

NET ZERO ENERGY RETROFIT OF AN EXISTING OFFICE BUILDING

A Thesis

Submitted in partial fulfillment of the requirements for the
award of
Master of Architecture degree in Sustainable Architecture

by

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**DEPARTMENT OF ARCHITECTURE
SCHOOL OF BUILDING AND ENVIRONMENT**

SATHYABAMA

**INSTITUTE OF SCIENCE AND
TECHNOLOGY (DEEMED TO BE
UNIVERSITY)**

**Accredited with Grade "A" by NAAC
JEPPIAAR NAGAR, RAJIV GANDHI SALAI, CHENNAI - 600 119**

MAY 2021



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This is to certify that this Report is the bonafide work of **AUSHWINLAL J (39890003)** who carried out the Thesis entitled "**NET-ZERO ENERGY RETROFIT OF AN EXISTING OFFICE BUILDING**" under our supervision from January 2021 to May 2021.

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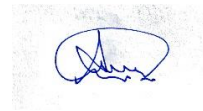
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DECLARATION

I **AUSHWINLAL J** hereby declare that the Thesis Report entitled “**NET-ZERO ENERGY RETROFIT OF AN EXISTING OFFICE BUILDING**” done by me under the guidance of **Ar. SHEETAL AMRAOTKAR** (Internal) and **Ar. P.S. GANESH, Principal Architect – GREENVIRON / Ar. BALAMURUGAN RAJKUMAR, Principal Architect -Proton Ateliers** (External) at Sathyabama Institute of Science and Technology is submitted in partial fulfillment of the requirements for the award of Master of Architecture degree in Sustainable Architecture.

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ABSTRACT

The economic development of a country is closely linked to its energy consumption. Currently India is ranked 6th in total energy consumption it still need more energy to keep the pace in control with its future development. In present changes have made to make building more energy efficient keeping the usage of buildings energy consumption in mind

The main objective of this thesis is to obtain clear understanding of the usage of building energy consumption and To study the economic benefits and advantages of a NZE office building in hot and Humid climate and reduce the carbon footprint in future where the energy demands is increasing day by day and to achieve it in a low cost. It is done through evaluating the building performance and energy usage (EUI) by modeling and stimulation by analyzing energy use index, various optimistic design solution and life cycle cost. The study also deals with finding solutions that reflect current trends achieved towards making building more intelligent, self-sustained and more sustainable

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1. INTRODUCTION

1.1 INTRODUCTION

“Energy saved is energy created”. Energy performance and energy efficiency have become the growing concern of the economic activity in today’s world to achieve sustainability.

Sustainability, of which energy plays a major role, encompasses all facets of economic activity such as Agriculture, Manufacturing, Services and Infrastructure including commercial buildings. Sustainability in developing nations poses specific challenges as the country has to cope up with diagonally opposite phenomena in terms of current GDP and Sustainability. Infrastructure including Commercial and IT buildings is a major stream of economic activities. Energy in these sectors is, of course, a factor to be reckoned with. This research work addresses the need of energy efficiency in commercial buildings in the developing nation’s context.

1.2 AIM

The aim of this thesis is to identify the most adequate design solutions for improving energy efficiency of the existing office building with NZEB strategies in warm and humid climate, considering the influence of the local climate, the endogenous energy resources and the local economic conditions.

1.3 OBJECTIVE

To study the important criteria for achieving net zero energy building.

- Conducting a comprehensive literature review of current and past studies on the building sustainability and net energy fields.
- To study the impact of building design, components and operational parameters on the overall building energy use.
- To study how the NEEB strategies help in improving the energy efficiency of the existing building through various example.
- Perform and analysis of building simulations to evaluate the effectiveness of various designs and operation strategies for each case study building and identify the most effective ways of achieving net energy in a building.

1.4 SCOPE AND LIMITATION

The scope of this thesis is to explore the NEEB strategies to reduce the energy consumption of an existing building through various optimistic design solution and to consider the relationship between energy efficiency issues and Net Energy Building Requirements to generate less impact sustainable environment design.

1.5 METHODOLOGY

The basic approach to achieve the objectives of this study will be to identify a set of system parameters that would influence the energy efficiency of the green building and decide on the best combination of parameters to achieve maximum efficiency. REVIT GREEN BUILDING STUDIO simulation software has been identified to perform the analysis. Sources like ASHRAE standards, IGBC/ USGBC have been used to identify the parameters and energy efficiency analysis. The research methodology has been broadly classified in four stages.

a) Data Collection

- a) Identify and collect primary and secondary data
- b) Identify energy optimization factors for an energy efficient building
- c) Identify parameters and options for each factor

b) Modelling Process

Generate scenarios with possible combination of factors and options.

Evaluate each scenario with respect to energy efficiency using energy modelling technique.

c) Simulation Output and Cost Analysis

Analyse the scenarios for optimum energy efficient design

Analyse the scenario for cost parameters.

d) Validation of Actual Data with Design Results.

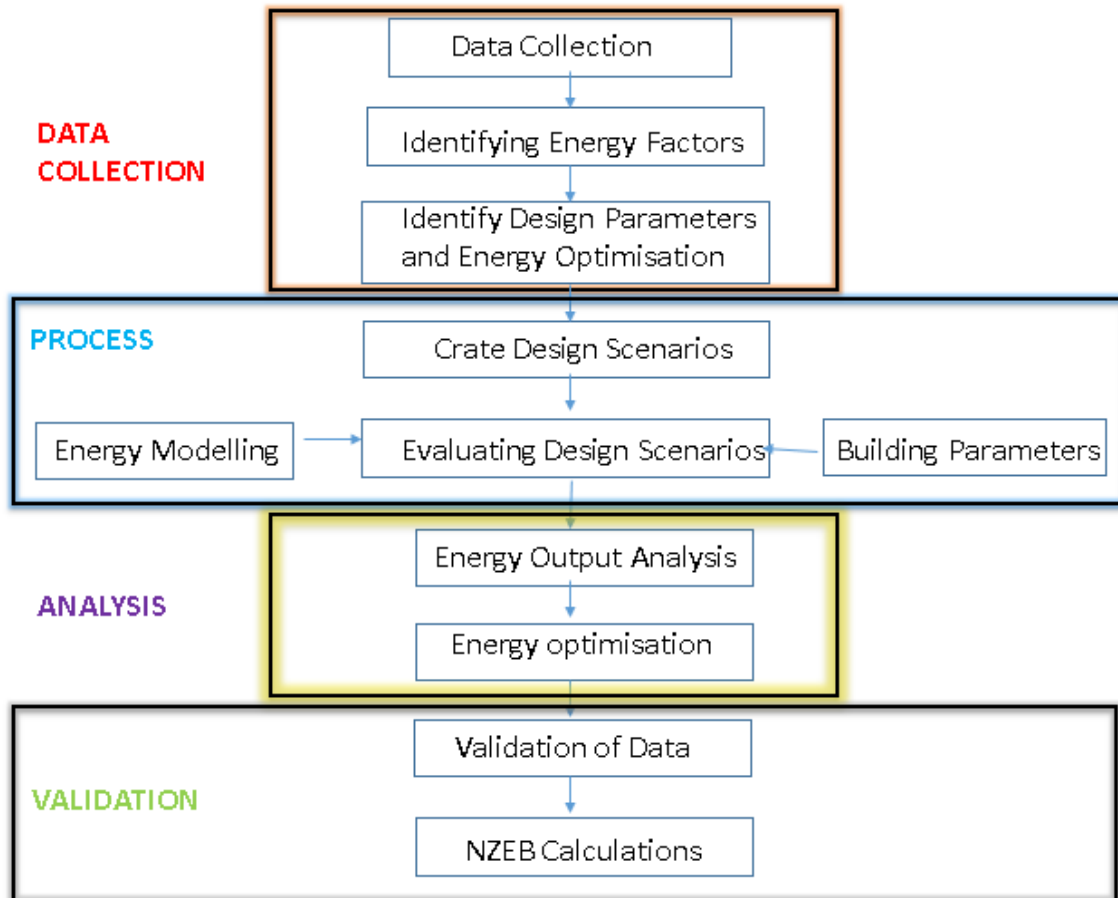


Table 1.1 Methodology of the design process

1.6 NEED FOR THE STUDY

The need for alternative energy sources is getting urgent, hence the development of renewable energy is moving fast nationally and internationally various individuals and research companies are creating new and exciting energy systems.

The first problem is that the fossil fuels are depleting in a rapid rate and are harder to ret revive. The consequence is that we can be facing an energy crisis in the future if we are not careful today. The energy prices will sky rocket and not be available for many individuals or countries to avoid this scenario we need to find alternatives and used them to their full potential luckily this is already happening.

The second problem is that the fossil fuels that widely used today are harmful for the environment. In the early seventies and eighties there were people and even scientist who preached otherwise, but today the negative effects are visible. The earth is warming up and climate is changing. There are parts in the world were there be more rain and sunshine and other parts will become dryer then they already are furthermore, the depletion of the ozone layer leads to the warming up of the earth. These two effects complement each other and make it even more crucial to take another step in a different direction this step leads us to the use of renewable energy.

1.7 LIMITATION

Obtaining net energy efficiency building requires a good design, construction process and operation stages, but due to time limitation only design process will be considered and the study is about to improve the energy efficiency of an existing office building by analyzing requirements and application of net energy strategies.

1.8 FRAMEWORK

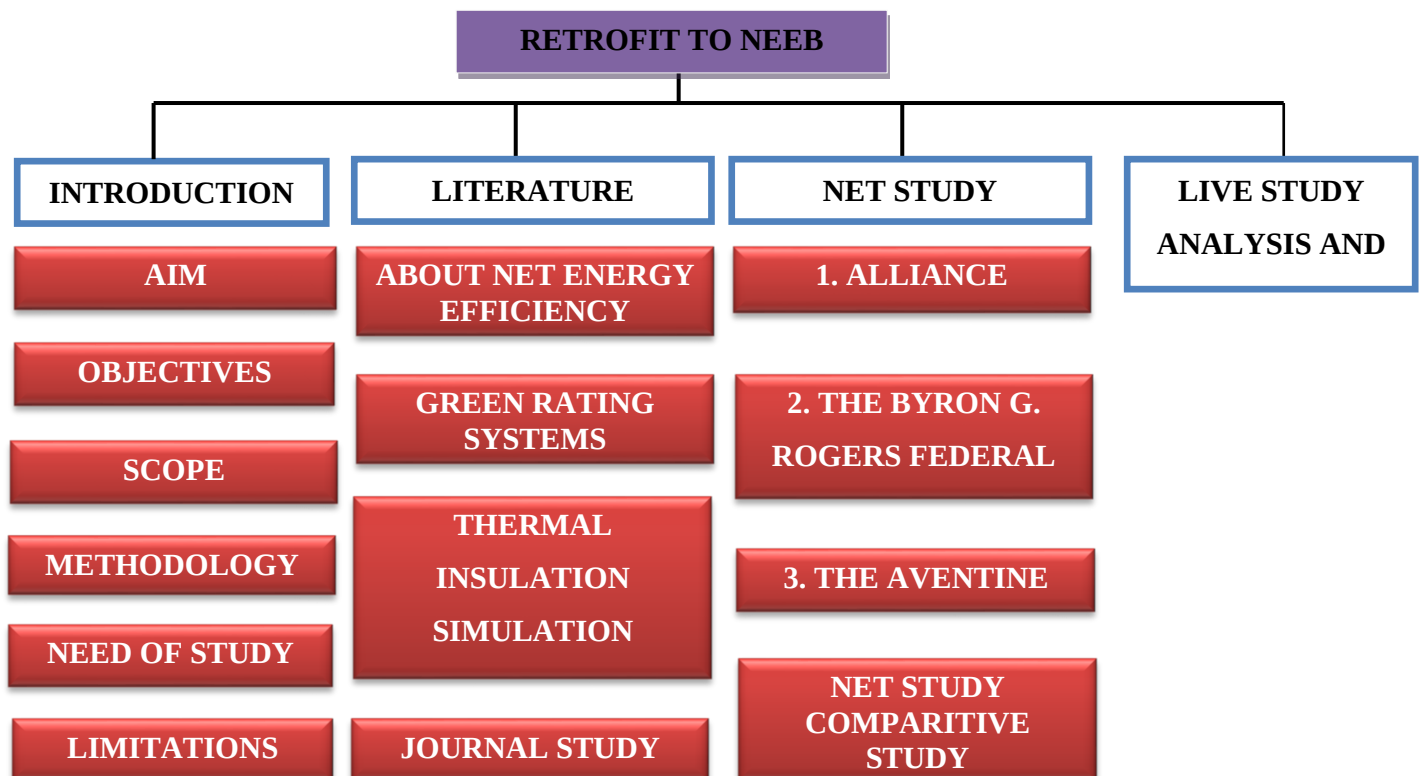


Table 1.2 Framework analysis of Retrofit Net Zero Energy Building .

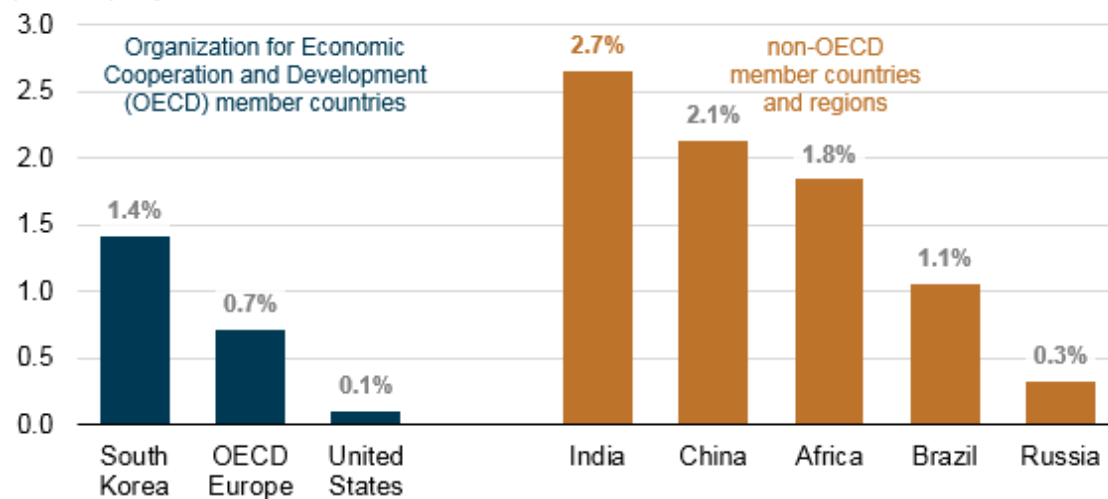
2.1 ENERGY ARCHITECTURE NZEB

With the mounting concern raised by global warming , architectural organizations and firms have adopted many new design practices keen to impede the growing stockpile of environmental problems that the buildings are adding on to and concurrently do not substantially alter the standard of living conditions to which we are so familiar with.

2.2 MODERN EVOLUTION

The development of modern energy buildings became possible not only through the progress made in new construction technologies and techniques, but it has also been significantly improved by academic research on traditional and experimental buildings, which collected precise energy performance data. Today's advanced computer models can show the efficacy of engineering design decisions.

Average annual change in buildings energy consumption, 2015-2040
percent per year



Energy

use can be measured in different ways (relating to cost, energy, or carbon emissions) and, irrespective of the definition used, different views are taken on the relative importance of energy harvest and energy conservation to achieve a net energy balance.

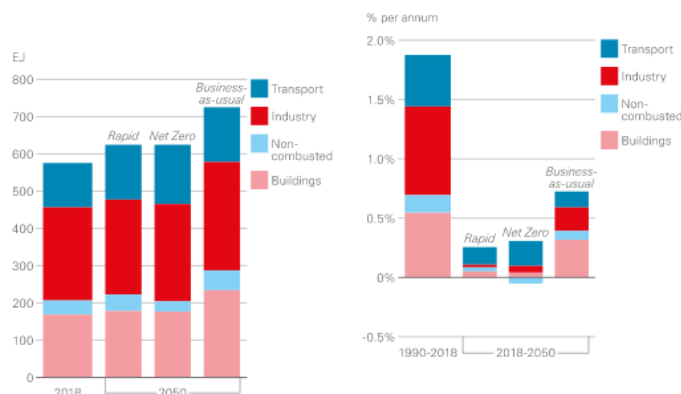


Fig.2.3 Energy efficiency and green conservative measures.

Using NEEB design goals takes us out of designing low-energy buildings with a percent energy savings goal and into the realm of a sustainable energy endpoint. The goals that are set and how those goals are defined are critical to the design process. The definition of the goal will influence designers who strive to meet it (Deru and Tortellini 2004). Because design goals are so important to achieving high-performance buildings, the way a NEEB goal is defined is crucial to understanding the combination of applicable efficiency measures and renewable energy supply options.

2.3 SUPPLY-SIDE TECHNOLOGIES ON AND OFF SITE

Various supply-side renewable energy technologies are available for ZEBs. Typical examples of technologies available today include PV, solar hot water, wind, hydroelectric, and bio-fuels these renewable sources are favorable over conventional energy sources such as coal and natural gas.

The principles that have been applied to develop this ranking are based on technologies that:

- Minimize overall environmental impact by encouraging energy-efficient building designs and reducing transportation and conversion losses.
- Will be available over the lifetime of the building.

Option Number	ZEB Supply-Side Options	Examples
1.	Reduce site energy use through low-energy building technologies	Day-lighting, high-efficiency HVAC equipment , natural ventilation, evaporative cooling, etc.
On-Site Supply Options		
2.	Use renewable energy sources available within the building's footprint	PV, solar hot water, and wind located on the building.
3.	Use renewable energy sources available at the site	PV, solar hot water, low-impact hydro, and wind located on-site, but not on the building.
Off-Site Supply Options		
4.	Use renewable energy sources available off site to generate energy on site	Bio mass, wood pellets, ethanol, or bio diesel that can be imported from off site, or waste streams from on-site processes that can be used on-site to generate electricity and heat.
5.	Purchase off-site renewable energy sources	Utility-based wind, PV, emissions credits, or other "green " purchasing options. Hydroelectric is sometimes considered.

Table 2.1 On-site and Off-site energy efficient measures.

2.4 GREEN BUILDING RATING SYSTEM

Green building rating system is an evaluation tool that measures environmental performance of a building through its lifecycle. Comprises of a set of criteria covering various parameters related to design, construction and operation of a green building

Each criterion has pre assigned points and sets performance benchmarks and goals that are largely quantifiable.

A project is awarded points once it fulfills the rating criteria. The points are added up and the final rating of a project is decided. Globally, green building rating systems are largely voluntary in nature and have been instrumental in raising awareness and popularizing green building design.

2.5 INTERNATIONAL RATING PROGRAMS: LEED

Leadership in Energy and Environmental Design (LEED®) was developed and piloted in the US in 1998 as a consensus-based building rating system based on the use of existing building technology. The rating system addresses specific environmental building related impact using a whole building environmental performance approach. The Indian Green Building Council has adapted LEED system and has launched LEED India version for rating of new construction.

Indian Green Building Council (IGBC) has launched several other products for rating of different typologies of buildings including homes, factories, among others.

Sustainable sites (construction related pollution prevention, site development impacts, transportation alternatives, storm water management, heat island effect, and light pollution)

Water efficiency (landscaping water use reduction, indoor water use reduction, and waste water management strategies)

Energy and atmosphere (commissioning, whole building energy performance optimization, refrigerant management, renewable energy use, and measurement and verification)

Materials and resources (recycling collection locations, building reuse, construction waste management, and the purchase of regionally manufactured materials, materials with recycled content, rapidly renewable materials, salvaged materials, and FSC certified wood products)

Indoor environmental quality (environmental tobacco smoke control, outdoor air delivery monitoring, increased ventilation, construction indoor air quality, use low emitting materials, source control, and controllability of thermal and lighting systems)

Innovation and design process (LEED accredited professional, and innovative strategies for sustainable design)

The number of points a project earns determines the level of LEED certification. There are four levels of certification - the number of points a project earns determines the level of LEED certification that the project will receive. Typical certification thresholds are:

NO	POINTS	CERTIFICATES
1	80+ Points	PLATINUM
2	60-79 Points	GOLD
3	50-59 Points	SILVER
4	40-49 Points	CERTIFIED

Table 2.2 LEED certification and points.



Credit 1, Site Selection

Credit 2, Development Density & Community Connectivity
Credit 3, Brownfield Redevelopment
Credit 4, Alternative Transportation
Credit 5, Site Development
Credit 6, Storm water Design
Credit 7, Heat Island Effect
Credit 8, Light Pollution Reduction

Table 2.3 LEED criteria and credits.

2.5.1 Benefits of certification

LEED certification can provide a number of benefits for building owners. Along with the obvious environmental advantages, LEED-certified buildings cost less to operate and are more desirable for commercial and residential occupants. They also may qualify for significant financial benefits through tax rebates and incentives, making these green-friendly buildings an even better investment. Buildings that incorporate energy efficient lighting systems and low-flow bathroom fixtures can provide lower utility bills for tenants while ensuring a healthier environment for residents and occupants.

2.5.2 Certification for commercial buildings

In order to achieve LEED certification, commercial buildings must meet stringent standards as determined by the Green Building Certification Institute. This independent organization conducts third-party inspections of commercial buildings in accordance with ISO international certification standards. Building owners can achieve a number of different levels of LEED certification depending on the degree to which the building complies with environmental standards.

Certified buildings must achieve 40 or more points out of a possible 110

Silver certification is available to buildings that achieve 50 or more points.

Gold-certified buildings have achieved 60 or more points.

The highest level is Platinum certification, which requires 80 or more points. Points are awarded in all five major evaluation categories and are weighted toward those categories of greatest environmental significance. For instance, energy efficient lighting and HVAC systems can have a major impact on overall energy consumption by the building; lighting systems and heating and cooling devices are usually weighted more heavily than other criteria and are worth more points toward certification.

The best way to achieve LEED certification is to incorporate environmentally friendly construction methods, sustainable materials and energy-efficient systems into the overall building plans. Energy efficient lighting systems can be an important element in achieving LEED certification, as these systems use much less energy than traditional lighting methods.

Insulation and ENERGY STAR-rated windows can add points to the overall certification totals. Low-flow water fixtures reduce utility bills and protect the environment. Modern heat pumps and energy efficient HVAC systems can pave the way for LEED certification. Making environmentally sound choices is the first step toward LEED certification and can provide significant financial benefits for building owners as well.

2.6 ENERGY EFFICIENCY IN COMMERCIAL BUILDINGS

It is important to note that buildings are responsible for 43% of current energy usage. The Building Energy Efficiency Survey 2016 reported that 67% of energy consumption in commercial buildings was used to provide building services including lighting, heating, ventilation, cooling, and hot water. Therefore, making these factors more energy efficient could potentially produce massive energy saving gains.

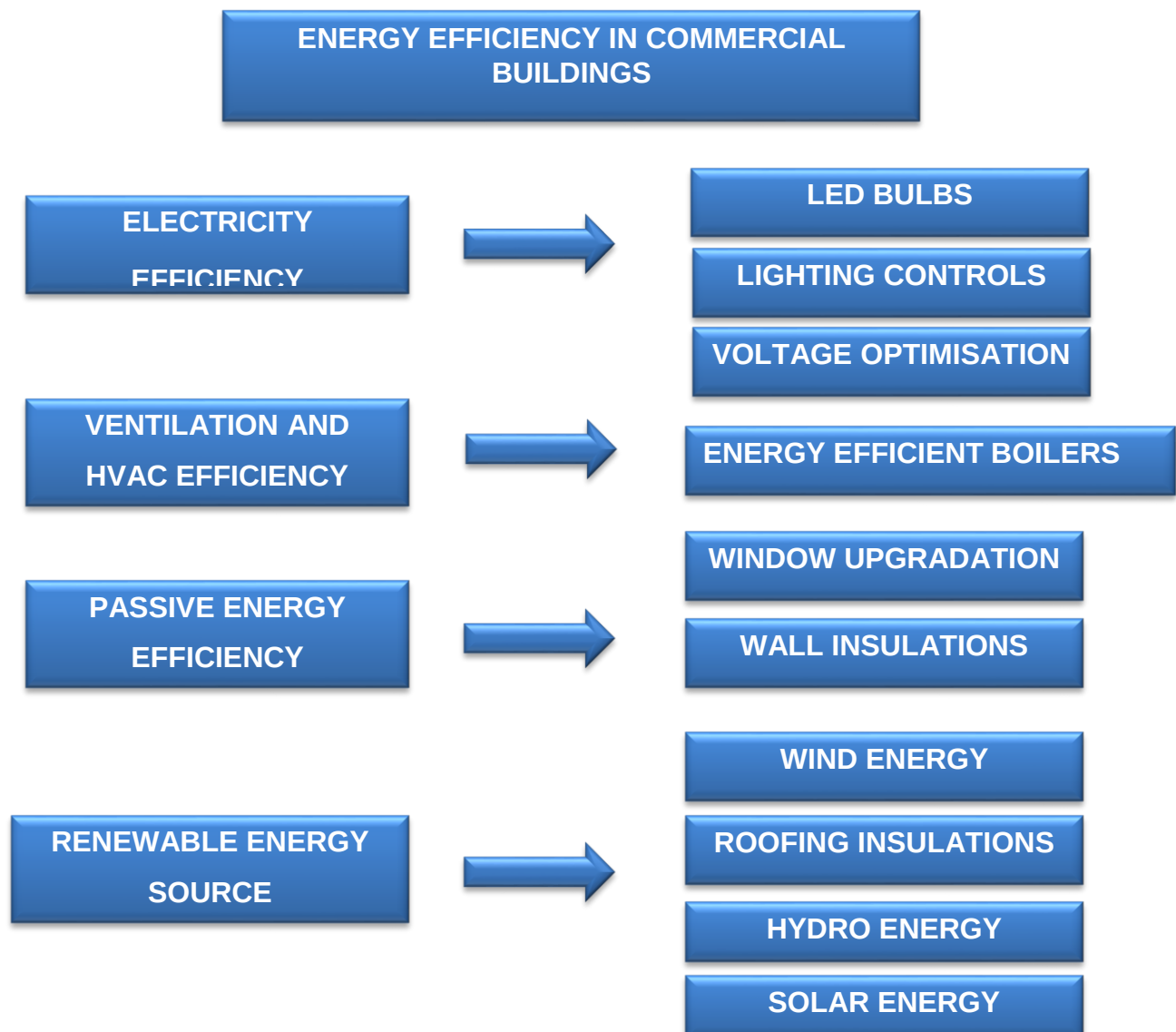


Table 2.4 Energy efficiency in commercial building.

