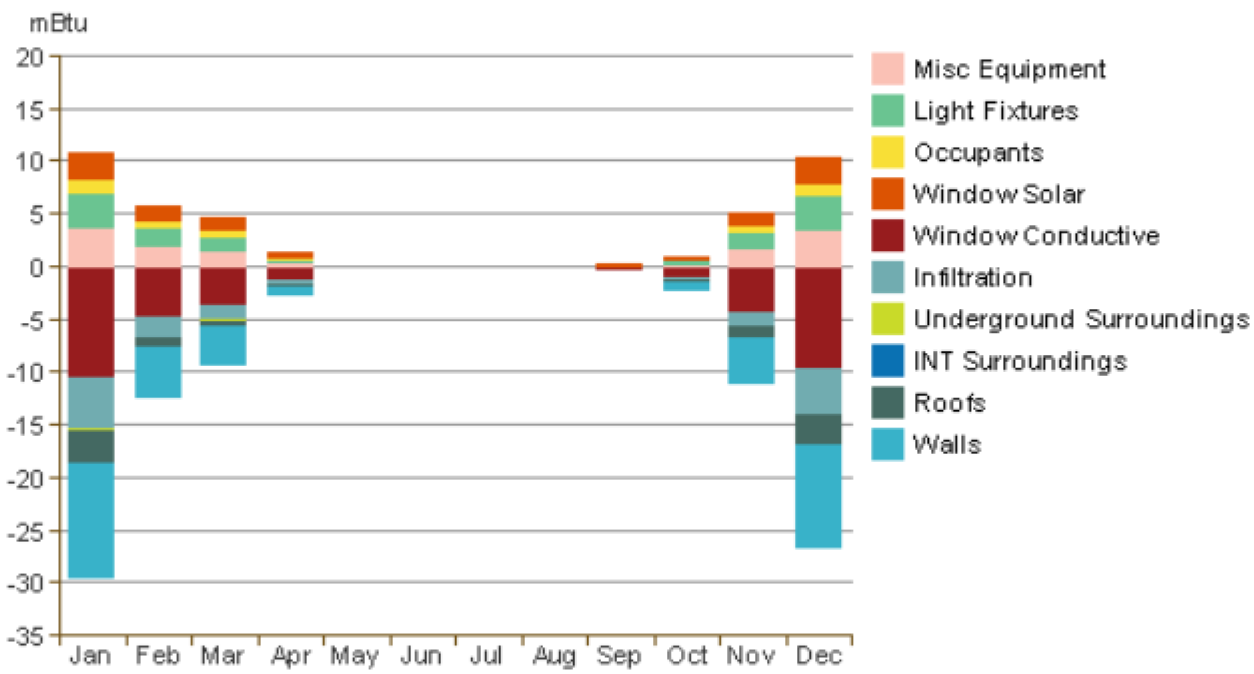


Figure 25

Maximum Negative load=29.5 mBtu

Maximum Positive load=11 mBtu

Maximum load difference=29.5-11=18.5mBtu

Extra Heating required is of 18.5 mBtu

Comparitive Analysis

Inefficient= 95 mBtu

Efficient=18.5 mBtu

Loading saved=95-18.5=76.5 mBtu

10.3. Cooling Load

Inefficient

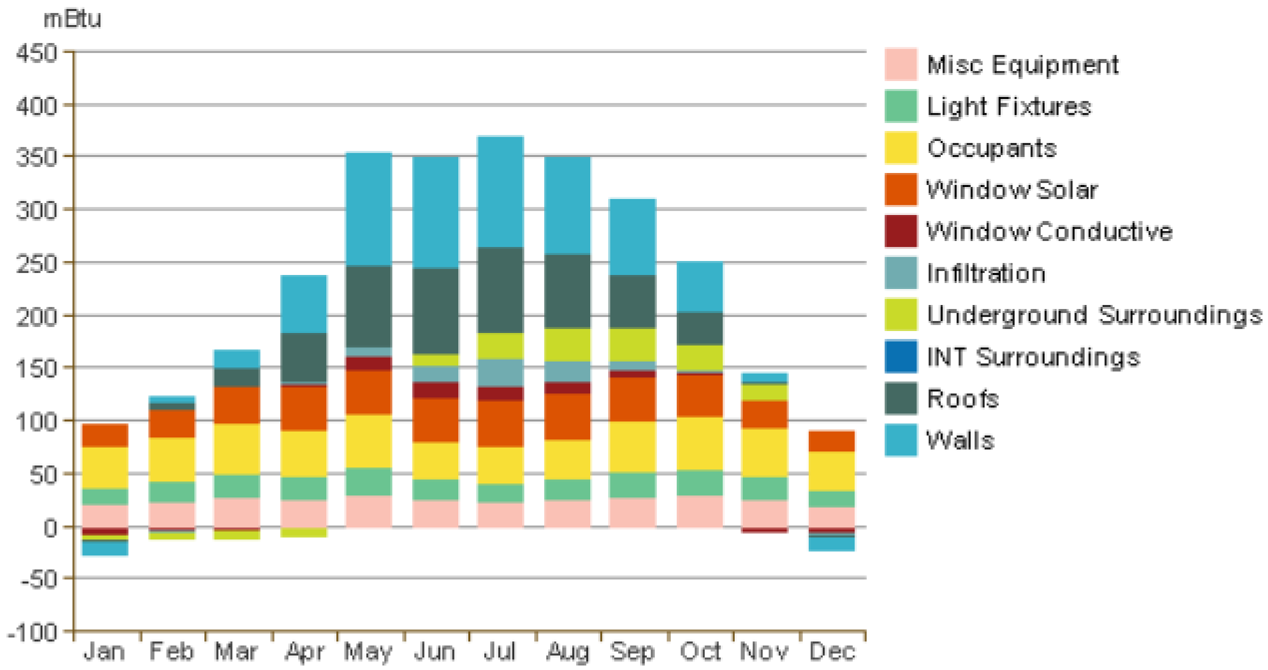


Figure 26

Maximum Negative load=25mBtu

