MULTI PARAMETER ANALYSIS FOR CALCULATING MINIMUM EUI OF A BUILDING USING GREEN BUILDING STUDIO AND REVIT

MAJOR PROJECT REPORT

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS

FOR THE AWARD OF THE DEGREE

OF

MASTER OF TECHNOLOGY

IN

ENVIRONMENTAL ENGINEERING

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CANDIDATE'S DECLARATION

I, Ravi Joshi, Roll No. 2K17/ENE/13 student of M. Tech (Environmental Engineering), hereby declare that the Major project report titled "MULTI PARAMETER OPTIMIZATION METHOD FOR CALCULATING MINIMUM EUI OF A BUILDING USING GREEN BUILDING STUDIO"

which is submitted by me to the Department of Environmental Engineering, Delhi Technological University, Delhi in partial fulfilment of the requirement for the award of the degree of Master of Technology, is original and not copied from any source without proper citation. This work has not previously formed the basis for the award of any Degree, Diploma Associateship, Fellowship or other similar title of recognition.

Place: Delhi **RAVI JOSHI**

Date:

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CERTIFICATE

I hereby certify that the Major project report titled "MULTI PARAMETER OPTIMIZATION METHOD FOR CALCULATING MINIMUM EUI OF A BUILDING USING GREEN BUILDING STUDIO" which is submitted by RAVI JOSHI, 2K17/ENE/13, Department of Environmental Engineering, Delhi Technological University, Delhi in partial fulfilment of the requirement for the award of the degree of Master of Technology, is a record of the project work carried out by the students under my supervision.

Place: Delhi | **Mr. ANUNAY GOUR**

Date: | **SUPERVISOR**

ACKNOWLEDGEMENT

I wish to express my profound gratitude and indebtedness to *Mr.AnunayGour*, Assistant Professor, Department of Environmental Engineering, Delhi Technological University, New Delhi, for introducing the present topic and for his inspiring guidance, constructive criticism and valuable suggestions throughout this project work.

I would also express my gratitude to all the professors of the Department of Environmental Engineering, Delhi Technological University, New Delhi, for their guidance and the support they have provided me.

Last but not least, my sincere thanks to all my friends & seniors who have patiently extended all sorts of help for accomplishing this undertaking.

ABSTRACT

A **zero energy building** (ZEB) or net zero energy building is a general term applied to a building with zero net energy consumption and zero carbon emissions, calculated over a period of time.The most important parameter in the analysis of a zero energy building is EUI. EUI stands for Energy Use Intensity;the EUI expresses a building's energy use as a function of its size or other characteristics.The EUI is expressed as energy per square metre per year. It's calculated by dividing the total energy consumed by the building in one year (MJ) by the total gross floor area of the building. In the analysis of a zero energy building our main motive is to minimize the EUI using different parameters.

So, the concept of Zero Energy Building has been analysed for different shape of buildings. Three different shapes were taken 120 shape, hollow cylinder shape, plus shape and out of these three shapes it was found out that hollow cylinder shape has minimum EUI, after that detailed analysis of G+10 Hollow cylindrical shape building considering material and glazing has been done. Seven cases has been analysed by changing the material and glazing. The minimum EUI case will be the best for the building to be considered as a zero energy building.The analysis is done in Autodesk Revit (2017) using Green Building Studio.

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CHAPTER 1

INTRODUCTION

1.1 Zero Energy Buildings

A **zero energy building** (ZEB) or net zero energy building is a term applied to a building with zero net energy consumption and zero carbon emissions, calculated over a period of time. Zero energy buildings consume lesser amount of energy as compare to traditional building and these buildings produces their own energy and use it in building. Many people in developing countries already live in zero energy buildings out of necessity, including huts, tents and caves exposed to temperature extremes and without access to electricity. The energy in the building can be measured in many ways (e.g. cost, energy, or carbon emissions) and different views exist on the relative importance of energy production and energy conservation in achieving a net energy balance.

1.2 Energy generation for ZEBs

ZEBs generate their own energy such that they fulfill their HVACs demand. Various micro generation technologies may be used to provide heat and electricity to the building, including:

• Solar: solar hot water, photovoltaics (PV)

• Wind: wind turbines

• Biomass: boilers, and community heating schemes

• Combined heat and power and micro CHP use with the following fuels: natural gas biomass sewerage gas and other biogases.

• Community heating, including utilising waste heat from large scale power generation.

1.3 FACTORS AFFECTING ENERGY UTILIZATION

1.3.1 ORIENTATION

If correct orientation of a building is chosen then one can decrease the negative effect of solar radiation inside the building which because solar radiation is responsible for increasing indoor temperature. Building should be oriented such that maximum amount of daylight can enter building so that there is lesser consumption of electricity. Symmetrical geometry of a building doesn't have major change in energy consumption. Wind Rose diagram is an important parameter for building orientation. Our building should be oriented so that it uses maximum amount of wind because it will help in reducing the load on HVAC system.

1.3.2 MATERIAL

Selection of material plays a vital role in minimizing the energy consumption. Every material has its own thermal capacity through which it stores heat. As we know that heat flows from higher temperature to lower temperature so we have to choose our material according to it. In hot places like Rajasthan, temperature is really high during day time and subsidize during night. So, we will choose material has high heat storage capacity because during day time as temperature is really high and by choosing high storage capacity material the heat will flow slowly from outside to inside of a building and load on HVAC system will reduce and as day passes the heat will start flowing inside and it will reach at night time when outside temperature start decreasing. So, ultimately material selection helps in reducing the load on HVAC system due to which energy consumption reduces.

1.3.3 SHADING

Shading is to protect our building from direct daylight which will protect building from heating up and reduces load on HVAC system. Our building shape should be such that the building facades are self-shaded during day light. Sheets and glasses are used for the purpose of shading also. Now-a-days double glass layer is used which is filled with helium gas.

1.3.4 GLAZING

Glazing is the glass component of a building which is useful for reducing energy consumption. Zero percent glazing means we haven't used any glass component i.e., opaque. Zero percent glazing gives minimum EUI but there is problem of daylight because we won't be able to use daylight due to which more lighting system will be used in our building which will ultimately increase the energy consumption. Whereas, 100% glazing has maximum EUI because 100% glazing means our building contains only glasses component due to which all the daylight will enter our building which will ultimately increases the load on our HVAC system. Optimum glazing for a building is 15-20%.

1.4 ABOUT SOFTWARE

1.4.1 AUTODESK REVIT

Autodesk Revit is building information modelling software for architects, landscape architects, structural engineers, MEP engineers, designers and contractors developed by Autodesk. It allows users to design a building and structure and its components in 3D, annotate the model with 2D drafting elements, and access building information from the building model's database. Revit is 4D BIM capable with tools to plan and track various stages in the building's lifecycle, from concept to construction and later maintenance and/or demolition.

1.4.2 GREEN BUILDING STUDIO

Building information modeling (BIM) is core to Autodesk's sustainable design approach for building performance analysis and simulation. Autodesk Green Building Studio is a web-based service that includes industry leading building energy and carbon analysis tools. Green Building Studio tools enable architects and designers to evaluate the energy profiles and carbon footprints of various building designs. Autodesk Green Building Studio supports the needs of those who challenge themselves with design of sustainable and environmentally responsible structures. With Autodesk Green Building Studio can perform whole building analysis, optimize energy efficiency, and work toward carbon neutrality earlier in the design process.

It gives the results of energy consumption such as water usage and costs, natural ventilation potential, carbon emissions based on an actual model, local energy sources and weather data.

CHAPTER 2

LITERATURE REVIEW

Ashwin Venkataraman1 and Ramesh Kannan.M2(2013) demonstrated a 3D BIM model of G+2 building is used as a reference for executing the energy simulations in the six major climatic zones (Cold and Sunny Zone, Cold and Cloudy Zone, Warm and Humid Zone, Hot and Dry Zone, Composite Zone and Moderate Zone) of India. The results obtained are the derivation of energy simulation patterns for different climatic zones in addition to the performance indicator, luminous intensity and other energy related factors. They have concluded that The companies which utilise energy simulation software the most successfully will be the ones attracting the greater number of clients as energy simulation models become a deliverable in every project proposal. If larger consultancies start to incorporate these methods into their design process then the smaller companies will follow to remain competitive. If the larger companies can ensure interoperability between the software used by their various departments, it will enable a seamless integration of the use of BIM throughout the building life cycle and thus lower costs and penalties that would have otherwise been incurred.

Hasan et al(2016) concluded that the new BIM concept and its tools have dramatically reduced the complexity of running simulations and creating models as well as the time spent doing this and this concept main advantage is then not only the collaborative work but also the possibility to test and choose between different solutions without spending a lot of time creating the models for each one. This is mainly interesting because of the potential of testing all possibilities and their impact on the energy efficiency before making a decision on the final renovation scenario.

Petri et al(2017) they have presented how building information modeling can be utilized to address energy efficiency in buildings in the operation phase , greatly contributing to achieving carbon emissions targets. They used BIM for the operation phase and emphasized the benefits that can be derived from such an approach regarding energy optimization and emission reductions. However, BIM for energy efficiency represents an on-going process requiring specialized training in order to develop skills and competencies for the entire construction community.

Torcellini et al(2006), demonstrates the progress toward achieving ZEB goals in real-world examples. They discovered that only the Science House has achieved the site and source

ZEB goal because it is a small building with a relatively large PV system. The other one-story buildings—Zion, BigHorn, and TTF—could achieve ZEB within their roof areas for all the definitions except cost ZEB. ZEB is not feasible for the two-story buildings unless their loads are further reduced. For Oberlin (currently closest to meeting a ZEB goal in a two-story building), the annual PV production is still less than the best-case energy consumption scenario. Oberlin is currently installing another 100-kW PV system in the parking lot (total installed DC capacity will be 160 kW), which will be tied into the building's electrical system. We expect that the building will achieve a site, source, and emissions ZEB, but that a cost ZEB will be difficult to reach without further demand management controls. To accomplish a ZEB, the PV system has been extended past the building footprint.

Perlova et al(2014)They have produced the series of studies and it corresponds to identifying and practical application of a body of architectural and planning solutions to reduce the heat loss through the building of the building envelope .They found that the optimal building orientation to the side of the light with the prevailing wind direction during the winter in order to neutralize the negative impact of climate change on the building and thermal balance. They also found that the presence of vestibule at the entrance, this avoids the additional heat loss.

Total energy demand in the building is a sum of thermal (heating, cooling) demand and electricity demand (appliances, lighting), however many studies focus only on one neglecting the other. This issue is raised by Able, (1994): "Many low-energy building projects seem to have been based on the idea 'decrease heat supply at any cost'. In some cases, this has resulted in 'zero-energy buildings' which, it is true, do not need any heat supply but do, instead, indirectly need electricity, e.g., to operate the heat pump included in the system."

Esbensen, et al. (1977) describe an experimental ZEB house in Denmark and point out: "With energy conservation arrangements, such as high-insulated constructions, heat recovery equipments and a solar heating system, the Zero Energy House is dimensioned to be self-sufficient in space heating and hot-water supply during normal climatic conditions in Denmark. Energy supply for the electric installations in the house is taken from the municipal mains."

Saitoh, (1984) and Saitoh, et al. (1985) in their studies present a Natural Energy Autonomous House in Japan. According to authors: "… a multi-purpose natural energy autonomous house will meet almost all the energy demands for space heating and cooling as well as supply of hot water for standard Japanese house in 10-15 years. For this purpose, solar energy, the natural underground coldness and sky radiation cooling are utilized."
In the NREL report "The Potential Impact of Zero Energy Homes" from 2006, authors use as basis for the ZEB description the definition given by The U.S. Department of Energy (DOE) Building Technologies Program: "a net zero energy building is a residential or commercial building with greatly reduced needs for energy through efficiency gains, with the balance of energy needs supplied by renewable technologies." and later extend it by saying:" A Zero Energy Home combines state-of-the-art, highly energy-efficient designs and equipment with on-site renewable energy generation (which typically includes a solar hot water production system and a rooftop photovoltaic, or PV, system) to return as much energy to the utility as it takes on an annual basis. Zero Energy Homes are designed to perform well, be comfortable, require only standard maintenance, and look no different from an ordinary home."

According to Lausten, (2008), "Zero Net Energy Buildings are buildings that over a year are neutral, meaning that they deliver as much energy to the supply grids as they use from the grids. Seen in these terms they do not need any fossil fuel for heating, cooling, lighting or other energy uses although they sometimes draw energy from the grid."

CHAPTER 3

METHODOLOGY

All the work has been done in Autodesk Revit and Green Building Studio. In minor project basically three different shapes were taken. The three shapes are:

1. 120 Shape
2. Plus Shape
3. Hollow Cylindrical Shape

So, after analyzing these three different shapes, it was found out to be that Hollow Cylindrical Shape has minimum EUI. In this report, further analysis has been done on Hollow Cylindrical Shape based on material and percent glazing.

Firstly, the shape was built after that column, wall and mass floor was added in it. Then, location of DTU was taken and then wall material, slab and percent glazing was changed in each cases. Then we have to find out the minimum EUI case.

Steps:

1. Make hollow cylindrical shape
2. Set up the 10 levels shape in any of the elevation view
3. Go to plan view make a grid array this grid radially from centre to have a circle of grids
4. Place 2 columns on grid 1 at a distance of 3m and 8 m from centre.
5. Select one column at a time and array it radially by taking the same centre of rotation as in previous case.
6. Draw beams connecting all columns in inner and outer circle. Draw beam from column to column.
7. Copy all columns and beams in other floors.
8. Now go to analyze tab and in energy settings, set the location
9. And do required settings over there.
10. Now create the energy model and run energy simulation.