2.7 ELECTRICITY EFFICIENCY IN COMMERCIAL BUILDINGS

For most commercial buildings, the high rate of electricity consumption is often overlooked especially by the people who use the properties on a day-to-day basis. Lights, heating, cooling and machines are often left running 24/7 even if it's not necessary.

The Environmental Protection Agency reported that 30% of energy used in a commercial building is wasted due to inefficiencies. This high energy consumption can then impact a company's bottom line.

Optimizing a building's energy efficiency may not always be the first thing that comes to mind when it comes to cost-cutting measures. However, if more commercial building owners work towards reducing electricity consumption, they will realise that these savings can actually free up funding. This funding can be devoted to other business projects that can help in supporting the company's goals.

2.7.1 LED BULBS AND LIGHTING CONTROLS



Fig 2.4 Energy efficiency by lighting control.

Lighting can consume a lot of power especially in commercial buildings. In fact, **lighting accounts for 20% of energy consumption** in the UK. But the good news is, it is also one of the easiest and more affordable to replace.

Switching to LED Lighting

One way to instantly save energy and make a property more efficient is by choosing LED lighting. In general, LED lights consume 70-90% less energy than a standard incandescent or CFL bulb. So just replacing one bulb already delivers significant savings.

2.7.2 INSTALLING LIGHTING CONTROLS



Fig 2.5 Energy conservation by lighting control system.

Basic Lighting Controls are manual on and off switches. This is similar to what is usually found in homes. For this to work, users need to manually turn on/off the switch.

Dimmer Switches are slightly more advanced as they give the user the ability to control the level of brightness in a given room. This can save energy as the lights will not be needed to function at full power all of the time.

Motion Sensors for Outdoor Lighting are activated when movement is detected at night, and they automatically turn off when movement is not detected. These are useful for porch lighting or parking spaces.

Occupancy Sensor for Indoor Lighting are activated as soon as a person enters a room and once movement is not detected after a few minutes, these automatically turn off. These are typically used for bathrooms, conference rooms, common rooms and other public spaces like schools, building towers, and hospitals.

Timer Controlled Lighting can be programmed to turn on and off at certain times which can be used for indoor and outdoor lighting.

Networked Lighting Control Systems or “Smart Switches” allows a user to manage the lighting through the use of a computer or a handheld device. The lighting is part of one network system that can be accessible through the controller.

2.7.3 VOLTAGE OPTIMISATION FOR ENERGY EFFICIENT BUILDINGS

Another energy saving technology that can help make a property more energy efficient is voltage optimization. This technology is used to regulate the incoming power supply and reduce the voltage supplied to the optimum rate for the electrical equipment being used.

Static / Fixed Reduction VO means that the voltage will be optimized at a set number. This is recommended if the property is not experiencing too much fluctuation from the power grid.

Dynamic Reduction VO is when voltage is optimized to react to fluctuations in grid voltage to ensure that minimum voltage levels are not compromised. This can provide maximum savings as the voltage optimization unit is set to maintain an optimal voltage level for the site.

2.7.4 VENTILATION AND AIR CONDITIONING

Ventilation and air conditioning also contribute largely to energy consumption of a commercial property. Air ventilation and air conditioning are usually interchanged but are completely different systems.

In air ventilation, the system takes the air in the building and mixes fresh air from outside, without changing the air's temperature. The purpose of this is to refresh and remove the harmful elements in the air by bringing fresh air inside.

Air conditioning on the other hand circulates air around the building and changes its temperature. This can be either warming or cooling the air depending on the desired temperature.

Recommended Temperature in the Workplace

Ventilation and air conditioning are important in any commercial space to ensure that workers in these spaces are comfortable. With most workers spending a bulk of their day in the workplace, a temperature controlled environment is a primary key to maximize productivity.

2.7.5 ELECTRICITY GENERATION

More and more companies are looking for ways to self-generate their own electricity in order to be less dependent on the National Grid. When companies are able to produce their own electricity, this reduces their electricity bills, protects them from sudden power cuts, shortages and price hikes, plus using renewable energy is more beneficial for the environment.

Some examples of **renewable energy sources** that commercial companies can explore include solar, wind, geothermal, bioenergy, hydroelectric, hydrogen and ocean energy. However two of the more accessible sources are solar and wind energy. This is because the other sources are either geographically dependent or may not be easily accessible or practical for smaller companies.

Solar Energy – Installing Photovoltaic / Solar Panels is a popular choice for most commercial buildings as they can be installed in unused roof spaces or car parking lots. Solar energy is a clean and renewable energy that does not emit greenhouse gasses so it's good for the environment, and at the same time can significantly lower electricity bills. Solar energy can be used in both urban and rural areas, as long as the solar panels can get optimal sun exposure. They are also widely available and not complicated to install which is why more properties choose this option.

Wind Energy – this is another fast-growing renewable energy source designed to be efficient in an environment with uniform and constant air flow. The wind energy propels three propeller like blades in a wind turbine that spins a generator to create electricity. A commercial property located in an open space may benefit from wind energy as long as the area meets the required wind conditions. This is not usually preferred in dense urban environments because having surrounding buildings and structures means that the wind flow is not constant.

2.7.6 ENERGY EFFICIENT BOILERS

Boilers are used to generate heat and hot water for domestic and commercial properties. They are also known to consume far more energy than any other appliance. In fact, boilers account for at least 55-60% of a person's annual spend on energy. This means that if an inefficient boiler is being used, so much energy is also wasted as a result.

According to a **report** by the Energy Saving Trust, if everyone in the UK with gas or oil central heating installed a high-efficiency condensing boiler, the country will save enough energy to heat 1.9 million homes for an entire year as well as save about 6.7 million tons of CO₂.

Combination Boilers are widely used in the UK which provide hot water and heat without the need for a water tank making it space-saving. Combi boilers can also deliver unlimited heat and hot water when needed. Water pressure may be reduced if more than one tap is being used at a time.

System Boilers come with a water cylinder but also without a water tank. In this type of boiler, hot water is not instant and there is a need to wait for the water to be heated.

Conventional Boilers are also known as regular boilers which come with a water cylinder and a water tank. Like the system boiler, there is a need for the water to be heated before use. A space for the water tank should also be considered.

2.7.7 UPGRADING EXTERNAL WINDOWS

Another method to reduce heat loss is to secure openings such as external windows and doors. An average home for example loses 40% of its heat through windows and doors. For commercial properties, this rate can be higher if external openings are not insulated.

A widely used method to prevent heat escaping is by double glazing windows. Windows that are double glazed have two sheets of glass with a gap between them usually about 16mm wide. The gap is responsible for creating an insulating barrier to slow down the escape of heat. The less heat that escapes, the less energy is required for heating.

2.7.8 CAVITY WALL INSULATION

Cavity walls that are not insulated can potentially lose 35% of the heat generated within the property. This can be avoided by choosing to insulate the cavity. There are different types of cavity wall insulation available.

Polyurethane Foam is an insulation material that is best in terms of performance. However, it is not as environmentally friendly and it is also the most expensive type.

High Efficiency Glass Wool or High Efficiency EPS Beads can be a great option if price is a consideration. They are of good quality but slightly less favorable than polyurethane foam in terms of performance. Glass wool is also the most environmentally-friendly when it comes to cavity wall insulation.

2.7.9 COMMERCIAL AND INDUSTRIAL ROOFING INSULATION

An average commercial building with a flat roof that is not properly insulated can potentially lose about 25% of its heat through the roof. If a property is having this same issue, applying roofing insulation is a great idea to avoid losing large amounts of heat.

Insulated Composite Panel Roofing System is comprised of a single-component installation roof panel. This is manufactured in varying range of thickness to specifically suit the building requirements.

Fiberglass Insulation is a common and widely available type of insulation in most homes and businesses. This is a popular choice because it is inexpensive and easy to install.

2.8 COMPARISON OF ENERGY SIMULATION SOFTWARES

NO	OPTIONS	REVIT	EQUEST	ECOTECH	IES
1	IMPORT FROM CAD	YES	YES	YES	YES
2	ZONING AND SYSTEM SUPPORTS	NO	YES	YES	NO
3	SHADING DEVICES	YES	YES	YES	YES
4	GH GAS EMISSION CALCULATIONS	YES	NO	YES	NO
5	SOLAR RADIATION PERFORMANCE	YES	YES	NO	YES
6	WIND DIRECTION WITH CLIMATIC ANALYSIS	YES	YES	YES	YES
7	WALL AND ROOFING INSULATIONS	YES	YES	YES	YES
8	HOURLY LOAD CALCULATIONS	NO	YES	NO	NO
9	USER CONFIGURED HVAC SYSTEMS	YES	NO	NO	NO

10	THERMAL COMFORT CALCULATIONS	YES	YES	YES	YES
11	PAY BACK CALCULATIONS	YES	NO	YES	YES
12	NATURAL VENTILATION	YES	YES	YES	YES
13	OPERABLE WINDOWS	YES	YES	YES	YES
14	WEATHER DATA AVAILABILITY	YES	YES	NO	NO

Table 2.5 Energy simulation and its comparative analysis.

3. JOURNAL STUDY

Topic and author	About	Methodology and tools	conclusion	inference
1.Net Zero Building Enclosure Retrofits for Houses: An Analysis of Retrofit Strategies	To identify and evaluate building enclosure retrofit strategies to use in near net zero retrofits for houses across all Canadian climate zones (ASHRAE/DOE Zones 4 through 8).	literature review Energy modeling program HOT2000 Version 10.51 (NRCan 2008). Building enclosure EEM packages	Study indicate that near net zero retrofits are technically feasible but cannot be justified in the short term on the basis of a simple payback analysis alone.	Short-term financial benefits should not be overstated. Low energy prices mean that it will take longer for energy savings to offset retrofit costs than in places with higher energy costs.

2.Feasibility Study for a Net-Zero Energy Campus Retrofit	It discusses a path to net-zero energy for the Akron Zoo campus that may be a model for other commercial facilities. This path includes aggressive energy-efficiency combined with on-site renewable energy installations.	The energy use breakdown Natural Gas Use Breakdown Energy simulations and calculations. eQuest2.	Identified over 40 energy-efficiency recommendations that result in a 30% decrease in campus-wide energy consumption for an average simple payback of about 7 years.	Original intent of the project was to use only PV as a renewable energy source, but their analysis shows that the campus cannot achieve net-zero site energy without the use of wind power.
3.Retrofitting an office building towards a net zero energy building	paper focuses, initially, on the reduction of energy consumption of an office building in the campus of the Technical University of Crete as well as on the cover of minimized energy demands with renewable energy sources	simulation-based approach TRNSYS software Four scenarios were examined aiming at minimizing the energy consumption of the building	Increasing the insulation on the walls and ceiling, replacement of windows and applying cool paint on external walls. . Replacement of lights and power supply of personal computers. .	It can be inferred that the PV panels produce more energy (24,000 kWh/year) than the wind turbines (20,000 kWh/year), contributing to greater extent in achieving NZEB.
4.Achieving Net Zero-Energy Buildings through Retrofitting Existing Residential	the analysis of the current situation of both the existing buildings and the	Study utilizes simulation to validate the proposed	The detailed steps of converting an already existing residential	The cost analysis implemented in the study reveals the exact costs of both

Buildings Using PV Panels	energy sector in Egypt, analyzing the energy consumption patterns and the inefficiencies leading to these patterns, then defining the nZEB concept to familiarize the reader with its different aspects	guideline by applying it on an already existing residential building. Using Design Builder software the electricity consumption of the existing building with its current situation is done	building to an nZEB is the final outcome of the research.	the retrofit actions – using materials existing in the market- and the PV panels’ installation and it was found to be affordable.
5.Retrofit of a UK residential property to achieve nearly zero energy building standard	the retrofitting of a UK residential dwelling using Thermal Analysis Simulation (TAS, EDSL) software by focusing on building fabric improvements and usage of on-site renewables	Thermal Analysis Simulation (TAS, EDSL) CIBSE Test Reference Year (TRY) weather data	The simulation results showed a reduction in the building’s annual energy consumption of 122.64kWh/m2 (90.24%). The greatest savings after this were achieved for the annual reduction.	The results of this paper should increase encouragement for retrofitting existing buildings into NZEBs, particularly, due to their positive environmental contributions
6.Potential for retrofitting a federal	This paper aims to assess the potential of	Virtual Reality (IES-VE)	The implementation of	Both passive and active measures

building in the UAE to net zero electricity building (nZEB)	retrofitting an existing federal office building to a net zero electricity building through a holistic retrofit approach.	building energy simulation software	active measures proven to be effective. The passive strategies reduced electricity demand by 14.7%, active measures reduced electricity demand by 63.2%.	play an important role in reducing electricity consumption
7.Design of Net Zero Energy Building (NZEB) for Existing Building in Jakarta	Design technical and financial viability of Net Zero Energy Building (NZEB) from a study case of existing building in Jakarta, first by reduce Building's energy consumption and employing renewable energy sources.	Methodology to calculate implementing BIPV is using Helioscope software	energy savings from implementing green building concept could reduce electricity usage by 18%and Return on Investment (ROI) 3.86 years	Although this research can reduce energy consumption by up to 47% but for existing building the NZEB is still difficult to achieve if only doing retrofitting and employing RES, it is recommended to improving the building's passive design
8.Regenerative Design of Existing Buildings for Net-Zero Energy Use	Explores feasibility of achieving net-zero energy goals in retrofitting commercial buildings. An existing commercial building in Holyoke	Using simulation software eQuest to build and analyze energy model of this commercial complex	The renewable energy systems that incorporate solar energy, wind energy, biomass, and hydro energy made it possible to achieve net-zero energy goals, thus meeting the	Multiple design considerations were investigated, such as material selection, improvements to building envelope, retrofitting of HVAC and lighting systems, occupancy

			energy demand of the building with renewable energy sources on site.	loads, as well as application of renewable energy sources.
9. Retrofit guidelines towards the achievement of net zero energy buildings for office buildings in Brasilia	aim of this article is to propose retrofit guidelines that meet a net zero energy target for four-story office buildings in the climactic conditions within Brasilia	Characterizing the four-story building type to develop the simulation model.	Through this research 240 office buildings in the downtown area of the Brazilian capital were morphologically characterized, which served as the basis for the definition of a representative model of the four-story office buildings. The model variations – 69 in total	This paper focuses on creating theoretical guidelines to achieve the net zero energy balance for the up-to-four-story buildings in the climatic context of Brasilia.
10. Retrofit strategies towards Net Zero Energy Educational Buildings: A case study at the University of the Basque Country	This article proposes a method to define and assess strategies to achieve NZEB in university buildings based on student comfort analysis under real conditions.	A questionnaire and monitoring campaign	Students prefer lower indoor temperatures (20–22.5 °C) than stated by theoretical comfort models.	The heating period in the retrofitted scenario is two months shorter. The potential energy saving of the

			Overheating problems might be solved by using day and night time natural ventilation.	retrofitting is up to 62%.
11. Regenerative design and adaptive reuse of existing commercial buildings for net-zero energy use	This article discusses feasibility of achieving net-zero energy goals in retrofitting commercial buildings. An existing commercial building located in Holyoke, Massachusetts was chosen as the research target.	The comparative analysis of simulation results was used to determine how specific techniques lead to energy savings.	Based on extensive energy modelling and simulations, multiple design considerations were investigated, such as material selection, improvements to building envelope	Research results show that this commercial building is able to meet net-zero energy use after appropriate design manipulations and use of multiple renewable energy sources.

Table 3.0 Comparative analysis of various journal and its inference.

4. NET STUDY

4.1 ALLIANCE CENTER

Owner	Location	Building Type	Project Description	Size SF	Stories	Project Completion	Year Built
Alliance for Sustainable Colorado	Denver, CO	Office	Major Renovation	38,000	6	2006	1908

Table 4.1 Project description of alliance center.

The Alliance for Sustainable Colorado is a nonprofit organization started in 2004 to “advance sustainability through collaboration among nonprofits, business, government and education.” To advance this mission, the Alliance purchased a 100-year-old warehouse, previously renovated in the 1970s, in Denver’s historic Lower Downtown; a major renovation to the building in 2006 created the Alliance Center.

The building provides tenant space for 35 sustainably- focused nonprofits, fostering communication and collaboration and serving as a demonstration project of advanced design strategies in a rehabilitated historic building.

The Alliance for Sustainable Colorado recently launched a project titled “Modeling a NetZero Future: Energy Efficiency in Existing Buildings” to explore options that will enable it to approach a zero-net energy goal. Several documents developed for the project were referenced in this report.

RECOGNITIONS:

LEED-EB Gold and LEED-CI Silver

Energy Star Leader

USGBC National Award for Education by an Organization

Colorado Energy Champion Award

Mayor’s Design Award:

It Isn’t Easy Being Green the Alliance Center performs very well in terms of actual energy use when compared with other buildings. The actual energy use of the building is currently 42 kBtu/sf/yr., which is 55% better than the average for U.S. office buildings.

4.1.1 ENERGY PERFORMANCE:

% Better than Baseline	Baseline	Measured Energy Use (KBtu/SF/yr)	Energy Star Score
55%	Average for U.S. Offices*	42	85

**CBECS – U.S. DOE Energy Information Agency’s Commercial Building Energy Use Index 2003*

Table 4.2 Energy performance of commercial building.

4.1.2 PROJECT GOAL:

Before the Alliance purchased it in 2004, the building was known as the Otero Building and served as the shipping and receiving warehouse for a local bookstore. As was the case with other buildings in this historic neighborhood, this building was purchased by the Alliance with the intention of converting it to a new use. Striving to meet its mission of achieving sustainability through collaboration, the Alliance converted this former warehouse to a multi-tenant nonprofit center that would provide multiple organizations a “healthy, efficient, quality, mission-enhancing workspace.”

4.1.3 BARRIERS AND RESOLUTIONS TO ENERGY EFFICIENCY MEASURES:

While the Alliance Center is a high-mass brick building, its construction is not very tight and it experiences considerable infiltration and heat loss. Because preserving the historic integrity of the building was a priority, only the more contemporary lobby windows received any kind of design treatment; the focus was shifted to improving the mechanical and electrical systems within the building.

4.1.4 HVAC:

The commissioning on the existing HVAC system determined a need to increase the ventilation level and identified an opportunity to install economizers. Pneumatic temperature controls were replaced with direct digital controls (DDC) which allow the building operators to set heating and cooling levels via computer. This system has the capability for both interior temperature monitoring and “load shedding”, saving the Alliance money on peak demand rates.

4.1.5 ENVELOPE:

A Mylar film was applied on the interior of the east and west lobby curtain wall system. This curtain wall was part of a more contemporary addition executed in the 1970s to provide greater accessibility to the upper floors. Because these windows face east and west, the design team was able to effectively reduce glare and reflect 60% of the heat on sunny days. In the winter, the film reduces heat loss by reflecting internal heat back into the space.

4.1.6 LIGHTING:

Nearly 1,000 40-watt T-12 lamps with magnetic ballasts were replaced with 32-watt T-8 lamps with high-efficiency electronic ballasts. This measure alone reduced the lighting energy consumption by approximately 40% and paid for itself in approximately 2.5 years.

4.1.7 DAYLIGHTING:

Super-efficient ballasts installed on the fifth-floor east wing include photocell sensors that dim the lights when sufficient daylight is present. Many office suites include translucent wall panels which allow the interior office spaces to receive natural daylight. The sixth-floor windows feature window shade screens which help to control light and glare levels and reduce heating gains and losses.

4.1.8 CONTROLS:

The lighting control system includes wall- and ceiling-mounted occupancy sensors in the private offices and meeting rooms. The time schedules for the air handling unit are set by a building automation system (BAS) which interfaces through the DDC system.

4.1.9 RETRO-COMMISSIONING:

The mechanical engineering firm that upgraded the HVAC system to digital controls also conducted the retro-commissioning process. The firm quickly learned that the mechanical plans provided to its staff were not accurate. Much of the work involved on-site investigation and documentation, which resulted in the replacement of a rooftop unit, the addition of economizers and increased ventilation levels.

4.1.10 RENEWABLES:

The 2.04 kW rooftop photovoltaic array was installed in 2009 through a grant from a local solar company.

4.1.11 MONITORING SYSTEMS:

The Alliance Center is installing sub-meters in the building to provide detailed information on energy use. A recently completed retro-commissioning report includes a disaggregation of the utility bills, offering some insight into how energy is consumed. Area lighting uses 27%, followed by space.

Heating at 25% and space cooling at 21 percent. The Alliance Center gets about 1,000 visitors a year given its role as a resource for implementing energy-efficient measures in businesses and homes.



Fig 4.1 Monitoring system in alliance center.

4.1.12 EFFICIENCY MEASURES

Direct Digital HVAC Control system

Occupancy sensors

Photocells for daylight harvesting (fifth floor only)

High-Efficiency glazing

Commissioning

T8 fixtures with dimmable ballasts

Commissioning

Photovoltaics

Translucent Wall Panels

Increased insulation

Sun Shades (sixth floor only)

Un-refrigerated water fountains

4.1.13 ENERGY PERFORMANCE

The Alliance Center is an all-electric building and uses utility bills to track its energy usage. Since the Center opened in 2004, its occupancy has nearly doubled while it has continued to reduce its energy use through targeted conservation measures such as keeping plug loads low through the sharing of resources like printers and copiers. Through energy savings initiatives the Alliance Center has reduced its energy consumption by 22% since 2004. It now uses 55% less energy compared to the average for offices in the U.S.¹ at 42 kBtu/sf/yr (EUI²). The U.S. average for all offices is a good basis for quickly comparing buildings of the same type. A more specific comparison can be made through the Energy Star Portfolio Manager program, which determines the energy use of comparable buildings of like type, size, hours of use and climate. In this example, the Energy Star program calculation showed that comparable buildings would use less energy than the average for U.S. office buildings. The Alliance outperforms this reference set as well, using 39% less energy than the Energy Star estimate. The building's Energy Star rating of 85 (out of 100) places it in the top 15% of office buildings nationally.

4.1.14 TOTAL PROJECT COST:

\$117,000 \$3.07/sf (after incentives) Funding and Incentives: The Alliance Center participated in the local utilities Demand Side Management program for the bulb and lighting ballast upgrades.

The daylight harvesting ballasts on the fifth floor were installed independently of this program. The photovoltaic installation was funded through an \$11,200 grant from a local solar company. The Alliance Center received a \$25,000 grant in 2006 from the Colorado Governor's Office of Energy Management and Conservation for installing informational and educational signs throughout the building, and for developing a self-guided tour and brochure.

In 2010, the Alliance Center was awarded a \$15,000 grant from the State Historic Fund in Colorado to provide a historic structure assessment and preservation plan, including detailed

guidance on historic renovations, upgrades, and general upkeep. The Alliance determined that the upgraded lighting system alone would reduce that portion of its energy costs by over 40%, and that the retrofit would pay for itself in 2½ years.

4.1.15 ESTIMATED ANNUAL COST SAVINGS:

The Alliance Center estimates the building energy upgrades provide annual cost savings of \$8,800.

4.1.16 USER SATISFACTION:

A report completed by students at the University of Colorado Denver titled “Measuring Sustainability: Quantifying Greenhouse Gas Emissions and Assessing the Value of Shared Services and Collaboration at the Alliance Center” contained a number of occupant surveys. When asked to describe the direct benefits of being associated with the Alliance Center, responses included: “Added organization legitimacy and credibility, recognition to organization name, a sense of unification and prestige, added recognition for dedication to the environment, built-in fundraising and networking opportunities, an enhanced organization profile as a sustainability leader.”