Maximum Positive load=370 mBtu

Maximum load difference=370-25=345mBtu

Extra Cooling required is of 345mBtu

Efficient

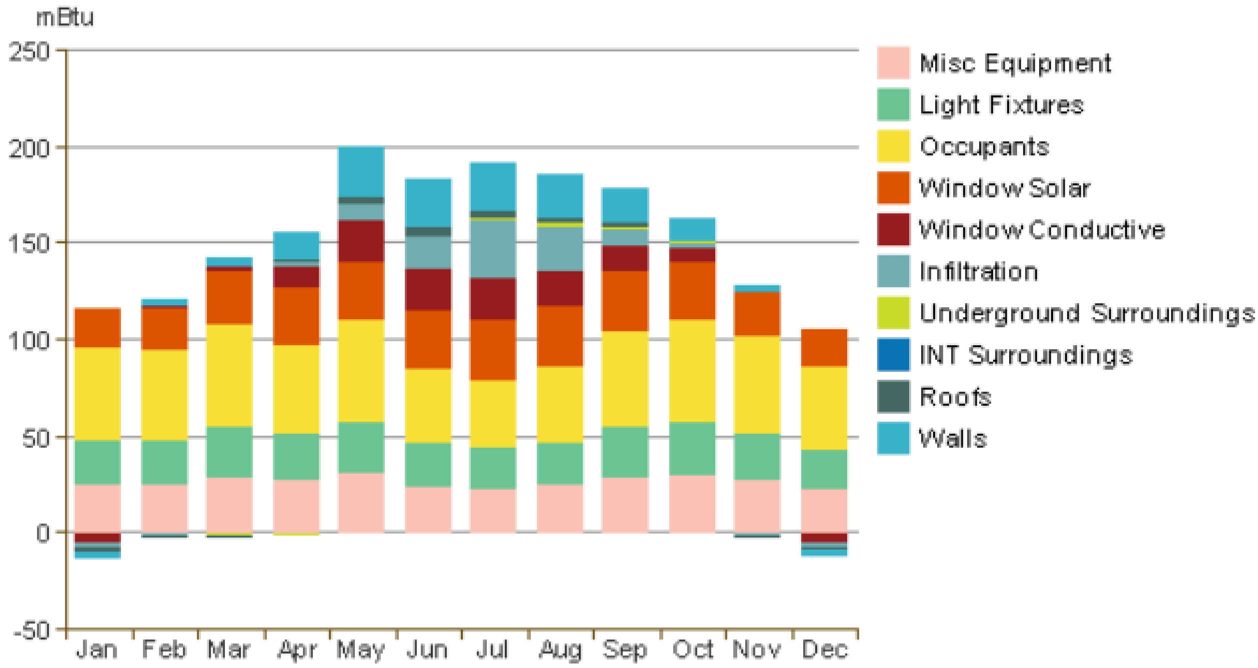


Figure 27

Maximum Negative load=10mBtu

Maximum Positive load=200 mBtu

Maximum load difference=200-10=190mBtu

Extra Cooling required is of 190 mBtu

Comparative Analysis

Inefficient=345 mBtu

Efficient=190

Loading Saved=345-190=155 mBtu

Almost 82% Cooling Load is saved.