CHAPTER 4

MODEL ANALYSIS

4.1 Autodesk Revit based Model for various shapes

1. PLUS SHAPE

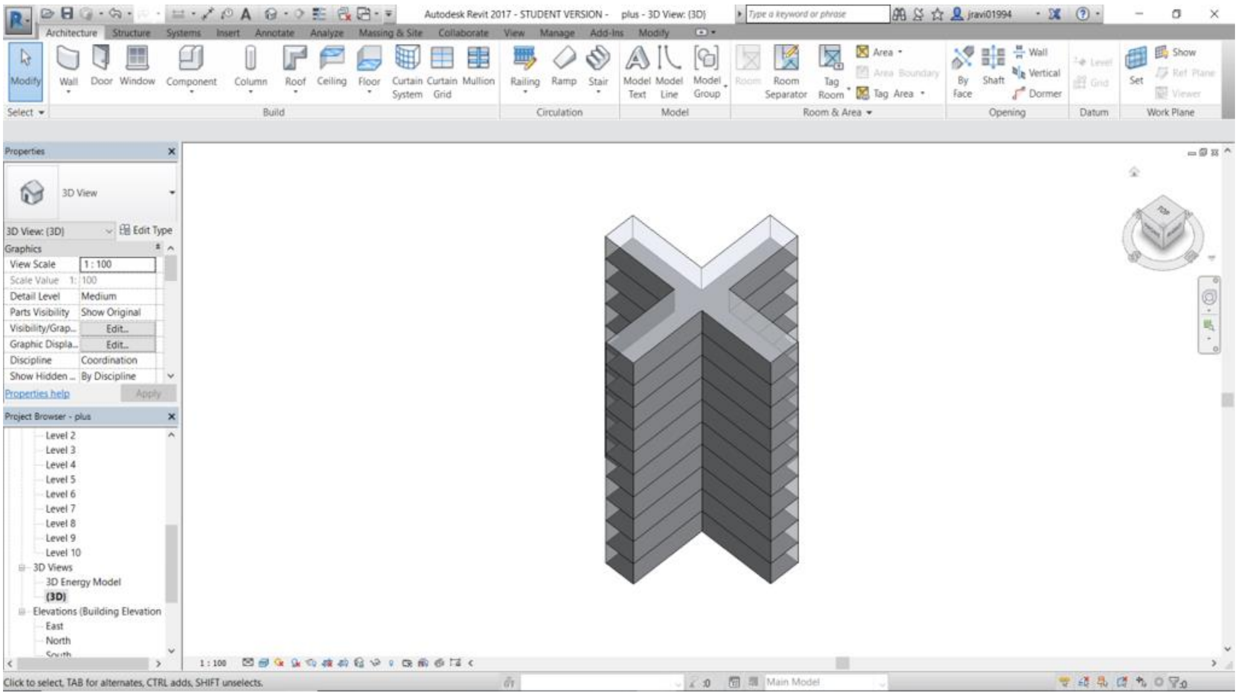


Figure 4.1PLUS SHAPE

2. HOLLOW CYLINDER SHAPE

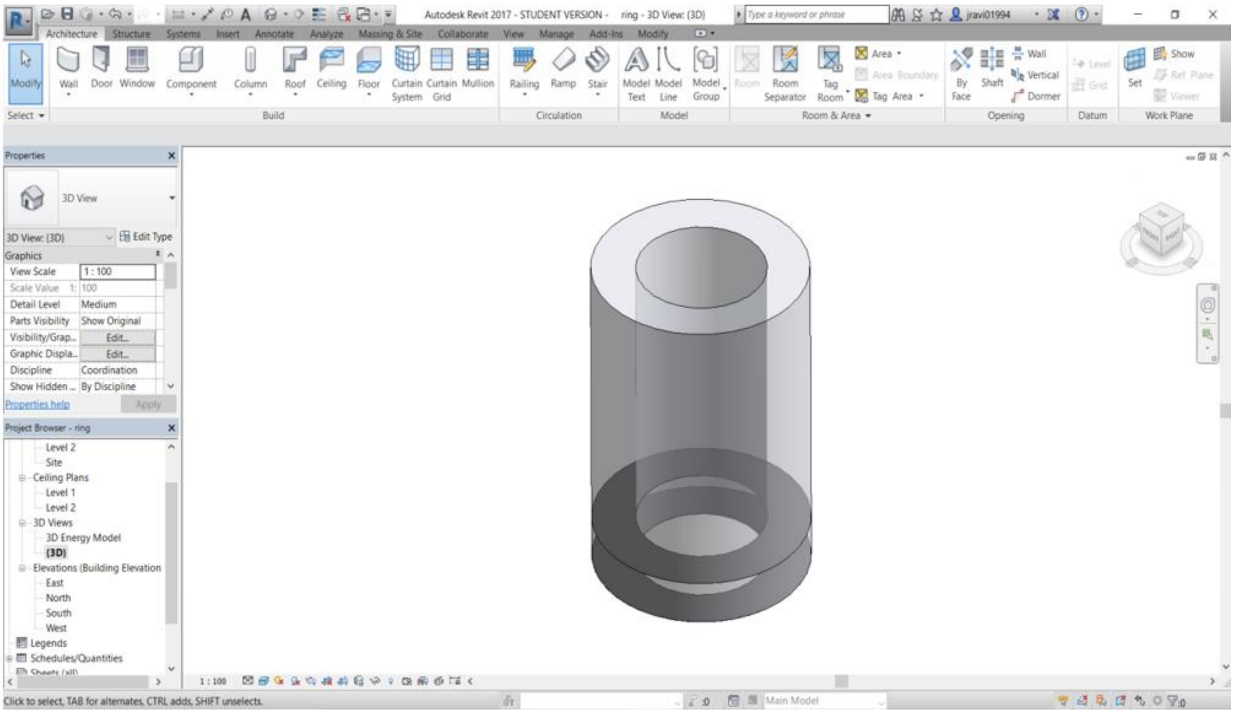


Figure 4.2HOLLOW CYLINDRICAL SHAPE

3. 120 SHAPE

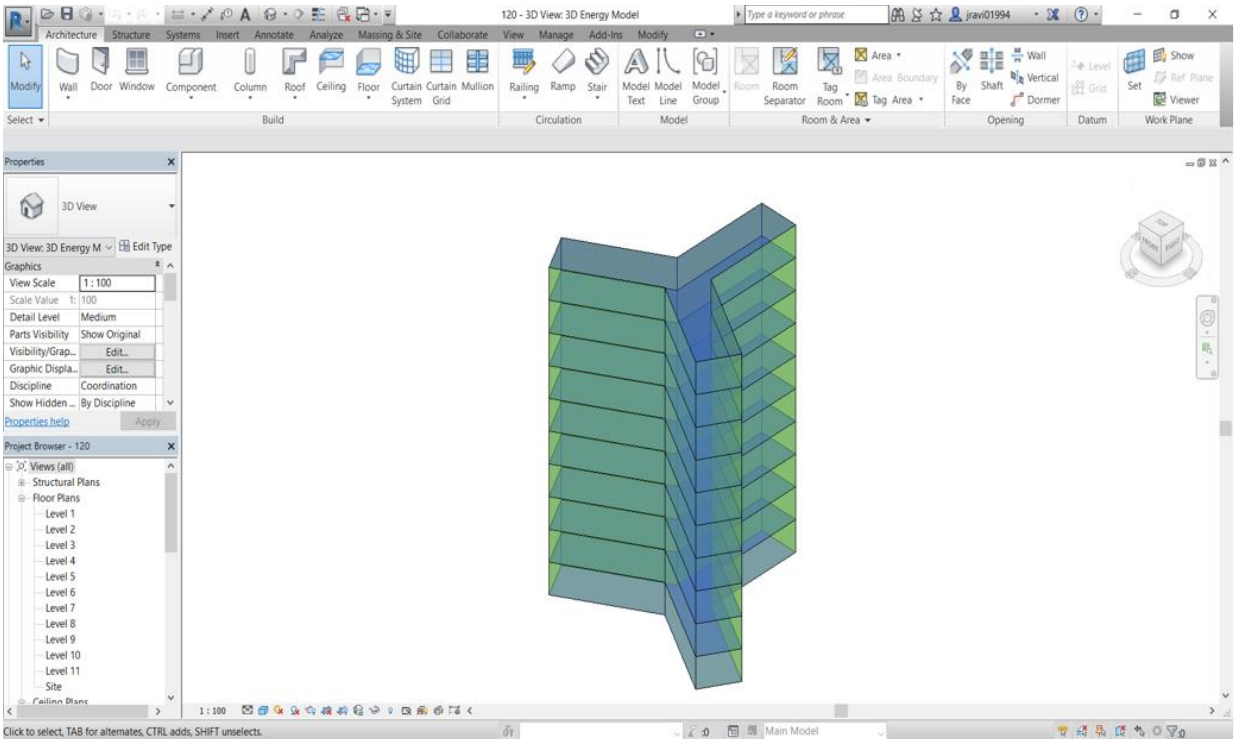


Figure 4.3120 SHAPE

4.2 VIEWS OF HOLLOW CYLINDRICAL SHAPE

1. 3D VIEW

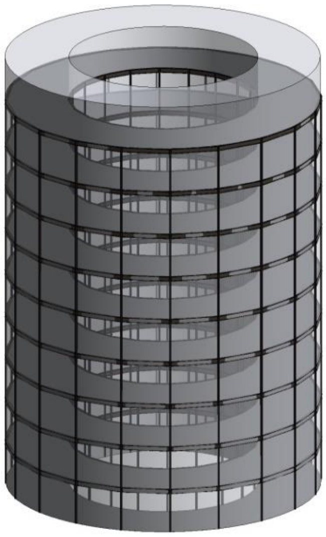


Figure 4.43D VIEW

2. ELEVATION VIEW

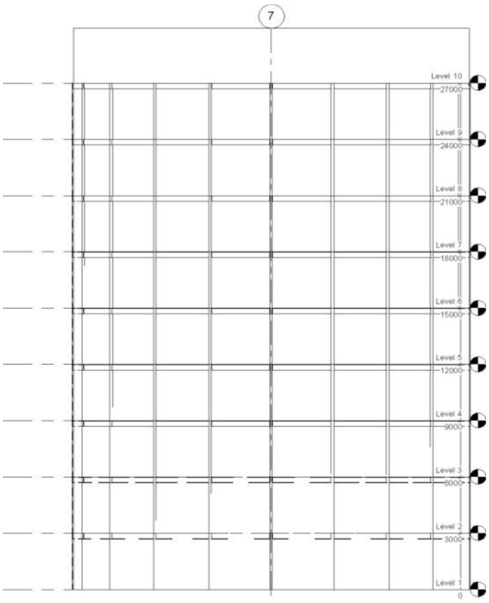


Figure 4.5ELEVATION VIEW

3. PLAN VIEW

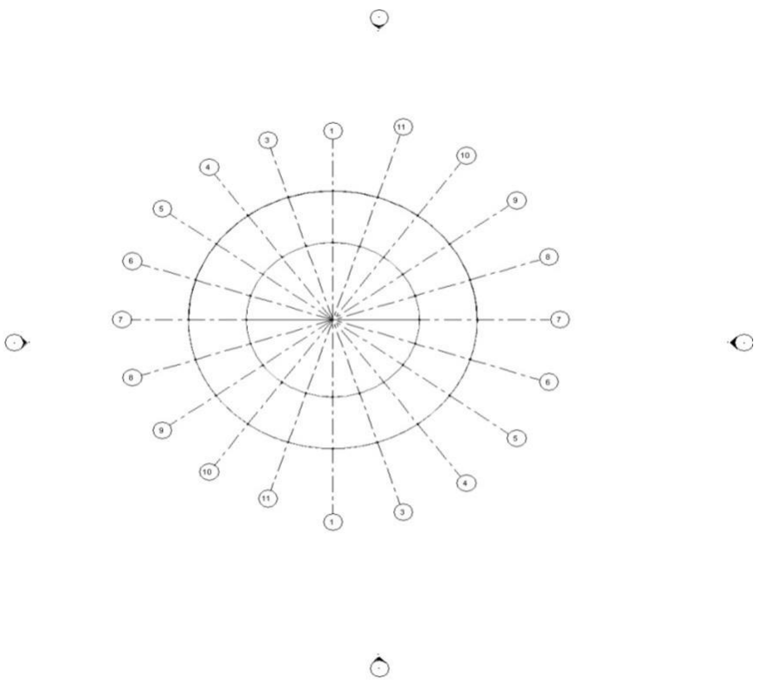


Figure 4.6PLAN VIEW

4.3 PARAMETERS OF ANALYSIS

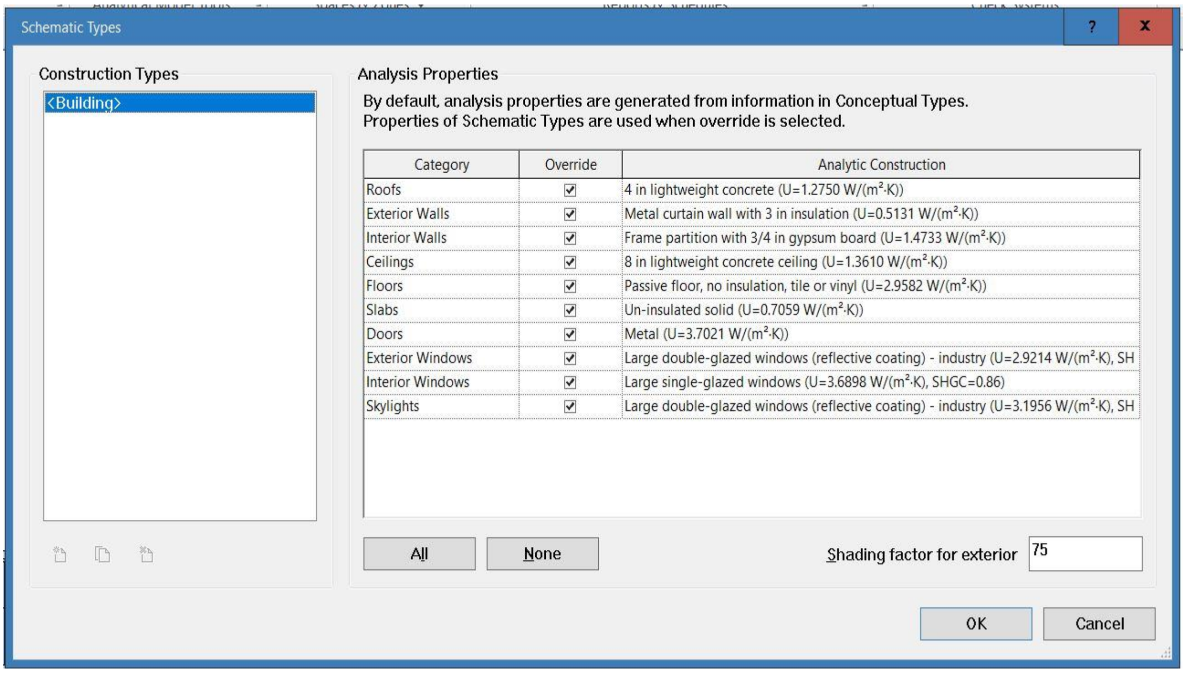


Figure 4.7 CURTAIN WALL PARAMETER

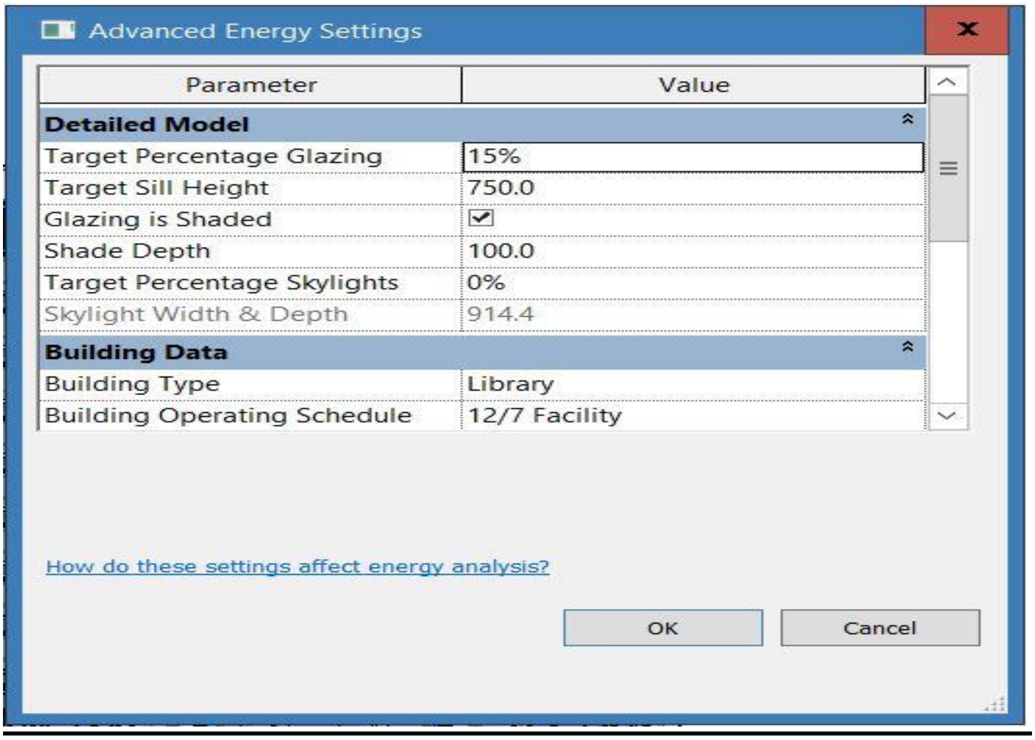


Figure 4.815% GLAZING

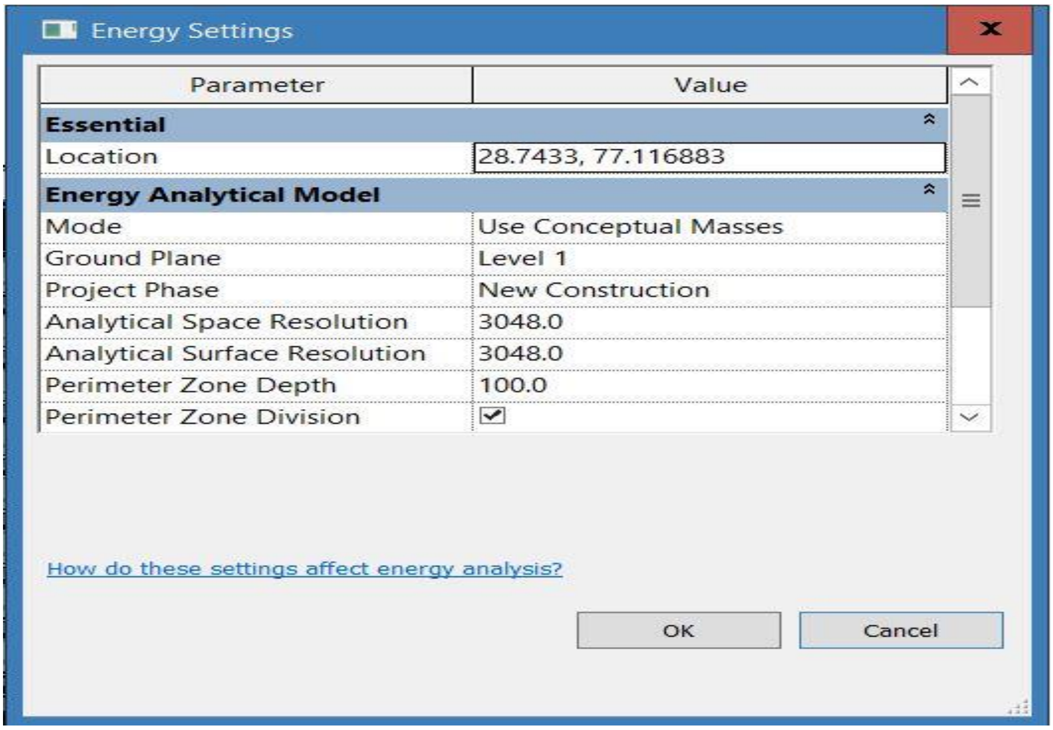


Figure 4.9GENERAL PARAMETER

CHAPTER 5

RESULTS

5.1 CURTAIN WALL+SUPER-INSULATED SLAB+20% GLAZING

Figure 5.1 Model

Building Performance Factors [See Annexure]

Location:	New Delhi, DL
Weather Station:	429042
Outdoor Temperature:	Max: 46°C/Min: 3°C
Floor Area:	2,010 m²
Exterior Wall Area:	3,008 m²
Average Lighting Power:	12.70 W / m²
People:	201 people
Exterior Window Ratio:	0.15
Electrical Cost:	$0.08 / kWh
Fuel Cost:	$0.78 / Therm

Energy Use Intensity

Electricity EUI:	268 kWh / sm / yr
Fuel EUI:	56 MJ / sm / yr
Total EUI:	1,023 MJ / sm / yr

Life Cycle Energy Use/Cost

Life Cycle Electricity Use:	16,193,157 kWh
Life Cycle Fuel Use:	3,382,311 MJ
Life Cycle Energy Cost:	$599,542
*30-year life and 6.1% discount rate for costs	

Renewable Energy Potential

Roof Mounted PV System (Low efficiency):	16,557 kWh / yr
Roof Mounted PV System (Medium efficiency):	33,114 kWh / yr
Roof Mounted PV System (High efficiency):	49,671 kWh / yr
Single 15' Wind Turbine Potential:	414 kWh / yr
*PV efficiencies are assumed to be 5%, 10% and 15% for low, medium and high efficiency systems	

Annual Carbon Emissions

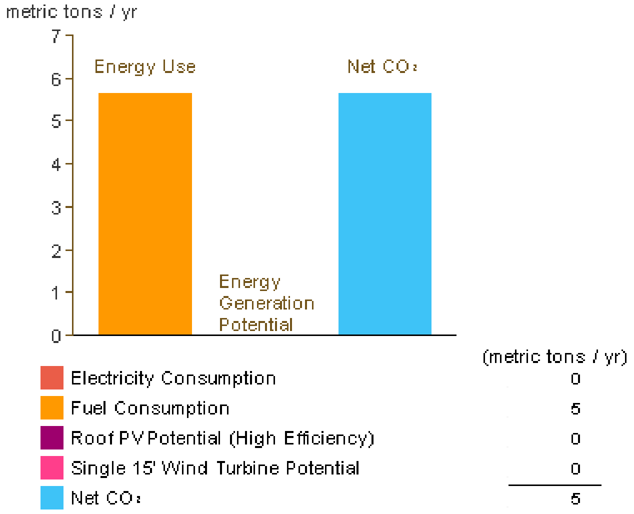


Figure 5.2 Annual Carbon Emissions Graph

Energy Use CO_2 - Energy Generation Potential CO2 = Net CO2

Energy Use is the estimated annual CO_2 emissions for electricity and fuel consumption as shown in fig 5.2.

Energy Generation Potential: A negative number representing tons of carbon one can potentially remove from the project by using renewable energy rather than obtaining power from the electricity grid.

Annual Energy Use/Costs

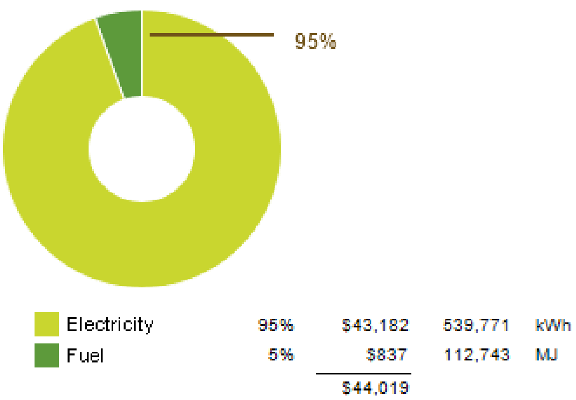


Figure 5.3 Annual Energy Use/Cost Pie Chart

Fig. 5.3 estimates energy use for electricity vs major fuel. Major fuels includes natural gas, propane, heating oil and other resources. Percentage breakdown is based on usage not cost.

1 therm = 100 kBtu

1 kilowatt-hour (kWh) = 3.413 kBtu

Energy Use: Fuel

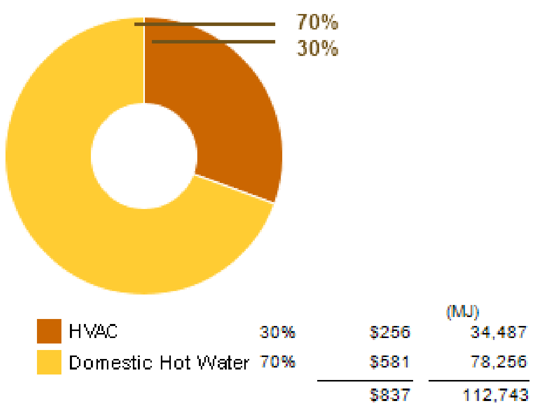


Figure 5.4 Energy Use: Fuel Pie Chart

Fig 5.4 compares estimated fuel use for HVAC and domestic hot water usage. It shows the percentage of total fuel use, costs, and therms for each end use. By identifying the end use that requires the most fuel, we can focus on strategies to reduce overall energy consumption.

Energy Use Intensity

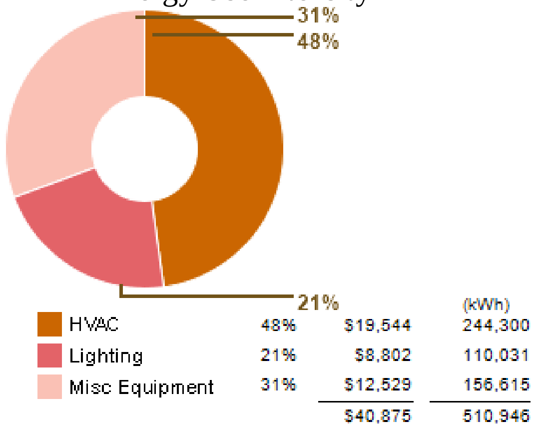


Figure 5.5 Energy Use: Fuel Pie Chart

Fig. 5.5 shows estimated electricity use for major end uses, including HVAC, lighting and equipment

1.0 kWh = 3.6 MJ = 3413 BTU

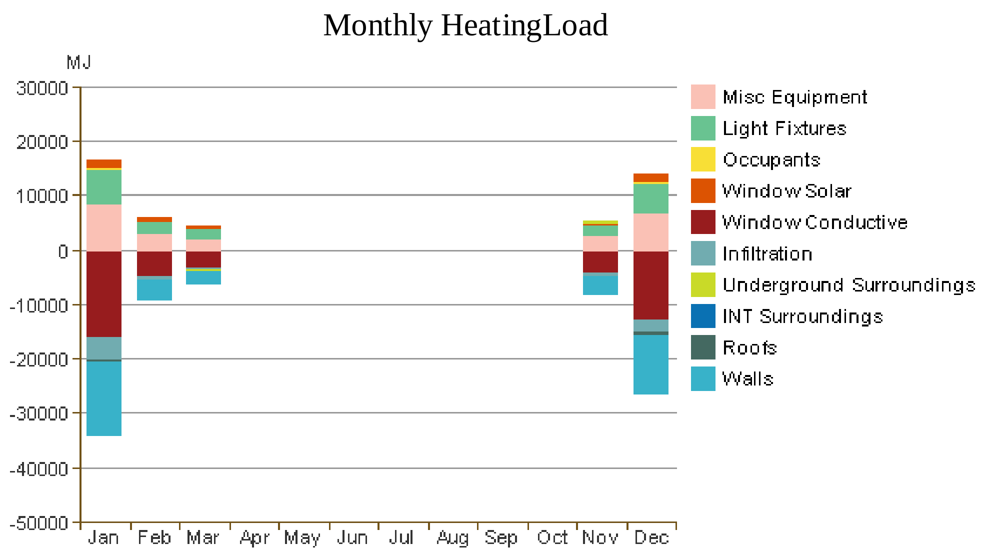


Figure 5.6 Monthly Heating Load Graph

Fig. 5.6 shows the cumulative heating loads on the analyzed model for each month. It does not represent the peak heating load used for sizing of heating equipment

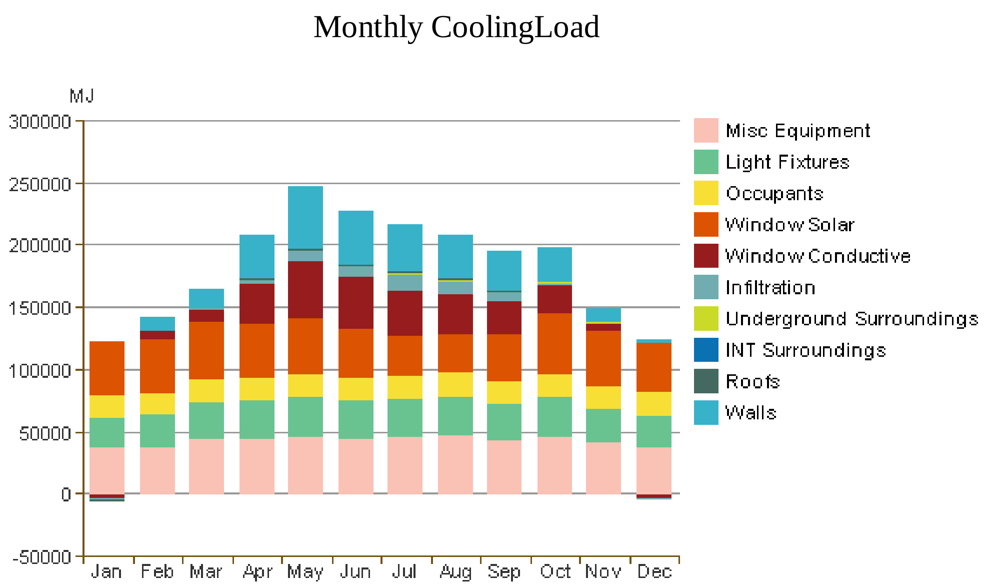


Figure 5.7 Monthly Cooling Load Graph

Fig. 5.7 shows the cumulative cooling loads on the project for each month. Positive values represent cooling demands that must be satisfied by a cooling system or other means. Negative values offset the need for cooling. For example, conduction through a closed window may provide some cooling to a building at night if the ambient temperature is low enough.

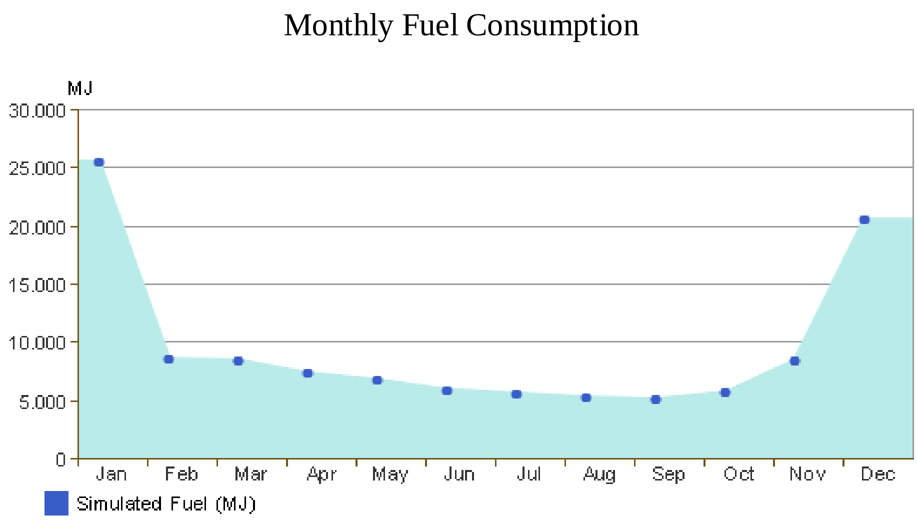


Figure 5.8 Monthly Fuel Consumption Graph

Fig. 5.8 displays the project's estimated fuel usage by month. If the project uses fuel for heating (as opposed to electric heating sources), fuel usage increases during the colder months of the year.

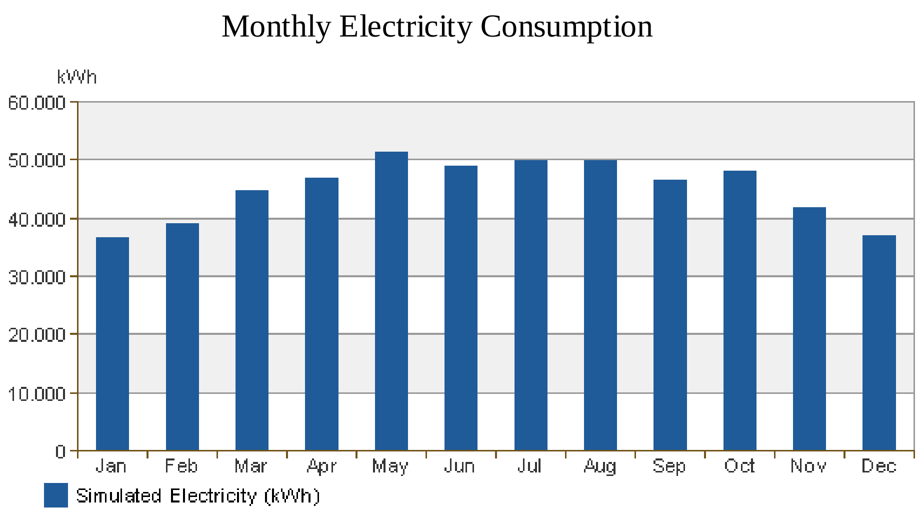


Figure 5.9 Monthly Electricity Consumption Graph

Fig 5.9 displays the project's estimated electricity usage by month. If the project uses air conditioning, electricity usage increases during the hotter months of the year.