4.1.17 INNOVATION:

In an interview, Alliance Center director Phillip Saige cited the DDC installation in the Alliance Center as especially innovative. This system has allowed the building operators to continue to fine-tune the heating and cooling requirements in this historic structure.

4.2 THE BYRON G. ROGERS FEDERAL OFFICE BUILDING, DENVER.



*Byron Rogers Hybrid
Heat Pump System*

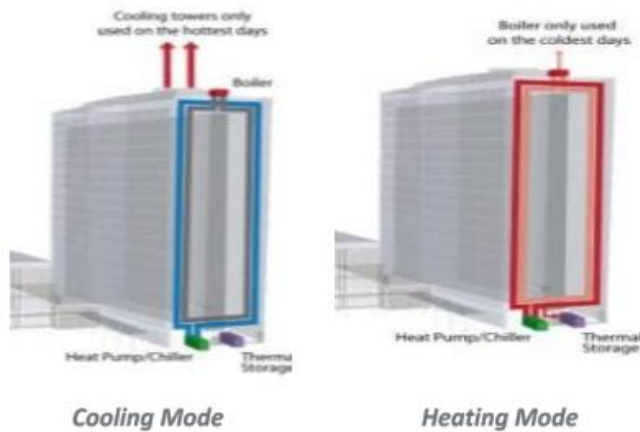


Fig 4.2 The byron g. rogers federal office building, denver.(top)

Fig 4.3 Building sectional view of cooling and heating mode.(below)

4.2.1 PROJECT OBJECTIVES

The Rogers modernization exemplifies the 2009 American Recovery and Reinvestment Act goals of creating jobs, spurring the economy, and constructing energy efficient Federal facilities that deliver lasting progress toward building a more sustainable national infrastructure while reducing the Federal government's consumption of energy and water, and increasing the use of clean and renewable sources of energy.

1. Daylighting.

2. Economic catalyst:

The project employed about 8,300 workers and \$59 million of the project's subcontracting work was performed by small business. This was a key project that put Americans back to work at a time our Country was experiencing an economic crisis.

Project energy goals

The project had an aggressive energy goal of less than 39.1 kBtu/SF/y, which achieves annual energy savings of approximately 55%, LEED GOLD certification, 50% better than ASHRAE.

4.2.2 PROJECT DESCRIPTION

Funded by the American Recovery and Reinvestment Act, the \$159M Byron G. Rogers Federal Office Building & Courthouse modernization project will deliver significant returns on sustainability investments and add 100 years of life to an important aging building. The 18-story 494,156 sq. ft. office building, home to 11 Federal agency tenants, was built in the 1960s and required a deep retrofit to reduce energy use while preserving its historical significance. The facility is expected to attain a LEED® New Construction GOLD certification. The primary goal of the modernization was to upgrade all of the major building systems. This included replacement of mechanical, electrical, and plumbing systems.

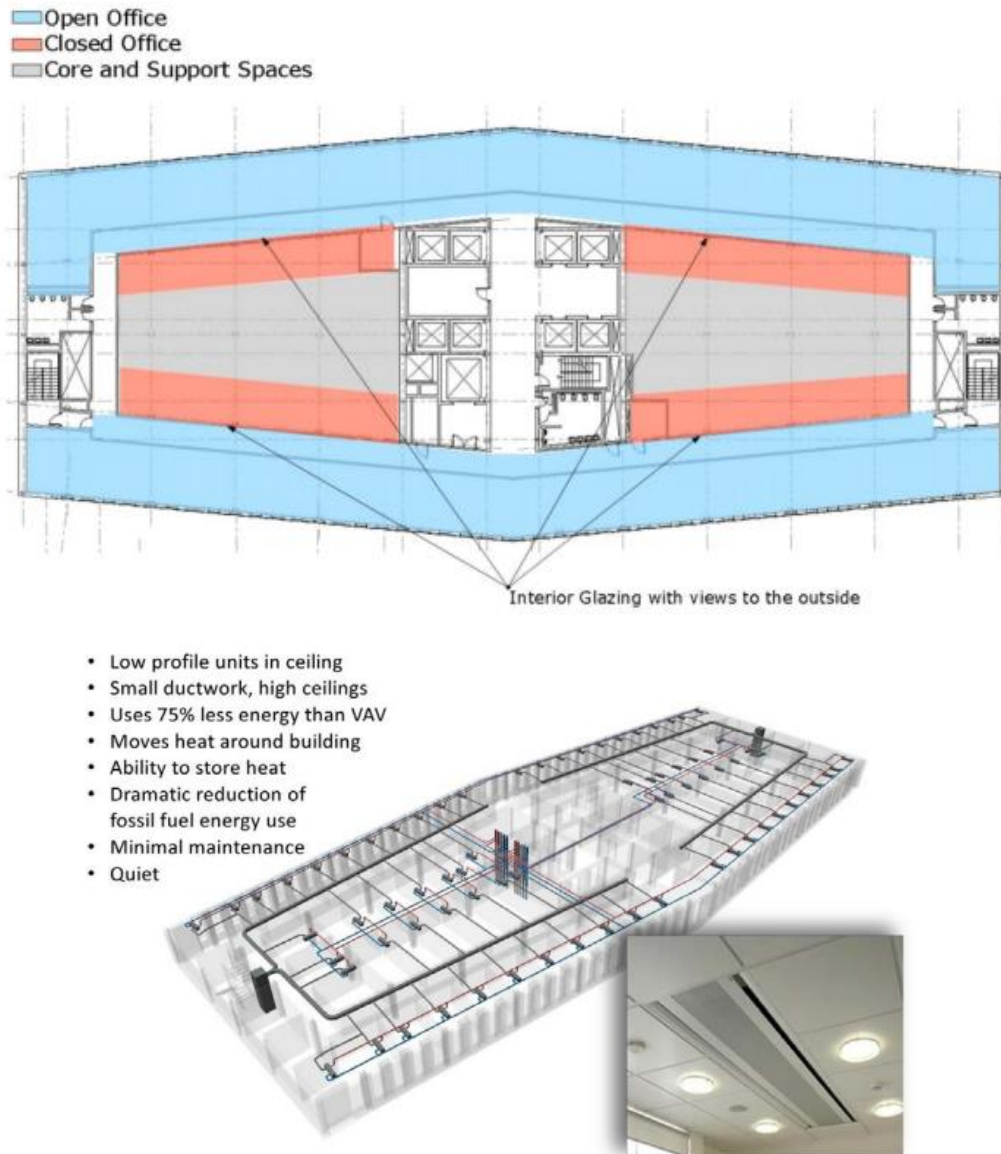


Fig .4.4 Axonometric view of federal office building.

The anticipated building energy use savings when compared to ASHRAE 90.1 2007 is expected to be 55%. • Building will achieve LEED Gold, Energy Star 95.

Awards or recognition

- LEED Gold.
- Energy Star 95.

SITE ENERGY COST INFORMATION (ELECTRICITY, \$/KWH; GAS, \$/M3, ETC.)

- Electricity and Gas: \$1,020,284.80 per year.
- Electric (blended): \$0.094/kWh.
- Gas: \$.0066/ft³.

PRE-RENOVATION BUILDING DETAILS

Poor quality envelope, window coverings blocked natural light.

R20 for the roof, envelope was evaluated at R5.

Standard conventional HVAC system

DESCRIPTION OF THE PROBLEM:

Reason for renovation (non-energy and energy related reasons. The Rogers modernization exemplifies the 2009 American Recovery and Reinvestment Act goals of creating jobs, spurring the economy, and constructing energy efficient Federal facilities that deliver lasting progress toward building a more sustainable national infrastructure while reducing the Federal government's consumption of energy and water, and increasing the use of clean and renewable sources of energy.

- Daylighting.
- Economic catalyst: The project employed about 8,300 workers and \$59 million of the project's subcontracting work was performed by small business. This was a key project that put Americans back to work at a time our Country was experiencing an economic crisis.
- A quote from GSA about the motivation for the project: "We are the largest commercial real estate agency in the nation, and we can leverage our buying power to call others to action. GSA is seizing opportunities to save taxpayer dollars by conserving energy, reducing water consumption, and implementing innovative technology in our buildings. GSA is a leader in sustainability.

From energy and water efficient buildings, to a fuel efficient fleet, to smarter electronics disposal and green acquisitions, GSA is working to ensure that the agency is going green and saving green."

4.2.3 RENOVATION SOW (NON-ENERGY AND ENERGY RELATED REASONS)

1. LOAD REDUCTION MEASURES	
Daylighting and controls	The project team was able to maximize daylighting by removing the existing induction units and raising acoustical ceiling heights that were installed during previous renovations. The ceilings and induction units had obstructed 30% of the windows. Where open floor plans were not possible because tenants valued private offices, the team considered translucent or transparent walls to private offices.
LED and task lighting	The building was fitted entirely with LED light fixtures. Even task lighting is LED
Insulation	The team super-insulated the exterior wall (without removal of the precast panels), which increased the overall R-value, including glass, from R5 to R20.
High-efficiency glazing on windows	All windows were fitted with high-efficiency glazing with a thermal break. Window glazing was chosen to maximize the amount of visible light and isolative properties, and to minimize solar heat gain.
Water savings	The project will achieve a water savings of 30% through the use of low-flow and infrared fixtures.
Efficient plug loads	The team engaged tenants early on and published a sustainability guide that includes information about reducing plug loads through efficient appliances and shutting off devices when not in use.
Efficient elevators	The team reduced vertical transportation energy by 15% using regenerative drive technology in the elevators.

Table 4.3 Load reduction measures and its parameter.

- Energy saving/process improvement concept and technologies used
- Super-insulated envelope achieves overall R-20 value.
- LED lighting retrofits in all fixtures in building.
- Solar thermal for water heating was installed.
- Coverings that blocked windows were removed, and open office spaces were constructed, to maximize daylighting. Acoustical ceiling heights were raised that previously had obstructed windows. Where tenants did not want open offices, translucent or transparent walls were considered. Window glazing was chosen to maximize the amount of visible light and solar heating.
- Energy consumption
- Pre-renovation energy use (total and per m2/year) 37,334 mmBTU and 75 kBTU/GSF. (It does not match with 24.14.4.)
- Predicted energy savings (site, source, GHG), total and per m2/year
 - 70%.
 - Site: 22,954 mmBTU, source: 44,643

Split in all energy forms – electricity, oil, district heating Electricity and gas = \$422,701.35 (63.49% cost savings).

4.2.4 RENOVATION COSTS: TOTAL AND PER M2

Item number	Description	Cost [\$] does not include mark-up, design, GCS and other soft costs
1	High Efficiency HVAC ACB and Thermal Storage - active chilled beams - dedicated outside air system - high efficiency chillers, cooling towers and pumps - thermal storage system	15,500,000

Item number	Description	Cost [\$] does not include mark-up, design, GCS and other soft costs
	- solar thermal system (30% of service hot water) - condensing boilers, pumps - BACnet/LonWorks controls system - Heat recovery on outside air (sensible wheel) - DCV in all spaces tied in to occupancy sensors	
2	High Efficiency Lighting System 1 – Direct Lithonia RT LED - 0.6 W/sf "white box" configuration (1x4 recessed LED luminaire, 8"x10" spacing) - 30 fc maintained illumination (assumed 80/50/20 reflections) - UGR = 19 (very uncomfortable) - daylight sensors and dimming controls - occupancy sensors in all spaces except back of house, which will have other automatic controls - lighting controls extend to each luminaire via individual addressable control	4,200,000

3	Regenerative Braking Elevator and Modernization	413,500
4	Office Tower Glazing Reglaze existing frames with 1 in.insulated glazing, interior dual pane blast window - 1/4 in. Crystal Gray w/ VE-2M #2 - Assembly U-0.14, SC-0.27, Tvis: 37%	4,650,000
5	Lav Low Flow Fixtures	250,000
6	Urinals Low Flow	47,000
7	Toilets 1.0 gpf pressure assist	150,000
8	High Efficiency Roof and Walls	815,000

Table 4.4 Energy conservation and its cost effective measure.

4.3 THE AVENTINE

Owner	Location	Building Type	Project Description	Size SF	Stories	Project Completion	Year Built
Glenborough, LLC	La Jolla, CA	Medium Office	Renovation	253,000	11	2010	1990



Fig 4.5 The Aventine office building

Built in 1990, the Aventine is a Class A office building designed by Michael Graves, one of the famous “New York Five” architects dedicated to modernism. The Aventine is located in La Jolla, California and consists of an eleven story office tower, an adjacent six-story office building, and a three-level underground parking garage. The Aventine is certified LEED

Existing Building Platinum and has an Energy Star rating of 100, the highest possible, and uses just 23 kBtus/sf, 75% less than the national average for offices. Retrofits addressed high-energy loads by replacing compressors and installing chillers, lighting and controls. The results are proof that substantial energy efficiency improvements can be made on a tight budget, especially if thermal envelope performance is already quite good. Building management and engineering staff show a continuing commitment to implementing cost-effective and new energy-saving technologies along with improving operational best practices.

% Better than Baseline	Baseline	Measured Energy Use (KBtu/SF/yr)	Energy Star Score
75%	Average for U.S. Offices*	23	100

**CBECS – U.S. DOE Energy Information Agency's Commercial Building Energy Use Index 2003*

Table 4.5 Energy performance of baseline building.

4.3.1 PROJECT GOALS:

Glenborough encountered a challenging leasing environment in the Aventine market, experiencing early lease terminations and low occupancy. The goal for the project was to improve the building with an emphasis on reducing operating expenses to be more competitive.

4.3.2 BARRIERS AND RESOLUTIONS:

The most challenging aspect of the retrofit was preventing disruption to occupants. The Aventine was 100-percent occupied throughout the retrofit. Glenborough coordinated the work during nights and weekends and engaged tenants in the process to convey the resultant benefits

4.3.3 HVAC:

A feasibility study revealed that upgrading to an all-variable-speed chiller plant with automated controls, while keeping the existing two centrifugal chillers, would result in the greatest energy savings Glenborough - The Aventine Building 3 NBI_ September 2011 with minimal capital investment. With a projected payback of less than three years, the decision was made to convert the facility's centrifugal chiller plant to a primary-only, all-variable-speed system and retrofit the two 300-ton chillers with oil-less variable frequency drive (VFD)

centrifugal compressors. The work was completed in early 2008. Carbon dioxide (CO₂) monitors were added to achieve optimal ventilation and to cycle down or off when occupancy was low to save energy.

4.3.4 LIGHTING:

A full lighting analysis and retrofit was conducted. High-pressure sodium lamps in the garage were replaced with CFLs, and stairwell occupancy sensors were added. Interior lamp wattage was reduced in existing fixtures. High wattage exterior lighting was replaced with low-wattage bulbs with higher lighting intensity to accent the building at night. Exterior wattage decreased more than 75 percent.

4.3.5 ENVELOPE:

The R-value of the building envelope – only 16 years old at the time – did not warrant any upgrades. The concrete walls have excellent thermal massing properties and glazing area allows almost 50 percent daylight views. A full air leakage test ensured the air barrier was intact. Glenborough installed an EPA cool roof as a part of the integrated approach to energy efficiency, lessening the load on the HVAC system.

4.3.6 CONTROLS:

Automated chiller controls were installed to reduce unnecessary loads, and lighting use is reduced through occupancy sensors and time controls.

4.3.7 MONITORING:

Glenborough analyzes several layers of data to dictate energy procurement strategies and make quick adjustments to building systems. The first layer of analysis is through Energy Star Portfolio Manager to compare against industry benchmarks.

4.3.8 PLANNED ENERGY EFFICIENCY UPGRADES (CURRENT 2011 INITIATIVES & BEYOND):

- Install (TRAV) technology
- Install Building Optimization Program estimated to reduce an additional 10% in Energy Costs.
- Implement Daylight cleaning to reduce night lighting use
- Convert Cooling Tower Water from Potable Water to Reclaimed Water

- Work with San Diego Gas & Electric to incorporate a Voluntary Demand Reduction Program.
- **EFFICIENCY MEASURES**
- Replaced chiller compressors
- Automated chiller controls
- EPA cool roof
- Lighting retrofit
- Automated lighting controls
- Daylighting: 50% daylighting views
- Whole Building Control / Mgmt.: Piloting integrated energy information systems program

4.3.9 ENERGY PERFORMANCE

The Aventine energy use intensity for 2007, pre-retrofit, was 62 kBtu/sf/yr (EUI1). After the renovation, energy use dropped by 63% to just 23 kBtu/sf/yr. The Aventine now uses 75% less energy per square foot than the average for offices in the U.S.² FINANCIAL The U.S. average for all offices is a good basis for quickly comparing buildings of the same type. A more specific comparison can be made through the Energy Star Portfolio Manager program, which determines the energy use of comparable buildings of like type, size, occupancy, hours of use and climate. In this example, the Energy Star program calculation showed that comparable buildings would use less energy than the average for U.S. office buildings. The Aventine outperforms this reference set, using 45% less energy than the Energy Star estimate. The Aventine's Energy Star rating of 100 is the best possible, and is a 15-point increase from the building's 2007 rating of 85.

Reasons for the building's competitive advantage include:

- Lower operating costs for tenants.
- Operations and maintenance program results in fewer equipment failures, and lower operating and replacement costs.
- Better indoor air quality from systems and controls using state of the art and/or next-generation technology. In the first year of operations post-retrofit, the Aventine:
- Saved over 2 million kWhs of electricity.

- Cut energy and operating expenses by more than \$116,000.
- Decreased carbon emissions by 600,000 lbs.
- Received a utility rebate of \$175,000.

5. NET STUDY COMPARITIVE ANALYSIS

NO	ASPECTS	ALLIANCE CENTER	THE BYRON G. ROGERS FEDERAL OFFICE BUILDING, DENVER, CO	THE AVENTINE
1.	Location	Denver, CO	Denver, CO	La Jolla, CA
2.	Building Type	Medium Office	. office building	large Office
3.	Owner Type	Owner Occupied Non-Profit + 50% tenants	Federal agency tenants	Private Investor Tenant Occupied
4.	Renewal Description	Historic Renovation	aggressive Renovation	Renovation
5.	Energy Star Score	100	90	85
6.	Climate zone(s)	(Warm-Marine), (3600 ≥ HDD65 °F)	(Warm-Marine), (3600 ≥ HDD65 °F)	(Mixed-Humid), (3600 < HDD65 °F ≤ 5400)
7.	Building Envelope	1.Mylar film 2.Occupancy sensors 3.High-Efficiency glazing 4.Translucent Wall Panels 5.Increased insulation	1. Wall insulation 2. Roof insulation 3. Floor insulation 4. New window/door	1. EPA cool roof

8.	Lighting and Electrical systems	1. T8 fixtures with dimmable ballasts 2. Super-efficient ballasts	1. Efficiency lighting/control	1. Lighting retrofit 2. Automated lighting controls 3. Daylighting: 50% daylighting views
9.	HVAC	1. Direct Digital HVAC Control system	1. New heat – cooling supplier/distribution system	1. Replaced chiller compressors 2. Automated chiller controls
10.	Renewable energy systems	1. Photocells for daylight harvesting (fifth floor only) 2. Photovoltaics 3. Un-refrigerated water fountains	1. Solar thermal system	1. Solar thermal system
11	Total% energy saving after DER	45%	51%	35%
12	Total% energy savings after solar production	75%	72%	55%

Table 5.1 Comparative analysis of various office building building and energy performance.

Approximately 100 square feet of space is required for the installation of the rooftop PV system.

The average cost of installation of rooftop PV system without subsidy is around Rs 60,000 - 70,000.

After leveraging 30% subsidy, people just have to pay Rs 42,000 - 49,000 for installing a rooftop PV system.

In order to avail generation-based incentive, the customer should generate 1100 kWh - 1500 kWh per year.

Under the scheme, a customer can earn up to Rs 2000 to 3000 per annum as generation-based incentive.

Average solar irradiation in TAMIL NADU state is 1266.52 W / sq.m
1kWp solar rooftop plant will generate on an average over the year 5.0 kWh of electricity per day (considering 5.5 sunshine hours)

1. Size of Power Plant	
Feasible Plant size as per your Roof Top Area :	2.6kW
2. Cost of the Plant :	
MNRE current Benchmark Cost :	Rs. 43000 Rs. / kW
Without subsidy (Based on current MNRE benchmark) :	Rs. 111800
With subsidy 40% (Based on current MNRE benchmark) :	Rs. 67080
3. Total Electricity Generation from Solar Plant :	
Annual :	3900kWh
Life-Time (25 years):	97500kWh
4) Financial Savings :	
a) Tariff @ Rs.8/ kWh (for top slab of traffic) - No increase assumed over 25 years :	
Monthly :	Rs. 2600
Annually :	Rs. 31200
Life-Time (25 years) :	Rs. 780000

Table 5.2 Energy and cost effective measures of solar plant.

WATER PUMPING WINDMILL

The present cost of the WPWM is about Rs.1 lakh.

The Central Govt. Subsidy of Rs.30, 000/-

User's Share is about Rs.70,000/-

Application for Subsidy can routed to MNRE through GEDA.

Approx. cost for installation of Wind Solar Hybrid System is Rs.2.50 lakh per kW.

The subsidy of Rs.1.50 lakh per kW is available for Govt./Public/Charitable/R&D, Academic and other non-profit making institutions.

The subsidy of Rs. 1.00 lakh per kW is available for all other category.

The cost of wind-solar hybrid system is less than only Solar Systems giving better reliability

1 kW Wind Aero generator would generate 4 units per day at 5 m/sec wind speed.

1 kW Wind Solar Hybrid System would generate 6 units per day at 4 m/sec.

Advantage of Hybrid System is assured generation due to solar energy availability for almost 300 days per annum

6.LIVE CASE STUDY

6.1 SITE STUDY



Fig 6.1 Aerial view and building view of Ramaniyam building

This building is known as Ramaniyam Lord's Building or Virtusa building. The function of the building is official usage. For 1000sqft 2 -Two Wheeler Parking, 1-Car Parking for 17,000 sq.ft has been allocated for Parking zone.

6.1.1 PROJECT DESCRIPTION

BUILDING NAME	RAMANIYAM LORDS
TPOLOGY	Office
LOCALITY	Guindy

YEAR BUILT	2006
STOREY	6
TYPICAL FLOOR AREA	17000sq.ft
TOTAL AREA	102000sq.ft
PARKING RATIO	1:1000

Table 6.1 Project description of the building

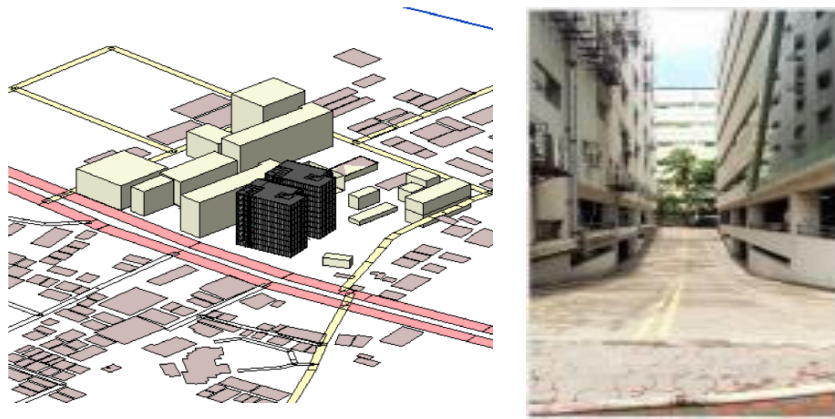


Fig 6.2 Building view in various aspects.

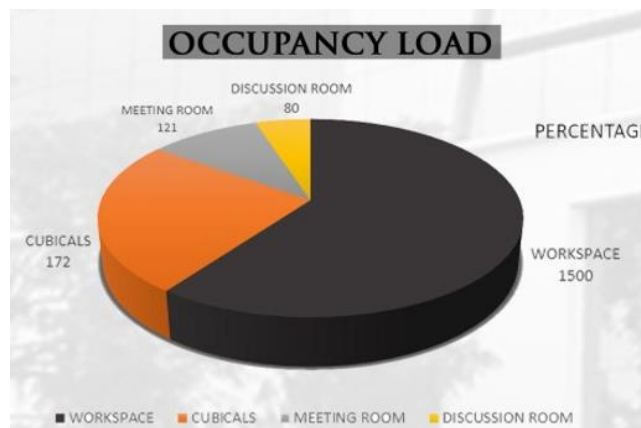


Fig 6.3 Occupancy load of the building.

6.1.2 SPATIAL PLANNING

There is slope running between the two blocks, which connects to the parking space and service rooms.



Fig 6.4 Spatial planning of the building.



The basement floor level has been designed in a way of arrangement of all the services technical rooms. Which involves Electricity DG Room TECHNICAL ROOM Water Supply FIRE Fighting System Room In the stilt level designed in a arrangements of both Car and two-Wheeler parking.

6.1.3 TOPOGRAPHY





Fig 6.5 Sectional topographic analysis of the site.