10.4. Annual Carbon Foot Print

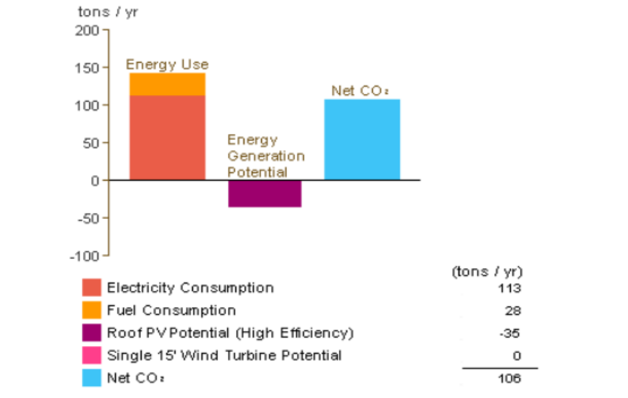
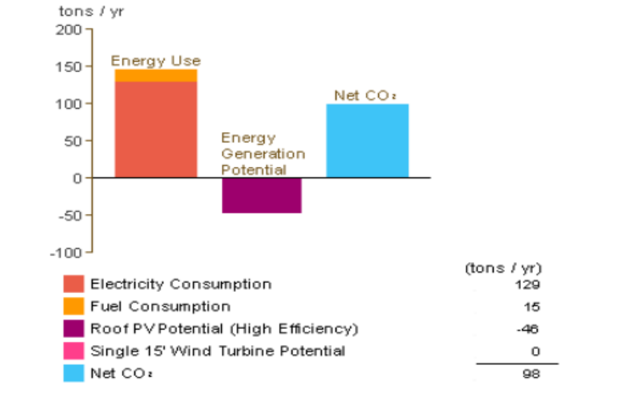
Energy Efficient	Energy Inefficient
	

Figure 28

Parameter	Inefficient	Efficient
Unit	**tons/year**	
Electricity	129	113
Gas	28	20
Solar PV	-35	-35
Wind Turbine	0	0
Total	122	98

Figure 29

Net savage=24%

10.5. Shadow Analysis

Building Shadow analysis were carried out so to get the time at which building is exposed to maximum light.

Shadow analysis were done for two days i.e Summer and winter solstice

For summers 21June was selected because it is the longest day while for winter 22 Dec was selected because it is the shortest day of a year.

10.5.1. Strategy

Four elevations were taken in a view i.e. N S E W, then these elevations were divided into the grid of 10x10.Screen shot of each elevation was taken after every 15 minutes interval and then the face area covred by the grid boxes is counted and then the grids which comes under the light were calculated, after that these counted boxes were then divided by the face area of a building, hence % exposure was graphed as shown below