Monthly Peak Demand

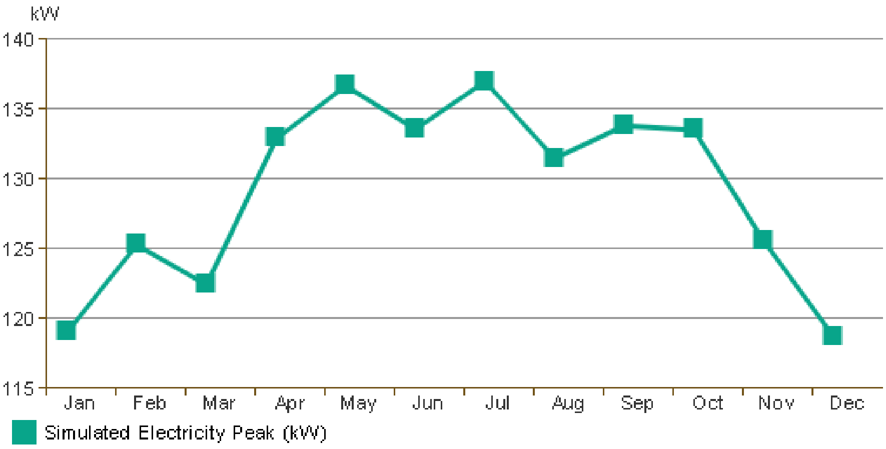


Figure 5.10 Monthly Peak Demand Graph

Fig 5.10 displays the project's estimated peak electricity demand by month. Peak demand is the maximum instantaneous electrical load.

Annual Wind Rose (Speed Distribution)

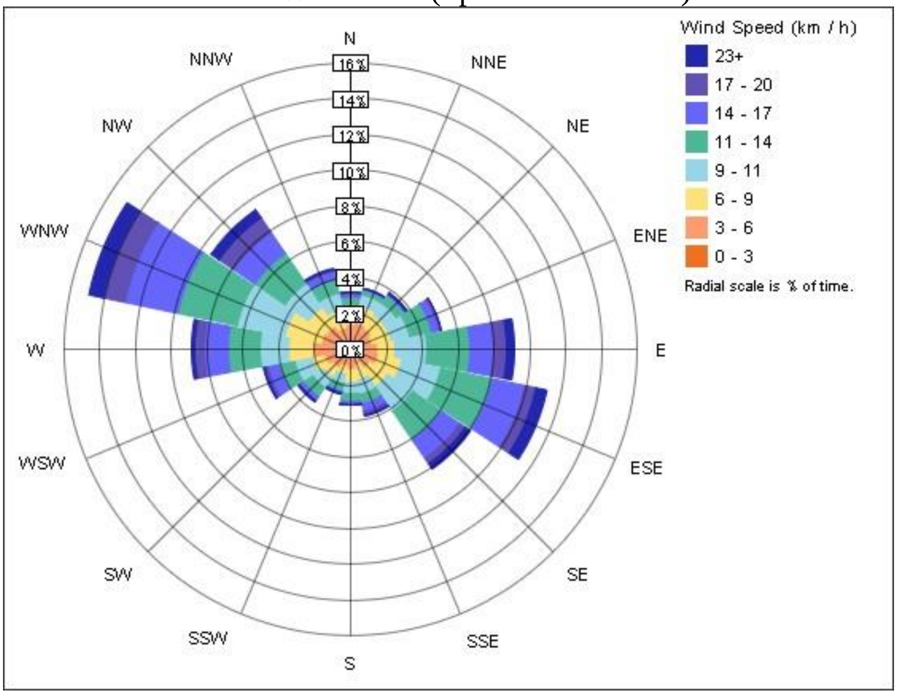


Figure 5.11 Annual Wind Rose (Speed Distribution)

Fig. 5.11 shows the Wind Rose diagram for speed distribution. 16 cardinal direction are used in these wind roses. Speed is maximum in the WNW direction.

Annual Wind Rose (Frequency Distribution)

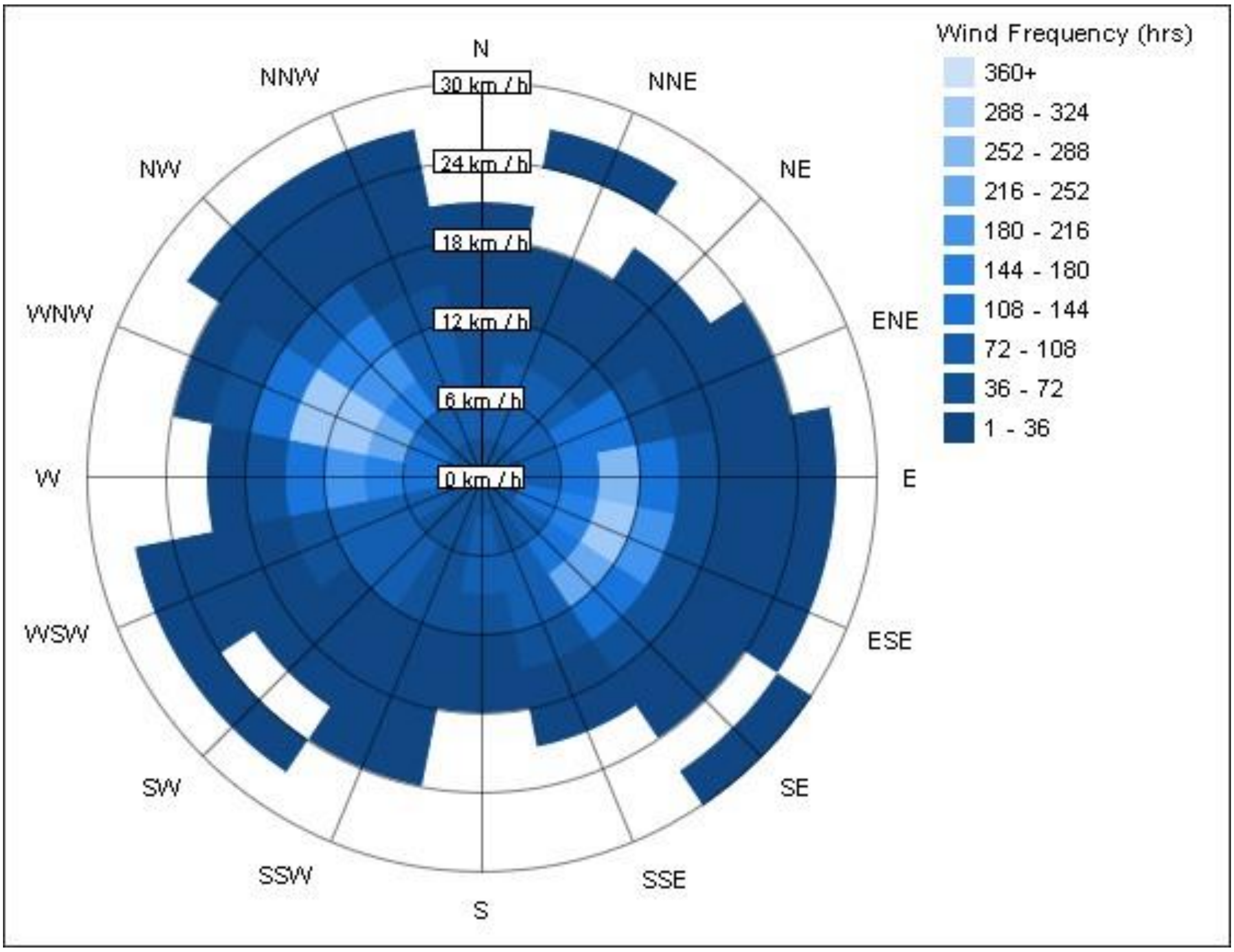


Figure 5.12 Annual Wind Rose (Frequency Distribution)

This wind rose shows the same data as the Speed Distribution wind rose, except the radial scale now represents wind speed rather than percent of time. Also, the colored segments of each spoke represent hours rather than wind speed.

Monthly Wind Roses

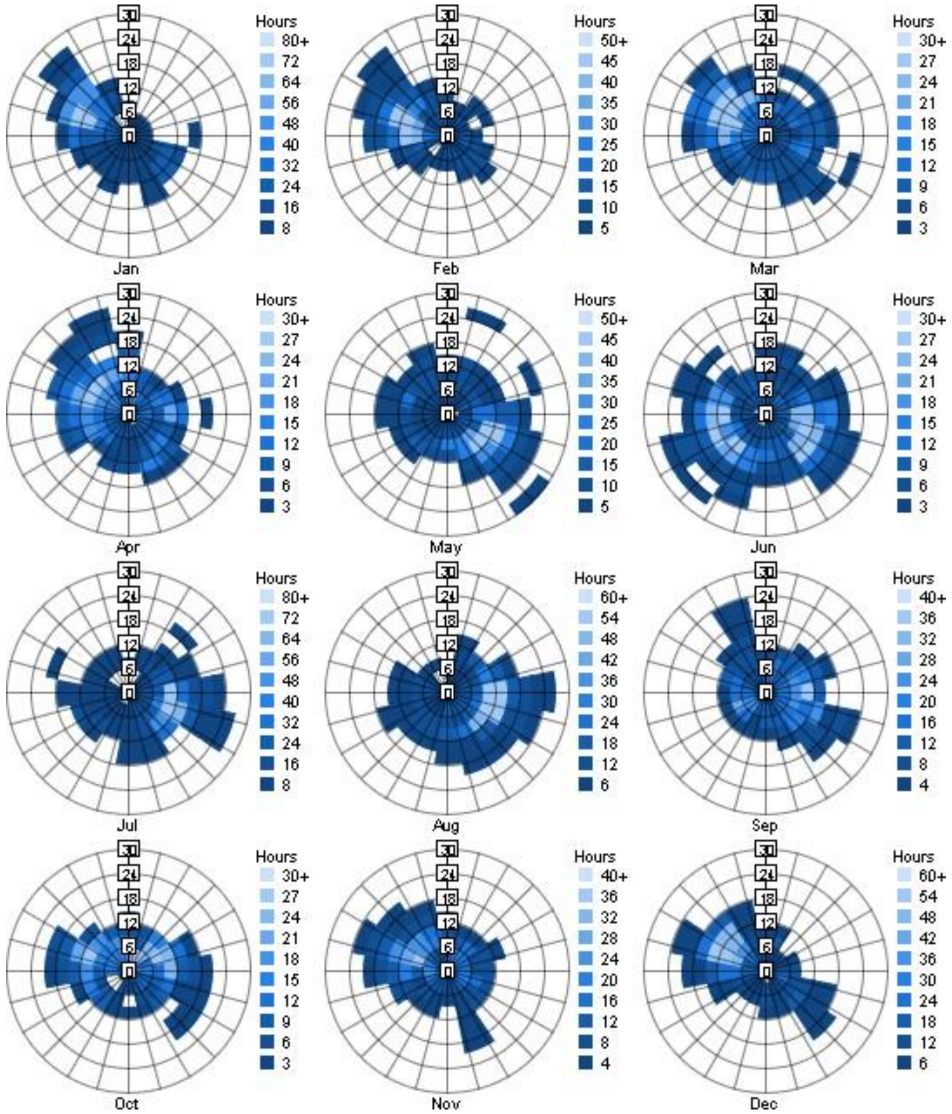


Figure 5.13 Monthly Wind Roses

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

5.2 CONCRETE BLOCK WALL+SUPER-INSULATED SLAB+20% GLAZING

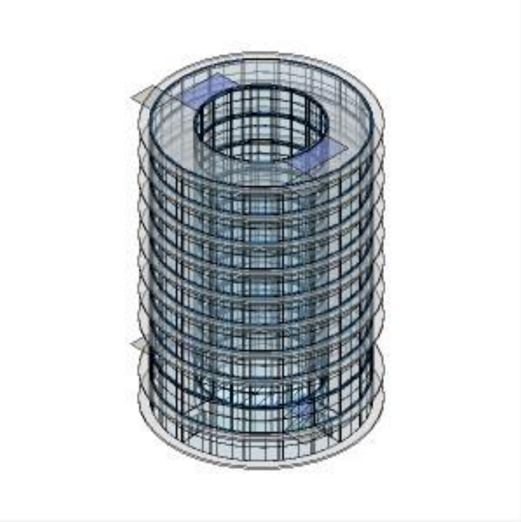


Figure 5.14 Model

Building Performance Factors [See Annexure]

Location:	New Delhi, DL
Weather Station:	429042
Outdoor Temperature:	Max: 46°C/Min: 3°C
Floor Area:	14 m²
Exterior Wall Area:	0 m²
Average Lighting Power:	12.70 W / m²
People:	1 people
Exterior Window Ratio:	∞
Electrical Cost:	$0.08 / kWh
Fuel Cost:	$0.78 / Therm

Energy Use Intensity

Electricity EUI:	508 kWh / sm / yr
Fuel EUI:	288 MJ / sm / yr
Total EUI:	2,117 MJ / sm / yr

Life Cycle Energy Use/Cost

Life Cycle Electricity Use:	215,591 kWh
Life Cycle Fuel Use:	122,012 MJ
Life Cycle Energy Cost:	$8,242
*30-year life and 6.1% discount rate for costs	

Renewable Energy Potential

Roof Mounted PV System (Low efficiency):	2,491 kWh / yr
Roof Mounted PV System (Medium efficiency):	4,983 kWh / yr
Roof Mounted PV System (High efficiency):	7,474 kWh / yr
Single 15' Wind Turbine Potential:	414 kWh / yr
*PV efficiencies are assumed to be 5%, 10% and 15% for low, medium and high efficiency systems	

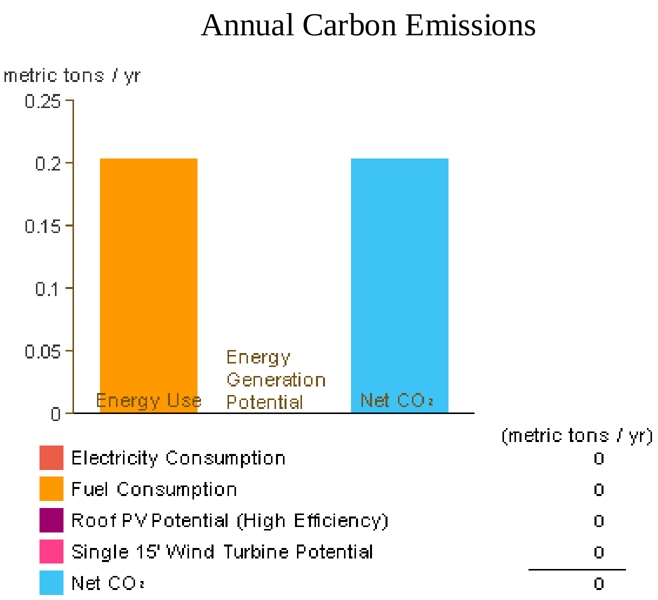


Figure 5.15 Annual Carbon Emissions Graph

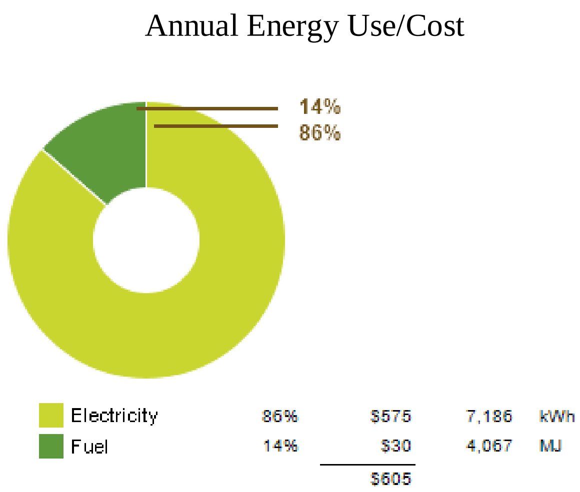


Figure 5.16 Annual Energy Use/Cost Pie Chart

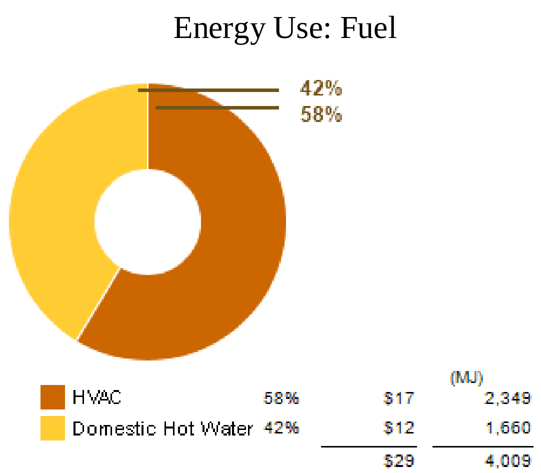


Figure 5.17 Energy Use: Fuel Pie Chart

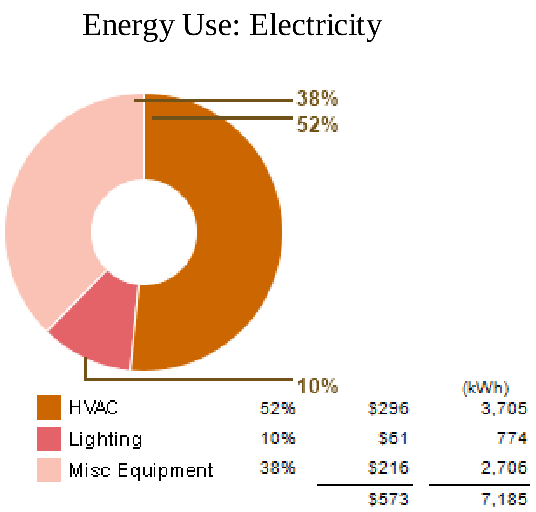


Figure 5.18 Energy Use: Electricity Pie Chart

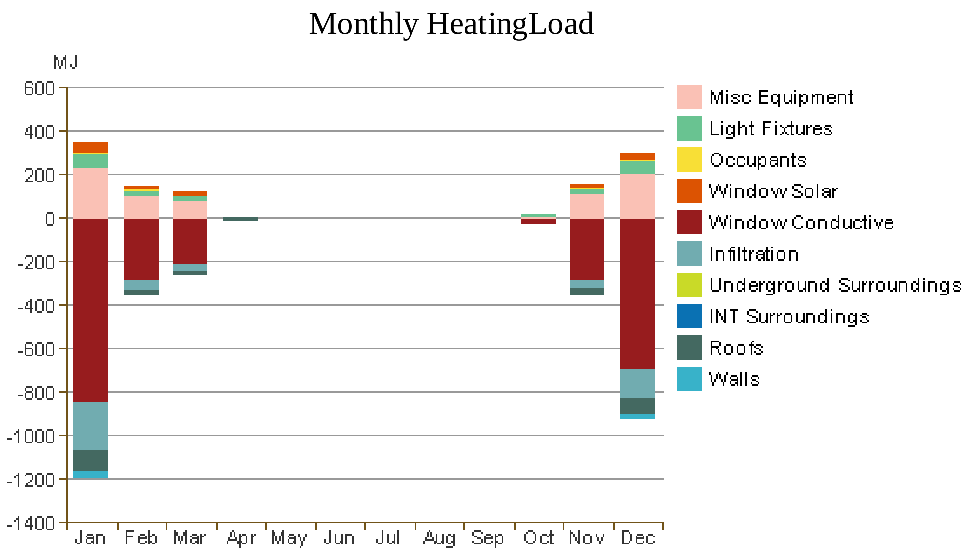


Figure 5.19 Monthly Heating Load Graph

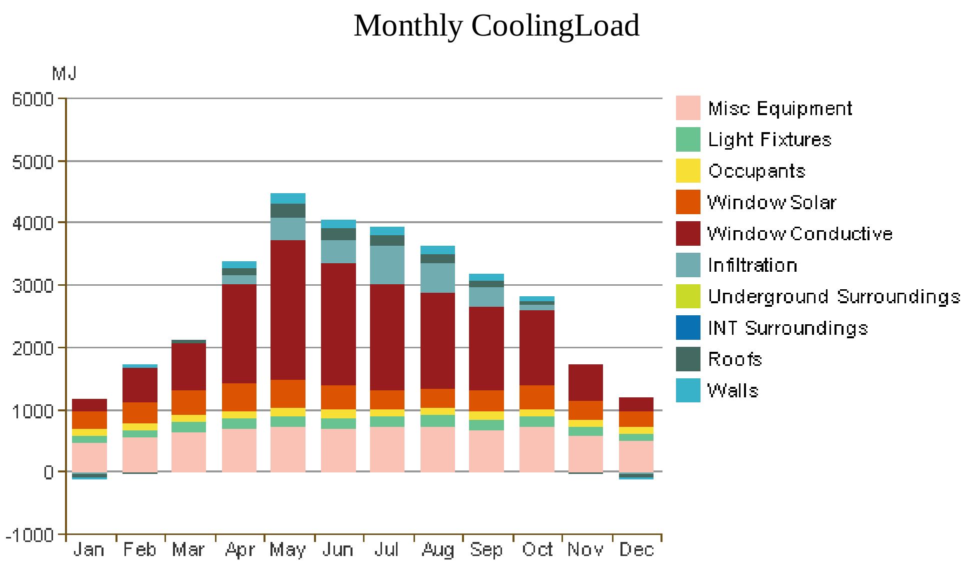


Figure 5.20 Monthly Cooling Load Graph

5.3 CURTAIN WALL + UN-INSULATED SLAB + 5% GLAZING

Building Performance Factors[See Annexure]

Location:	28.7433, 77.116883
Weather Station:	429042
Outdoor Temperature:	Max: 46°C/Min: 3°C
Floor Area:	14 m²
Exterior Wall Area:	0 m²
Average Lighting Power:	12.70 W / m²
People:	1 people
Exterior Window Ratio:	∞
Electrical Cost:	$0.08 / kWh
Fuel Cost:	$0.78 / Therm

Energy Use Intensity

Electricity EUI:	437 kWh / sm / yr
Fuel EUI:	231 MJ / sm / yr
Total EUI:	1,806 MJ / sm / yr

Life Cycle Energy Use/Cost

Life Cycle Electricity Use:	185,601 kWh
Life Cycle Fuel Use:	98,070 MJ
Life Cycle Energy Cost:	$7,072
*30-year life and 6.1% discount rate for costs	

Renewable Energy Potential

Roof Mounted PV System (Low efficiency):	2,491 kWh / yr
Roof Mounted PV System (Medium efficiency):	4,983 kWh / yr
Roof Mounted PV System (High efficiency):	7,474 kWh / yr
Single 15' Wind Turbine Potential:	414 kWh / yr
*PV efficiencies are assumed to be 5%, 10% and 15% for low, medium and high efficiency systems	