The slope is inclined from west to east and the rainwater catchment area are also placed on this particular location

6.1.4 HVAC SYSTEM

Type of Chiller Plant : Air Cooled System

Total number of plants : 6

Capacity of one plant: 100T

Total number of AHU units: 5

Each floor has a capacity of 90T



Fig 6.6 View of chiller plant and Air handling unit

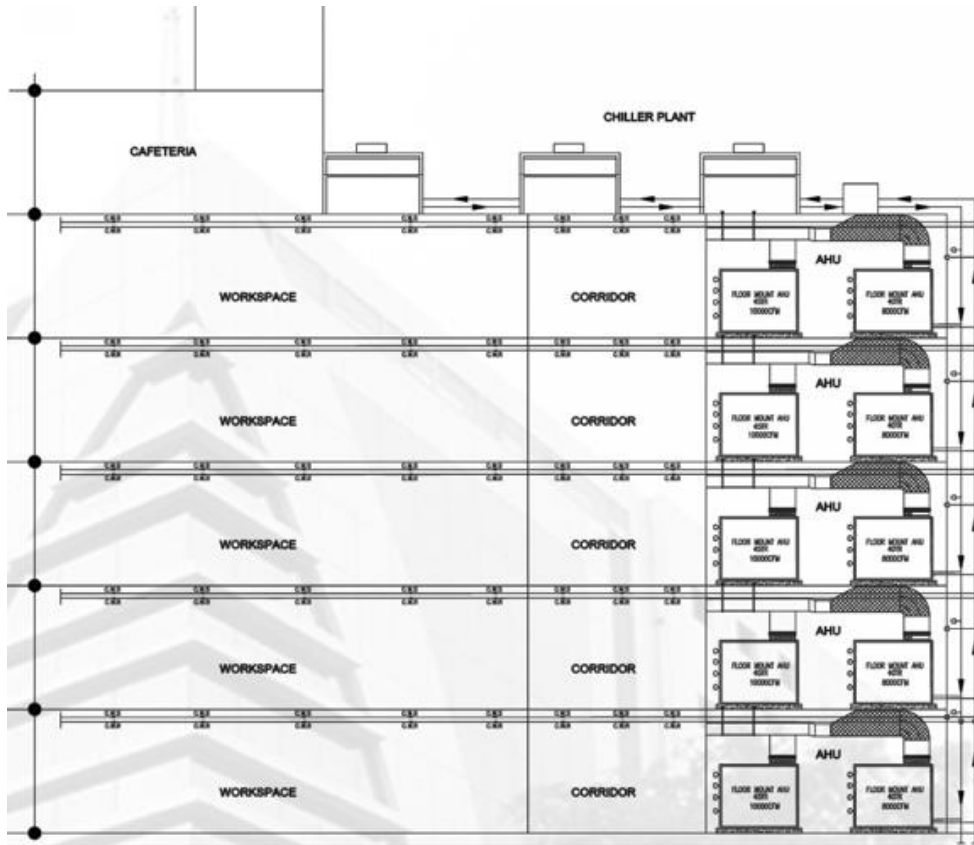


Fig 6.7 HVAC sectional layout in the building

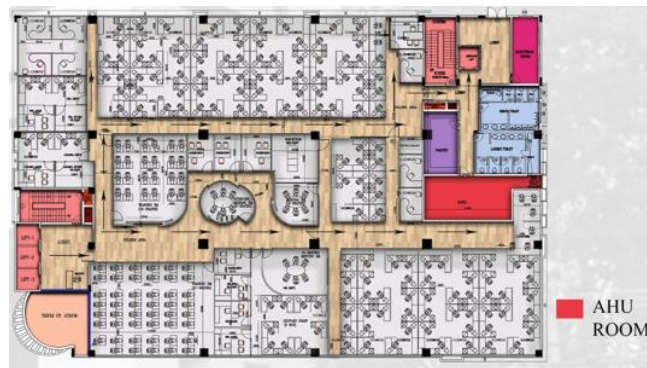


Fig 6.8 AHU spatial planning in the building.

6.1.5 SUMP

The water supply that is been provided is sufficient for the building. The amount of water that is been provided is more than the essential There are two pump rooms been provided and one operates when the other one fails

6.1.6 RAINWATER HARVESTING

The location of the storm water collection is located in such a way that all the rain water slopes into the tank the capacity of the tanks are not sufficient enough to collect all the water

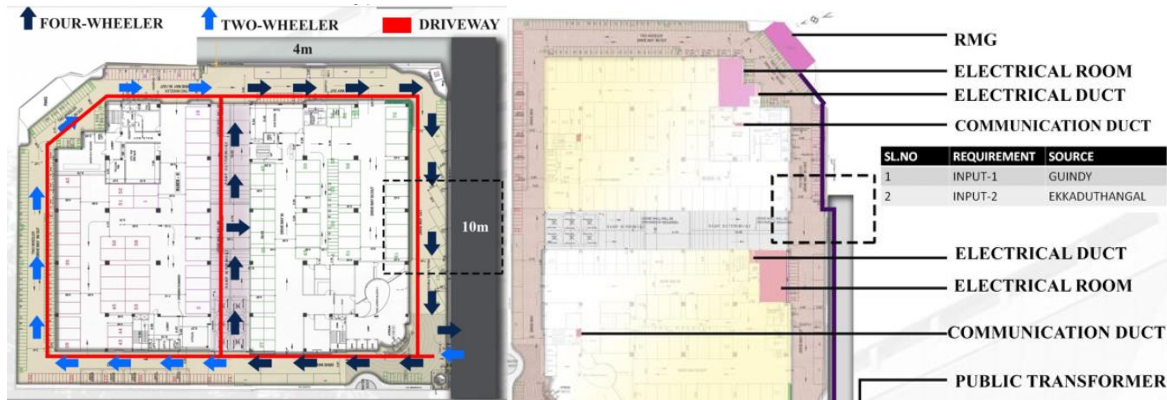


Fig 6.9 Road network and Electrical layout of the building.

6.2 SITE JUSTIFICATION:

1. Perfectly suitable for the climatic condition of warm humid
2. The selected office building is not accredited with the leed ratings so retrofitting them with respect to energy efficiency will help in fetching the leed ratings
3. Considering the amount of space which has been used the electric consumption is little high so providing energy efficient installations will help in reducing the energy usage

6.3 BUILDING MODELLING

6.3.1 SUN PATH – ANALYSIS AND INFERENCE

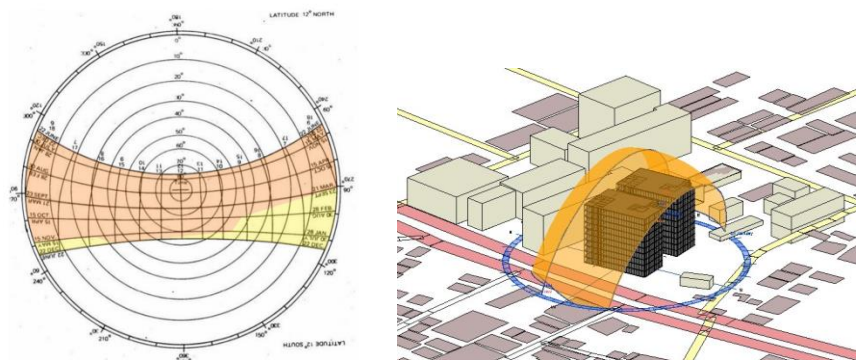


Fig 6.10 Solar analysis of the building in aerial view.

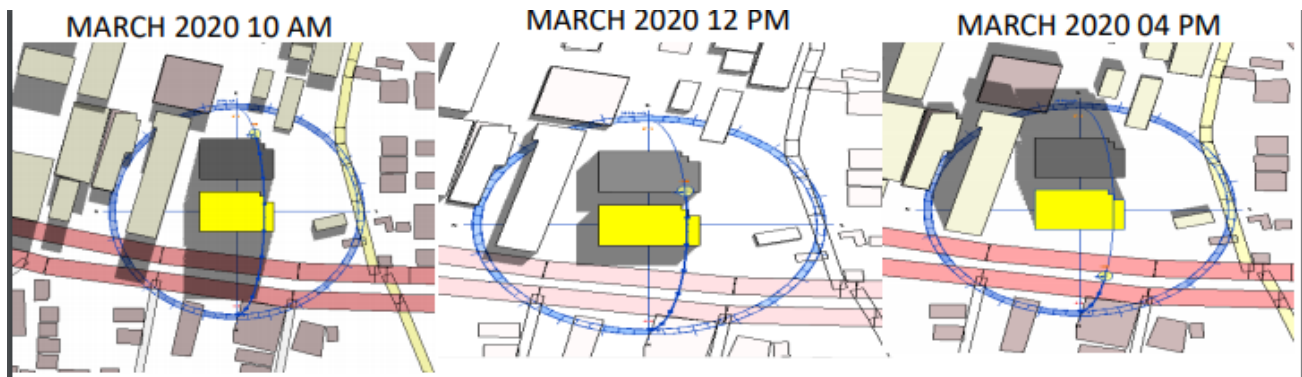
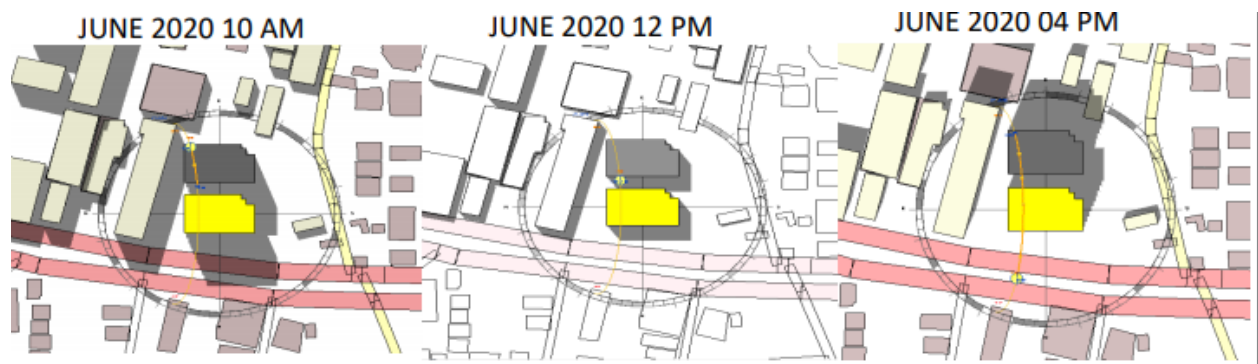


Fig 6.11 Solar analysis of the building in march at different time interval.

The building gets shaded by the block b during morning and evening and it reduces the solar exposure to the building wall surface



Same as spring equinox the building gets shaded by the block b during morning and evening and it reduces the solar exposure.

Fig 6.12 Solar analysis of the building in June at different time interval.

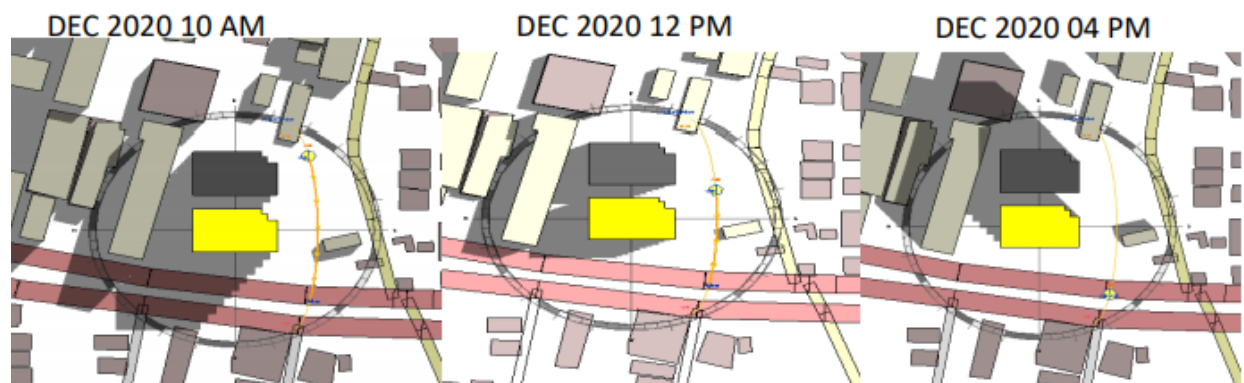


Fig 6.13 Solar analysis of the building in December at different time interval

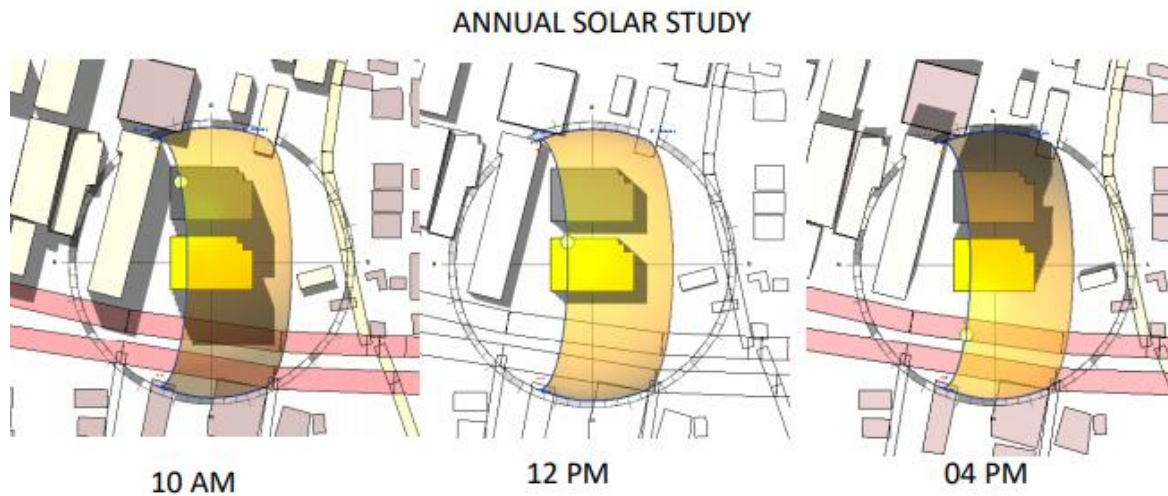


Fig 6.14 Solar analysis of the building in June at different time interval.

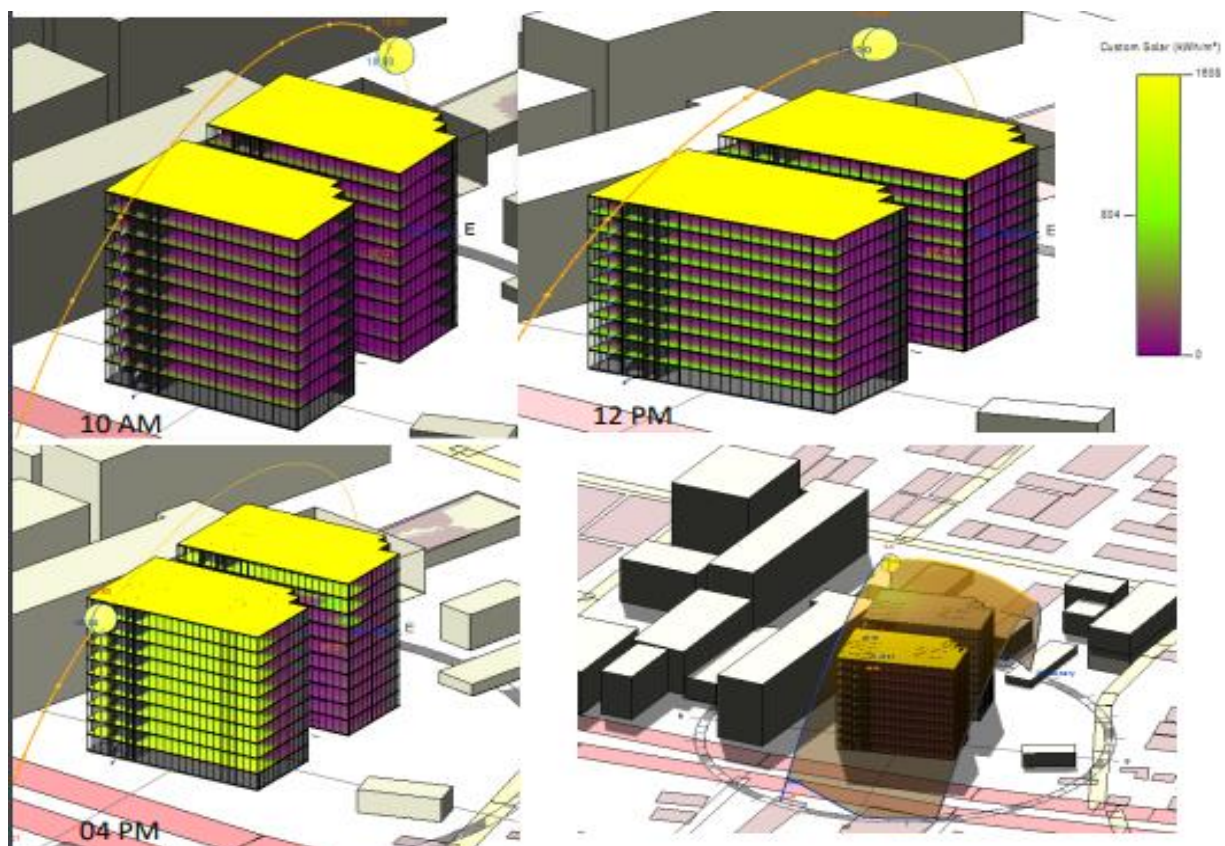


Fig 6.15 Solar analysis of the building at different time interval.

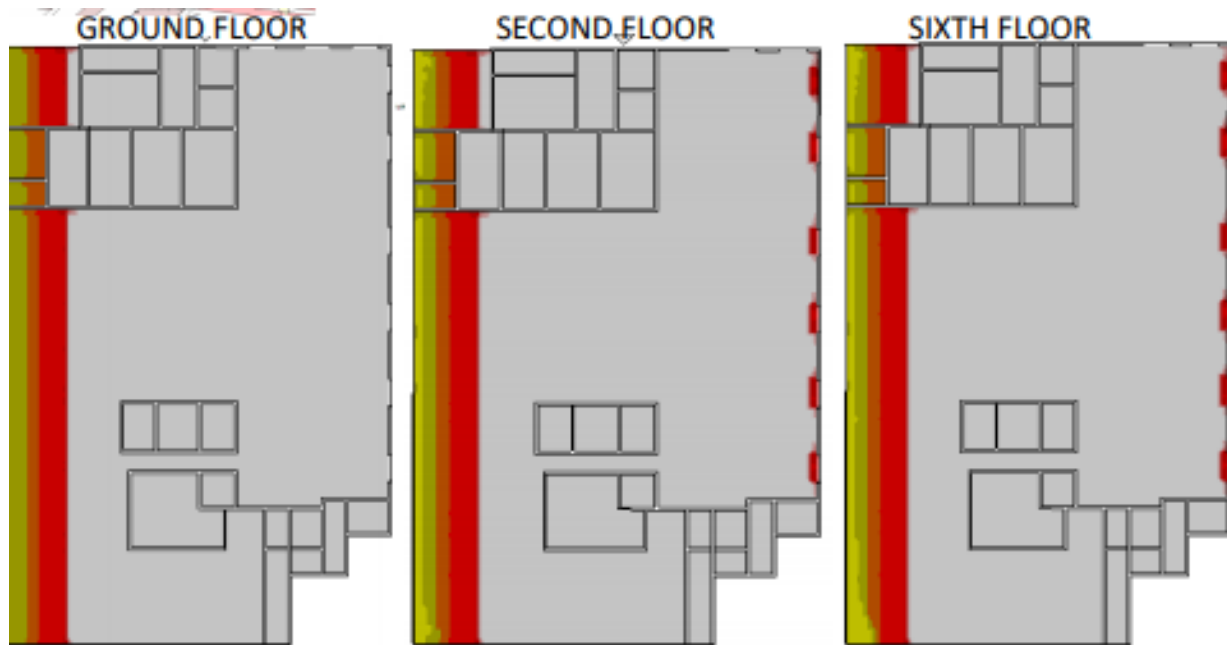
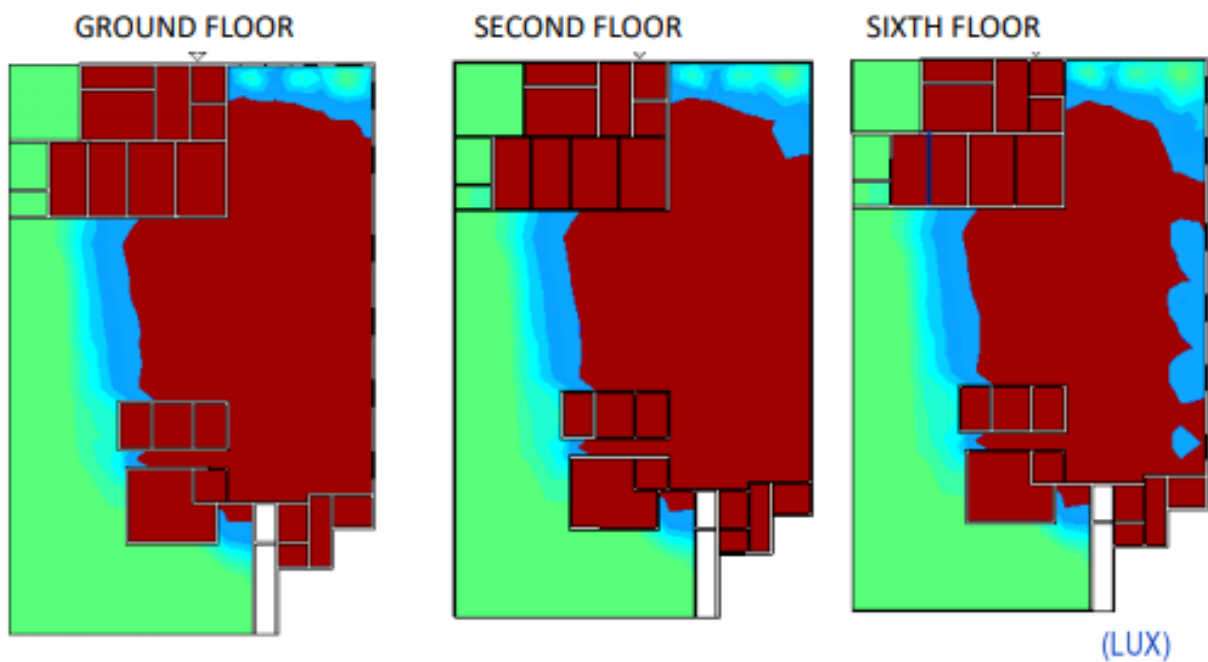


Fig 6.16 Annual Solar analysis of the building in different floor levels..

In the annual solar exposure the sixth floor receives more solar exposure when compared to ground and 4th floor.



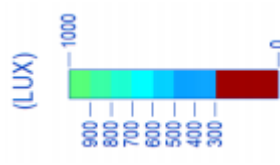


Fig 6.17 Daylight analysis of the building at various levels.

In the daylight analysis the sixth floor receives the maximum amount of daylight and in all the floors the east side of the building receives less daylight because the building is overshadowed by the block

6.4 CLIMATE– ANALYSIS AND INFERENCE

6.4.1 TEMPERATURE RANGE

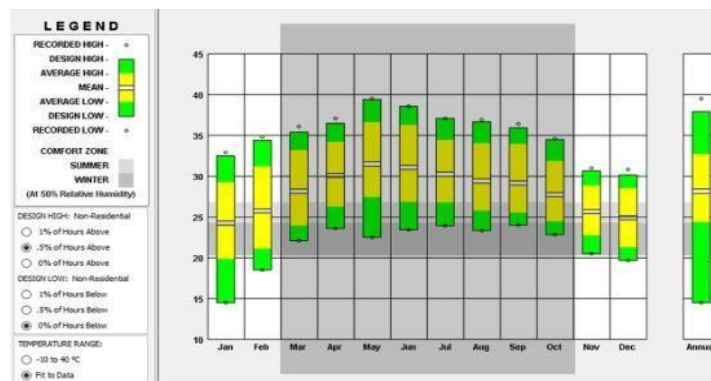


Fig 6.18 Temperature range in Chennai.

- Max average high - May - 36°C
- Min average high - December - 28°C
- Annual max average high - 33°C
- Annual mean temperature - 28°C
- Comfort zone - 20°C - 26°C
- Critical month March – October

6.4.2 WIND VELOCITY

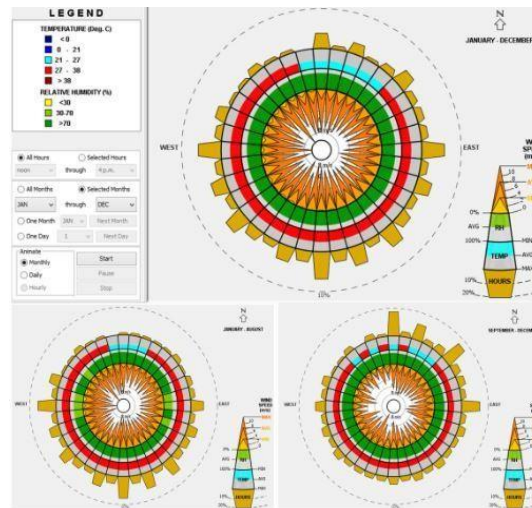


Fig 6.19 Wind velocity in Chennai.