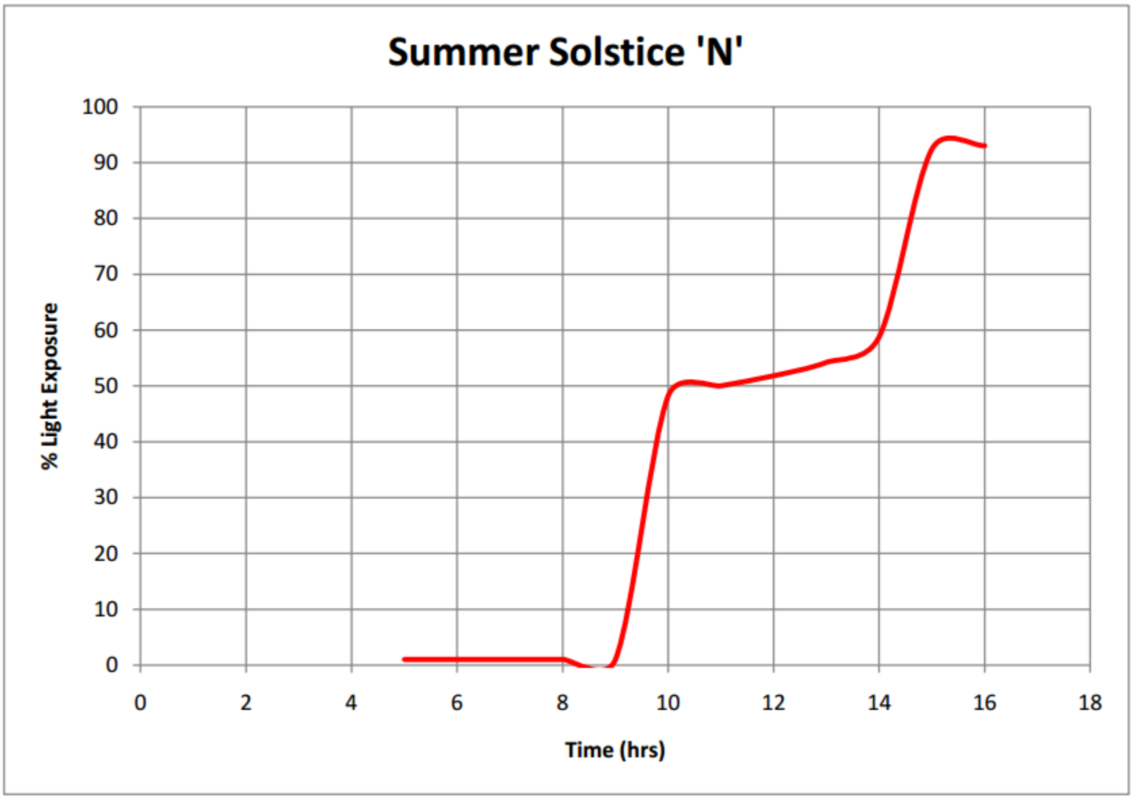


Figure 30

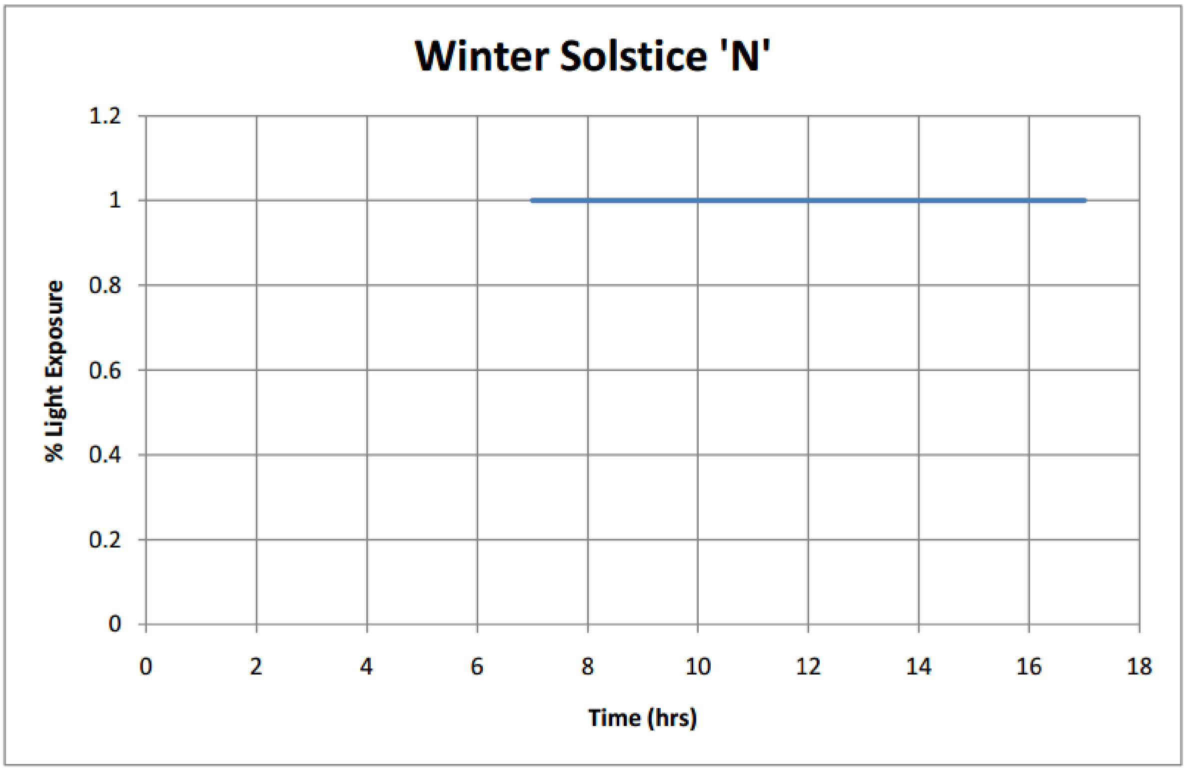

Winter Solstice 'N'
% Light Exposure
1.2
1
0.8
0.6
0.4
0.2
0
0
2
4
6
8
10
12
14
16
18
Time (hrs)