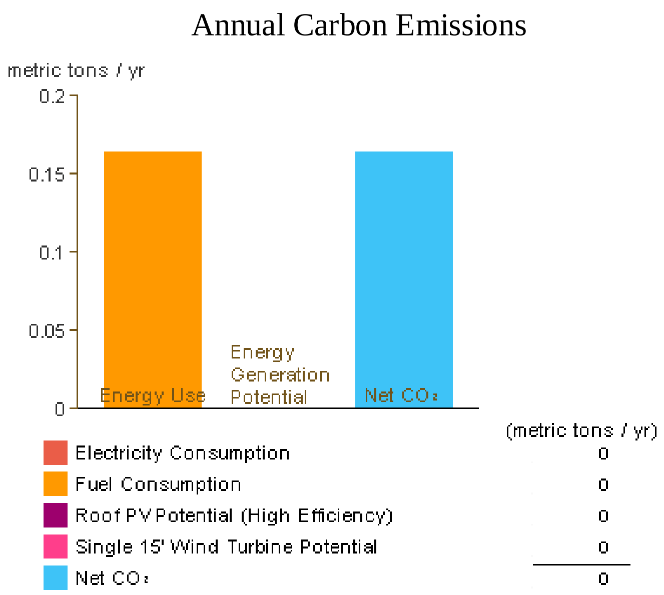


Figure 5.21 Annual Carbon Emissions Graph

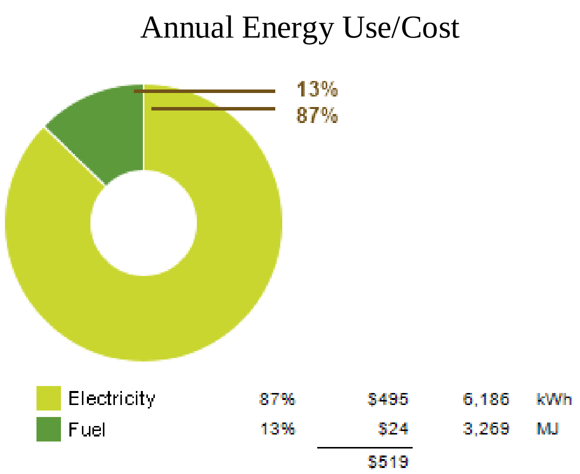


Figure 5.22 Annual Energy Use/Cost Pie Chart

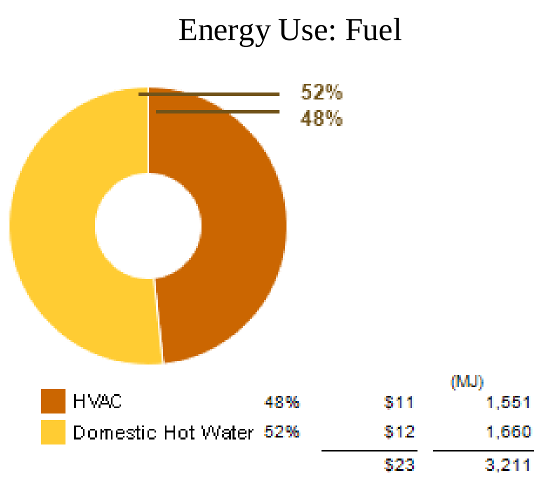


Figure 5.23 Energy Use: Fuel Pie Chart

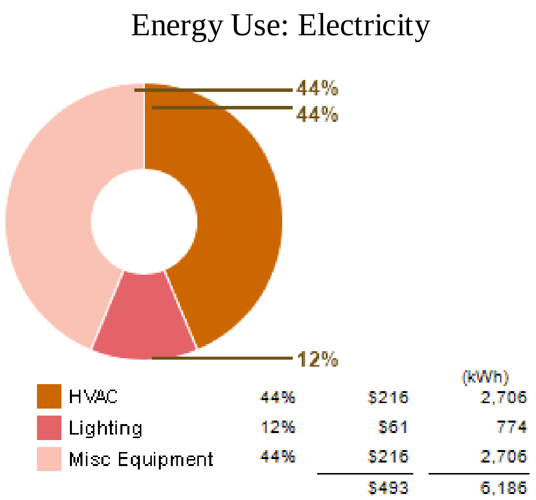


Figure 5.24 Energy Use: Electricity Pie Chart

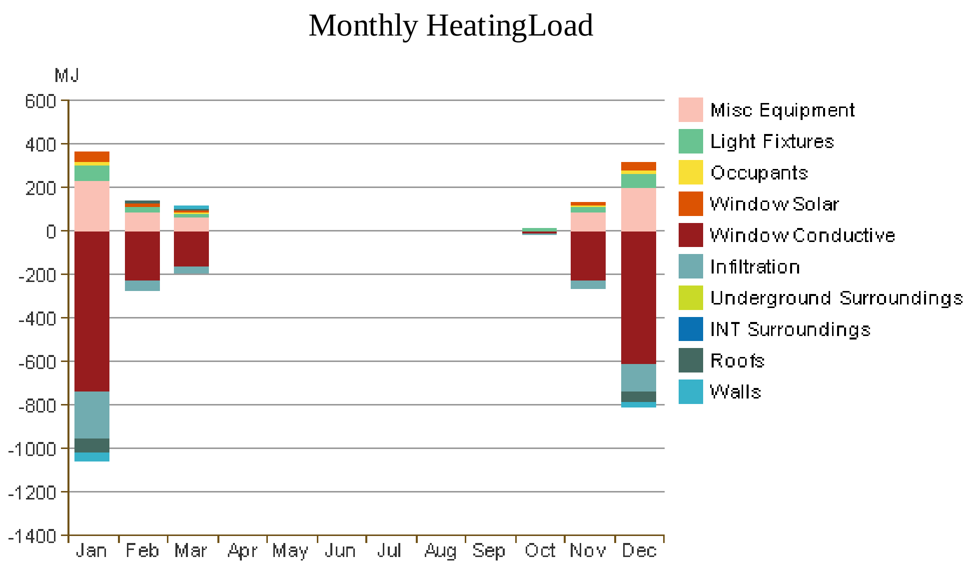


Figure 5.25 Monthly Heating Load Graph

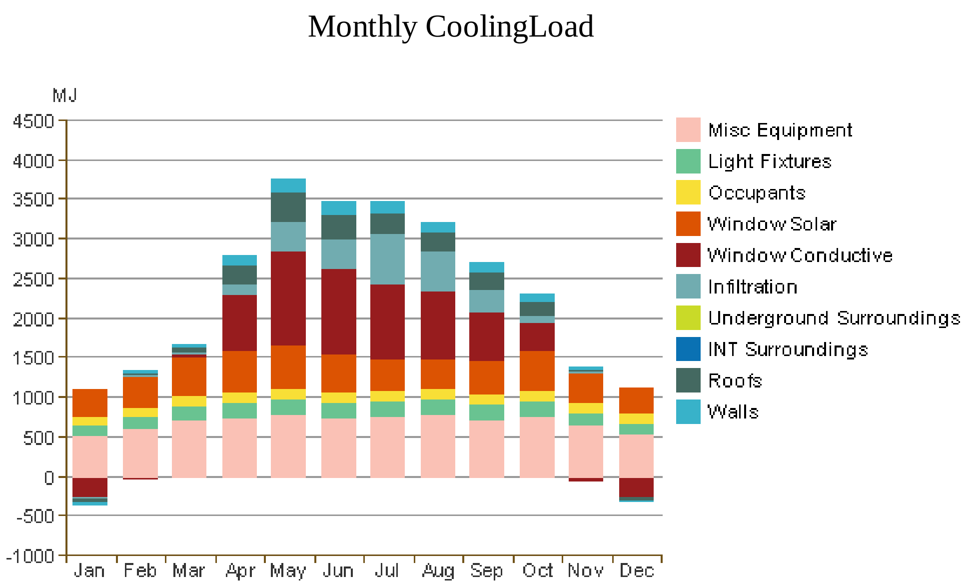


Figure 5.26 Monthly Cooling Load Graph

5.4 CURTAIN WALL + UN-INSULATED SLAB + 20% GLAZING

Building Performance Factors[See Annexure]

Location:	28.7433, 77.116883
Weather Station:	429042
Outdoor Temperature:	Max: 46°C/Min: 3°C
Floor Area:	14 m²
Exterior Wall Area:	0 m²
Average Lighting Power:	12.70 W / m²
People:	1 people
Exterior Window Ratio:	∞
Electrical Cost:	$0.08 / kWh
Fuel Cost:	$0.78 / Therm

Energy Use Intensity

Electricity EUI:	431 kWh / sm / yr
Fuel EUI:	260 MJ / sm / yr
Total EUI:	1,812 MJ / sm / yr

Life Cycle Energy Use/Cost

Life Cycle Electricity Use:	182,945 kWh
Life Cycle Fuel Use:	110,115 MJ
Life Cycle Energy Cost:	$7,016
*30-year life and 6.1% discount rate for costs	

Renewable Energy Potential

Roof Mounted PV System (Low efficiency):	2,491 kWh / yr
Roof Mounted PV System (Medium efficiency):	4,983 kWh / yr
Roof Mounted PV System (High efficiency):	7,474 kWh / yr
Single 15' Wind Turbine Potential:	414 kWh / yr
*PV efficiencies are assumed to be 5%, 10% and 15% for low, medium and high efficiency systems	

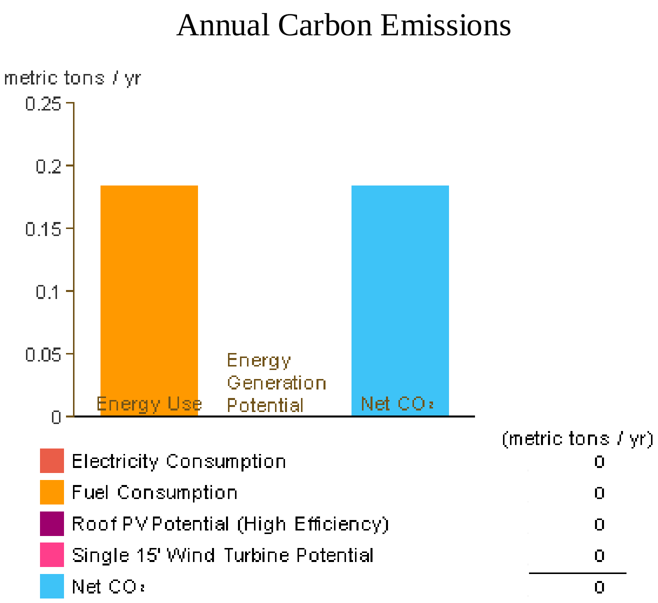


Figure 5.27 Annual Carbon Emissions Graph

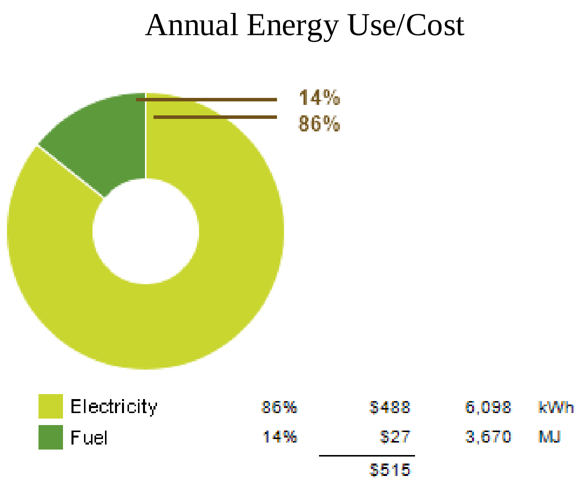


Figure 5.28 Annual Energy Use/Cost Pie Chart

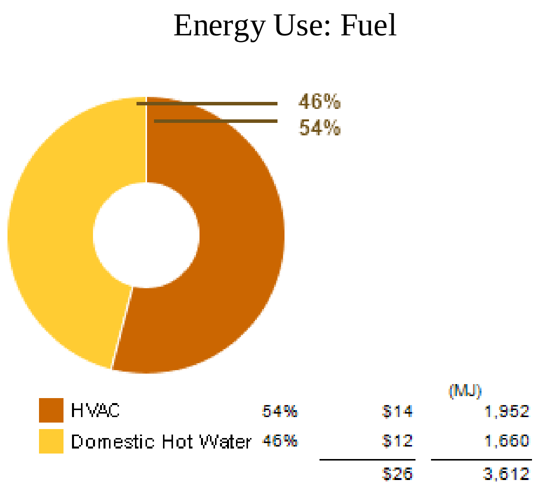


Figure 5.29 Energy Use: Fuel Pie Chart

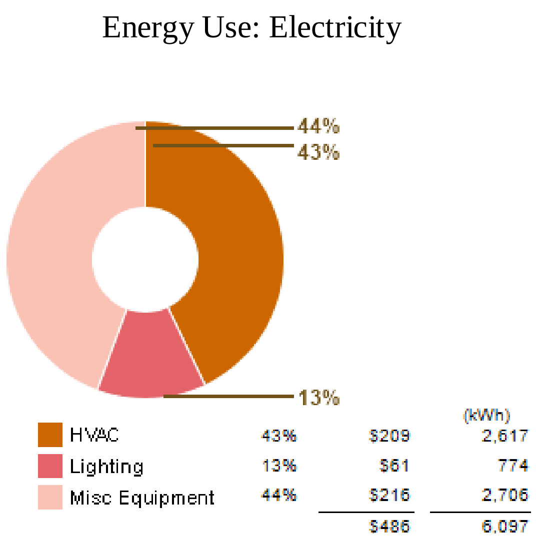


Figure 5.30 Energy Use: Electricity Pie Chart

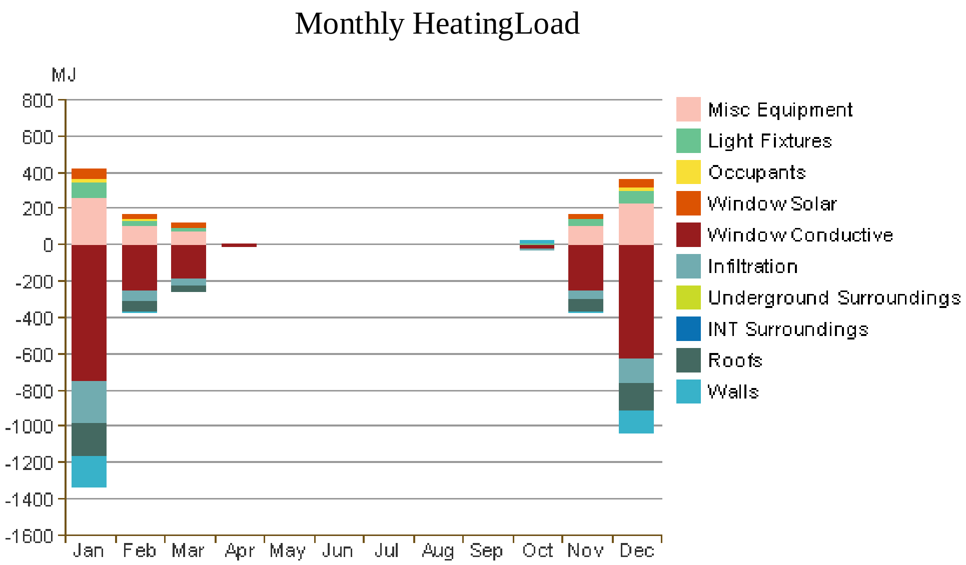


Figure 5.31 Monthly Heating Load Graph

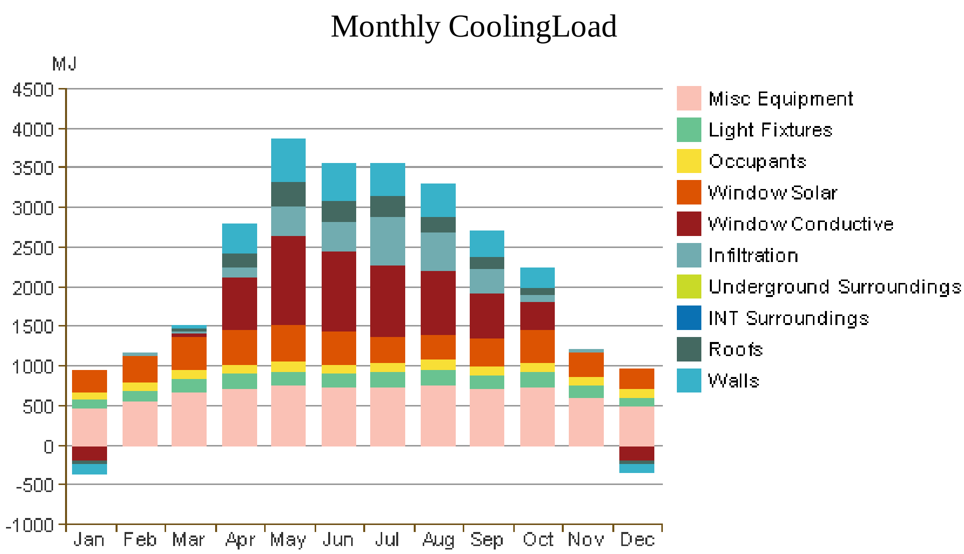


Figure 5.32 Monthly Cooling Load Graph

5.5 CURTAIN WALL + SUPER-INSULATED SLAB + 10% GLAZING

Building Performance Factors[See Annexure]

Location:	28.7433, 77.116883
Weather Station:	429042
Outdoor Temperature:	Max: 46°C/Min: 3°C
Floor Area:	2,010 m²
Exterior Wall Area:	3,008 m²
Average Lighting Power:	12.70 W / m²
People:	201 people
Exterior Window Ratio:	0.15
Electrical Cost:	$0.08 / kWh
Fuel Cost:	$0.78 / Therm

Energy Use Intensity

Electricity EUI:	256 kWh / sm / yr
Fuel EUI:	56 MJ / sm / yr
Total EUI:	978 MJ / sm / yr

Life Cycle Energy Use/Cost

Life Cycle Electricity Use:	15,446,106 kWh
Life Cycle Fuel Use:	3,363,345 MJ
Life Cycle Energy Cost:	$572,345
*30-year life and 6.1% discount rate for costs	

Renewable Energy Potential

Roof Mounted PV System (Low efficiency):	16,557 kWh / yr
Roof Mounted PV System (Medium efficiency):	33,114 kWh / yr
Roof Mounted PV System (High efficiency):	49,671 kWh / yr
Single 15' Wind Turbine Potential:	414 kWh / yr
*PV efficiencies are assumed to be 5%, 10% and 15% for low, medium and high efficiency systems	

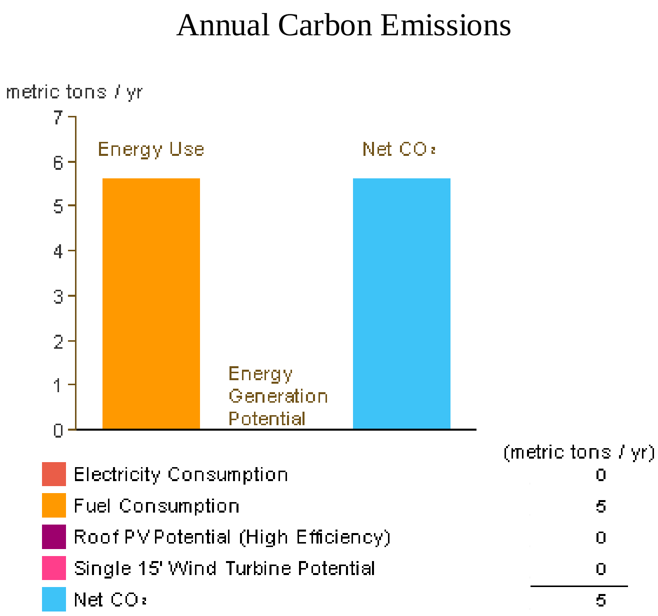


Figure 5.33 Annual Carbon Emissions Graph

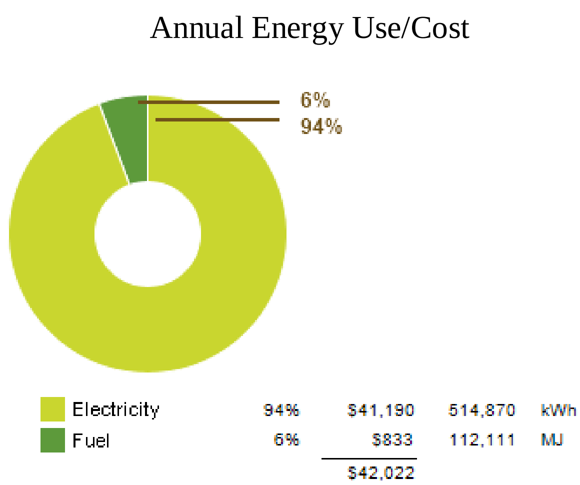


Figure 5.34 Annual Energy Use/Cost Pie Chart

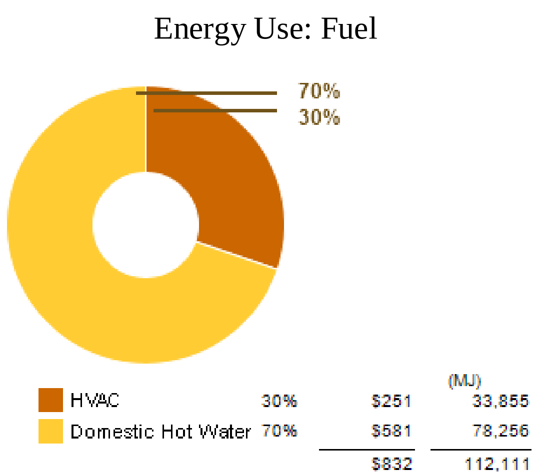


Figure 5.35 Energy Use: Fuel Pie Chart

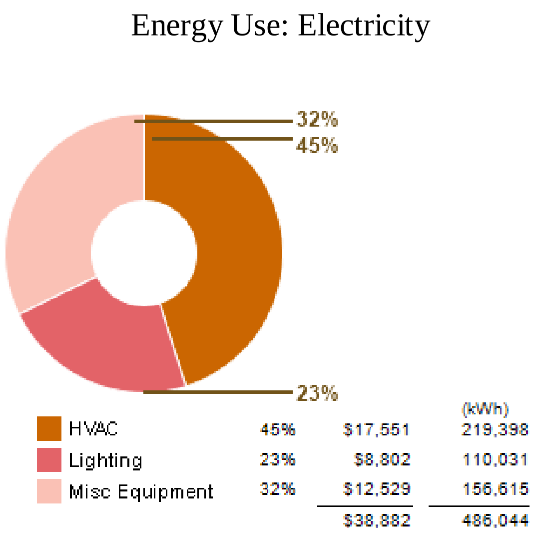


Figure 5.36 Energy Use: Electricity Pie Chart

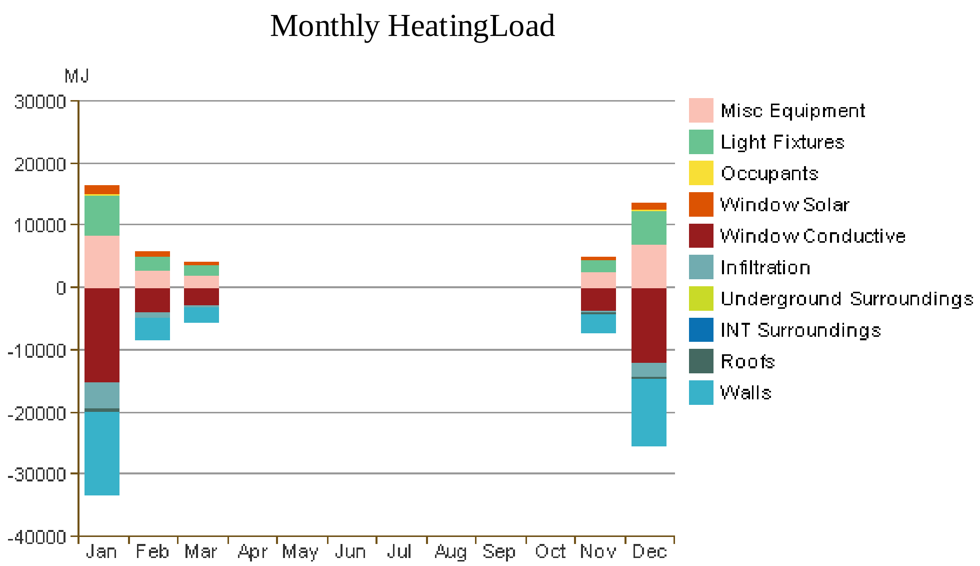


Figure 5.37 Monthly Heating Load Graph

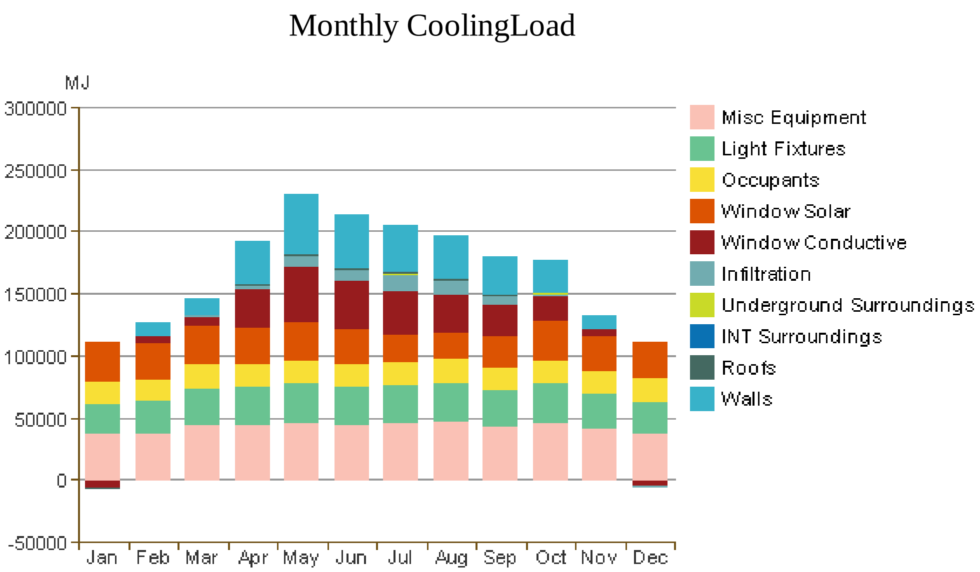


Figure 5.38 Monthly cooling load graph

5.6 CURTAIN WALL + UN-INSULATED SLAB + 15% GLAZING

Building Performance Factors[See Annexure]