- The average annual high velocity is about 3.5m/s
- The average wind speed is about 2m/s
- Except for North West, the other directions have a maximum travel hours.
- The temperature is almost maintained at about 24°C-38°C and humidity >70%.

6.4.3 RADIATION RANGE



Fig 6.20 Radiation range in Chennai.

- As Chennai comes under the Warm- Humid zone the radiation is found to be greater in all the month
- The annual mean radiation is 400Wh/sq.m per hour

- Maximum annual radiation is 800Wh/sq.m per hour
- Highest in May, 920 Wh/sq.m per hour
- Lowest in November, 620Wh/sq.m per hour
- The amount of radiation influences the temperature and the lux level

6.4.4 DRY BULB RELATIVE HUMIDITY



Fig 6.21 Dry bulb and relative humidity range in Chennai.

- The relative humidity is found to be inversely proportional to the dry bulb temperature
- Very low humidity level is found in May and June
- In the month of September, the temperature exceeds the comfort zone between 8:00am - 4:00pm
- About 88% of the mean annual temperature lies between 24°C -38°C
- Only 1% of temperature is >38 in the month of May & June between 10:00am - 4:30pm.

6.4.5 RAINFALL

Months	Min .temp	Max.temp	Avg.temp	Netural	Lower Limit	Upper Limit
Jan	23.7	26.7	25.2	42.906	41.406	44.406
Feb	23.8	26.8	25.3	42.984	41.484	44.484
Mar	23.9	26.9	25.4	43.062	41.562	44.562
Apr	24.1	27.1	25.6	43.218	41.718	44.718
May	24.3	27.3	25.8	43.374	41.874	44.874
Jun	24.3	27.3	25.8	43.374	41.874	44.874
Jul	24.2	27.2	25.7	43.296	41.796	44.796
Aug	24.1	27.1	25.6	43.218	41.718	44.718
Sep	24.1	27.1	25.6	43.218	41.718	44.718
Oct	24	27	25.5	43.14	41.64	44.64
Nov	23.9	26.9	25.4	43.062	41.562	44.562
Dec	23.8	26.8	25.3	42.984	41.484	44.484

Fig 6.22 Average rainfall range in Chennai.

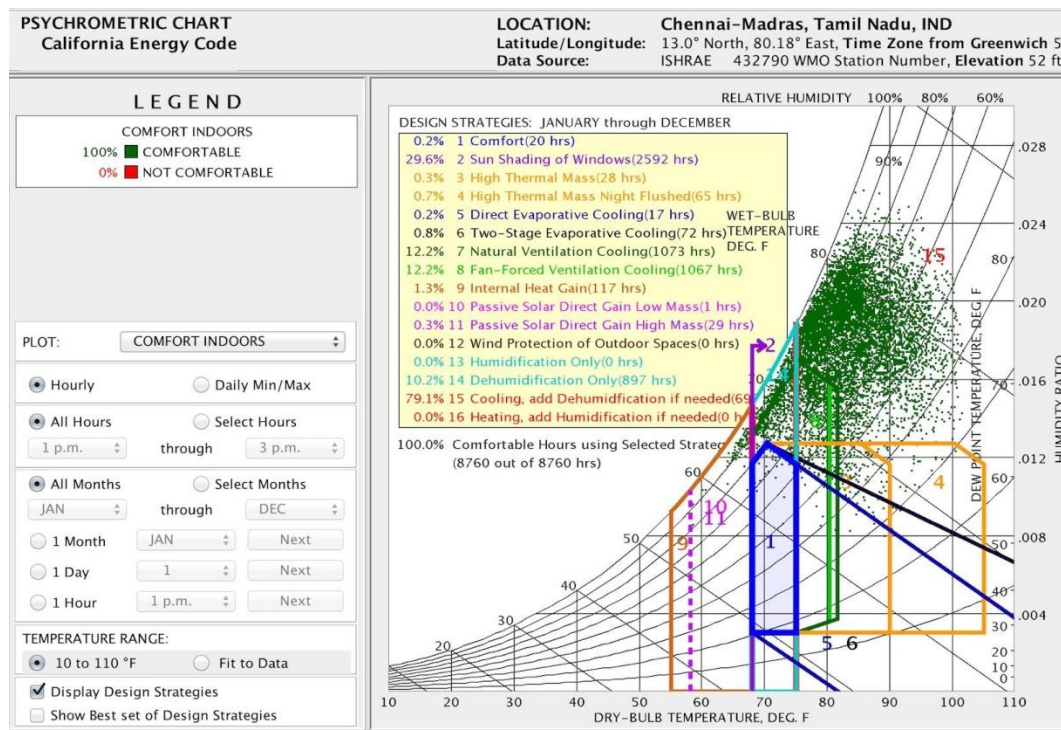


Fig 6.23 Psychrometric chart of Chennai.

- The average moderate rainfall received by the city of Chennai all through the year is about 1,300 mm.
- Wettest month (with highest rainfall) is November (407.4mm).

- Driest month (with lowest rainfall) is February (2.2mm).
- The amount of rainfall, sky cover and the radiation level are inter linked to each other contributing to the temperature and lux level
- In the month of September the average sky cover of September is 60% and rainfall is about 137.3mm

6.4.6 SKY COVER

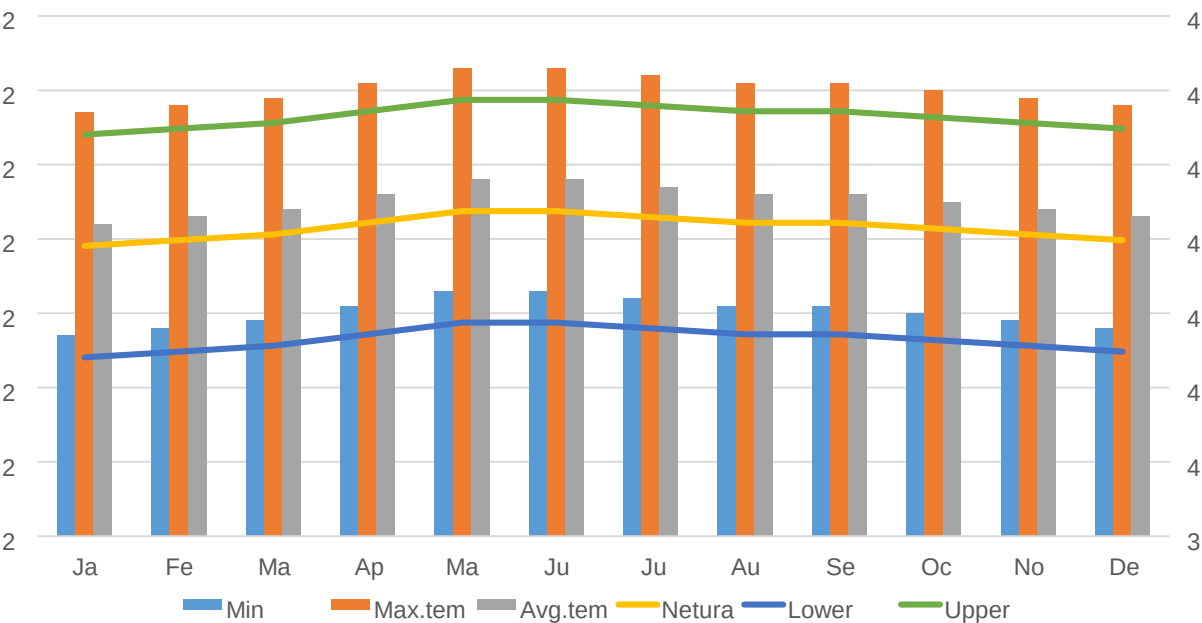


Fig 6.24 Sky cover range in Chennai.

- High in July and August - more than 90%
- Annual average high - 74%
- Annual mean - 49%

The comfortable temperature lies between 23.5-26.5 degree according to Nicol's graph

7 ENERGY ANALYSIS

7.1 ENERGY ANALYSIS OF BUILDING (revit modelling)

Project: OP 2 DAY LIGHT		Run List		Base Run: OP 2 DAY LIGHT, Energy Cost: \$161,795		Project settings	
General		Lighting	Roof	Northern Walls	Southern Walls	Western Walls	Eastern Walls
Rotation	0	Lighting Efficiency	Construction	Construction	Construction	Construction	Construction
HVAC	No Change	No change	No Change	No Change	No Change	No Change	No Change
Outside Air Flow Per Person Value	default	Lighting Control	Glazing Type	Glazing Type	Glazing Type	Glazing Type	Glazing Type
Infiltration	No Reduction	No change	No Change	No Change	No Change	No Change	No Change
InfiltrationValue	default	Equipment Power Density Value	Shade	Shade	Shade	Shade	Shade
Outside Air Flow Per Floor Area Value	0 CFM/sqft	Default	No change	No change	No change	No change	No change
Outside Air Change Per Hour Value	0 ACH	Light Power Density Value	Window to Wall Ratio	Window to Wall Ratio	Window to Wall Ratio	Window to Wall Ratio	Window to Wall Ratio
Outside Air Flow Per Person	No change	Default	No Change	No Change	No Change	No Change	No Change
Outside Air Flow Per Floor Area	No change	Equipment Efficiency					
Occupancy Schedule	Default	No change					
		Number of People					
		Default					
		Occupancy					
		No change					
		Daylighting Control					
		Off					
		Occupancy Sensor					
		Off					

1. Select Changes Below 2. Enter Alternative Name: 3. Add Alternative 4. Run Added Alternatives

Reset Dropdown Selections Below Save Added & Unrun Alternatives Cancel & Don't Save Added Alternatives

General		Lighting	Roof	Northern Walls	Southern Walls	Western Walls	Eastern Walls
Alternatives	Annual Energy Cost	Rotation	HVAC	Outside Air Flow Per Person Value	Infiltration		
	0	▼	No Change	default ▼	No Reduction		
Min Max Form Min Form							
	\$161,795						

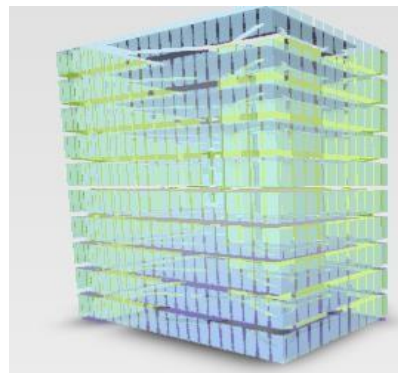
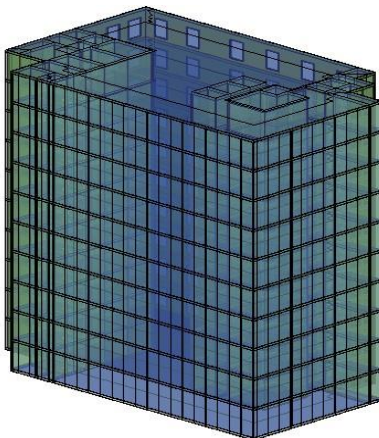


Fig 7.1 Energy analysis of the building

S no	Model input's	Parameters
1	Exterior Wall Construction	9 inch Brick Wall
2	Roof Construction	RCC Roof without Insulation 6" R.C.C slab + 3" XPS Insulation + 4" screed + 1" PCC
3	Window to Wall Ratio	40% ,35%, 30%
4	Glazing	Single Clear, Double glazed unit
5	Shading Devices	None 6 Inches Recessed Windows Deep Recessed Windows
6	Lighting Power Density	Base case 20% Reduction from Base case
7	HVAC System Type	Constant Air Volume Variable Air Volume
8	Fan Control in A.H.U.'s	Constant Speed ,Variable Air speed
9	Demand Control Ventilation	Yes
10	Ventilation	None, CO2 sensors in parking

Table 7.1 Energy model input and its parameters

7.2 BASECASE MODEL PARAMETERS

DETAILS	KWHr
Total consumption	516720
3 rd party	255764
Wind adjustment	19354
Net consumption	241602

Annual Energy of Base case building

Energy Use Intensity (EUI)	1328.3 MJ / m ² / year
Electric	3,068,951 kWh
Fuel	10,900,370 MJ
Annual Peak Demand	577.5 kW

Table 7.2 Basecase energy analysis of the building

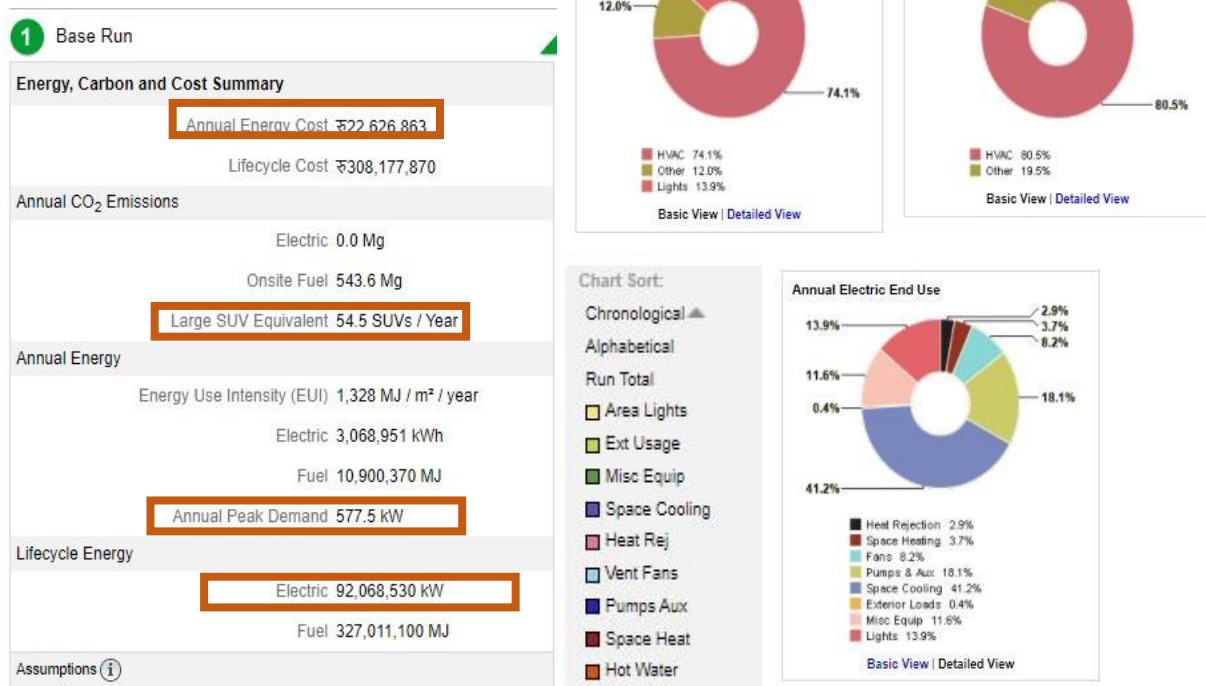


Fig 7.2 Electric cost for the building 28, 99,224 per annum

7.3 MODEL INPUT PARAMETERS

7.3.1 Exterior Wall Construction

Exterior walls are water-tight vertical surfaces, exposed to a greater extent to the atmosphere than any other components of a building. Hence they absorb radiation directly and have a major impact on the indoor temperature.

BASECASE	SCENARIO 1	SCENARIO 2	SCENARIO 3	SCENARIO 4	SCENARIO 5
230mm Brick Wall U-value: 0.32 Btu/hr.ft2 0F	250mm Cavity Brick Wall U value: 0.24 Btu/hr.ft2 0F	250mm Cavity Brick Wall U- value: 0.24 Btu/hr.ft2 0F)	10mm thk. Concrete board + 25mm XPS insulation + 460mm airgap + 4mm ACP Cladding U- Value = 0.14 Btu./hr.ft2 0F	10mm thk. Concrete board + 25mm XPS insulation + 460mm airgap + 4mm ACP Cladding U- Value = 0.14 Btu./hr.ft2 0F	Steel Frame U value- 0.124 Btu/hr.ft2 0F

Table 7.3 Wall component with different insulation material

U-value, is the rate of transfer of heat through a structure in order to maintain heat flow needs to consider low u value materials like brick, cavity brick, concrete board

POLYURETHANE FOAM WAL INSULATION (XPS INSULATION)

It has good thermal insulating properties, low moisture-vapor permeability, and high resistance to water absorption, relatively high mechanical strength and low density. In addition, it is relatively easy and economical to install. The thermal conductivity (K) of rigid Polyurethane of 45 mm thickness is 0.019 w/m. while that of expanded Polystyrene is 0.04 (for an 80 mm thickness) and of glass wool is 0.055 for a 100 mm thickness

7.3.2 Roof Construction

Comparatively smaller horizontal structural component, which absorbs the heat directly and transmits to the space below and has an impact on the HVAC.

BASECASE	SCENARIO 1	SCENARIO 2	SCENARIO 3	SCENARIO 4	SCENARIO 5
RCC Roof without Insulation Uvalue: 0.35 Btu/hr.ft2 0F	150mm R.C.C slab + 75mm XPS Insulation + 100mm screed + 25mm PCC Uvalue= 0.05 Btu/hr.ft2 0F	150mm R.C.C slab + 75mm XPS Insulation + 100mm screed + 25mm PCC Uvalue= 0.05 Btu/hr.ft2 0F	150mm R.C.C slab + 75mm XPS Insulation + 100mm screed + 25mm PCC Uvalue= 0.05 Btu/hr.ft2 0F	150mm R.C.C slab + 75mm XPS Insulation + 100mm screed + 25mm PCC Uvalue= 0.05 Btu/hr.ft2 0F	insulation entirely above deck U value0.063 Btu/hr.ft2 0F

Table 7.4 Roof component with different insulation material

Insulated roof construction will provide ample thermal comfort to the building.

7.3.3 Window to Wall Ratio

The ratio of glazing to the area of external wall. Higher ratio increases the heat gain inside the building.

BASECASE	SCENARIO 1	SCENARIO 2	SCENARIO 3	SCENARIO 4	SCENARIO 5
40%	35%	35%	30%	30%	30%

Table 7.5 Wall to window ratio with various aspect ratio

The optimal window to external wall ratio was 40% and 60%. In addition to this, the costly optimal façade solution was high transparent triple, low-emissivity glazing with window to external wall ratio of 25% and the external wall insulation of 200 mm ($U = 0.16$).

7.3.4 Glazing

Openings in the exterior walls with glazing for allowing natural daylight. Transmits heat easily due to lesser thickness than walls.

BASECASE	SCENARIO 1	SCENARIO 2	SCENARIO 3	SCENARIO 4	SCENARIO 5
Single Clear, U Value: 1 Btu/hr.ft2 0F SC : 0.87	DGU U Value: 0.32 Btu/hr.ft2 0F SC : 0.62	DGU U Value: 0.32 Btu/hr.ft2 0F SC : 0.62	DGU U Value: 0.32 Btu/hr.ft2 0F SC : 0.62	solar Control Low-E Coatings (Soft-Coat)	U Value : 1.22 Btu/h.ft2°F SC (All) : 0.29

Table 7.6 Building glazing ratio with different parameters.

For shaded windows, products with lower U values perform better. Direct radiation falling on the windows should be minimized

7.3.5 Shading Devices

Horizontal or vertical architectural feature which helps in avoiding direct heat radiation through the glazing.

BASECASE	SCENARIO 1	SCENARIO 2	SCENARIO 3	SCENARIO 4	SCENARIO 5
None	6 Inches Recessed	6 Inches Recessed	Deep Recessed	Deep Recessed	None

Table 7.7 Shading device with different parameters.

As per the ashrae standards provided recession for shading devices

7.3.6 Lighting Power Density

Lighting Power Density technically represents the load of any lighting equipment in any defined area, or the watts per square meter of the lighting equipment.

BASECASE	SCENARIO 1	SCENARIO 2	SCENARIO 3	SCENARIO 4	SCENARIO 5
Same as ASHRAE base case	20% Reduction from base case LPD: 8.6W/Sq.m	20% Reduction from base case LPD: 8.6W/Sq.m	30% Reduction from base case LPD: 8.6W/Sq.m	30% Reduction from base case LPD: 8.6W/Sq.m	As per the Building Area Method ASHRAE 90.1- 2004. Office Floor - 10.76 W/sq.m Parking Area – 3.23 W/sq.m

Room Type	Light Level (Foot Candles)	IECC 2021 Lighting Power Density (Watts per SF)
Lobby - Office/General	20-30 FC	0.84
Locker Room	10-30 FC	0.52
Lounge / Breakroom	10-30 FC	0.59
Mechanical / Electrical Room	20-50 FC	0.43

Table 7.8 Lighting power density with different parameters.

Recommended level of LPD in office spaces is 8.4 w/sq.m low level of LPD means high level of energy savings.

7.3.7 HVAC System

Two types - Fixed air volume & variable air volume. The variable air volume is more efficient and energy saving as it regulates the flow of air depending on the indoor conditions such as occupancy, heat load, etc.

BASECASE	SCENARIO 1	SCENARIO 2	SCENARIO 3	SCENARIO 4	SCENARIO 5
Constant Air Volume	Variable Air Volume	Variable Air Volume	Variable Air Volume	Variable Air Volume	Table G3.1.1.B System 8 – PFP-VAV with reheat with electric resistance as heating type

Table 7.9 HVAC system with different parameters.

7.3.8 Fan Control in A.H.U.'s

Two types - Fixed speed & variable speed. Variable speed is more efficient and energy saving as it regulates the flow of air depending on the indoor conditions such as occupancy, heat load, etc.

BASECASE	SCENARIO 1	SCENARIO 2	SCENARIO 3	SCENARIO 4	SCENARIO 5
Constant Speed	Variable speed	Variable speed	Variable speed	Variable speed	Variable speed

Table 7.10 A.H.U with different parameters.

7.3.9 Chillers Parameter

Two types of chillers - Screw chillers and centrifugal chillers, which again can be cooled either by air or water. Centrifugal chillers are more efficient as it is technically advanced and using water for cooling is more energy efficient as water is a natural cooler.

By their design and operation, air-cooled chillers appear costlier at face value. To begin with, air-cooled systems will feature installation costs for air ducts, fans and thermoregulation

controls. Additionally, these chiller systems consume larger amounts of energy to power the fans that facilitate their cooling effect which will translate into higher electrical bills.

BASECASE	SCENARIO 1	SCENARIO 2	SCENARIO 3	SCENARIO 4	SCENARIO 5
10X800 TR	10X800 TR	20X400 TR	8X900 TR	8X900 TR	10X800 TR
Water-cooled	Water-cooled	water-cooled	Water Cooled	Water Cooled	Water Cooled
Rotary	Rotary	Rotary	Centrifugal	Centrifugal	Centrifugal
Screw	Screw	Screw	Chillers	Chillers	Chillers
Chillers	Chillers	Chillers	COP - 6.1	COP - 6.1	COP - 6.1
COP – 5.5	COP – 5.5	COP – 5.5			

Table 7.11 Chiller plant with different parameters.

7.3.10 Demand Control Ventilation

The right quantum of ventilation, at the right time and place, will help in saving both money and energy rather than supply ventilated air based on assumed, rather than actual occupancy.

BASECASE	SCENARIO 1	SCENARIO 2	SCENARIO 3	SCENARIO 4	SCENARIO 5
None	Yes	Yes	Yes	Yes	None

Table 7.12 Demand controlventilation with different parameters.

7.3.11 Ventilation

It is the process of "changing" or replacing air in any space to provide high indoor air quality i.e. to control temperature, replenish oxygen and remove moisture, odor, smoke, heat, dust, airborne bacteria and carbon dioxide.

BASECASE	SCENARIO 1	SCENARIO 2	SCENARIO 3	SCENARIO 4	SCENARIO 5
----------	---------------	---------------	---------------	---------------	---------------

None	CO sensors in parking	CO sensors in parking	CO sensors in parking	CO sensors in parking	None
------	--------------------------	--------------------------	--------------------------	--------------------------	------

Table 7.13 Ventilation with different parameters.

Carbon monoxide detectors sound an alarm when they sense a certain amount of carbon monoxide over time. Different sensors set off different types of alerts. ... Metal oxide semiconductor:



Fig 7.3 Carbon mono oxide sound detector.