Figure 31

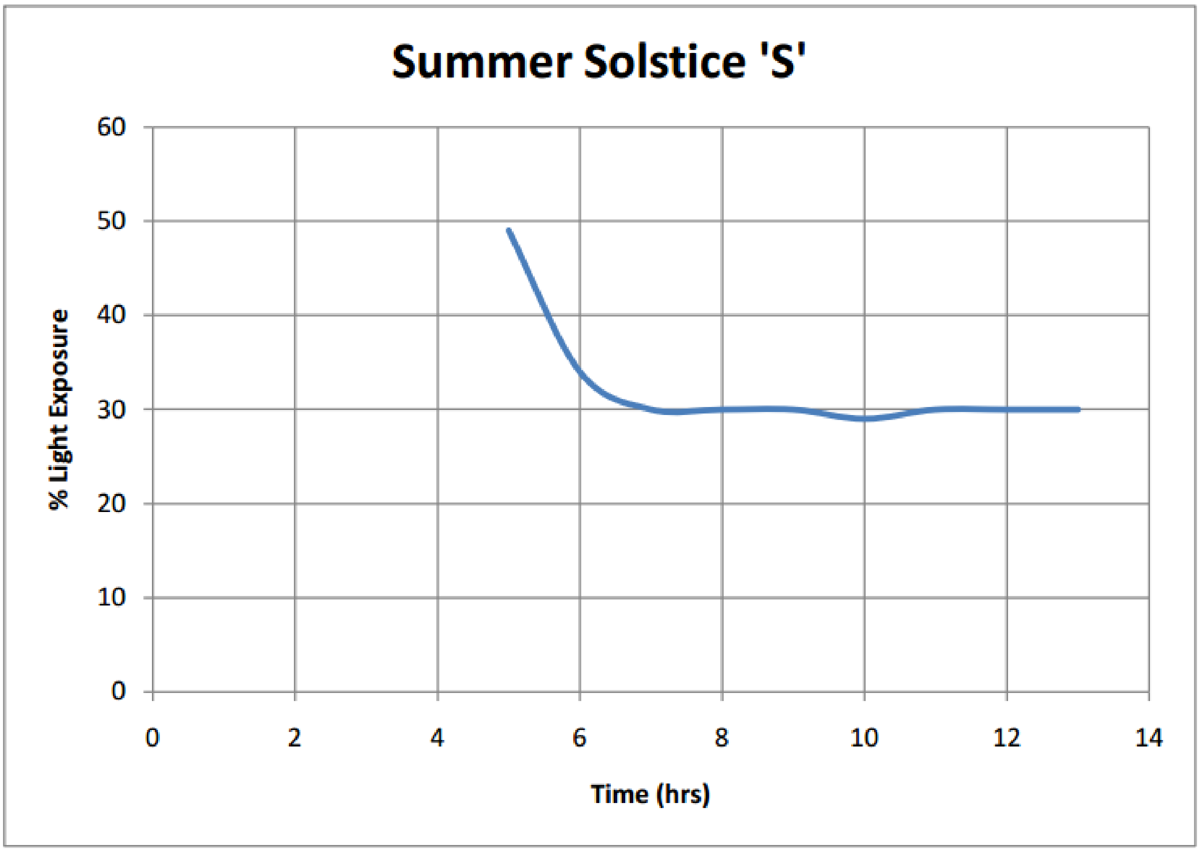

Summer Solstice 'S'
% Light Exposure
60
50
40
30
20
10
0
0
2
4
6
8
10
12
14
Time (hrs)