Location:	New Delhi, DL
Weather Station:	429042
Outdoor Temperature:	Max: 46°C/Min: 3°C
Floor Area:	14 m²
Exterior Wall Area:	0 m²
Average Lighting Power:	12.70 W / m²
People:	1 people
Exterior Window Ratio:	∞
Electrical Cost:	$0.08 / kWh
Fuel Cost:	$0.78 / Therm

Energy Use Intensity

Electricity EUI:	431 kWh / sm / yr
Fuel EUI:	260 MJ / sm / yr
Total EUI:	1,812 MJ / sm / yr

Life Cycle Energy Use/Cost

Life Cycle Electricity Use:	182,945 kWh
Life Cycle Fuel Use:	110,115 MJ
Life Cycle Energy Cost:	$7,016
*30-year life and 6.1% discount rate for costs	

Renewable Energy Potential

Roof Mounted PV System (Low efficiency):	2,491 kWh / yr
Roof Mounted PV System (Medium efficiency):	4,983 kWh / yr
Roof Mounted PV System (High efficiency):	7,474 kWh / yr
Single 15' Wind Turbine Potential:	414 kWh / yr
*PV efficiencies are assumed to be 5%, 10% and 15% for low, medium and high efficiency systems	

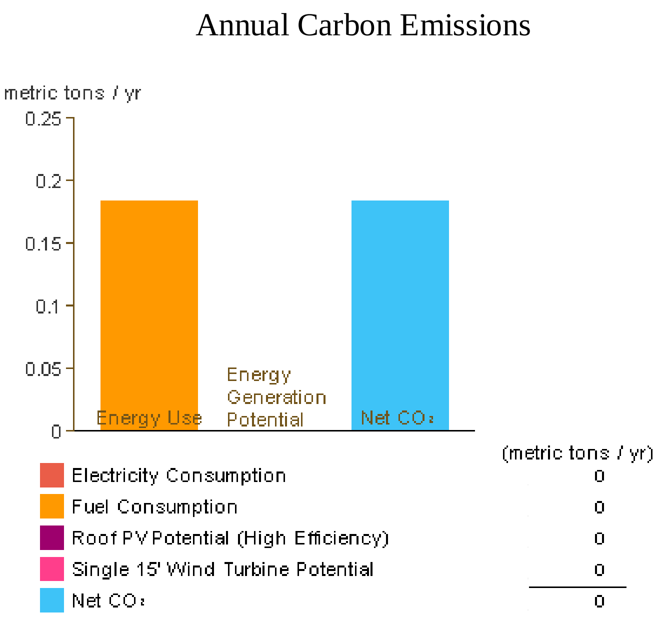


Figure 5.39 Annual Carbon Emissions Graph

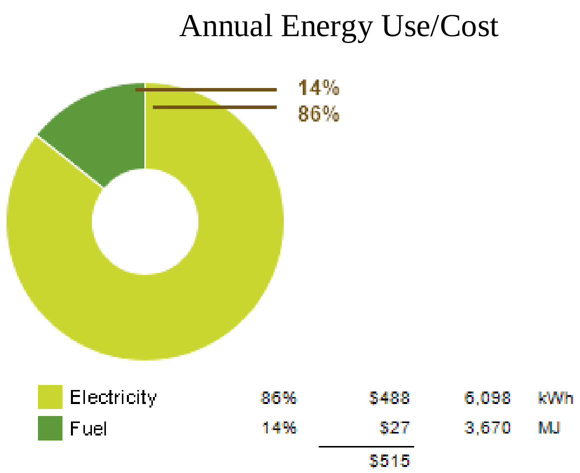


Figure 5.40 Annual Energy Use/Cost Pie Chart

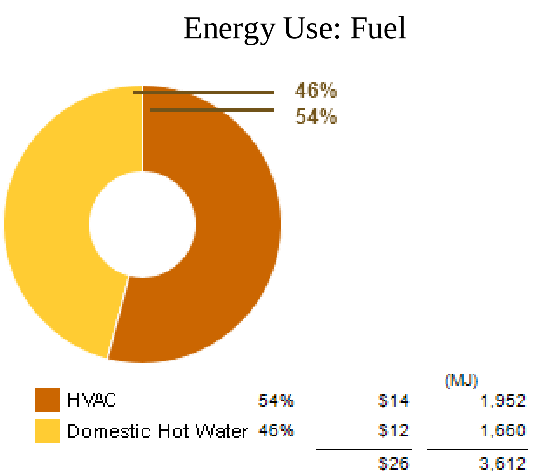


Figure 5.41 Energy Use: Fuel Pie Chart

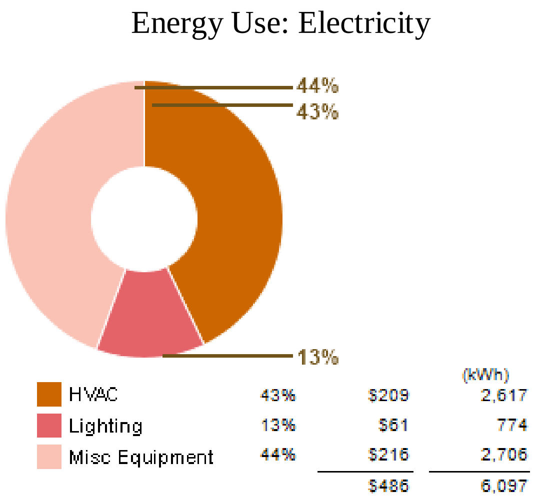


Figure 5.42 Energy Use: Electricity Pie Chart

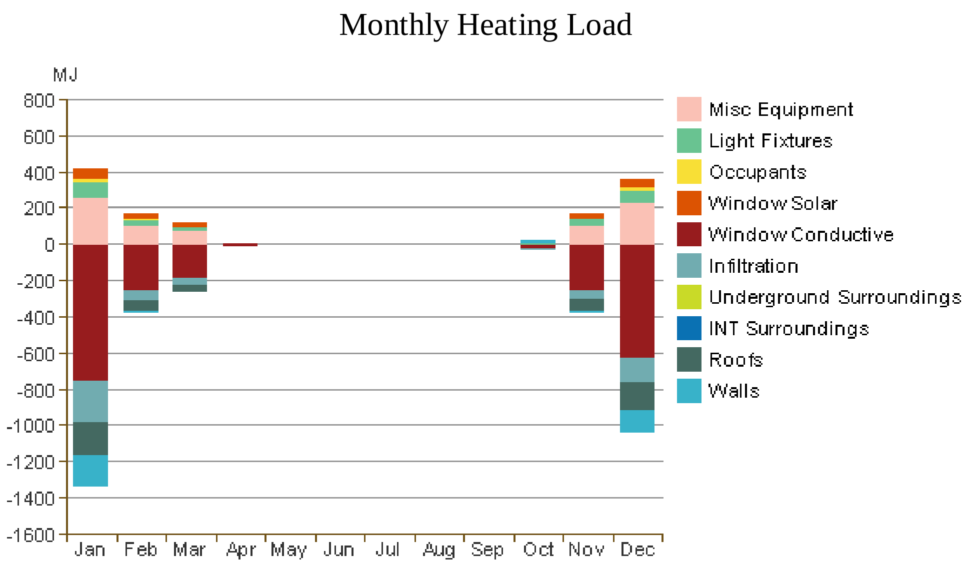


Figure 5.43 Monthly Heating Load Graph

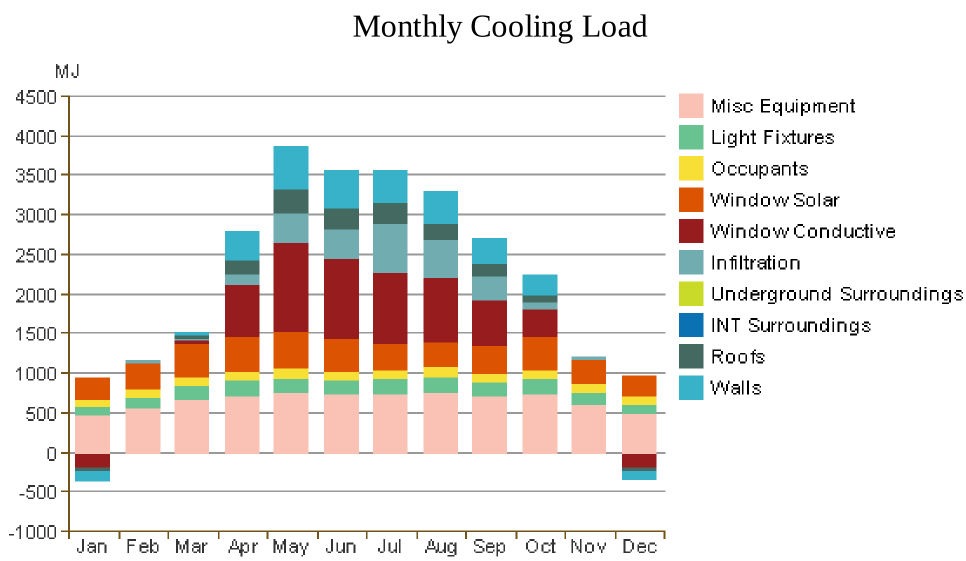


Figure 5.44 Monthly Cooling Load Graph

5.7 CURTAIN WALL + SUPER-INSULATED SLAB + 5% GLAZING

Building Performance Factors [See Annexure]

Location:	New Delhi, DL
Weather Station:	429042
Outdoor Temperature:	Max: 46°C/Min: 3°C
Floor Area:	2,010 m²
Exterior Wall Area:	3,008 m²
Average Lighting Power:	12.70 W / m²
People:	201 people
Exterior Window Ratio:	0.05
Electrical Cost:	$0.08 / kWh
Fuel Cost:	$0.78 / Therm

Energy Use Intensity

Electricity EUI:	235 kWh / sm / yr
Fuel EUI:	50 MJ / sm / yr
Total EUI:	896 MJ / sm / yr

Life Cycle Energy Use/Cost

Life Cycle Electricity Use:	14,171,130 kWh
Life Cycle Fuel Use:	2,998,549 MJ
Life Cycle Energy Cost:	$524,808
*30-year life and 6.1% discount rate for costs	

Renewable Energy Potential

Roof Mounted PV System (Low efficiency):	16,557 kWh / yr
Roof Mounted PV System (Medium efficiency):	33,114 kWh / yr
Roof Mounted PV System (High efficiency):	49,671 kWh / yr
Single 15' Wind Turbine Potential:	414 kWh / yr
*PV efficiencies are assumed to be 5%, 10% and 15% for low, medium and high efficiency systems	

Annual Carbon Emissions

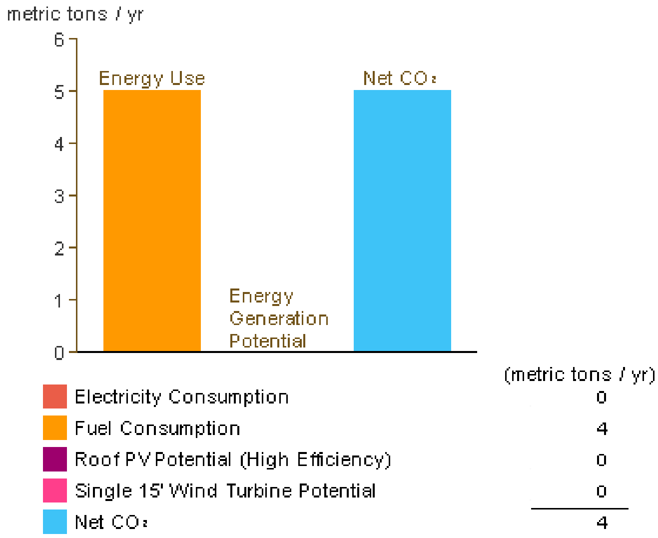


Figure 5.45 Annual Carbon Emissions Graph

Annual Energy Use/Cost

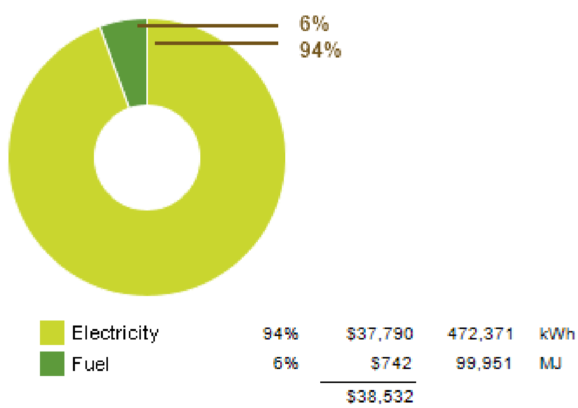


Figure 5.46 Annual Energy Use/Cost Pie Chart

Energy Use: Fuel

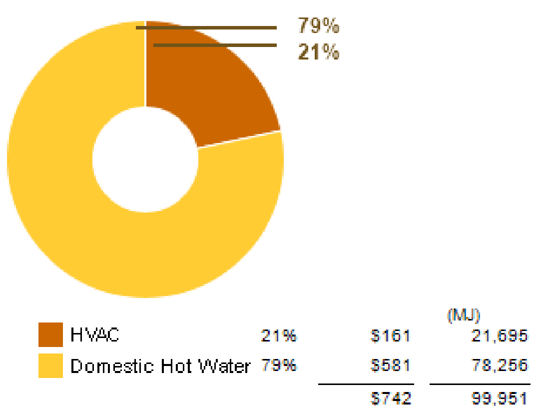


Figure 5.47 Energy Use: Fuel Pie Chart

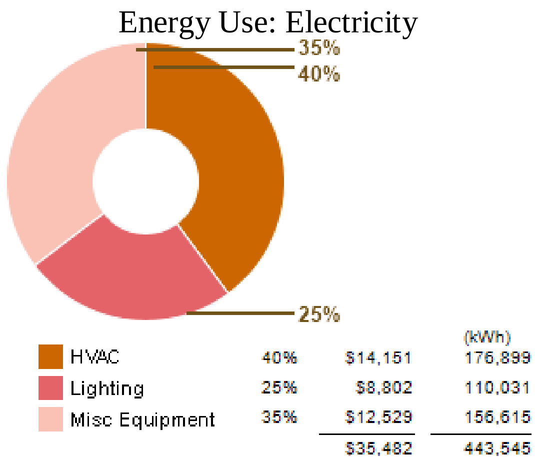


Figure 5.48 Energy Use: Electricity Pie Chart

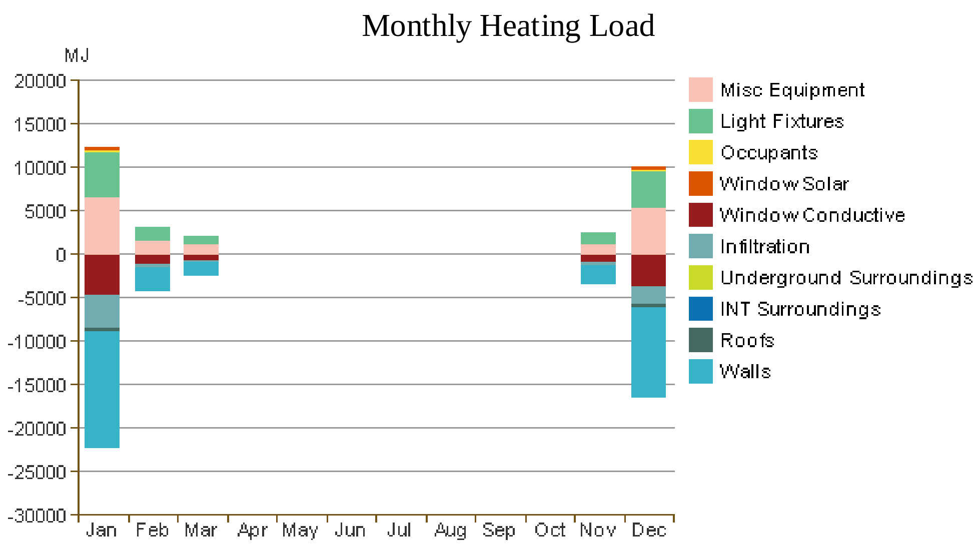


Figure 5.49 Monthly Heating Load Graph

CHAPTER 6

DISCUSSION

General Material Used:

Thermal transmittance, U (W/m^2K)

- Lightweight concrete roof, U=1.2750
- Lightweight concrete ceiling, U=1.3610
- Metal doors, U=3.7021
- Large single-glazed windows, U=3.6898
- Large double-glazed windows, U=3.1956
- Passive floor U=2.9582

Case 1: CURTAIN WALL+SUPER-INSULATED SLAB+20% GLAZING

Thermal transmittance, U(W/m^2K) value used:

- Curtain wall, U=0.5131
- Super-insulated slab, U= 0.2756

In this case metallic curtain wall, super-insulated slab and glazing with 20 percent is used.

EUI comes out to be 1023 MJ/sm/yr.

Metal curtain wall is being used here for analysis whose thermal transmittance value is given above. Since the curtain wall is non-structural, it can be made of lightweight materials, thereby reducing construction costs.

Case 2: CONCRETE BLOCK WALL+SUPER-INSULATED SLAB+20% GLAZING

Thermal transmittance, U (W/m^2K) value used:

- Concrete block wall, U=2.4866
- Super-insulated slab, U= 0.2756

In this case concrete block wall, super-insulated slab and glazing with 20 percent is used.

EUI comes out to be 2117 MJ/sm/yr, which is maximum of all the cases.

As it can be seen that except concrete block rest of the 2 things are same but EUI comes out to be very high because Thermal transmittance value of concrete block is quite high as compare to curtain wall.

Case 3: CURTAIN WALL+UN-INSULATED SLAB+5% GLAZING

Thermal transmittance, U (W/m^2K) value used:

- Curtain wall, U=0.5131
- Un-insulated slab, U= 0.7059

In this case metallic curtain wall, super-insulated slab and glazing with 5 percent is used.

EUI comes out to be 1806 MJ/sm/yr.

Case 4: CURTAIN WALL+UN-INSULATED SLAB+20% GLAZING

Thermal transmittance, U (W/m^2K) value used:

- Curtain wall, U=0.5131
- Un-insulated slab, U= 0.7059

In this case metallic curtain wall, super-insulated slab and glazing with 20 percent is used.

EUI comes out to be 1812 MJ/sm/yr.

As it can be seen that in this case un- insulated slab has been used and rest two conditions are same but EUI comes out to be more than super-insulated one, it is due to the reason because un-insulated slab has more thermal transmittance value than super-insulated slab

Case 5: CURTAIN WALL+SUPER-INSULATED SLAB+10% GLAZING

Thermal transmittance, U (W/m^2K) value used:

- Curtain wall, U=0.5131
- Super-insulated slab, U= 0.2756

In this case metallic curtain wall, super-insulated slab and glazing with 10 percent is used.

EUI comes out to be 978 MJ/sm/yr.

It can be seen here that as glazing is changed from 20% to 10%, the EUI value reduces. It is because as we allowed more daylight to enter inside building and it will increase the load on HVAC system and hence more energy will be consumed.

Case 6: CURTAIN WALL+UN-INSULATED SLAB+15% GLAZING

Thermal transmittance, U (W/m^2K) value used:

- Curtain wall, U=0.5131
- Un-insulated slab, U= 0.7059

In this case metallic curtain wall, super-insulated slab and glazing with 20 percent is used.

EUI comes out to be 1812 MJ/sm/yr.

Case 7: CURTAIN WALL+SUPER-INSULATED SLAB+5% GLAZING

Thermal transmittance, U (W/m^2K) value used:

- Curtain wall, U=0.5131
- Super-insulated slab, U= 0.2756

In this case metallic curtain wall, super-insulated slab and glazing with 10 percent is used.

EUI comes out to be 896 MJ/sm/yr, which is minimum among all above cases.

This case is coming out to be minimum among all above cases because curtain wall and super-insulated slab has very low thermal transmittance value and only 5% glazing is done.

CHAPTER 7

CONCLUSION

The study yields that material, glazing, shading and orientation plays important role in analyzing the zero energy building. The thesis considers material and glazing as its major parameters and analyses 7 cases by changing material and percent of glazing. The EUI of different cases are as follows:

TABLE 6.1: RESULTS OF DIFFERENT CASES

Sr. NO.	CASES	EUI (MJ/sm/yr)
1.	CONCRETE BLOCK WALL+SUPER-INSULATED SLAB+20% GLAZING	2117
2.	CURTAIN WALL + SUPER-INSULATED SLAB + 20% GLAZING	1023
3.	CURTAIN WALL + UN-INSULATED SLAB + 5% GLAZING	1806
4.	CURTAIN WALL + UN-INSULATED SLAB + 20% GLAZING	1812
5.	CURTAIN WALL + SUPER-INSULATED SLAB + 10% GLAZING	978
6.	CURATAIN WALL + UN-INSULATED SLAB + 15% GLAZING	1812
7.	CURTAIN WALL + SUPER-INSULATED SLAB + 5% GLAZING	896

EUI value for concrete block wall with super-insulated slab and 20% glazing is found to be highest out of all cases (2117 MJ/sm/yr) due to high thermal transmittance offered by Concrete block wall.

After replacing the wall material with metallic curtain wall and same model parameters and condition, the EUI value reduces to 1812 MJ/sm/yr. Hence further cases will be utilizing metallic curtain wall as wall material. Thermal Transmittance is the rate at which heat transfer through matter.

As after the analysis, the results of 7 different cases and it is concluded that out of the 7 cases, 7thcase of CURTAIN WALL + SUPER-INSULATED SLAB + 5% GLAZING has minimum EUI and it is most suitable. EUI value of this parameter comes out to be 896 MJ/sm/yr.

CHAPTER 8

Limitations &Future Scope

In this report, building has been analyzed on the basis of 2 parameters material and glazing. This building cannot be analyzed on the basis of orientation and shading depth as the building is in hollow cylindrical shape and the results will not change if building orientation changes.

Further, an unsymmetrical building can be analyzed so that orientation and shading parameters also taken into consideration in future work.

REFERENCES

1. Torcellini,Pless, and Deru . Zero Energy Buildings: A Critical Look at the Definition NREL/CP-550-39833 June 2006

2. Perlova ,2014.Concept Project of Zero Energy Building

3. Able, E. (1994). Low-Energy buildings. Energy and Buildings Vol.21, 1994, pp. 169-174

4. Esbensen, T.V. &Korsgaard, V. (1977). Dimensioning of the solar heating system in the zero energy house in Denmark. Solar Energy Vol. 19, Issue 2, 1977, pp. 195-199

5. Saitoh, T (1984). Natural energy autonomous house with underground water reservoir. Bulletin of the JSME Vol. 27, Issue 226, April 1984, pp. 773-778

6. Laustsen, J. (2008). Energy Efficiency Requirements in Building Codes, Energy Efficiency Policies for New Buildings. International Energy Agency (IEA).

7. Saitoh, T., Matsuhashi, H. & Ono, T. (1985). An energy-independent house combining solar thermal and sky radiation energies. Solar Energy Vol. 35, Issue 6, 1985, pp. 541-547.

8. AshwinVenkataraman and Ramesh Kannan.(2013) Whole Building Energy Analysis Using BIM ,Proc. of Int. Conf. on Advances in Civil Engineering, AETACE

9. AshwinVenkataraman and M. Ramesh Kannan, “Building Energy Simulation using Building InformationModeling,” 5th International Conference on Science, Engineering and Technology (SET), Vellore Institute of Technology University, Vellore, India, 2012.