7.4 Analysis of parameter for different cases

S No	Model Input Parameter	Scenario Base case	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6 (ASHRAE 90.1-
1	Exterior Wall Construction	230mm Brick Wall U-value: 0.32 Btu/hr.ft ² OF	250mm Cavity Brick Wall U-value: 0.24 Btu/hr.ft ² OF	(250mm Cavity Brick Wall U-value: 0.24 Btu/hr.ft ² OF)	10mm thk. Concrete board + 25mm XPS insulation + 460mm airgap + 4mm ACP Cladding U-Value = 0.14 Btu./hr.ft ² OF	10mm thk. Concrete board + 25mm XPS insulation + 460mm airgap + 4mm ACP Cladding U-Value = 0.14 Btu./hr.ft ² OF	Steel Frame U value-0.124 Btu/hr.ft ² OF
2	Roof Construction	RCC Roof without Insulation U-value: 0.35 Btu/hr.ft ² OF	150mm R.C.C slab + 75mm XPS Insulation + 100mm screed + 25mm PCC U-value= 0.05 Btu/hr.ft ² OF	150mm R.C.C slab + 75mm XPS Insulation + 100mm screed + 25mm PCC U-value= 0.05 Btu/hr.ft ² OF	150mm R.C.C slab + 75mm XPS Insulation + 100mm screed + 25mm PCC U-value= 0.05 Btu/hr.ft ² OF	150mm R.C.C slab + 75mm XPS Insulation + 100mm screed + 25mm PCC U-value= 0.05 Btu/hr.ft ² OF	Insulation entirely above deck U value- 0.063 Btu/hr.ft ² OF
3	Window to Wall Ratio	40%	35%	35%	30%	30%	30%
4	Glazing	Single Clear, U Value: 1 Btu/hr.ft ² OF SC : 0.87	DGU U Value: 0.32 Btu/hr.ft ² OF SC : 0.62	DGU U Value: 0.32 Btu/hr.ft ² OF SC : 0.62	DGU U Value: 0.32 Btu/hr.ft ² OF SC : 0.62	DGU U Value: 0.32 Btu/hr.ft ² OF SC : 0.62	U Value : 1.22 Btu/h.ft ² °F SC (All) : 0.29
5	Shading Devices	None	6 Inches Recessed	6 Inches Recessed	Deep Recessed	Deep Recessed	None

6	Lighting Power Density	Same as ASHRAE Basecase	20% Reduction from Basecase LPD: 8.6W/Sq.m	20% Reduction from Basecase LPD: 8.6W/Sq.m	30% Reduction from Basecase LPD: 8.6W/Sq.m	30% Reduction from Basecase LPD: 8.6W/Sq.m	As per the Building Area Method ASHRAE 90.1-2004. Office Floor - 10.76 W/sq.m Parking Area – 3.23 W/sq.m
7	HVAC System Type	Constant Air Volume	Variable Air Volume	Variable Air Volume	Variable Air Volume	Variable Air Volume	Table G3.1.1.B System 8 – PFP-VAV with reheat with electric resistance as heating type
8	Fan Control in A.H.U.'s	Constant Speed	Variable speed	Variable speed	Variable speed	Variable speed	Variable speed

S No	Model Input Parameter	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
9	Chillers Parameter	10X800 TR Water-Cooled Rotary Screw Chillers COP – 5.5	10X800 TR Water- Cooled Centrifugal Chillers COP – 5.5	20X400 TR Air-Cooled Rotary Screw Chillers COP – 5.5	8X900 TR Water Cooled Centrifugal Chillers COP - 6.1	8X900 TR Water Cooled Centrifugal Chillers COP - 6.1	10X800 TR Water Cooled Centrifugal Chillers COP - 6.1
10	Demand Control Ventilation	None	Yes	Yes	Yes	Yes	None
11	Ventilation	None	CO sensors in parking	CO sensors in parking	CO sensors in parking	CO sensors in parking	None

Table 7.13 Analysis of parameter for different cases

7.5 Analysis of building modeling

7.5.1 Based on various parameters

Input parameter's	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
Interior lights	8117	7007	7007	6890	6890	8117
% decrease	0	15.11	15.11	17.11	17.11	0
equipment	10322	10322	10322	10322	10322	10322
Space cooling	34467	28457	43245	24567	19569	27563
% decrease	-19.23	0	-47.56	8.09	23.67	0
Heat rejection	572	277	386	254	246	271
% decrease	-102.4	0	-36.54	7.8	9.1	0
Pumps and aux	3043	2345	1789	1923	2256	2471
% decrease	-23.53	0	23.55	19.67	9.89	0
fans	16161	5096	5096	4967	5071	5096
% decrease	-217.4	0	0	4.54	0.78	0
elevators	2650	2650	2650	1500	1500	2650
% decrease	0	0	0	43.4	43.4	0

Exterior lights	153	153	153	153	153	153
total	75567	55678	69678	49876	45890	56754
savings	-29.78	3.78	-22.43	10.67	18.13	2.67

Table 7.14 Analysis of building with different parameters.

7.5.2 Based on different HVAC system and Materials.

Estimated Energy & Cost Summary	Estimated Energy & Cost Summary	Energy, Carbon and Cost Summary
Annual Energy Cost \$564,823	Annual Energy Cost \$538,776	Annual Energy Cost \$524,430
Lifecycle Cost \$7,692,888	Lifecycle Cost \$7,338,133	Lifecycle Cost \$7,142,737
Annual CO ₂ Emissions	Annual CO ₂ Emissions	Annual CO ₂ Emissions
Electric 0.0 Mg	Electric 0.0 Mg	Electric 0.0 Mg
Onsite Fuel 478.3 Mg	Onsite Fuel 380.9 Mg	Onsite Fuel 375.4 Mg
Large SUV Equivalent 47.9 SUVs / Year	Large SUV Equivalent 38.2 SUVs / Year	Large SUV Equivalent 37.6 SUVs / Year
Annual Energy	Annual Energy	Annual Energy
Energy Use Intensity (EUI) 922 MJ / m ² / year	Energy Use Intensity (EUI) 831 MJ / m ² / year	Energy Use Intensity (EUI) 812 MJ / m ² / year
Electric 3,198,444 kWh	Electric 3,166,311 kWh	Electric 3,074,954 kWh
Fuel 9,591,208 MJ	Fuel 7,637,611 MJ	Fuel 7,526,554 MJ
Annual Peak Demand 979.5 kW	Annual Peak Demand 965.6 kW	Annual Peak Demand 952.6 kW
Lifecycle Energy	Lifecycle Energy	Lifecycle Energy
Electric 95,953,320 kWh	Electric 94,989,330 kWh	Electric 92,248,620 kWh
Fuel 287,736,240 MJ	Fuel 229,128,330 MJ	Fuel 225,796,620 MJ

Base case

scenario 1

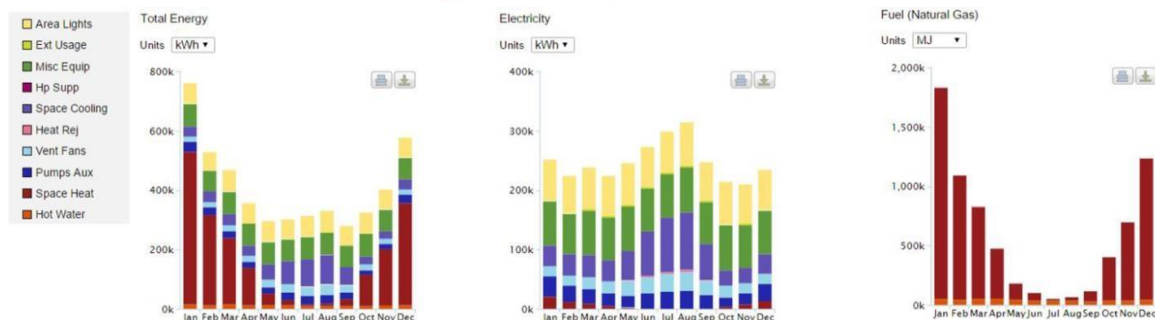
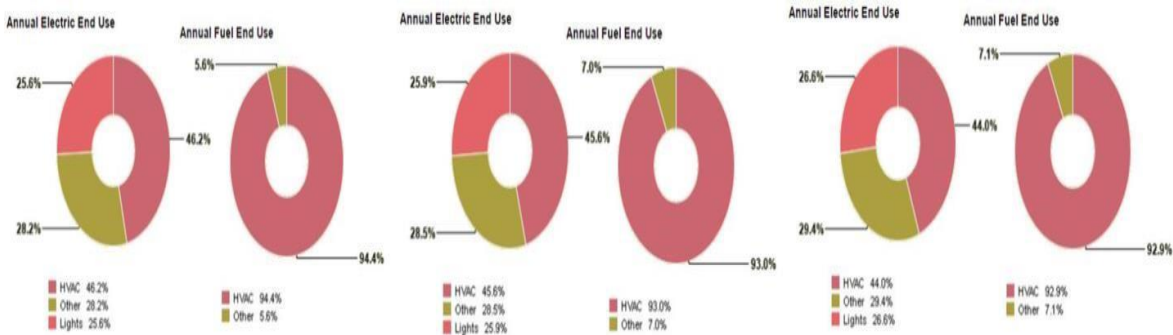
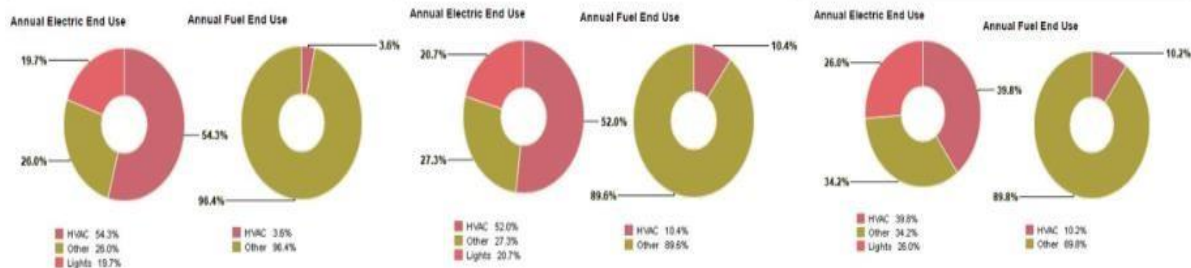
scenario 2

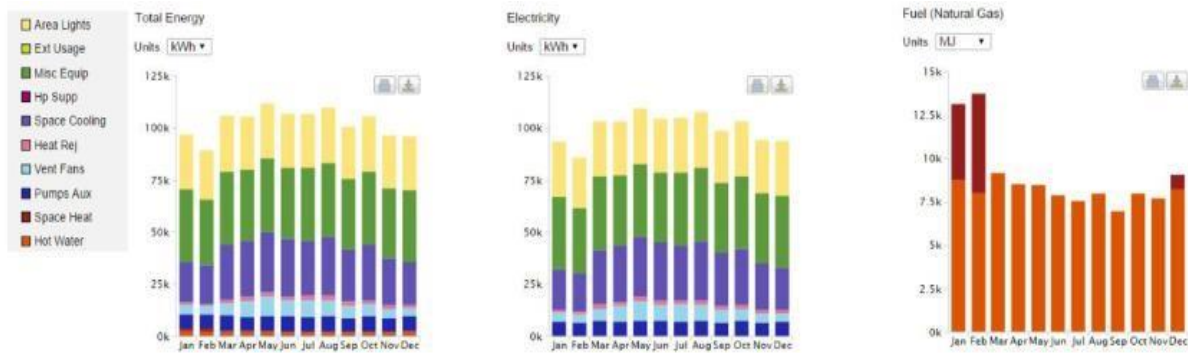
factors	Base case	scenario 1	scenario 2
Installation cost	30,45,324	26,67,785	25,78,987
EUI	922 MJ/m/year	831 MJ/m/year	812 MJ/m/year

Table 7.15 Analysis of building with Different HVAC and material.

Alternate Scenario – 1 (Conventional building) Building and system design using conventional features & general specifications.

Estimated Energy & Cost Summary	Energy, Carbon and Cost Summary	Estimated Energy & Cost Summary
Annual Energy Cost \$127,508	Annual Energy Cost \$121,483	Annual Energy Cost \$96,995
Lifecycle Cost \$1,736,662	Lifecycle Cost \$1,654,593	Lifecycle Cost \$1,321,072
Annual CO ₂ Emissions	Annual CO ₂ Emissions	Annual CO ₂ Emissions
Electric 0.0 Mg	Electric 0.0 Mg	Electric 0.0 Mg
Onsite Fuel 5.7 Mg	Onsite Fuel 6.1 Mg	Onsite Fuel 5.4 Mg
Large SUV Equivalent 0.6 SUVs / Year	Large SUV Equivalent 0.6 SUVs / Year	Large SUV Equivalent 0.5 SUVs / Year
Annual Energy	Annual Energy	Annual Energy
Energy Use Intensity (EUI) 559 MJ / m ² / year	Energy Use Intensity (EUI) 533 MJ / m ² / year	Energy Use Intensity (EUI) 426 MJ / m ² / year
Electric 1,583,323 kWh	Electric 1,507,199 kWh	Electric 1,202,394 kWh
Fuel 113,380 MJ	Fuel 122,043 MJ	Fuel 108,151 MJ
Annual Peak Demand 477.9 kW	Annual Peak Demand 401.2 kW	Annual Peak Demand 301.7 kW
Lifecycle Energy	Lifecycle Energy	Lifecycle Energy
Electric 47,499,690 kW	Electric 45,215,970 kW	Electric 36,071,820 kW
Fuel 3,401,397 MJ	Fuel 3,661,278 MJ	Fuel 3,244,536 MJ





factors	scenario 3	scenario 4	scenario 5
Installation cost	22,78,760	21,59,550	26,55,345
EUI	922 MJ/m/year	831 MJ/m/year	812 MJ/m/year

Table 7.16 Comparative analysis of Energy with flow chart.

Alternate Scenario – 2 to 5 (Proposed optional design cases) Building and system design with permutation and combination of alternate ‘Green’ features such as water cooled chillers, building envelope, lighting options, window wall ratio, insulation systems

Alternate Scenario – 6: (Baseline case) Building and system design with parameters confirming to ASHRAE building standards (ASHRAE 90.1-2004)

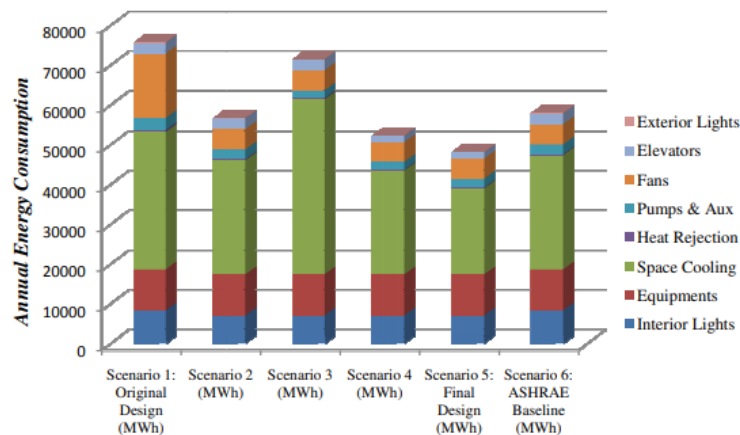
SCENARIO – 1 (CONVENTIONAL BUILDING PARAMETERS)

The design was modelled with all conventional building features and general specifications but no ‘Green’ features included. The building envelope comprises of 230mm thick brick exterior wall with a U-value of 0.32 Btu./hr.ft²° F. The roof construction is of RCC slab without Insulation with a U-value of 0.35 Btu./hr.sq.ft.F. The fenestration type is single clear glass for a window to wall ratio of 40% and U-Value of 1.0 Btu/hr.sq.ft.F and with no shading devices. The Lighting equipment has an average lighting power density of 10.76 W/sq. (building area method) in office and 3.23 W/sq. in parking with no day lighting control. The air side HVAC System has constant air volume with no economizer and no heat recovery wheel. The central plant consists of water cooled Rotary Screw Chillers with COP of 5.5 (10 x 800 TR).

SCENARIO – 6: BASELINE MODEL (BUILDING DESIGN WITH ASHRAE STANDARDS)

The ASHRAE 90.1- ‘Minimally Compliant Baseline’ model is used to benchmark the proposed design, as well as determine the LEED points. This model is based upon the proposed design,

but the performance parameters are defined to reflect the minimum efficiency levels that ASHRAE 90.1-2004 defines for various building components. The window wall ratio and the variable speed drive are the only common factors between the as built case and this baseline case. The building envelope considered for exterior wall construction is of steel frame with a U-value of 0.124 Btu./hr.sq.ft.F. The roof construction had insulation entirely above the deck with a U-value of 0.063 Btu./hr.sq.ft.F. The fenestration assembly comprised of window to wall ratio of 30% with a U-Value of 1.22 Btu./hr.sq.ft.F and no Shading devices. The lighting equipment had an average lighting power density of 10.76 W/sq. in office and 3.23 W/sq. in parking areas with no day lighting control. Air side HVAC System comprised of VAV system with PFP boxes, no economizer and no heat recovery wheel. The Central Plant was assumed with Water Cooled Centrifugal chillers with COP of 6.1 at ARI conditions (10 x 800 TR) with VSD's on Secondary Pumps and AHUs and cooling towers with two-speed fans



UTILITY-RATE	RESOURCE	METERS	METERED ENERGY UNITS/YR	TOTAL CHARGE	VIRTUAL RATE (\$/UNIT)	RATE USED ALL YEAR?
Utility Rate 1	Electricity	EMI	32832022. kWh	174009728	5.3	YES

Fig 7.4 Annual energy consumption of the building.

7.6 DESIGN CASE COST SIMULATION FILE OUTPUT

For the above scenario, it is observed that the effective energy requirement for the optimized design as well as the cost of operations per unit is 18.13% lower than the ASHRAE baseline design.

This means a single campus can be optimized with higher energy efficiency compared to a multi campus. Few comparative cases were considered for captive usage wherein the optimized energy efficient design could be made up to 23% as per ASHRAE standards as one of the cases is highlighted in the literature study.

In this study, it can be seen that the design case simulation only fulfils the required criteria on LEED credit (above 10% over baseline). The energy consumption showed a 18.13% savings over the baseline figures for Scenario 5

While comparing all other scenarios the scenario number 5 provides energy savings up to 18%. Total electricity load calculations

7.7 LIGHTING LOADS

NO	ARENA	LOAD CALCULATIONS
1	1 st floor summary	11.53 KW
2	2 nd floor summary	10.03 KW
3	3 rd floor summary	9.58 KW
4	4 th floor summary	11.53 KW
5	5 th floor summary	10.26 KW
6	cafeteria	2.25 KW
7	basement	4.25 KW
8	Stilt floor	25.5 KW

9	Exterior lighting	6.25 KW
	Total	91.2015 KW

Table 7.16 Lighting load at various floor.

7.8 HVAC LOADS

NO	ARENA	LOAD CALCULATIONS
1	Screw chiller 100 kw * 6	600 KW
2	Primary pumps 12kw* 6	72 KW
	Total	672 KW

Table 7.17 HVAC load calculation.

7.9.APPLIANCE LOADS

NO	ARENA	LOAD CALCULATIONS
1	1 st floor summary	45.31 KW
2	2 nd floor summary	41.51 KW
3	3 rd floor summary	41.51 KW
4	4 th floor summary	45.31 KW
5	5 th floor summary	40.72 KW
	Total	213.941 KW
1	Elevator	57 kw

2	Other loads	100 kw
---	-------------	--------

Table 7.18 Appliance load calculation.

TOTAL ELECTRICAL LOAD IN THE BUILDING 1418 KVA

1. MAXIMUM DEMAND CALCULATION

Load factor considered for Software Industry = 0.6
Maximum Demand = $1418 \times 0.6 = 850 \text{ KVA}$

2. TRANSFORMER CAPACITY

Transformer Capacity: 800 KVA x 2Nos. But one Transformer of **1600 KVA** is proposed.

Maximum demand in the building reaches up to 850 kva it has been served with the inclusion of the 1600 kva transformer. When we consider scenario 5 we can save nearly 18% of overall energy usage and electrical consumption.

ELECTRIC COST FOR THE BUILDING IN NOVEMBER MONTH 2021 28, 99,224

Average electric cost for the building 25, 56,750

When retrofit it with scenario 5 parameters we can expect 18.14% savings.

After retrofit average electrical cost 2,111,194

Total cost difference 18.14% 4, 45,556

While installing solar panels

Average solar irradiation in **TAMIL NADU** state is **1266.52** W / sq.m

1kWp solar rooftop plant will generate on an average over the year **5.0** kWh of electricity per day (considering 5.5 sunshine hours)

1. Size of Power Plant	
Feasible Plant size as per your Roof Top Area :	71.1kW
2. Cost of the Plant :	
MNRE current Benchmark Cost :	Rs. 38000 Rs. / kW
Without subsidy (Based on current MNRE benchmark) :	Rs. 2701800
With subsidy 0 (Based on current MNRE benchmark) :	Rs. 2701800
3. Total Electricity Generation from Solar Plant :	
Annual :	106650kWh
Life-Time (25 years):	2666250kWh
4) Financial Savings :	
a) Tariff @ Rs.6.35/ kWh (for top slab of traffic) - No increase assumed over 25 years :	
Monthly :	Rs. 56436
Annually :	Rs. 677227.5
Life-Time (25 years) :	Rs. 16930687.5

Table 7.19 Solar power plant load calculation.

Roof top area	17000 sq.ft
Usable area for installing solar panels	8000 sq.ft
Monthly savings savings)	56436rs (2.4%

By installing solar panel and retrofitting into scenario 5 parameters can provide savings in electricity up to 20.54%

Capital Budgeting Payback Period Calculation

Select Currency

Rupee (₹) ▼

Initial Investment Amount

2701800

₹

Number of years

5

Year

Annual Cash Flow

1

677227.5

₹

2

675467

₹

3

626789

₹

4

598765

₹

5

588989

₹

Average Annual Cash Flow

633447.5

₹

Payback Period

4.265

Years

Installation cost will be payback within a period of 4 years, and the lifecycle of the solar panel is 25 years (max), hence it will be act as an ample replacement of non-renewable energy source. Overall savings after retrofitting them is 20.54%

Energy Efficiency Credits in USGBC LEED CS v2009 Rating

Intent: To achieve increasing levels of energy performance beyond the prerequisite standard to reduce environmental and economic impacts associated with excessive energy use.

Whole Building Energy Simulation (1– 19 Points)

Demonstrate a percentage improvement in the proposed building performance rating compared with the baseline building performance rating. Calculate the baseline building performance according to Appendix G of ANSI / ASHRAE / IESNA Standard 90.1-2007 (with errata but without addenda) using a computer simulation model for the whole building project. The minimum energy cost savings percentage for each point threshold is as follows:

New Buildings	Existing Renovations	Points
12 %	8 %	3
14 %	10 %	4
16 %	12 %	5
18 %	14.0 %	6
20 %	16 %	7
22 %	18 %	8
24 %	20 %	9
26 %	22 %	10
28 %	24 %	11
30 %	26 %	12
32 %	28 %	13
34 %	30 %	14
36 %	32 %	15
38 %	34 %	16
40 %	36 %	17
42 %	38 %	18
44 %	40 %	19
46 %	42 %	20
48 %	44 %	21

Table 7.20 Energy efficiency credit in LEED rating system.

Above table shows the consideration for the leed ratings as per the 2009 rating system existing renovations which has the savings percentage of 20% holds 9 points in the rating system

8 OTHER ENERGY CONSERVATION MEASURES

8.1 BIO-ALGAE FACADE

An algae facade is designed to improve indoor air quality through O_2 and CO_2 absorption as a result of photosynthesis of algae.

In addition, algae grown from bio facades have the potential to be converted into renewable fuel stocks such as biomass or biofuel

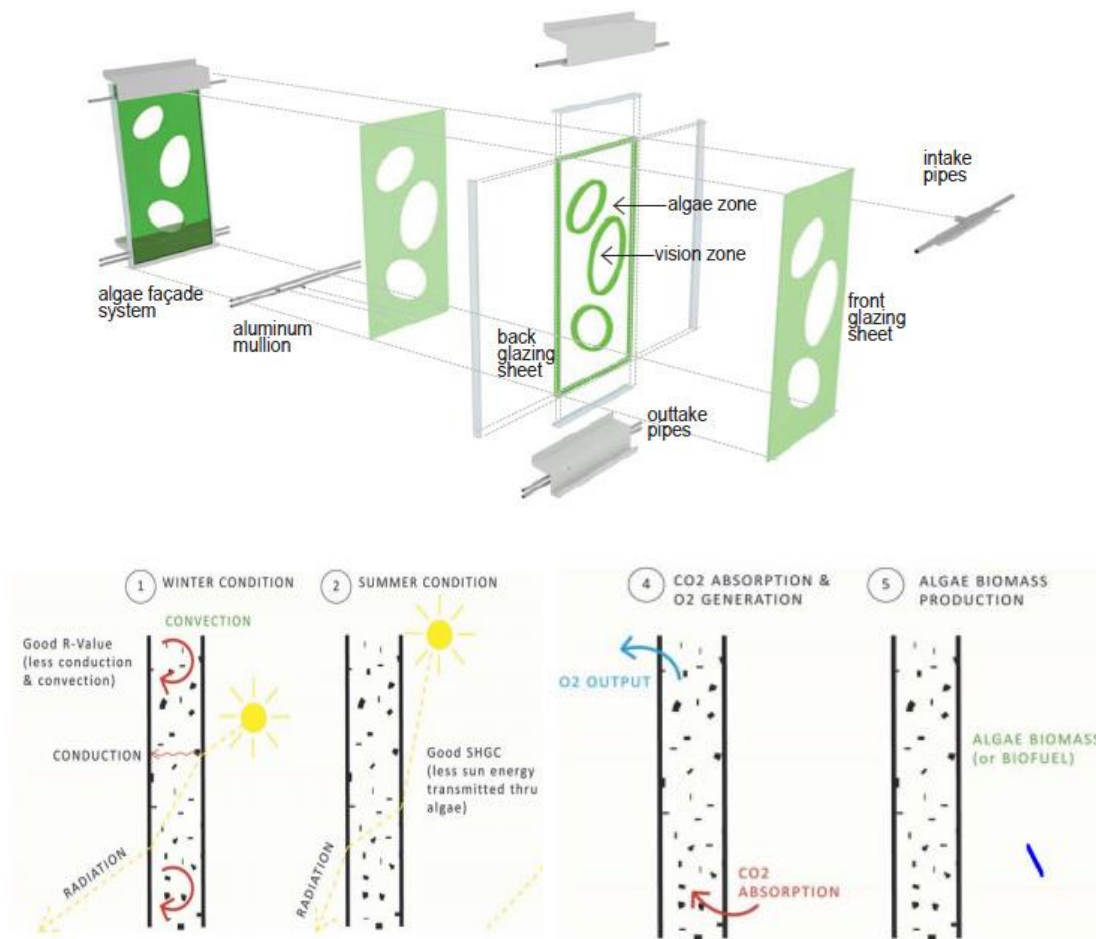


Fig 8.1 Bio-Algae facade and its energy conservation measure.