Figure 32

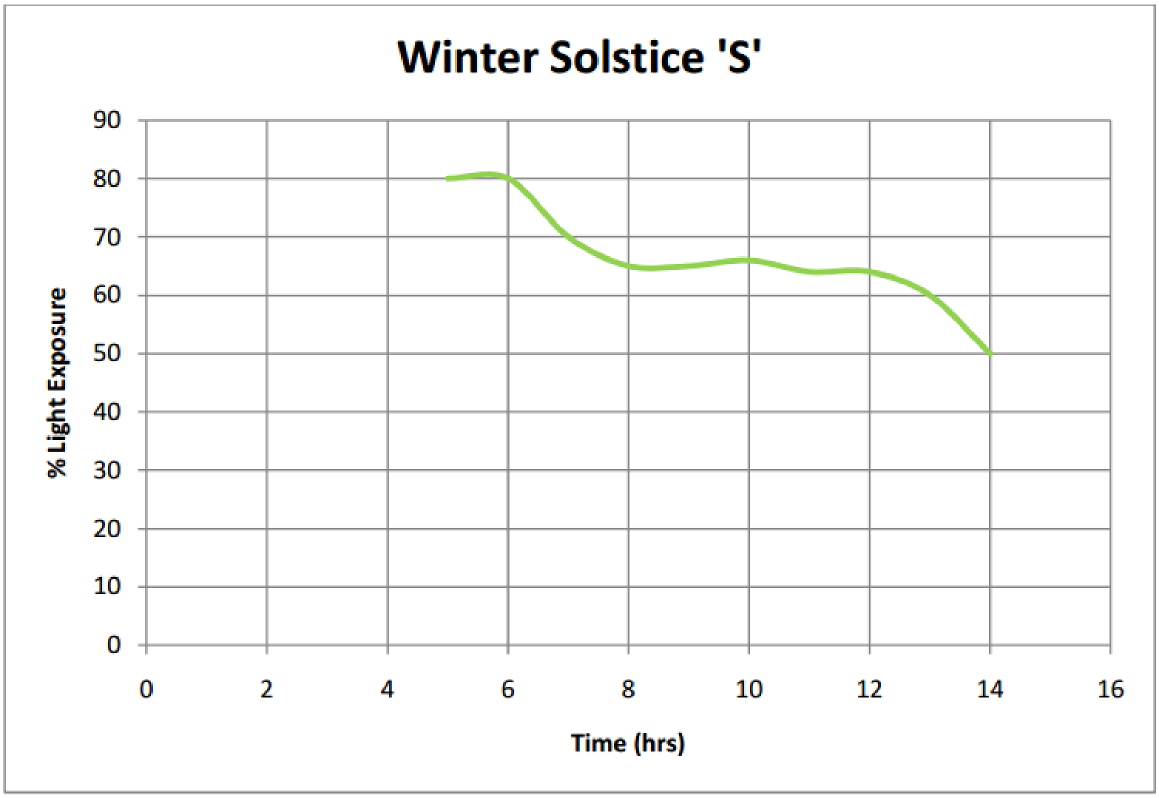


Figure 33

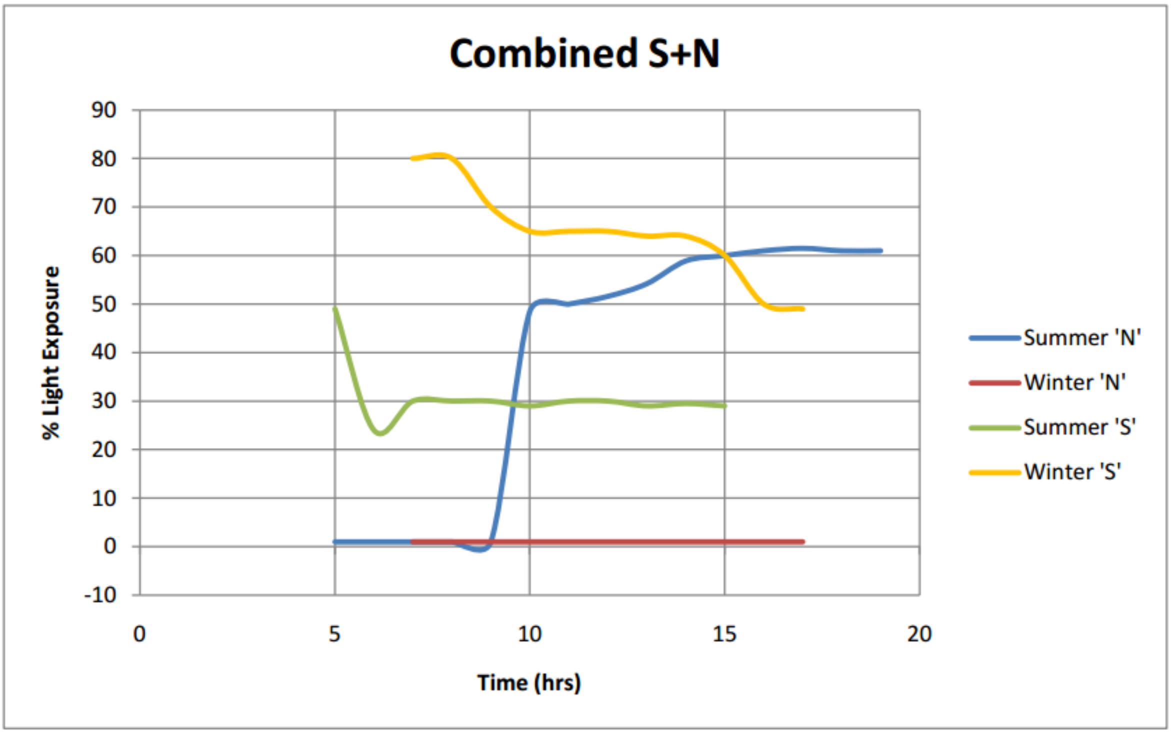


Figure 34

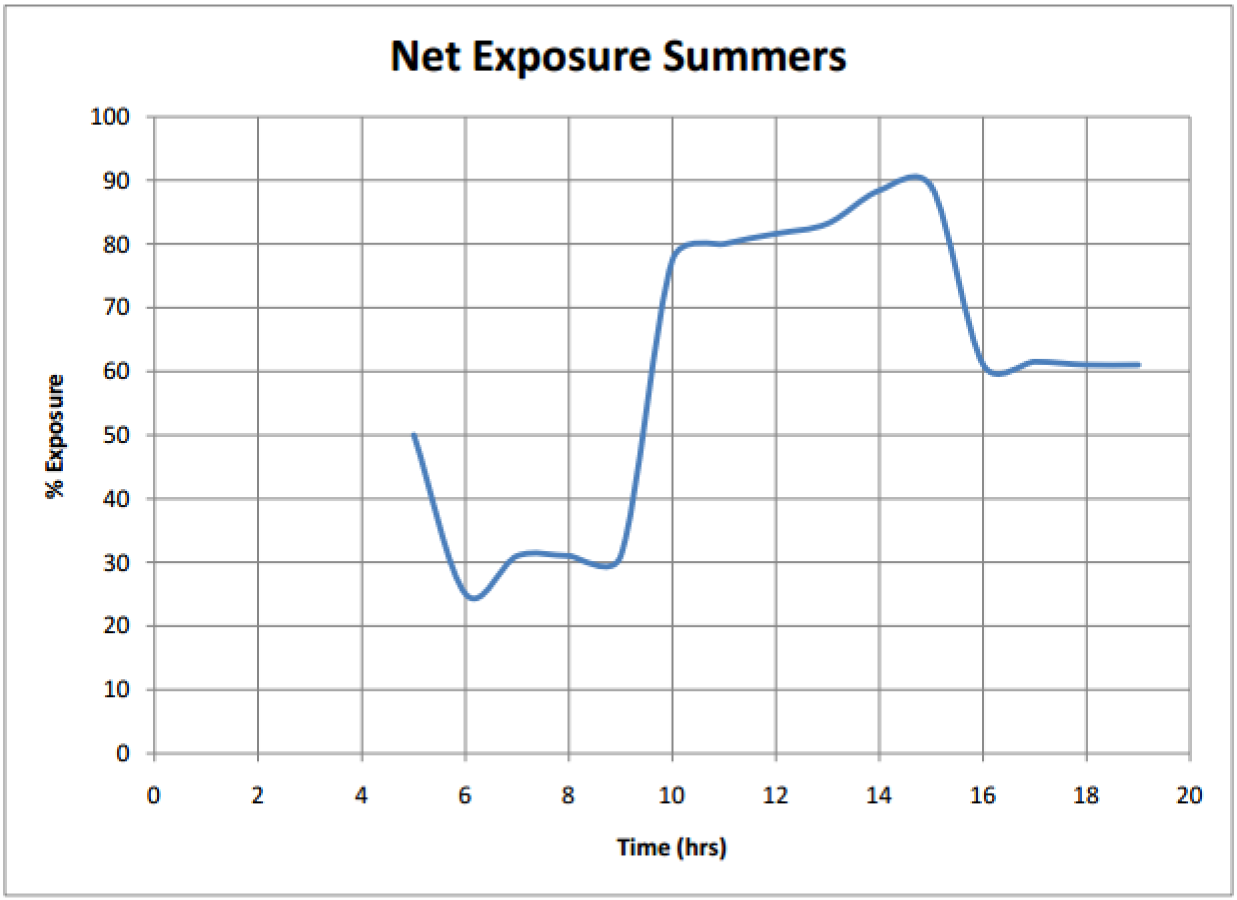


Figure 35

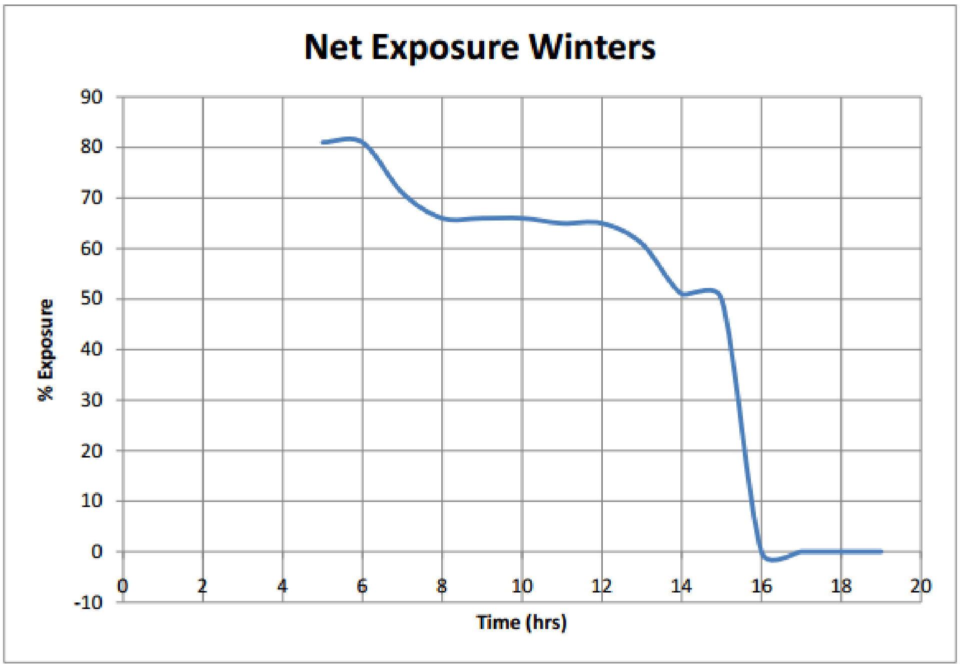


Figure 36