10. Hasan, Kesteloot, Defer, Ammeux. Employing BIM For the Optimization Of Energy Efficiency In Renovation Projects: EITRE Case Study.Proceedings of 2nd International Conference on Structural Civil and Architectural Engineering Held on 27th - 28th Aug 2016, in Montreal, Canada, ISBN: 9788193137369

11. Petri, Kubicki, Rezgui, Guerriero, Li. Optimizing Energy Efficiency in Operating Built Environment Assets through Building Information Modeling: A Case Study. Energies **2017**, 10, 1167; doi:10.3390/en10081167

ANNEXURE

Annex 1 Curtain Wall + Super-Insulated Slab + 20% Glazing

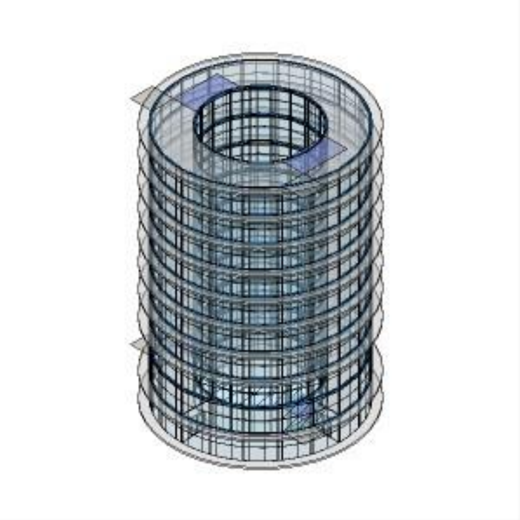
AUTODESK.

Exercise 2

ring Analysis

Analyzed at 5/18/2019 10:45:03 AM

Energy Analysis Result



Building Performance Factors

Location:	28.7433, 77.116883
Weather Station:	429042
Outdoor Temperature:	Max: 46°C/Min: 3°C
Floor Area:	14 m²
Exterior Wall Area:	0 m²
Average Lighting Power:	12.70 W / m²
People:	1 people
Exterior Window Ratio:	∞
Electrical Cost:	$0.08 / kWh
Fuel Cost:	$0.78 / Therm

Energy Use Intensity

Electricity EUI:	437 kWh / sm / yr
Fuel EUI:	231 MJ / sm / yr
Total EUI:	1,806 MJ / sm / yr

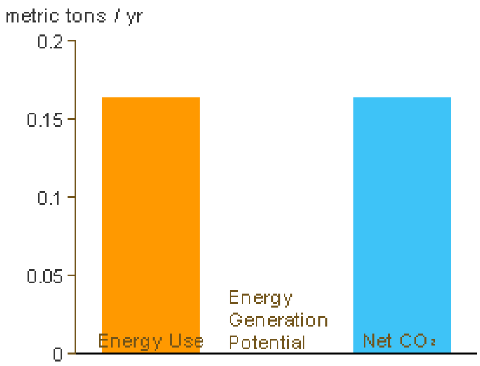
Life Cycle Energy Use/Cost

Life Cycle Electricity Use:	185,601 kWh
Life Cycle Fuel Use:	98,070 MJ
Life Cycle Energy Cost:	$7,072
*30-year life and 6.1% discount rate for costs	

Renewable Energy Potential

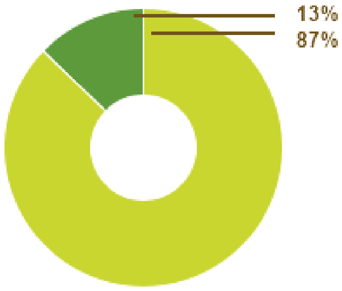
Roof Mounted PV System (Low efficiency):	2,491 kWh / yr
Roof Mounted PV System (Medium efficiency):	4,983 kWh / yr
Roof Mounted PV System (High efficiency):	7,474 kWh / yr
Single 15' Wind Turbine Potential:	414 kWh / yr
*PV efficiencies are assumed to be 5%, 10% and 15% for low, medium and high efficiency systems	

Annual Carbon Emissions



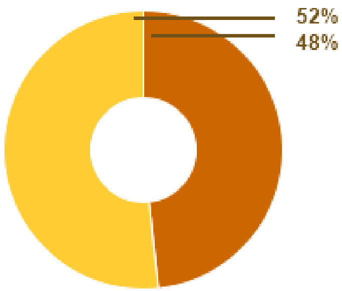
	(metric tons / yr)
Electricity Consumption	0
Fuel Consumption	0
Roof PV Potential (High Efficiency)	0
Single 15' Wind Turbine Potential	0
Net CO_2	0

Annual Energy Use/Cost



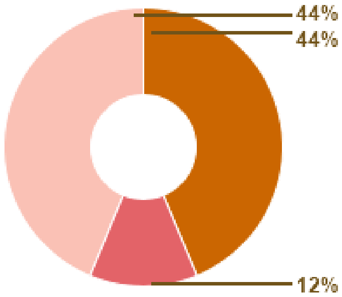
Electricity	87%	$495	6,186	kWh
Fuel	13%	$24	3,269	MJ
		$519		

Energy Use: Fuel



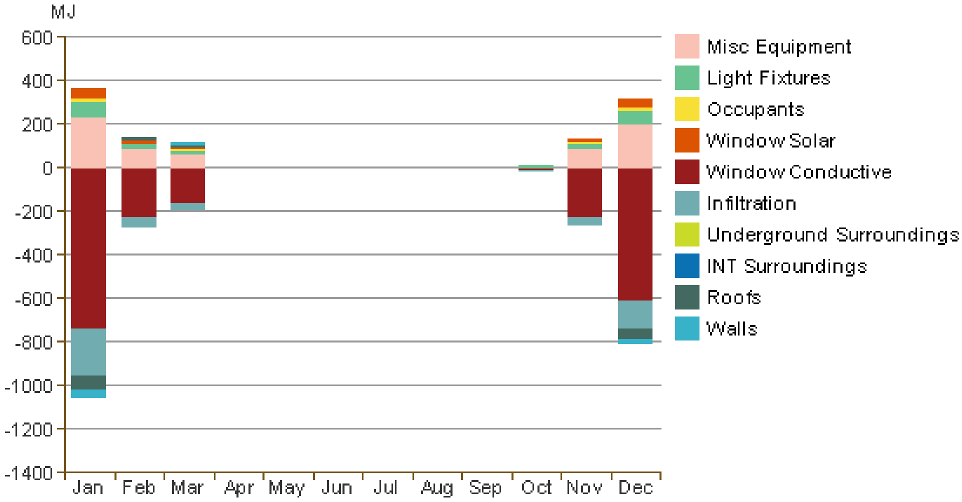
			(MJ)
HVAC	48%	$11	1,551
Domestic Hot Water	52%	$12	1,660
		$23	3,211

Energy Use: Electricity

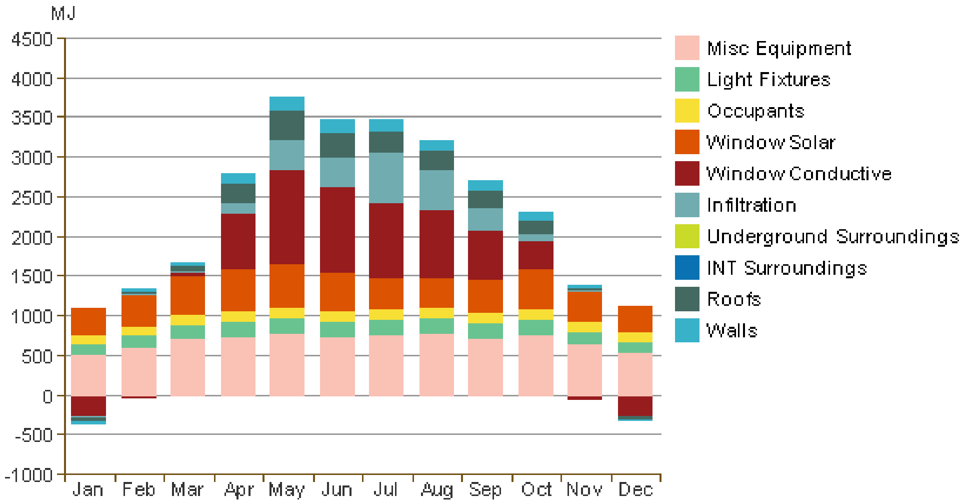


			(kWh)
HVAC	44%	$216	2,706
Lighting	12%	$61	774
Misc Equipment	44%	$216	2,706
		$493	6,186

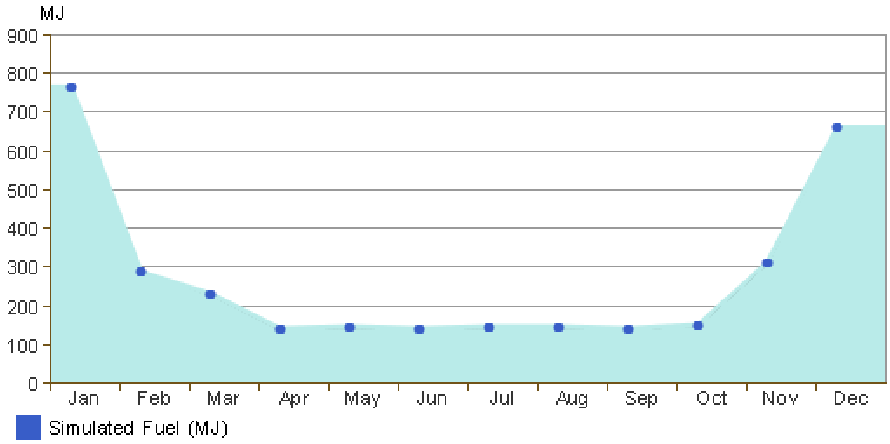
Monthly Heating Load



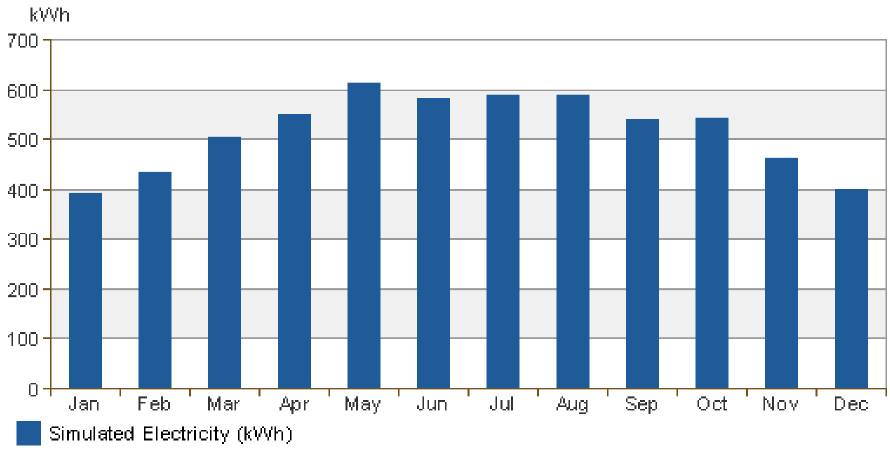
Monthly Cooling Load



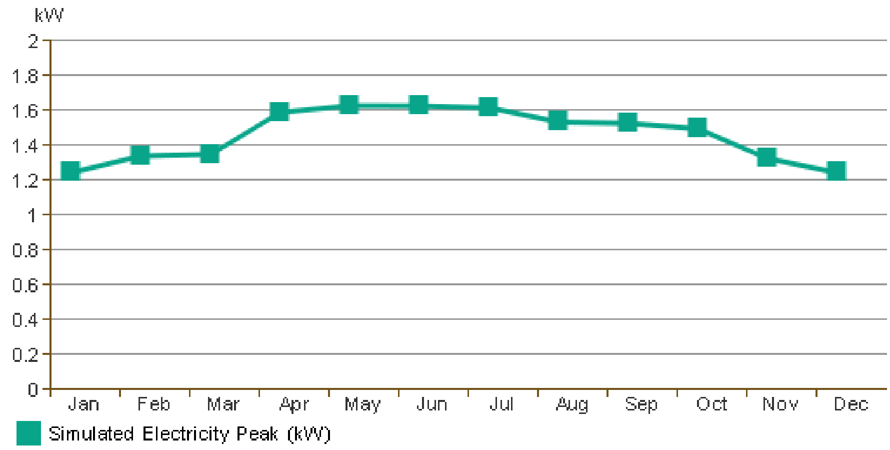
Monthly Fuel Consumption



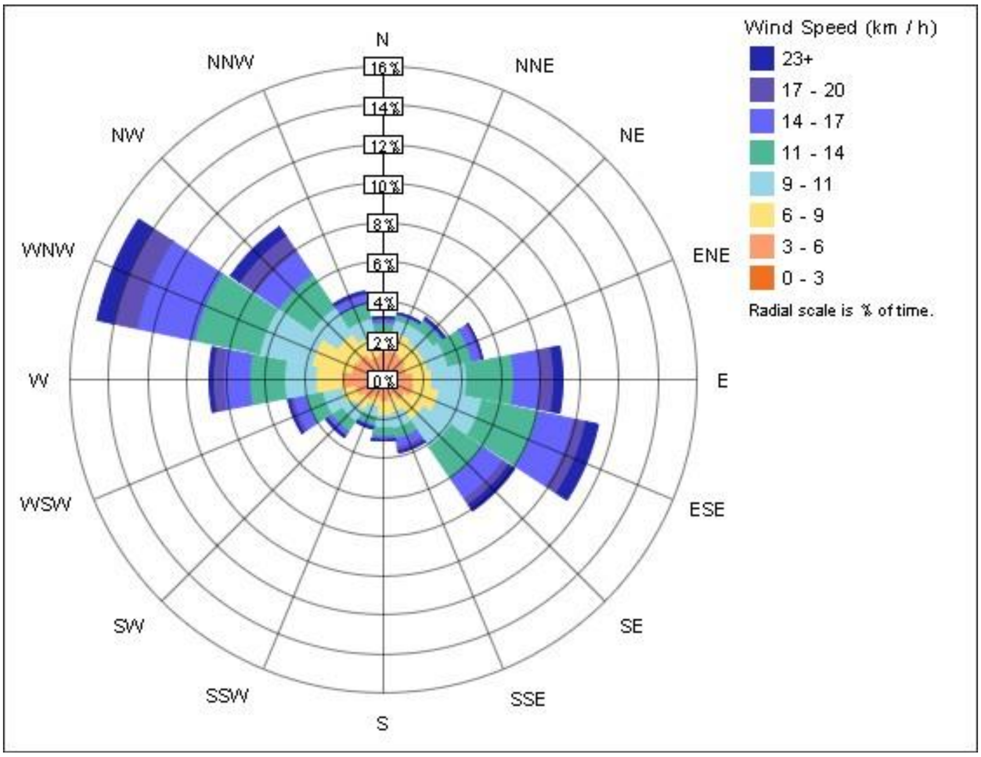
Monthly Electricity Consumption



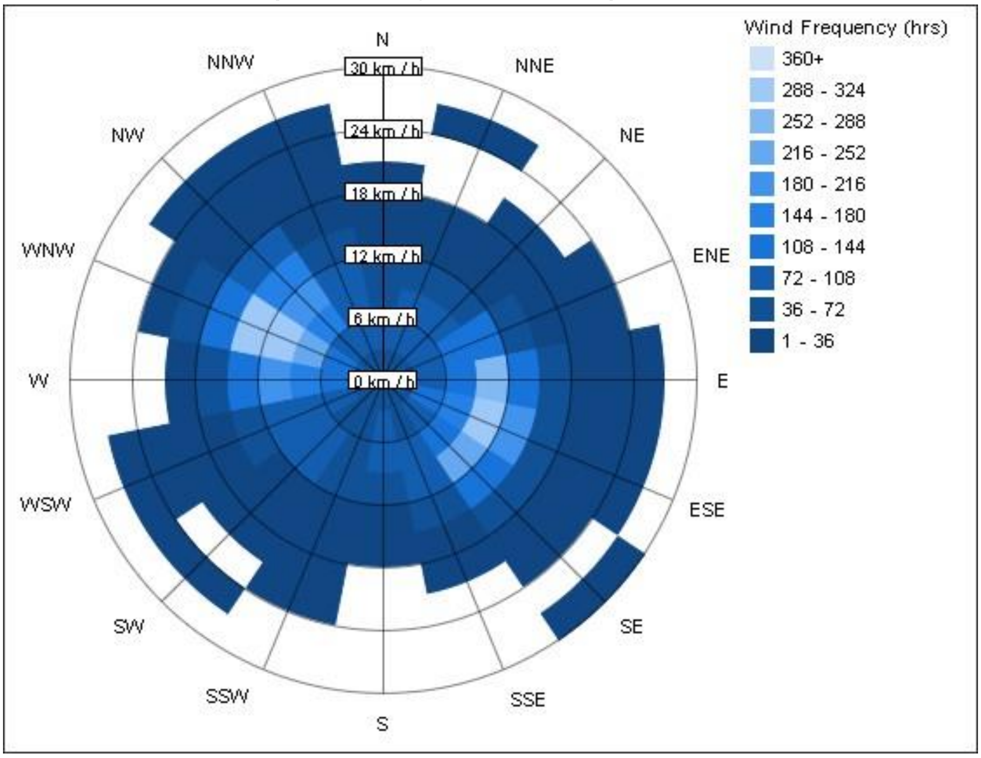
Monthly Peak Demand



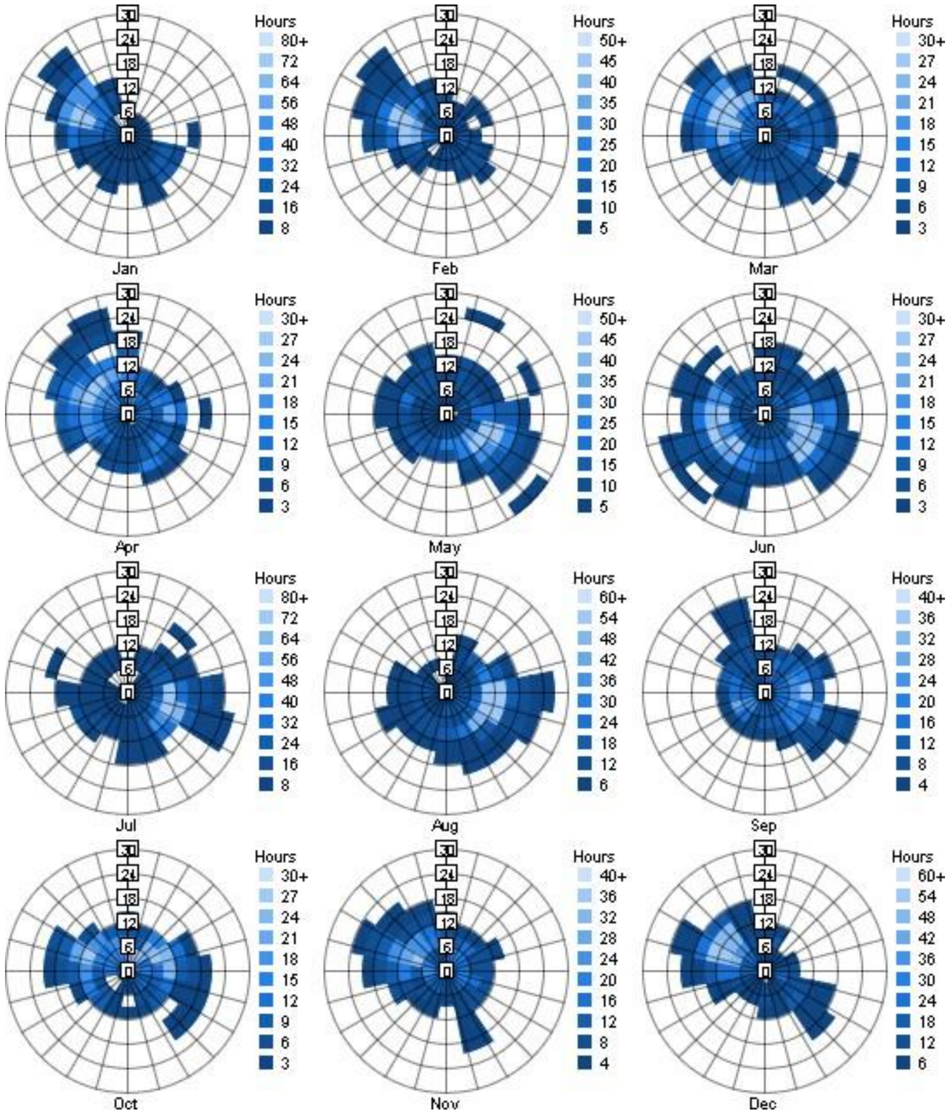
Annual Wind Rose (Speed Distribution)



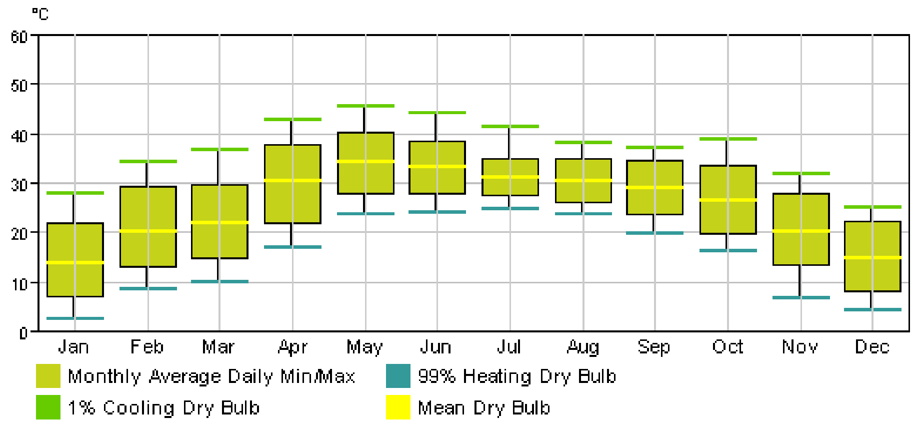
Annual Wind Rose (Frequency Distribution)