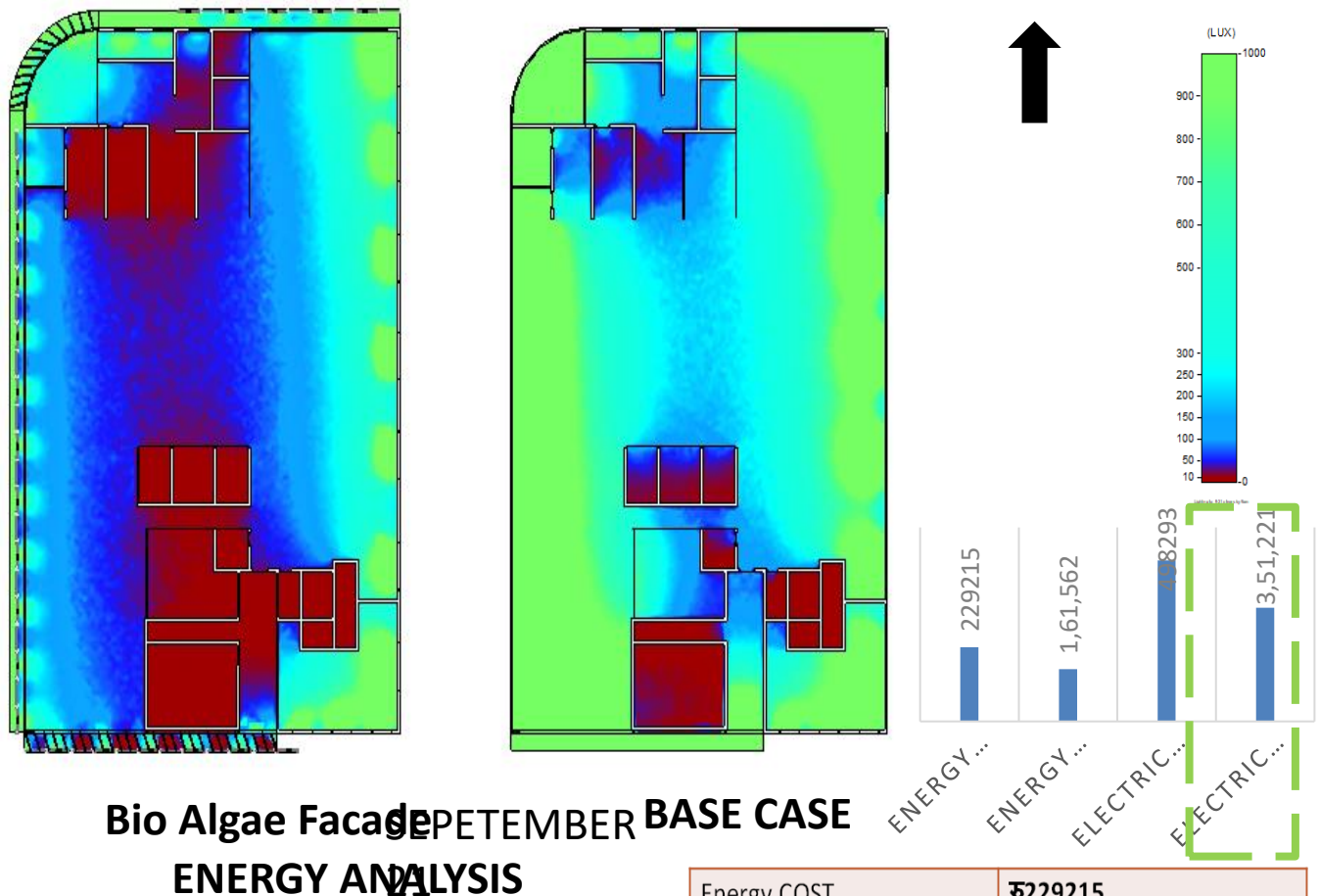


Fig 8.2 Bio-Algae facade energy modeling in base case and final output.

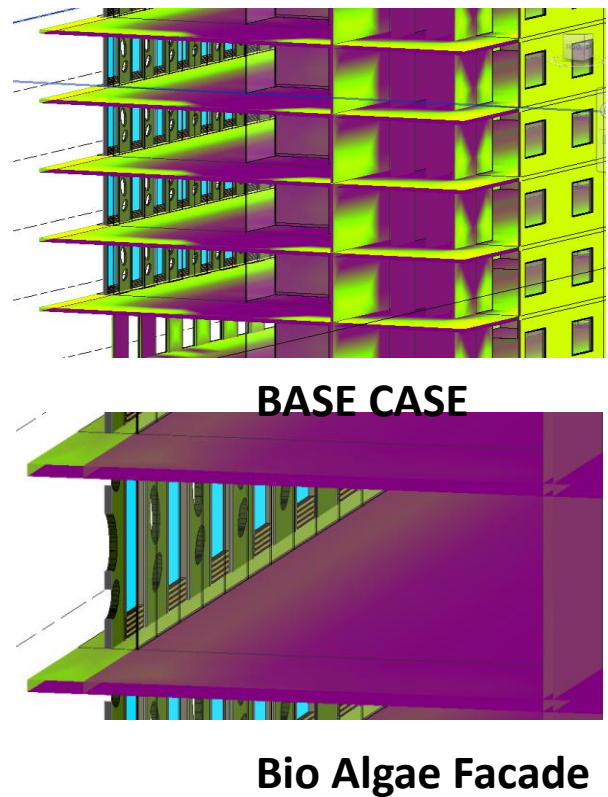
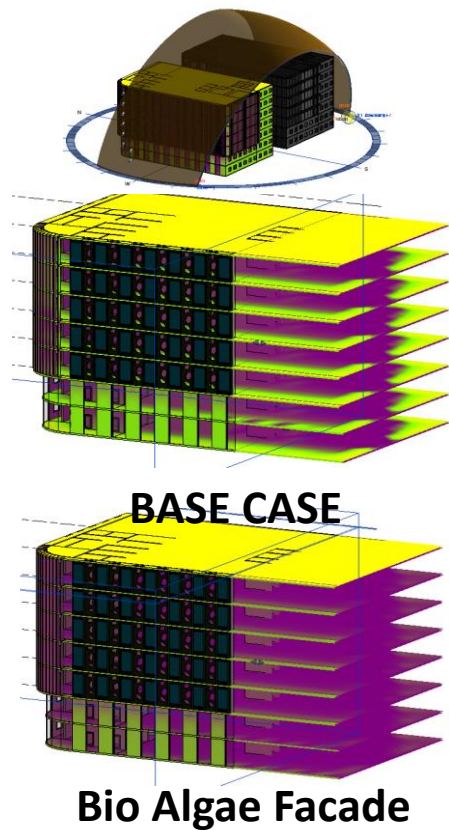


Fig 8.3 Bio-Algae facade energy modeling in base case and final output in view.

8.2 AUTOMATED VERTICAL LOUVERS

Vertical louvers with fully automated system respond to the sun angle and adjust the louver angle to prevent any direct sun penetration.

The levels are automatically adjusted to supplement natural daylight where required.

The shaft box type window facade system help in cooling the building more effectively .

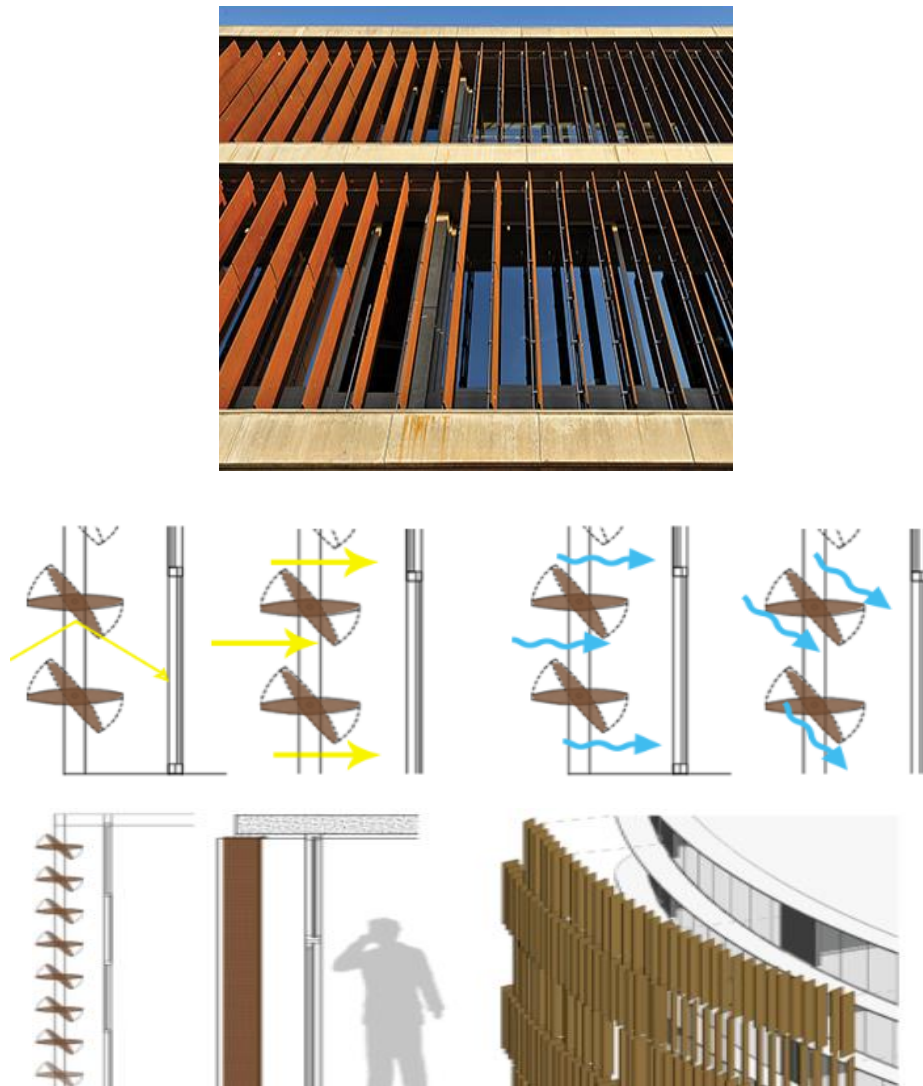


Fig 8.4 Automated louvers and its wind analysis.

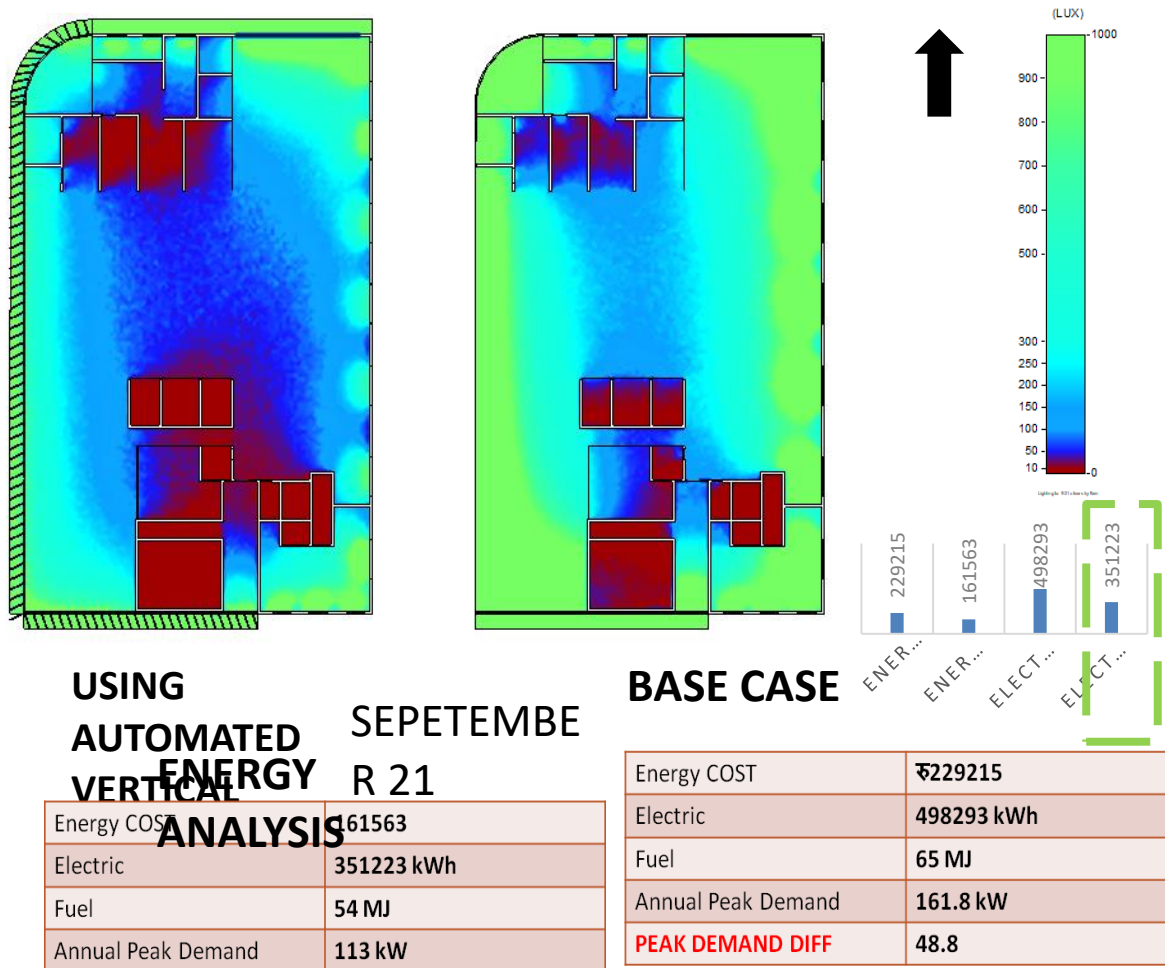


Fig 8.5 Automated louvers modeling in base case and final output.

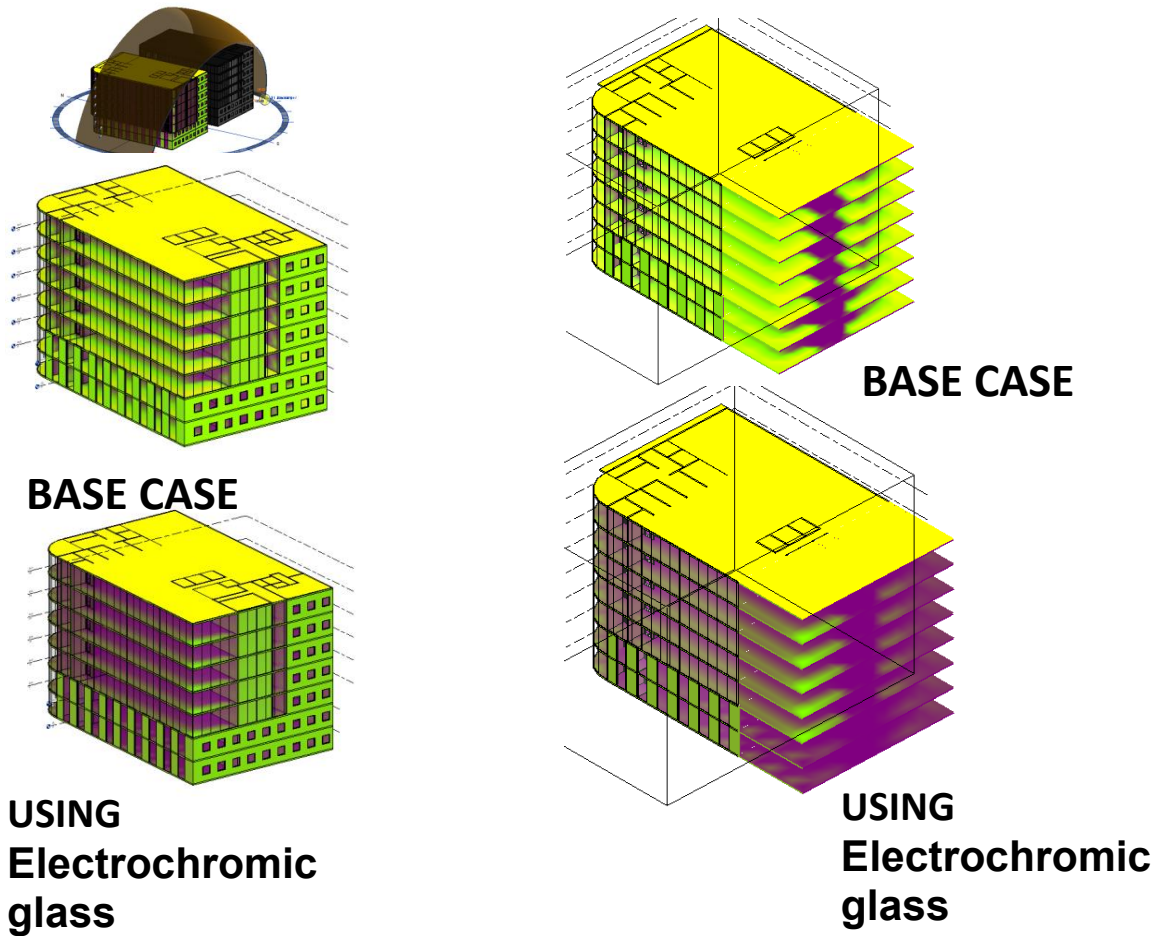


Fig 8.6 Bio-Algae facade energy modeling in base case and final output in view.

8.3 ELECTROCHROMIC GLASS

Electrochromic glass, electronically switchable glass, is an innovative and modern building glass material.

Electrochromic glass is so unique that it allows users to control the amount of heat or light that passes through the glass at the flick of a switch, giving them the ability to regulate temperatures or create privacy at the flick of a switch.

	Solar transmissi- on	Direct solar transmissi- on	Light transmis- sion	U- value
1. Multilayer glazing				
Single Clear Glazing	0.810	0.775	0.881	6.121
Double Clear Glazing	0.693	0.604	0.781	3.157
Triple Clear Glazing	0.675	0.595	0.738	2.166
2. Low-emittance glass				
Single Low-e Glass	0.710	0.680	0.811	4.233
Double Low-e Glass	0.595	0.538	0.769	2.440
3. Electrochromic glass				
Double Electrochromic Glass	0.638	0.545	0.727	1.772

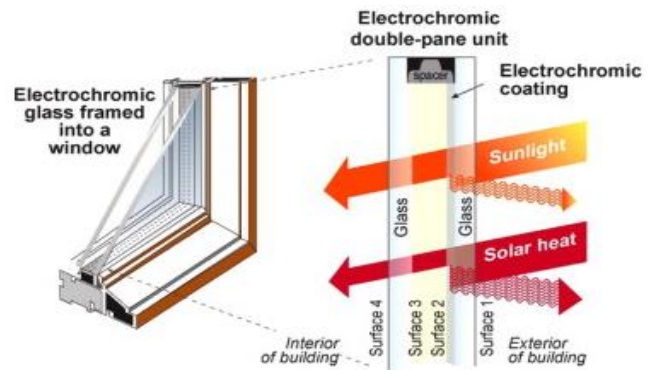


Fig 8.7 Electro chromatic glass and its parameters

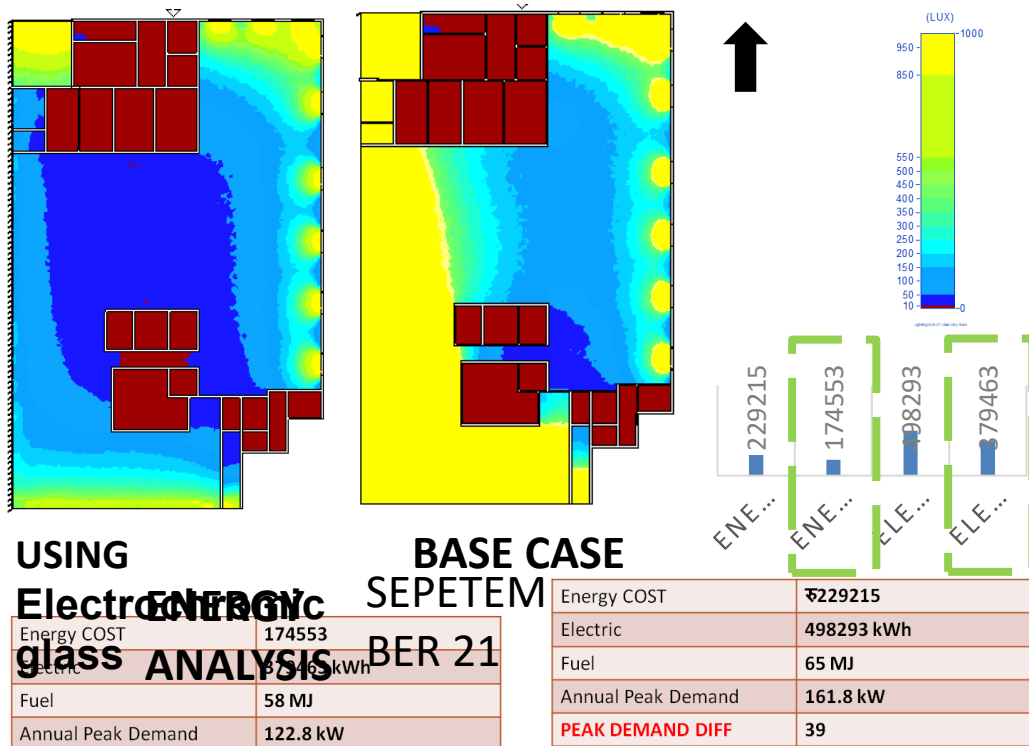


Fig 8.8 ECG in base case and final output.

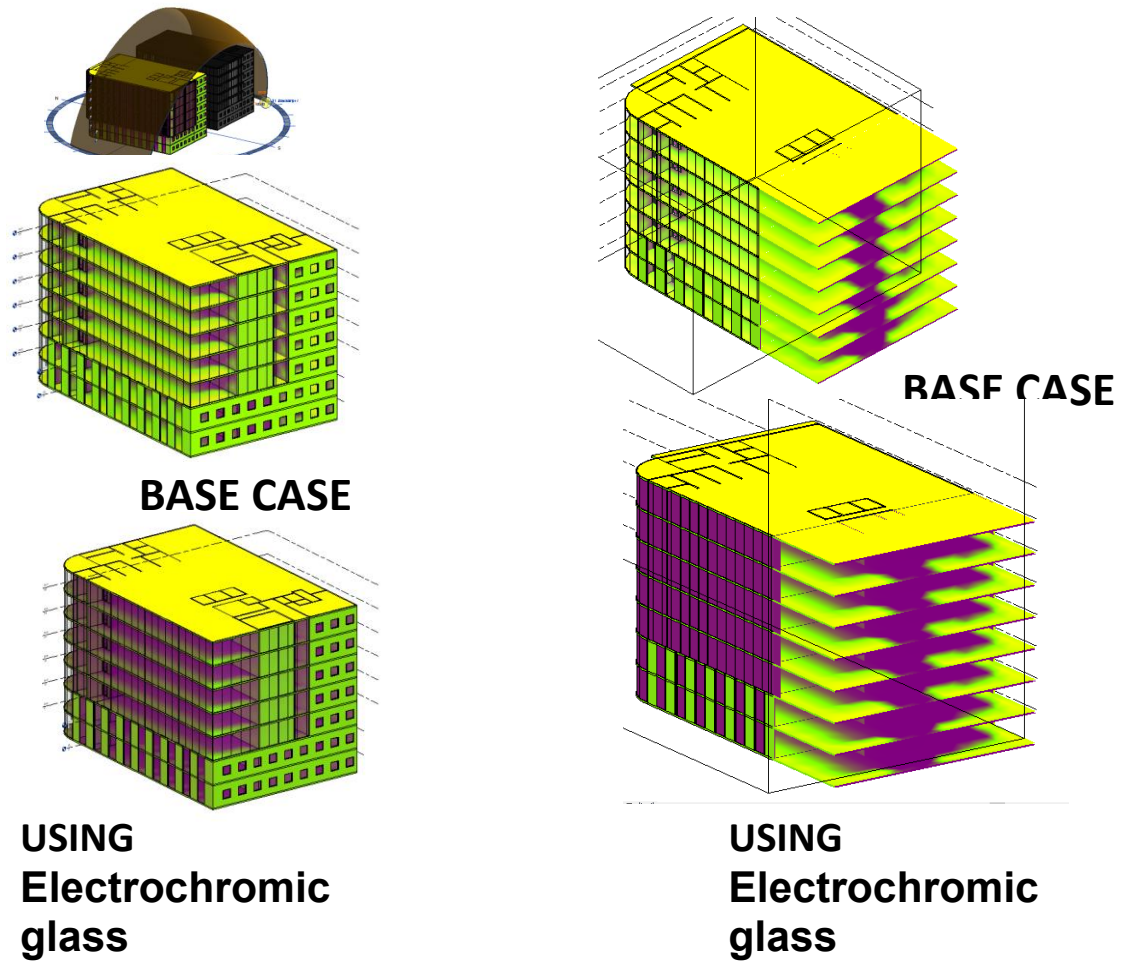


Fig 8.9 ECG in base case and final output in view.