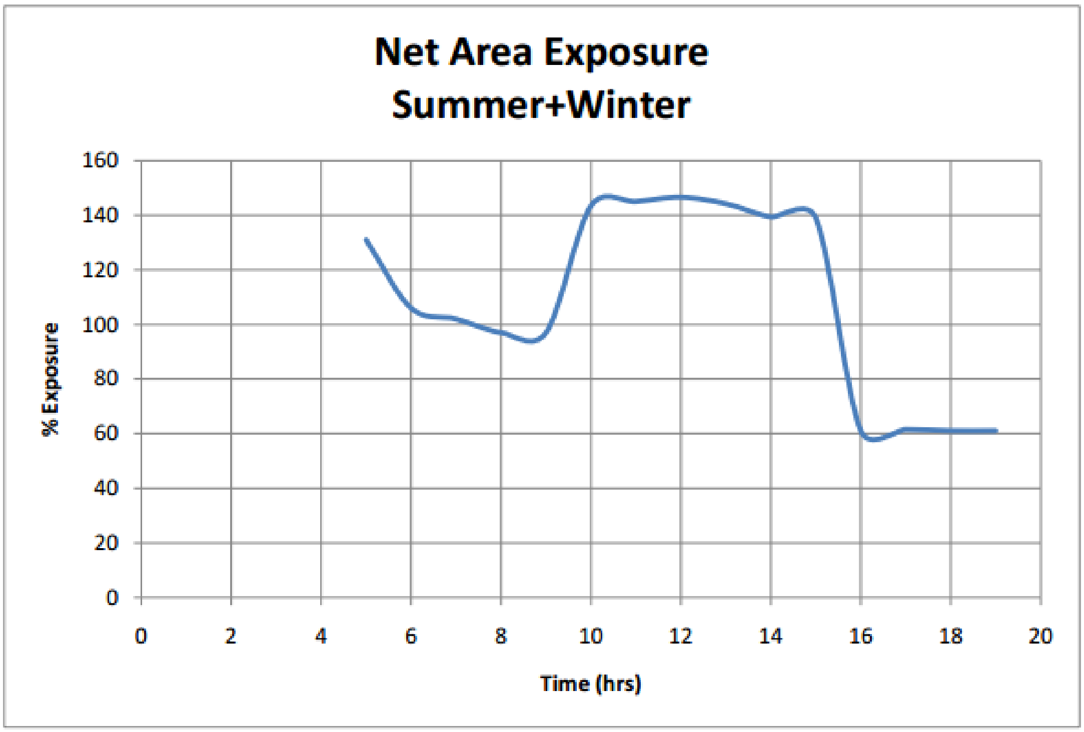


Figure 37

At the end it was concluded that the building exposure to light is 92% at 2pm- 4pm on 21 June (summer solstice).

11. Figures

12. Conclusion

Our conclusion were very close to expected one we successfully made or building 14% more efficient than the inefficient building.

Use of hempcrete in our building doesnot only makes it energy efficient but is also very chep to make it on site.

13. *References*

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