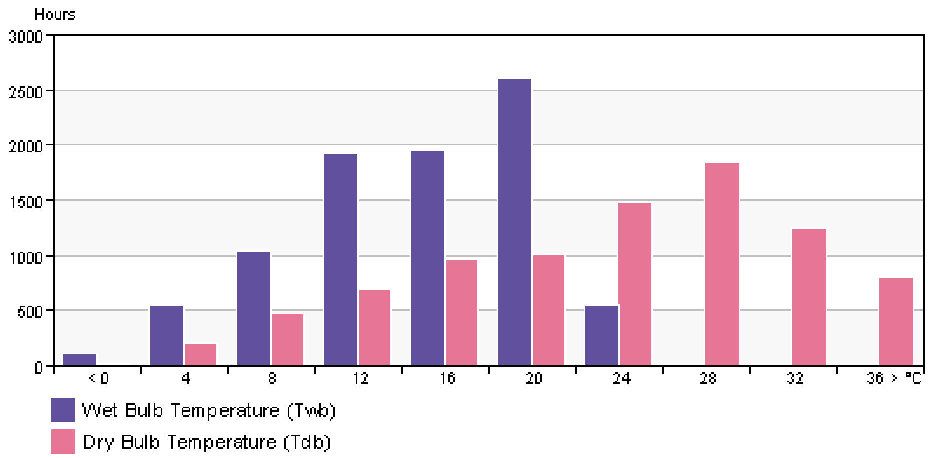
Monthly Wind Roses



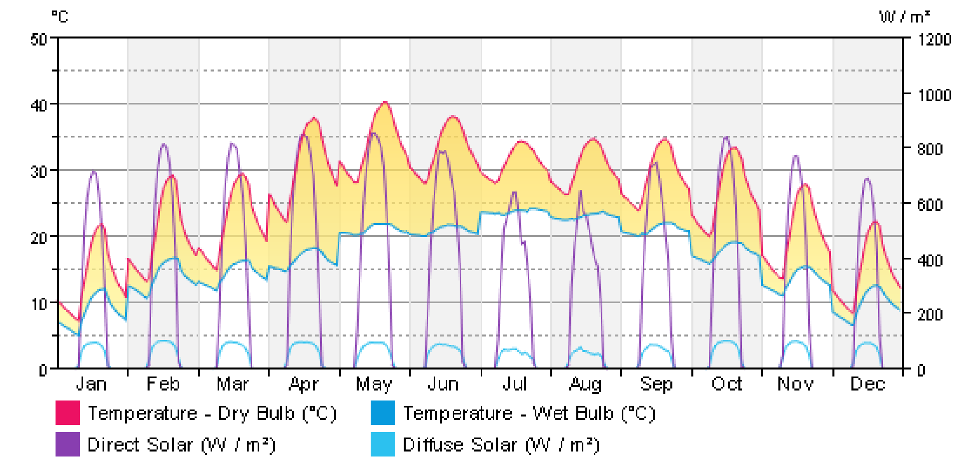
Monthly Design Data



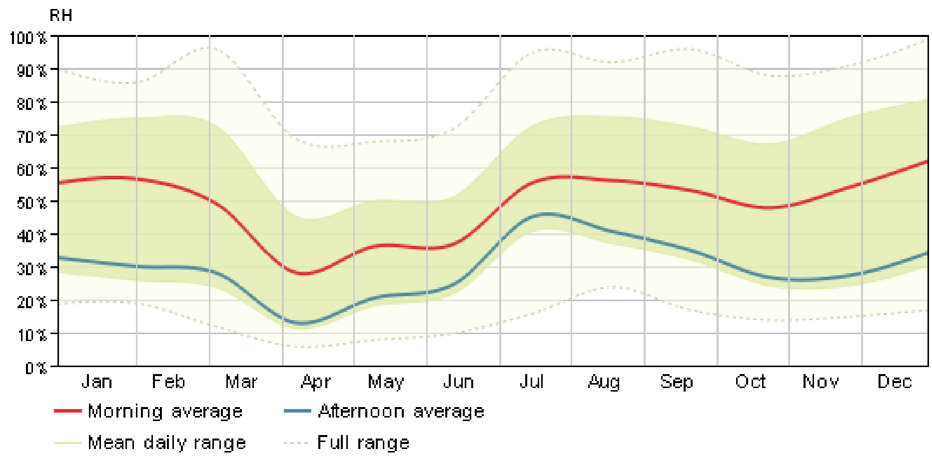
Annual Temperature Bins



Diurnal Weather Averages



Humidity



Energy Analysis Data

Annex 2 Concrete Block Wall + Un-Insulated Slab + 20% Glazing

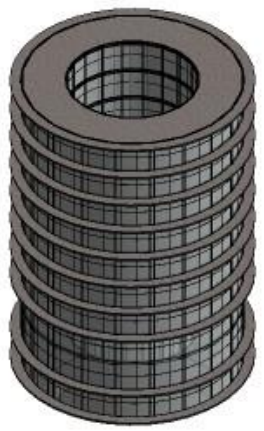
AUTODESK.

ring

ring Analysis

Analyzed at 5/5/2019 2:58:53 PM

Energy Analysis Result



Building Performance Factors

Location:	New Delhi, DL
Weather Station:	429042
Outdoor Temperature:	Max: 46°C/Min: 3°C
Floor Area:	14 m²
Exterior Wall Area:	0 m²
Average Lighting Power:	12.70 W / m²
People:	1 people
Exterior Window Ratio:	∞
Electrical Cost:	$0.08 / kWh
Fuel Cost:	$0.78 / Therm

Energy Use Intensity

Electricity EUI:	431 kWh / sm / yr
Fuel EUI:	260 MJ / sm / yr
Total EUI:	1,812 MJ / sm / yr

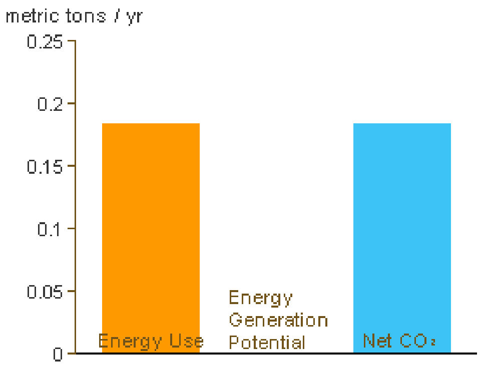
Life Cycle Energy Use/Cost

Life Cycle Electricity Use:	182,945 kWh
Life Cycle Fuel Use:	110,115 MJ
Life Cycle Energy Cost:	$7,016
*30-year life and 6.1% discount rate for costs	

Renewable Energy Potential

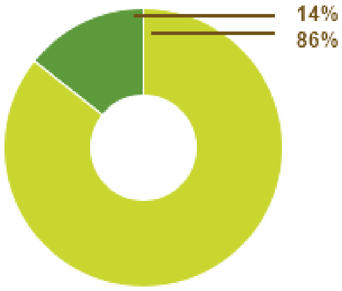
Roof Mounted PV System (Low efficiency):	2,491 kWh / yr
Roof Mounted PV System (Medium efficiency):	4,983 kWh / yr
Roof Mounted PV System (High efficiency):	7,474 kWh / yr
Single 15' Wind Turbine Potential:	414 kWh / yr
*PV efficiencies are assumed to be 5%, 10% and 15% for low, medium and high efficiency systems	

Annual Carbon Emissions



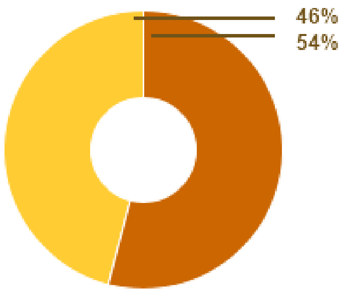
	(metric tons / yr)
Electricity Consumption	0
Fuel Consumption	0
Roof PV Potential (High Efficiency)	0
Single 15' Wind Turbine Potential	0
Net CO_2	0

Annual Energy Use/Cost



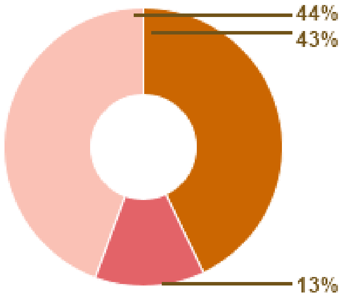
Electricity	86%	$488	6,098	kWh
Fuel	14%	$27	3,670	MJ
		$515		

Energy Use: Fuel



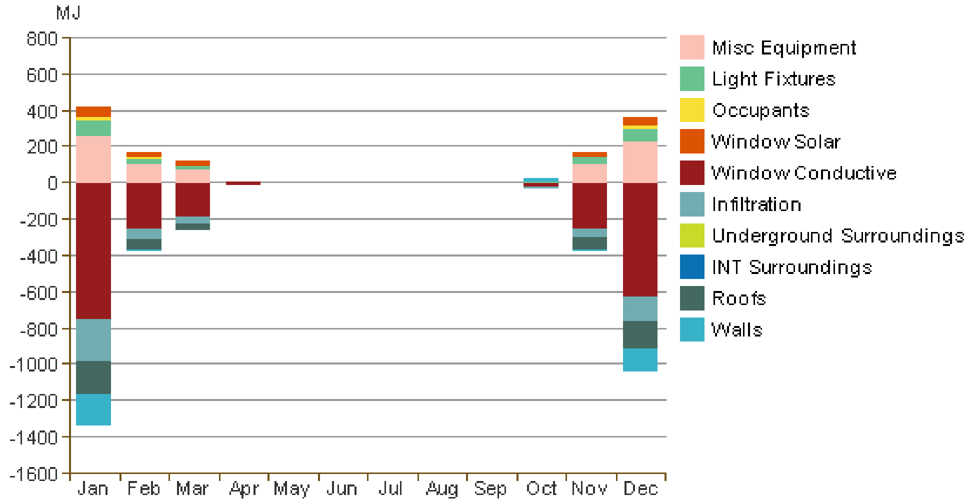
			(MJ)
HVAC	54%	$14	1,952
Domestic Hot Water	46%	$12	1,660
		$26	3,612

Energy Use: Electricity

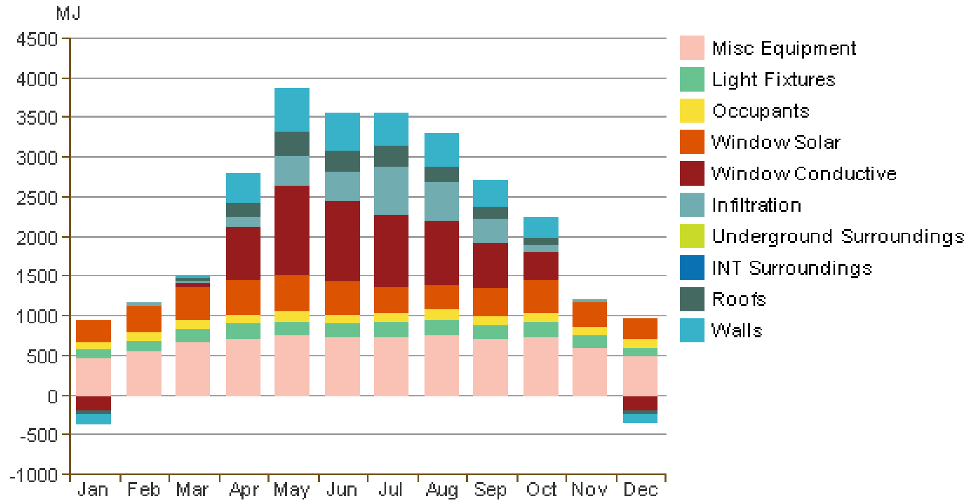


			(kWh)
HVAC	43%	$209	2,617
Lighting	13%	$61	774
Misc Equipment	44%	$216	2,706
		$486	6,097

Monthly Heating Load



Monthly Cooling Load



Monthly Fuel Consumption

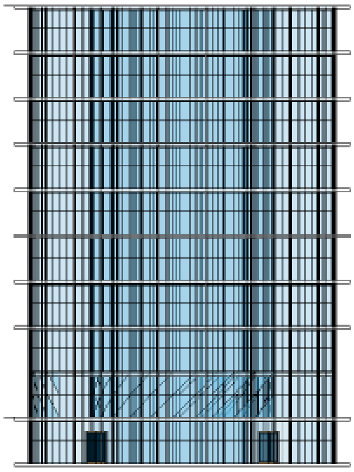
Annex 3 Curtain Wall+ Super-Insulated Slab+5% Glazing

ring

Ring_General elements with 3 insulation in curtain wall

Analyzed at 5/11/2019 12:17:34 PM

Energy Analysis Result



Building Performance Factors

Location:	New Delhi, DL
Weather Station:	429042
Outdoor Temperature:	Max: 46°C/Min: 3°C
Floor Area:	14 m²
Exterior Wall Area:	0 m²
Average Lighting Power:	12.70 W / m²
People:	1 people
Exterior Window Ratio:	∞
Electrical Cost:	$0.08 / kWh
Fuel Cost:	$0.78 / Therm

Energy Use Intensity

Electricity EUI:	431 kWh / sm / yr
Fuel EUI:	260 MJ / sm / yr
Total EUI:	1,812 MJ / sm / yr

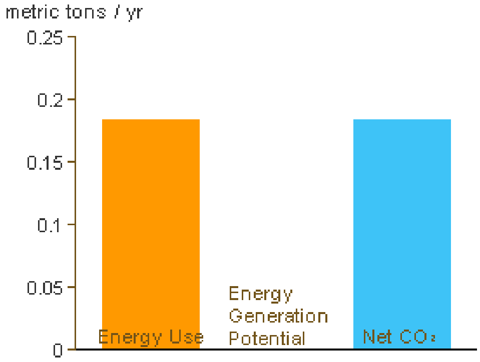
Life Cycle Energy Use/Cost

Life Cycle Electricity Use:	182,945 kWh
Life Cycle Fuel Use:	110,115 MJ
Life Cycle Energy Cost:	$7,016
*30-year life and 6.1% discount rate for costs	

Renewable Energy Potential

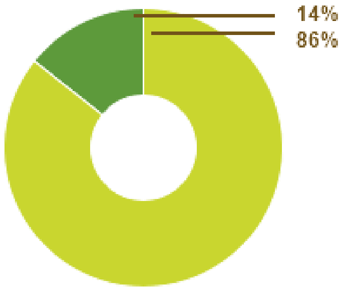
Roof Mounted PV System (Low efficiency):	2,491 kWh / yr
Roof Mounted PV System (Medium efficiency):	4,983 kWh / yr
Roof Mounted PV System (High efficiency):	7,474 kWh / yr
Single 15' Wind Turbine Potential:	414 kWh / yr
*PV efficiencies are assumed to be 5%, 10% and 15% for low, medium and high efficiency systems	

Annual Carbon Emissions



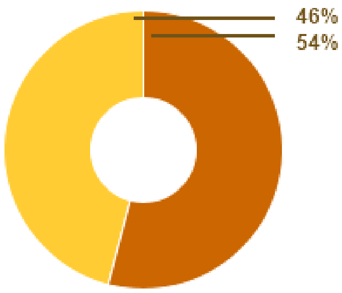
	(metric tons / yr)
Electricity Consumption	0
Fuel Consumption	0
Roof PV Potential (High Efficiency)	0
Single 15' Wind Turbine Potential	0
Net CO_2	0

Annual Energy Use/Cost



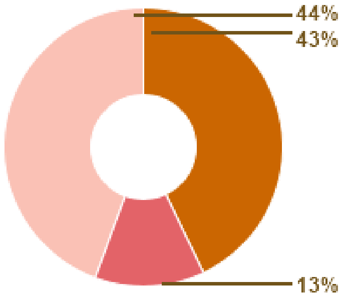
Electricity	86%	$488	6,098	kWh
Fuel	14%	$27	3,670	MJ
		$515		

Energy Use: Fuel



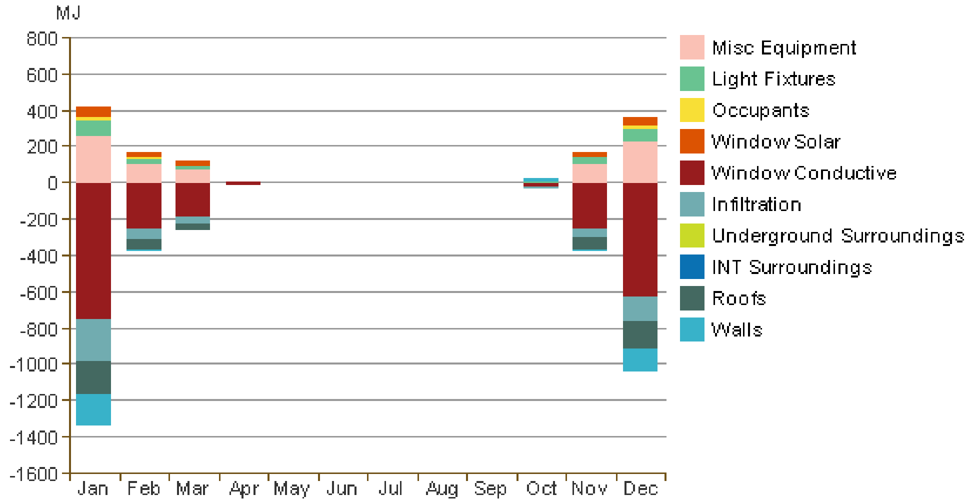
			(MJ)
HVAC	54%	$14	1,952
Domestic Hot Water	46%	$12	1,660
		$26	3,612

Energy Use: Electricity

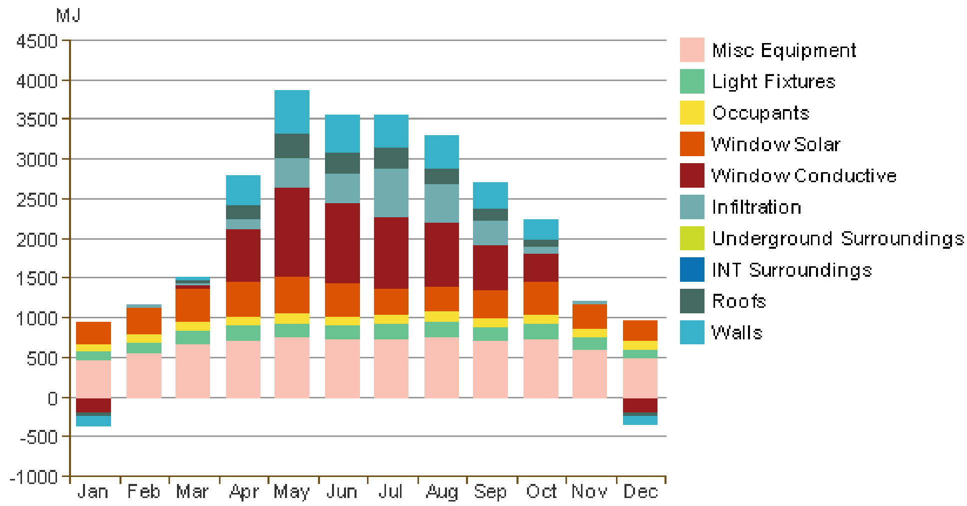


			(kWh)
HVAC	43%	$209	2,617
Lighting	13%	$61	774
Misc Equipment	44%	$216	2,706
		$486	6,097

Monthly Heating Load



Monthly Cooling Load



Monthly Fuel Consumption

Annex 4 Curtain Wall+ Un-Insulated Slab+20% Glazing

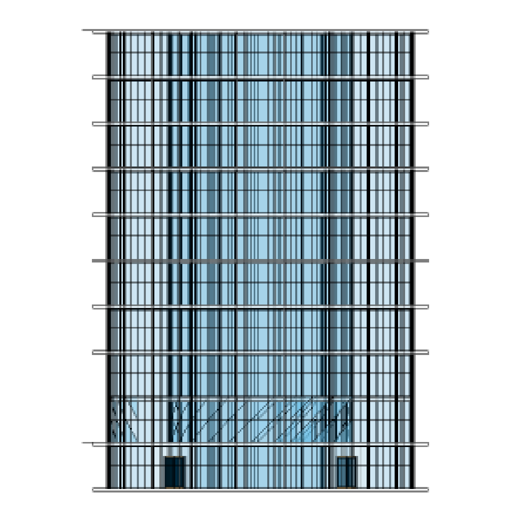
AUTODESK.

ring

Ring_General elements with 3 insulation in curtain wall + superinsulated slab

Analyzed at 5/11/2019 12:35:40 PM

Energy Analysis Result



Building Performance Factors

Location:	New Delhi, DL
Weather Station:	429042
Outdoor Temperature:	Max: 46°C/Min: 3°C
Floor Area:	14 m²
Exterior Wall Area:	0 m²
Average Lighting Power:	12.70 W / m²
People:	1 people
Exterior Window Ratio:	∞
Electrical Cost:	$0.08 / kWh
Fuel Cost:	$0.78 / Therm

Energy Use Intensity

Electricity EUI:	431 kWh / sm / yr
Fuel EUI:	260 MJ / sm / yr
Total EUI:	1,812 MJ / sm / yr

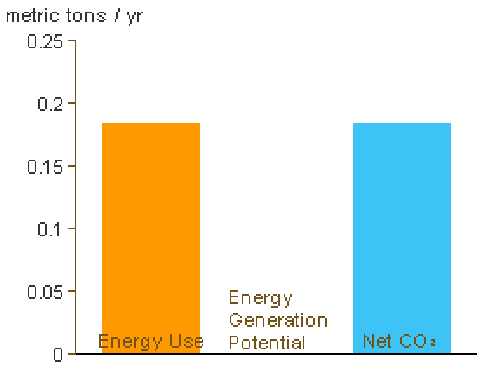
Life Cycle Energy Use/Cost

Life Cycle Electricity Use:	182,945 kWh
Life Cycle Fuel Use:	110,115 MJ
Life Cycle Energy Cost:	$7,016
*30-year life and 6.1% discount rate for costs	

Renewable Energy Potential

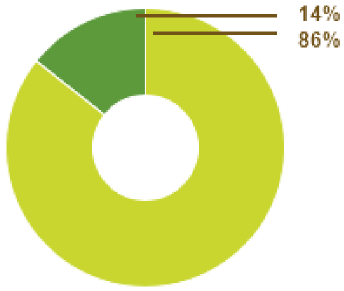
Roof Mounted PV System (Low efficiency):	2,491 kWh / yr
Roof Mounted PV System (Medium efficiency):	4,983 kWh / yr
Roof Mounted PV System (High efficiency):	7,474 kWh / yr
Single 15' Wind Turbine Potential:	414 kWh / yr
*PV efficiencies are assumed to be 5%, 10% and 15% for low, medium and high efficiency systems	

Annual Carbon Emissions



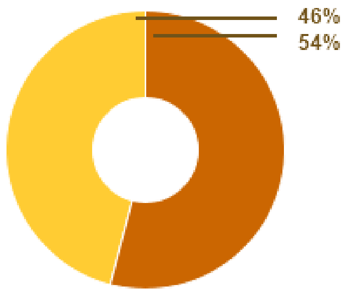
	(metric tons / yr)
Electricity Consumption	0
Fuel Consumption	0
Roof PV Potential (High Efficiency)	0
Single 15' Wind Turbine Potential	0
Net CO_2	0

Annual Energy Use/Cost



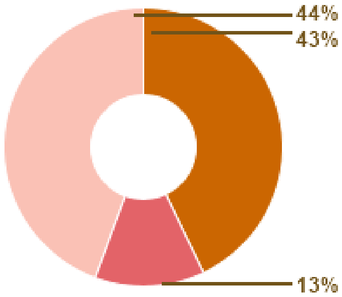
Electricity	86%	$488	6,098	kWh
Fuel	14%	$27	3,670	MJ
		$515		

Energy Use: Fuel



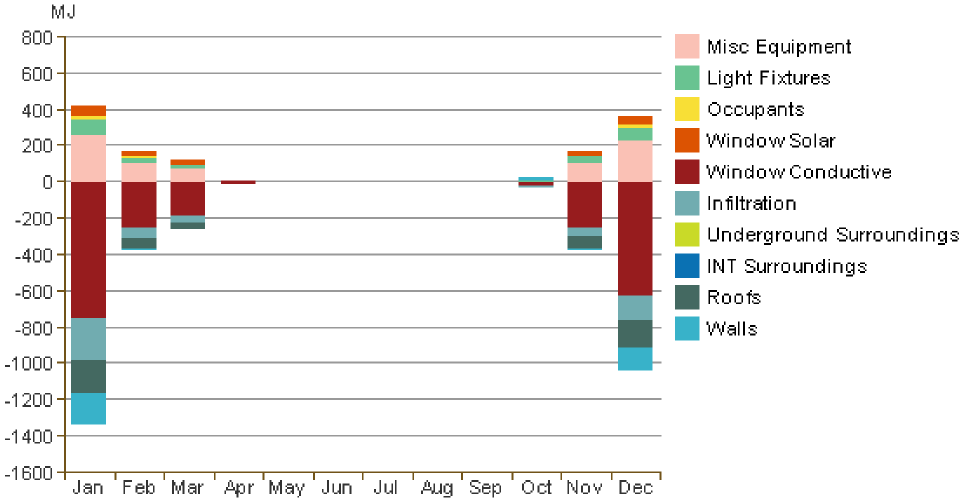
			(MJ)
HVAC	54%	$14	1,952
Domestic Hot Water	46%	$12	1,660
		$26	3,612