USING BIO ALGAE

FACADE	
Energy COST	₹161,562
Electric	351,221 kWh
Fuel	54 MJ
Annual Peak Demand	112.9 kW

Energy COST	₹229215
Electric	498293 kWh
Fuel	65 MJ
Annual Peak Demand	161.8 kW
PEAK DEMAND DIFF	48.9

USING AUTOMATED VERTICAL

LOUVERS	
Energy COST	161563
Electric	351223 kWh
Fuel	54 MJ
Annual Peak Demand	113 kW

Energy COST	₹229215
Electric	498293 kWh
Fuel	65 MJ
Annual Peak Demand	161.8 kW
PEAK DEMAND DIFF	48.8

USING AEROGEL

Energy COST	164733
Electric	358115 kWh
Fuel	55 MJ
Annual Peak Demand	115 kW

Energy COST	₹229215
Electric	498293 kWh
Fuel	65 MJ
Annual Peak Demand	161.8 kW
PEAK DEMAND DIFF	46.8

USING Electrochromic

glass	
Energy COST	174553
Electric	379463 kWh
Fuel	58 MJ
Annual Peak Demand	122.8 kW

Energy COST	₹229215
Electric	498293 kWh
Fuel	65 MJ
Annual Peak Demand	161.8 kW
PEAK DEMAND DIFF	39

Table 8.1 Comparative analysis of building with energy efficient parameters

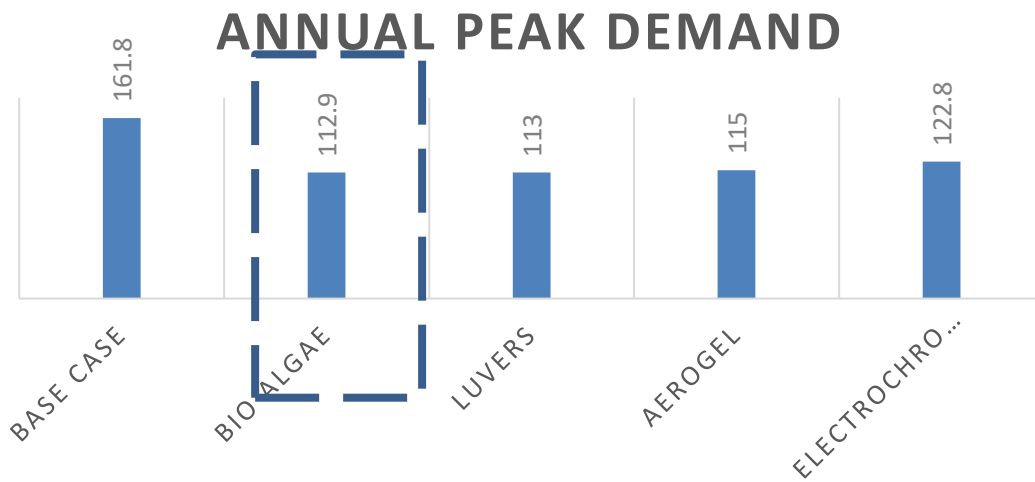
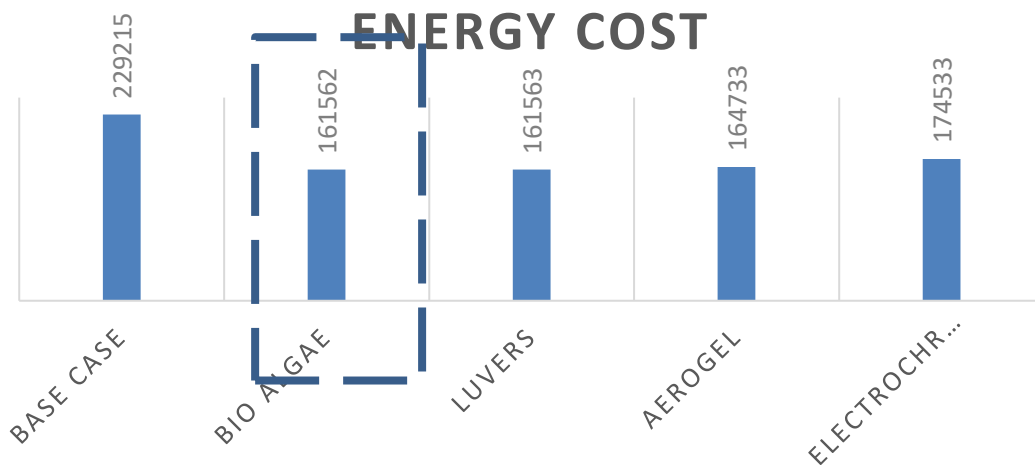


Table 8.2 Comparative Energy load of the building.

9. LOAD CALCULATION

9.1 BUILDING ENERGY LOAD

NO	ARENA	LOAD CALCULATIONS
1	1 st floor summary	11.53 KW
2	2 nd floor summary	10.03 KW
3	3 rd floor summary	9.58 KW
4	4 th floor summary	11.53 KW
5	5 th floor summary	10.26 KW
6	cafeteria	2.25 KW
7	basement	4.25 KW
8	Stilt floor	25.5 KW
9	Exterior lighting	6.25 KW
	Total	91.2015 KW

Table 9.1 Energy efficient load calculation of the building at various levels.

9.2 HVAC LOAD

NO	ARENA	LOAD CALCULATIONS
1	Screw chiller 100 kw * 6	600 KW
2	Primary pumps 12kw* 6	72 KW
	Total	672 KW

Table 9.2 Energy efficient load calculation of the building HVAC system.

9.3 APPLIANCE LOAD

NO	ARENA	LOAD CALCULATIONS
1	1 st floor summary	45.31 KW
2	2 nd floor summary	41.51 KW
3	3 rd floor summary	41.51 KW
4	4 th floor summary	45.31 KW
5	5 th floor summary	40.72 KW
	Total	213.941 KW
1	Elevator	57 kw
2	Other loads	100 kw

Table 9.3 Energy efficient load calculation of the building Appliance system.

POWER FACTOR APPLIED = 0.8

LOAD FACTOR FOR SOFTWARE INDUSTRY =
0.6

MAXIMUM DEMAND =
 $1418 * 0.6 = 850 \text{ KVA}$

TRANSFORMER CAPACITY REQUIRED

TRANSFORMER CAPACITY = 800

NOV/Δ

ELECTRICITY BILL

DETAILS	KWHr
TOTAL CONSUMPTION	516720
THIRD PARTY	255764
WIND ADJUSTMENT	19354
NET CONSUMPTION	241602

DEC ELECTRICITY

DETAILS	KWHr
TOTAL CONSUMPTION	418700
THIRD PARTY	195432
WIND ADJUSTMENT	141744
NET CONSUMPTION	81524

AS PER NBC

Area of one floor = 17 000 sq.ft

STANDARDS

Total number of floors with
workstations = 6

Occupant load factor = 10

Total area = 9476.11 sq.m

PROVIDED

Area of one floor = 17 000 sq.ft

Total number of floors with
workstations = 6

Occupant load factor = 9

Total area = 9476.11 sq.m

Note : (1) The District Rainfall in millimeters (R/F) shown below are the arithmetic averages of Rainfall of Stations under the District.
(2) % Dep. are the Departures of rainfall from the long period averages of rainfall for the District.
(3) Blank Spaces show non-availability of Data

YEAR	JAN		FEB		MAR		APR		MAY		JUN		JUL		AUG		SEPT		OCT		NOV		DEC	
	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP
2014	32.0	67	16.5	77	41.5	235	8.0	60	48.0	700	15.0	-59	27.5	-85	25.0	-89	67.0	-47	9.0	-75	0.0	-100	9.0	67
2015	50.0	160	0.0	-100	77.0	521	55.0	1000	4.0	-33	59.0	60	144.0	-21	201.0	-12	0.0	-100	0.0	-100	0.0	-100	0.0	-100
2016	0.0	-100	0.0	-100	0.0	-100	0.0	-100	4.0	-33	4.0	-89	72.0	-60	87.0	-62	150.0	19	13.0	-64	0.0	-100	0.0	-100
2017	4.0	-79	0.0	-100	7.0	-64	0.0	-100	3.0	-50	69.0	87	28.0	-85	42.0	-82	151.1	20	0.0	-100	0.0	-100	1.0	-81
2018	5.0	-74	0.0	-100	0.0	-100	1.0	-80	0.0	-100	55.0	49	248.0	36	46.0	-80	405.0	222	0.0	-100	0.0	-100	0.0	-100

**Total volume of water area rainfall (m) *coefficient of
runoff for.me of runoff:**

ANNUAL RAINFALL IN MM = 1382

Roof Area- 2395 *0.05*0.9=124.8

Road Area 110.*0.05* 0.8 =4.4

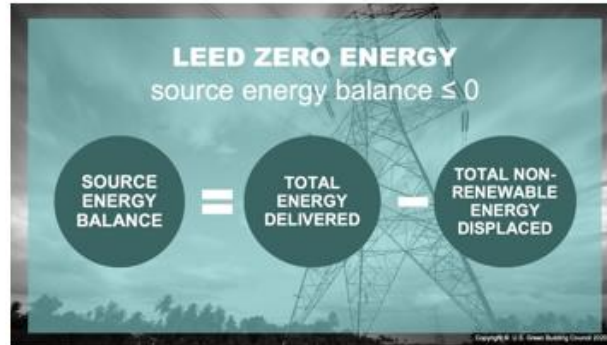
Green Area- 80.*0.05* 0.15=0.6

Total volume of rainfall runoff will be

62.8+62.8+4.4+0.6=130.6 cu.m/hour **1.30,600 liters**

Fig 9.1 Water and energy conservation of the building

LEED ZERO ENERGY ANALYSIS



LEED Zero Energy (BASE CASE)

Source Energy Balance = (Total Source Energy Delivered) – (Total Non-Renewable Source Energy Displaced)

TOTAL ELECTRICAL LOAD IN THE BUILDING = 1418 KVA
Actual annual energy consumed: = 442416kwhr electricity
Off-site wind power procured = 195431Kwhr

Energy Delivered

Energy Delivered = (442416) x 2.80

= **1238764.8 kwhr**

Non-Renewable Energy Displaced

Non-Renewable Energy Displaced = 195431 x 2.80 = **396883.2 kwhr**

Source Energy Balance

Source Energy Balance (E_{source}) = **1238764.8 kwhr** – **396883.2 kwhr** = **841881.6 kwhr**

Because $E_{\text{source}} \leq 0$, the building can achieve LEED Zero Energy certification.

LEED Zero Energy

Source Energy Balance = (Total Source Energy Delivered) – (Total Non-Renewable Source Energy Displaced)

TOTAL ELECTRICAL LOAD IN THE BUILDING = 982Kwhr
Annual energy consumed: = 306384kwhr
Off-site wind power procured = 195431Kwhr
On-site PV power procured = 225000Kwhr

Energy Delivered

Energy Delivered = (306384 – 225000) x 2.80
= 81384 x 2.80
= **227875.2 kwhr**

Non-Renewable Energy Displaced

Non-Renewable Energy Displaced = 195431 x 2.80 = **396883.2 kwhr**

Source Energy Balance

Source Energy Balance (E_{source}) = 227875.2 kwhr – 396883.2 kwhr = **-169008 kwhr**

Because $E_{\text{source}} \leq 0$, the building can achieve LEED Zero Energy certification.

LEED ZERO CARBON ANALYSIS



LEED Zero Carbon

Carbon Emitted

Co-efficient to convert electricity to GHG emission = 558.2 lbCO₂e/MWh (NEWE (NPCC New England) eGrid emissions factor) 1

Source	Annual Consumption	Calculate Carbon Emitted	Total Carbon Emitted (lbCO ₂ e/year)
Electricity	81 MWH	81 x 558.2 lbCO ₂ e/MWh	45214.2
Transportation			1,50,369
		Total Carbon Emitted	195583.2

Carbon Avoided

Source	Annual Consumption	Calculate Carbon Emitted	Total Carbon Emitted (lbCO ₂ e/year)
Off-site renewable energy	196	196 x 1,009.2 lbCO ₂ e/MWh	197764
		Total Carbon AVOIDED	197764

Carbon Balance

Carbon Balance = 195583.2 lbCO₂ e/year – 197764 lbCO₂ e/year

This project has a carbon imbalance of = -2180.8 lbCO₂ e/year

The Project achieve LEED Zero Carbon certification

ENERGY EFFICIENCY IN PLUMBING SYSTEM

Building Summary					Efficiency Savings			
	Total	Male	Female	Employee Only	Efficiency	Percent of Indoor Usage (%)	Gallons per Year	Annual Cost Savings (\$)
Toilets:	108	48	60	0	Standard	0	0	0
Urinals:	24	24	0	0	Standard	0	0	0
Sinks:	63	36	27	0	Standard	0	0	0
Showers:	0	0	0	0	Standard	0	0	0
Clothes Washers:	0	0	0	0	Standard	0	0	0
Dishwashers:	0	0	0	0	Standard	0	0	0
Cooling Towers:	0	0	0	0	Standard	0	0	0
☐ Include cooling tower blowdown in sewer costs					Total Efficiency Savings:	0%	0	0

Building Summary					Efficiency Savings			
	Total	Male	Female	Employee Only	Efficiency	Percent of Indoor Usage (%)	Gallons per Year	Annual Cost Savings (\$)
Toilets:	108	48	60	0	Low-Flow	10.6	106,827	172
Urinals:	24	24	0	0	Waterless	6.4	64,681	104
Sinks:	63	36	27	0	Hands-Free	1.1	11,296	18
Showers:	0	0	0	0	Standard	0	0	0
Clothes Washers:	0	0	0	0	Standard	0	0	0
Dishwashers:	0	0	0	0	Standard	0	0	0
Cooling Towers:	1	0	0	0	Ozone	34.5	347,736	560
☒ Include cooling tower blowdown in sewer costs					Total Efficiency Savings:	52.7%	530,539	\$854

Run-off Calculation

S.No.	Zone	Area (sq.m.)	Run-off Coefficient	Cu.m
1	Cemented Roof	2790.00	0.95	125.6
2	Vegetation	80.00	0.20	0.6
3	Hardscape (Pathways/Driveways)	110.00	0.95	4.4
Total Run-off Volume (Cu.m.)				130.60

130600 liters

AS PER NBC STANDARDS

Area of one floor = **17 000 sq.ft**
Total number of floors with workstations = **6**
Occupant load factor = **10**
Total area = **9476.11 sq.m**
Total number of occupants = **950**

PROVIDED Block -1

Area of one floor = **17 000 sq.ft**
Total number of floors with workstations = **6**
Occupant load factor = **9**
Total area=**9476.11 sq.m**
Total number of occupants = **1053**

Total number of occupants In Block 1 = 1053

Water required for Domestic purpose by 1 Person in office building =20 Liters

Total amount of water used for domestic = $1053 \times 20 = 21060$ Liters

Water used for flushing by 1 person in office building = 25 Liters

Total amount of water used for flushing = $1053 \times 25 = 26325$ Liters

Total water used = 47385 Liters

STP CALCULATION

Total number of occupants in Block 1 = 1053

water used for domestic purpose by 1 person in office building = 35 liters

Total amount of water used for domestic = $1053 \times 35 = 36855$ liters

water used for flushing purpose by 1 person in office building = 45 liters

Total amount of water used for flushing = $1053 \times 45 = 47385$ liters

Total water used = 84240 liters

INLET CAPACITY

Amount of Domestic water for recycling = 85% of 36855 liters = 31326 liters

Amount of Flushing water for recycling = 100% of 47385 liters = 47385 liters

Total=78711 liters

OUTLET CAPACITY

Amount of water got after recycling = 85% of total inlet = $78711 \times 0.85 = 66904$ liters

SUSTAINABLE SITES		26	P o i n t s
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Credit 1	LEED Certified Design and Construction	4	
Credit 2	Building Exterior and Hardscape Management Plan	1	1
Credit 3	Integrated Pest Management, Erosion Control, and Landscape Management Plan	1	1
		3	
Credit 4	Alternative Commuting Transportation	to 15	
		3	
	Reduce by 10%	4	
	Reduce by 13.75%	5	
	Reduce by 17.5%	6	
	Reduce by 21.25%	7	7
	Reduce by 25%	8	
	Reduce by 31.25%	9	
	Reduce by 37.5%	10	
	Reduce by 43.75%	11	
	Reduce by 50%	12	
	Reduce by 56.25%	13	
	Reduce by 62.5%	14	
	Reduce by 68.75%	15	
	Reduce by 75%		
Credit 5	Site Development - Protect or Restore Open Habitat	1	
Credit 6	Stormwater Quantity Control	1	1
Credit 7.1	Heat Island Reduction - Nonroof	1	1
Credit 7.2	Heat Island Reduction - Roof	1	1
Credit 8	Light Pollution Reduction	1	

WATER EFFICIENCY		14	P o i n t s
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Prereq 1	Minimum Indoor Plumbing Fixture and Fitting Efficiency	Re qui red	
Credit 1	Water Performance Measurement	1 to 2	
		1	
	Whole building metering	2	2
	Submetering	1	
Credit 2	Additional Indoor Plumbing Fixture and Fitting Efficiency	to 5	
		1	
	Reduce by 10%	2	
	Reduce by 15%	3	
	Reduce by 20%	4	4
	Reduce by 25%	5	
	Reduce by 30%		

Credit 3	Water Efficient Landscaping		1 to 5	
		Reduce by 50%	1	
		Reduce by 62.5%	2	
		Reduce by 75%	3	
		Reduce by 87.5%	4	4
		Reduce by 100%	5	
Credit 4	Cooling Tower Water Management		1 to 2	
		Chemical Management	1	
		Non-Potable Water Source Use	1	1
ENERGY & ATMOSPHERE			35	P o i n t s

Prereq 1	Energy Efficiency Best Management Practices -Planning, Documentation, and Opportunity Assessment		Re qui red
Prereq 2	Minimum Energy Efficiency Performance		Re qui red
Prereq 3	Fundamental Refrigerant Management		Re qui red
Credit 1	Optimize Energy Efficiency Performance		1 to 18
		ENERGY STAR Rating of 71 or 21st Percentile Above National Median	1
		ENERGY STAR Rating of 73 or 23rd Percentile Above National Median	2
		ENERGY STAR Rating of 74 or 24th Percentile Above National Median	3
		ENERGY STAR Rating of 75 or 25th Percentile Above National Median	4
		ENERGY STAR Rating of 76 or 26th Percentile Above National Median	5
		ENERGY STAR Rating of 77 or 27th Percentile Above National Median	6
		ENERGY STAR Rating of 78 or 28th Percentile Above National Median	7

		ENERGY STAR Rating of 79 or 29th Percentile Above National Median	8	
		ENERGY STAR Rating of 80 or 30th Percentile Above National Median	9	
		ENERGY STAR Rating of 81 or 31st Percentile Above National Median	10	
		ENERGY STAR Rating of 82 or 32nd Percentile Above National Median	11	
		ENERGY STAR Rating of 83 or 33rd Percentile Above National Median	12	12
		ENERGY STAR Rating of 85 or 35th Percentile Above National Median	13	
		ENERGY STAR Rating of 87 or 37th Percentile Above National Median	14	
		ENERGY STAR Rating of 89 or 39th Percentile Above National Median	15	
		ENERGY STAR Rating of 91 or 41st Percentile Above National Median	16	
		ENERGY STAR Rating of 93 or 43rd Percentile Above National Median	17	
		ENERGY STAR Rating of 95+ or 45th+ Percentile Above National Median	18	
Credit 2.1	Existing Building Commissioning - Investigation and Analysis		2	2
Credit 2.2	Existing Building Commissioning - Implementation		2	2
Credit 2.3	Existing Building Commissioning - Ongoing Commissioning		2	1
Credit 3.1	Performance Measurement - Building Automation System Performance		1	1
Credit 3.2	Measurement - System-Level Metering		1 to 2	
		40% Metered	1	
		80% Metered	2	2
Credit 4	On-site and Off-site Renewable Energy		1 to 6	
		3% On-site or 25% Off-site Renewable Energy	1	
		4.5% On-site or 37.5% Off-site Renewable Energy	2	
		6% On-site or 50% Off-site Renewable Energy	3	
		7.5% On-site or 62.5% Off-site Renewable Energy	4	

			9% On-site or 75% Off-site Renewable Energy	5	
			12% On-site or 100% Off-site Renewable Energy	6	6
Credit 5	Enhanced Refrigerant Management			1	
Credit 6	Emissions Reduction Reporting			1	
MATERIALS & RESOURCES				10	P o i n t s

Prereq 1	Sustainable Purchasing Policy			Re qui red	
Prereq 2	Solid Waste Management Policy			Re qui red	
Credit 1	Sustainable Purchasing - Ongoing Consumables			1	1
Credit 2	Sustainable Purchasing - Durable Goods			1	
			40% of Electric	1	1
			40% of Furniture	1	
Credit 3	Sustainable Purchasing - Facility Alterations and Additions			1	
Credit 4	Sustainable Purchasing - Reduced Mercury in Lamps			1	1
Credit 5	Sustainable Purchasing - Food			1	
Credit 6	Solid Waste Management - Waste Stream Audit			1	
Credit 7	Solid Waste Management - Ongoing Consumables			1	
Credit 8	Solid Waste Management - Durable Goods			1	1
Credit 9	Solid Waste Management - Facility Alterations and Additions			1	

INDOOR ENVIRONMENTAL QUALITY				15	P o i n t s
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Prereq 1	Minimum Indoor Air Quality Performance			Re qui red	
Prereq 2	Environmental Tobacco Smoke (ETS) Control			Re qui red	
Prereq 3	Green Cleaning Policy			Re qui red	
Credit 1.1	Indoor Air Quality Best Management Practices - Indoor Air Quality Management Program			1	1
Credit 1.2	Indoor Air Quality Best Management Practices - Outdoor Air Delivery Monitoring			1	1
Credit 1.3	Indoor Air Quality Best Management Practices - Increased Ventilation			1	1

Credit 1.4	Indoor Air Quality Best Management Practices - Reduce Particulates in Air Distribution	1	1
Credit 1.5	Indoor Air Quality Best Management Practices - Indoor Air Quality Management for Facility Alterations and Additions	1	
Credit 2.1	Occupant Comfort - Occupant Survey	1	
Credit 2.2	Controllability of Systems - Lighting	1	1
Credit 2.3	Occupant Comfort - Thermal Comfort Monitoring	1	
Credit 2.4	Daylight and Views	1	1
Credit 3.1	Green Cleaning - High-Performance Cleaning Program	1	
Credit 3.2	Green Cleaning - Custodial Effectiveness Assessment	1	
Credit 3.3	Green Cleaning - Purchase of Sustainable Cleaning Products and Materials	1	
Credit 3.4	Green Cleaning - Sustainable Cleaning Equipment	1	
Credit 3.5	Green Cleaning - Indoor Chemical and Pollutant Source Control	1	
Credit 3.6	Green Cleaning - Indoor Integrated Pest Management	1	
INNOVATION IN DESIGN		6	P o i n t s

Credit 1	Innovation in Operations	1 to 4	
		1	1
		1	
		1	
		1	1
Credit 2	LEED® Accredited Professional	1	
Credit 3	Documenting Sustainable Building Cost Impacts	1	
REGIONAL PRIORITY		4	P o i n t s

Credit 1	Regional Priority	1 to 4	
		1	1
		1	
		1	
		1	
PROJECT TOTALS		110	62

THIS PROJECT CAN ACHIEVE 62 POINTS LEED GOLD RATING

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