Energy Use: Electricity

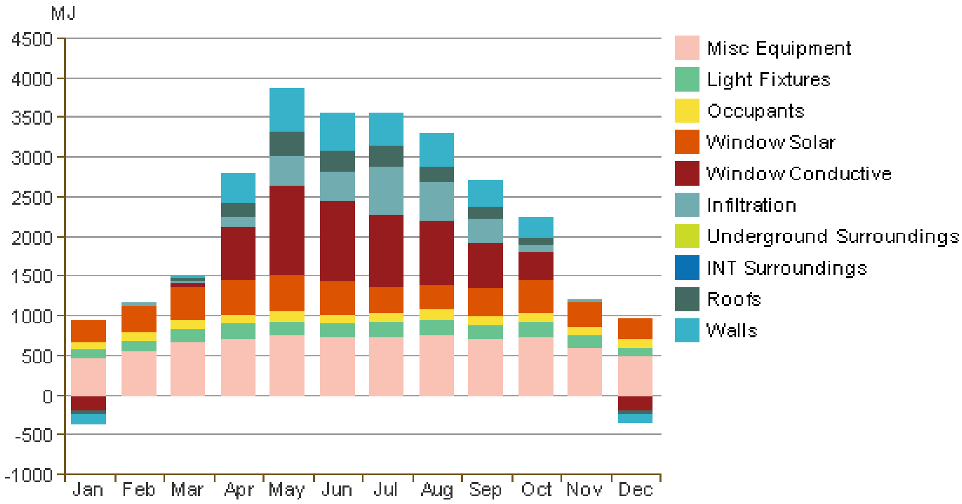


			(kWh)
HVAC	43%	$209	2,617
Lighting	13%	$61	774
Misc Equipment	44%	$216	2,706
		$486	6,097

Monthly Heating Load



Monthly Cooling Load



Monthly Fuel Consumption

Annex 5 Curtain Wall+ Super-Insulated Slab+10% Glazing

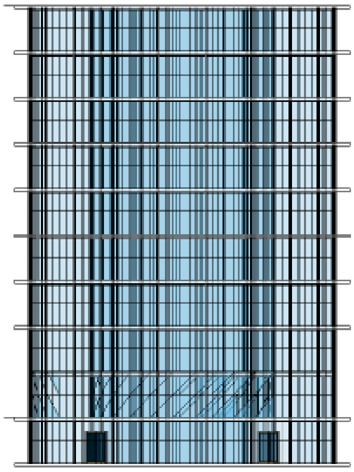
AUTODESK.

ring

Ring_General elements (3)

Analyzed at 5/11/2019 12:01:44 PM

Energy Analysis Result



Building Performance Factors

Location:	New Delhi, DL
Weather Station:	429042
Outdoor Temperature:	Max: 46°C/Min: 3°C
Floor Area:	14 m²
Exterior Wall Area:	0 m²
Average Lighting Power:	12.70 W / m²
People:	1 people
Exterior Window Ratio:	∞
Electrical Cost:	$0.08 / kWh
Fuel Cost:	$0.78 / Therm

Energy Use Intensity

Electricity EUI:	431 kWh / sm / yr
Fuel EUI:	260 MJ / sm / yr
Total EUI:	1,812 MJ / sm / yr

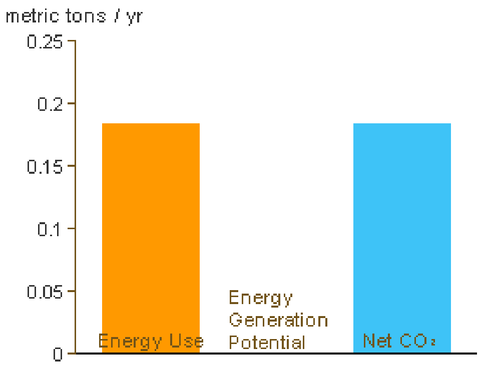
Life Cycle Energy Use/Cost

Life Cycle Electricity Use:	182,945 kWh
Life Cycle Fuel Use:	110,115 MJ
Life Cycle Energy Cost:	$7,016
*30-year life and 6.1% discount rate for costs	

Renewable Energy Potential

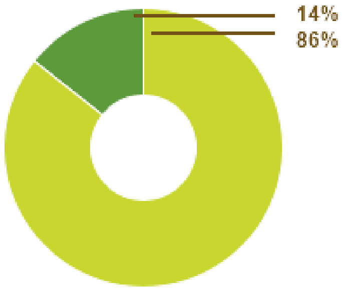
Roof Mounted PV System (Low efficiency):	2,491 kWh / yr
Roof Mounted PV System (Medium efficiency):	4,983 kWh / yr
Roof Mounted PV System (High efficiency):	7,474 kWh / yr
Single 15' Wind Turbine Potential:	414 kWh / yr
*PV efficiencies are assumed to be 5%, 10% and 15% for low, medium and high efficiency systems	

Annual Carbon Emissions



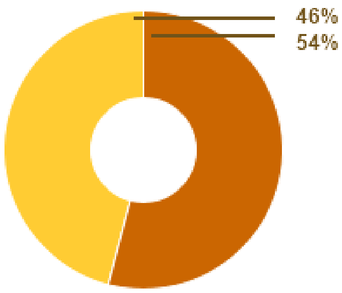
	(metric tons / yr)
Electricity Consumption	0
Fuel Consumption	0
Roof PV Potential (High Efficiency)	0
Single 15' Wind Turbine Potential	0
Net CO_2	0

Annual Energy Use/Cost



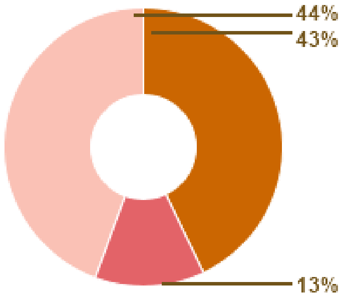
Electricity	86%	$488	6,098	kWh
Fuel	14%	$27	3,670	MJ
		$515		

Energy Use: Fuel



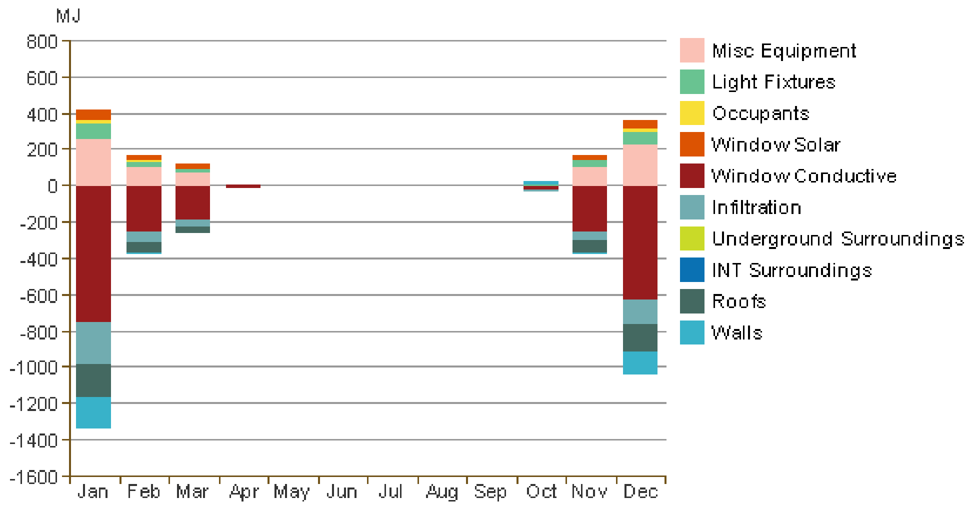
			(MJ)
HVAC	54%	$14	1,952
Domestic Hot Water	46%	$12	1,660
		$26	3,612

Energy Use: Electricity

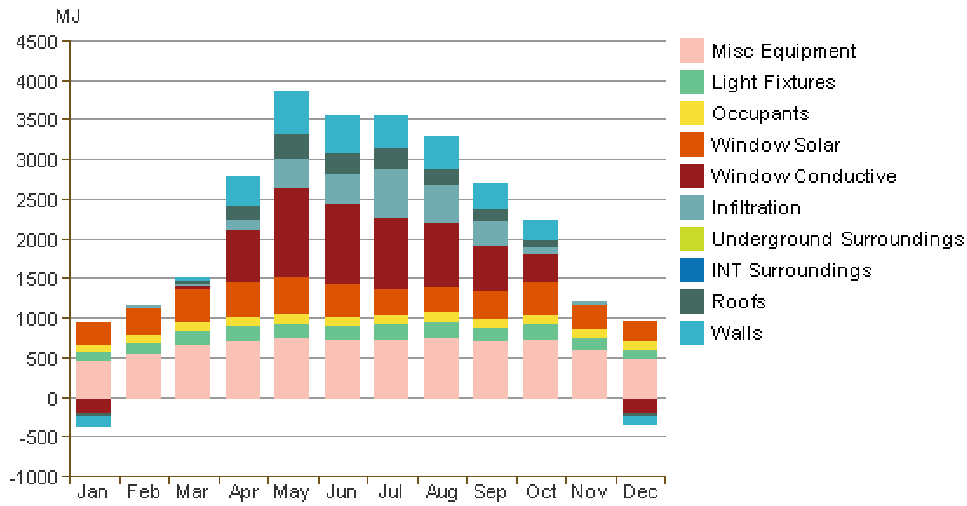


			(kWh)
HVAC	43%	$209	2,617
Lighting	13%	$61	774
Misc Equipment	44%	$216	2,706
		$486	6,097

Monthly Heating Load



Monthly Cooling Load



Monthly Fuel Consumption

Annex 6 Curtain Wall+ Un-Insulated Slab+15% Glazing

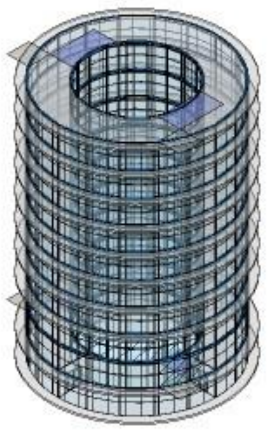
AUTODESK.

Exercise 2

ring Analysis unchecked on overrides

Analyzed at 5/18/2019 10:56:35 AM

Energy Analysis Result



Building Performance Factors

Location:	New Delhi, DL
Weather Station:	429042
Outdoor Temperature:	Max: 46°C/Min: 3°C
Floor Area:	14 m²
Exterior Wall Area:	0 m²
Average Lighting Power:	12.70 W / m²
People:	1 people
Exterior Window Ratio:	∞
Electrical Cost:	$0.08 / kWh
Fuel Cost:	$0.78 / Therm

Energy Use Intensity

Electricity EUI:	508 kWh / sm / yr
Fuel EUI:	288 MJ / sm / yr
Total EUI:	2,117 MJ / sm / yr

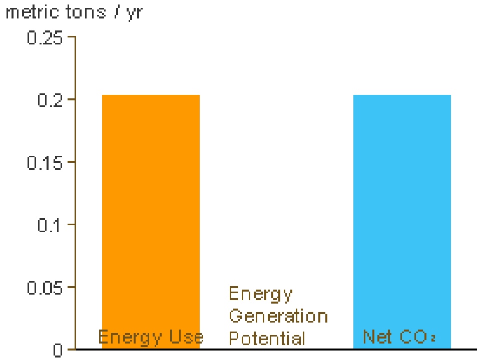
Life Cycle Energy Use/Cost

Life Cycle Electricity Use:	215,591 kWh
Life Cycle Fuel Use:	122,012 MJ
Life Cycle Energy Cost:	$8,242
*30-year life and 6.1% discount rate for costs	

Renewable Energy Potential

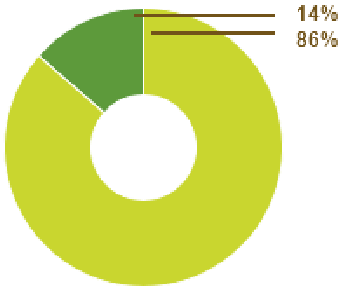
Roof Mounted PV System (Low efficiency):	2,491 kWh / yr
Roof Mounted PV System (Medium efficiency):	4,983 kWh / yr
Roof Mounted PV System (High efficiency):	7,474 kWh / yr
Single 15' Wind Turbine Potential:	414 kWh / yr
*PV efficiencies are assumed to be 5%, 10% and 15% for low, medium and high efficiency systems	

Annual Carbon Emissions



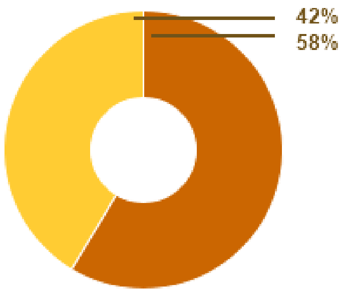
	(metric tons / yr)
Electricity Consumption	0
Fuel Consumption	0
Roof PV Potential (High Efficiency)	0
Single 15' Wind Turbine Potential	0
Net CO_2	0

Annual Energy Use/Cost



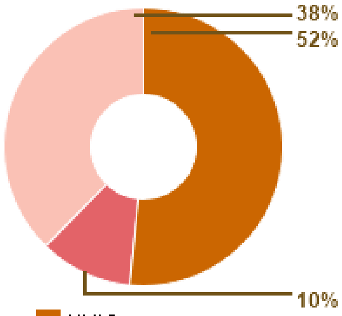
Electricity	86%	$575	7,186	kWh
Fuel	14%	$30	4,067	MJ
		$605		

Energy Use: Fuel



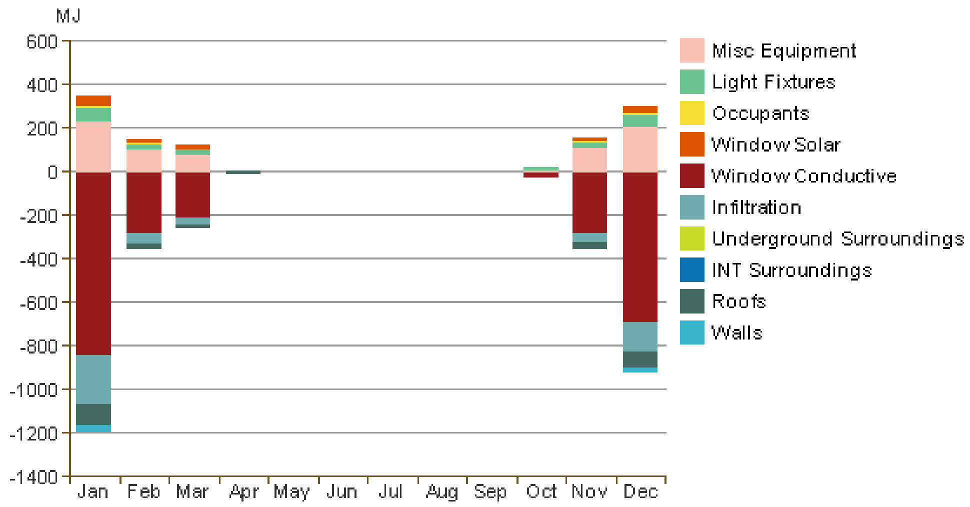
			(MJ)
HVAC	58%	$17	2,349
Domestic Hot Water	42%	$12	1,660
		$29	4,009

Energy Use: Electricity

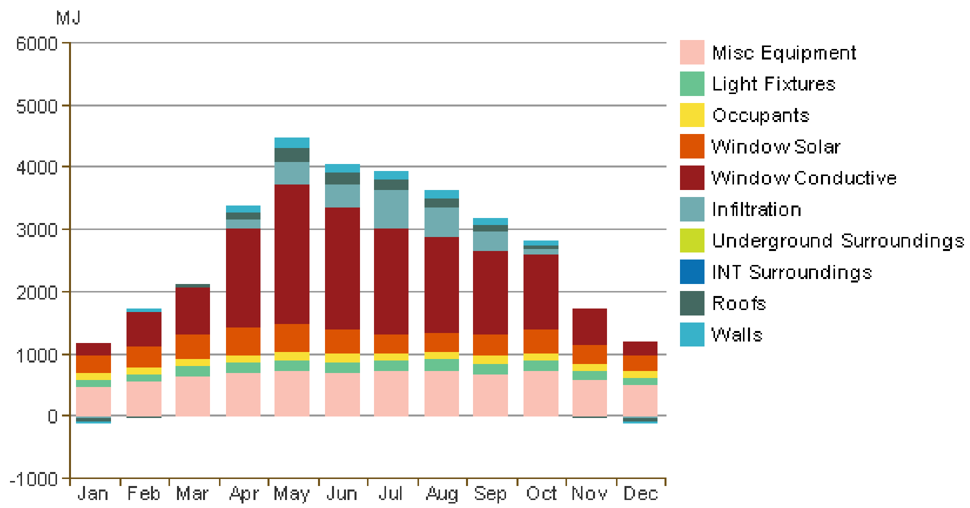


			(kWh)
HVAC	52%	$296	3,705
Lighting	10%	$61	774
Misc Equipment	38%	$216	2,706
		$573	7,185

Monthly Heating Load



Monthly Cooling Load



Monthly Fuel Consumption

Annex 7 Curtain Wall+ Super-Insulated Slab+5% Glazing

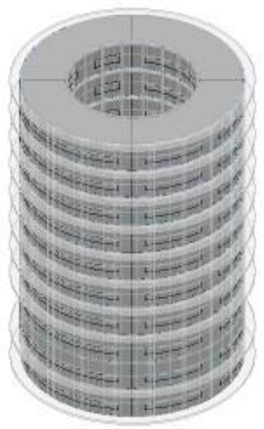
AUTODESK.

Exercise 2

ring Analysis C

Analyzed at 5/18/2019 11:10:04 AM

Energy Analysis Result



Building Performance Factors

Location:	New Delhi, DL
Weather Station:	429042
Outdoor Temperature:	Max: 46°C/Min: 3°C
Floor Area:	2,010 m²
Exterior Wall Area:	3,008 m²
Average Lighting Power:	12.70 W / m²
People:	201 people
Exterior Window Ratio:	0.15
Electrical Cost:	$0.08 / kWh
Fuel Cost:	$0.78 / Therm

Energy Use Intensity

Electricity EUI:	268 kWh / sm / yr
Fuel EUI:	56 MJ / sm / yr
Total EUI:	1,023 MJ / sm / yr

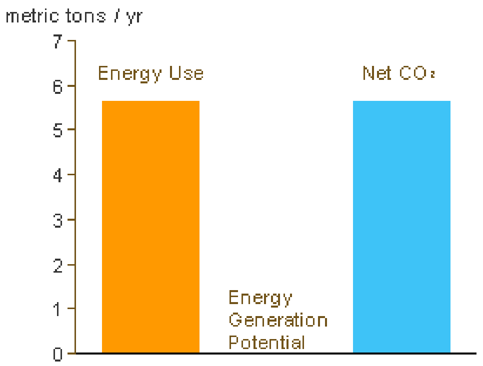
Life Cycle Energy Use/Cost

Life Cycle Electricity Use:	16,193,157 kWh
Life Cycle Fuel Use:	3,382,311 MJ
Life Cycle Energy Cost:	$599,542
*30-year life and 6.1% discount rate for costs	

Renewable Energy Potential

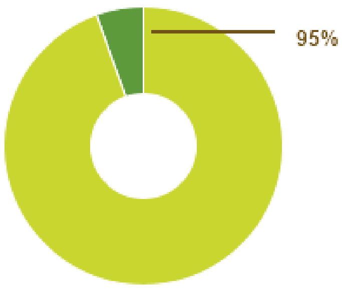
Roof Mounted PV System (Low efficiency):	16,557 kWh / yr
Roof Mounted PV System (Medium efficiency):	33,114 kWh / yr
Roof Mounted PV System (High efficiency):	49,671 kWh / yr
Single 15' Wind Turbine Potential:	414 kWh / yr
*PV efficiencies are assumed to be 5%, 10% and 15% for low, medium and high efficiency systems	

Annual Carbon Emissions



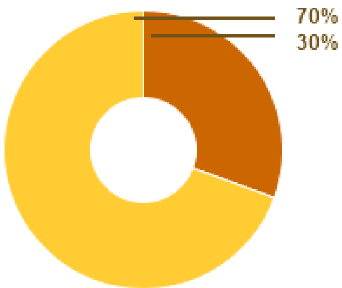
	(metric tons / yr)
Electricity Consumption	0
Fuel Consumption	5
Roof PV Potential (High Efficiency)	0
Single 15' Wind Turbine Potential	0
Net CO_2	5

Annual Energy Use/Cost



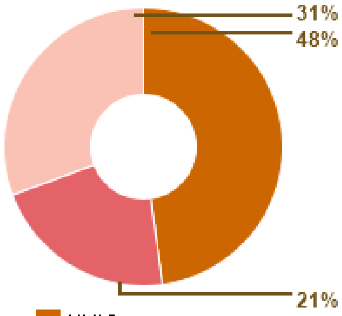
Electricity	95%	$43,182	539,771	kWh
Fuel	5%	$837	112,743	MJ
		$44,019		

Energy Use: Fuel



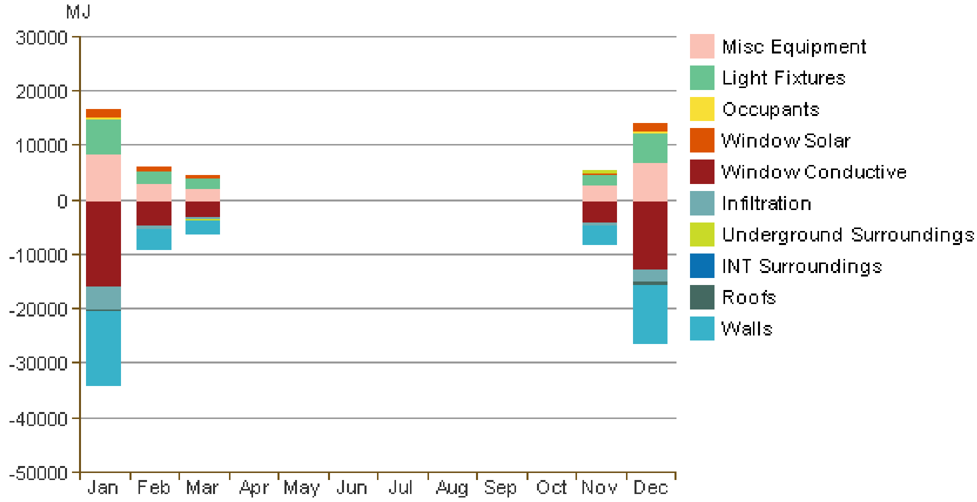
			(MJ)
HVAC	30%	$256	34,487
Domestic Hot Water	70%	$581	78,256
		$837	112,743

Energy Use: Electricity

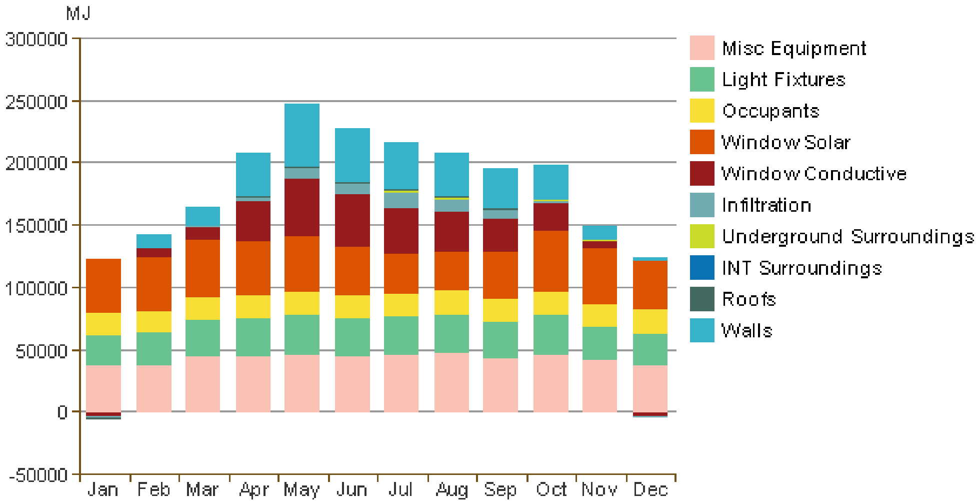


			(kWh)
HVAC	48%	$19,544	244,300
Lighting	21%	$8,802	110,031
Misc Equipment	31%	$12,529	156,615
		$40,875	510,946

Monthly Heating Load



Monthly Cooling Load



Monthly Fuel Consumption