GREEN RETROFIT MODELLING FOR EXISTING BUILDINGS

A DISSERTATION

Submitted in partial fulfillment of the requirements for the award of the degree of

MASTER OF ARCHITECTURE

By

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JUNE, 2009

CANDIDATE'S DECLARATION

I hereby certify that this report entitled **"GREEN RETROFIT MODELLING FOR EXISTING BUILDINGS"**, which has been submitted in partial fulfillment of the requirements for the award of the degree of **MASTER OF ARCHITECTURE** , in the Department of Architecture and Planning, **INDIAN INSTITUTE OF TECHNOLOGY ROORKEE, ROORKEE** is an authentic record of my own work carried out during the period from July 2008 to June 2009, under the supervision and guidance of **Dr. P. S. CHANI** and **Dr. PUSHPLATA**, Department of Architecture and Planning, Indian Institute of Technology Roorkee, Roorkee, India.

The matter embodied in this dissertation has not been submitted by me for the award of any other degree of this or any other Institute.

Date: 29th June, 2009

Place: Roorkee

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CERTIFICATE

This is to certify that above statement made by the candidate is correct to the best of my knowledge.

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The acknowledgement will not be complete till I express my regards and thanks to my parents and brother for their blessings, encouragement and support.

Date: 30th June 2009
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ABSTRACT

Buildings as they are designed and used today, symbolize unrestrained consumption of energy and other natural resources with its consequent negative environmental impact. In India, the residential and the commercial sector consume 25% of the total electricity usage of the country and a major portion of this is utilized in buildings. Designing and developing new buildings based on sound concepts of sustainability and applying suitable retrofit options to the existing buildings could substantially improve the energy use efficiency in the building sector with an associated reduction in both local as well as global emissions. With increasing prices, diminishing reserves of the conventional forms of energy and increasing emissions 'Green Buildings' are the need of the hour.

This dissertation project 'Green Retrofit Modeling for Existing Buildings' aims to retrofit an existing building within the IIT Roorkee campus as per the LEED-EB rating system and create a model for other existing buildings as a part of an attempt to make the whole campus green. The dissertation involves study of the issues revolving around 'Green Buildings' and the study of similar projects as the dissertation. The Central Library has been studied for its site criteria, energy and water consumption, materials and resources and indoor air quality as the main project study area. The recommendations provide the retrofit solution for each of the above mentioned issues to retrofit the Library building as Green Building. The simulation model of the Library calculate the energy requirement of the building and also calculate the energy savings and reduction in Carbon emission after the implication of the recommendations provided in this dissertation project. Ultimately the retrofit solutions provided for the Library building will promote the productivity, comfort and well being off the library users.

The ever rising energy consumption by the existing buildings and the tones of carbon emitted is an increasing threat. On the brighter side, the 'Green Retrofit Measures' can reduce this threat. As a solution to our problems caused by depleting resources and emissions it is absolutely pertinent that all the future buildings and most of the existing buildings should be designed and retrofitted to function as 'Green Buildings'.

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CHAPTER 1

INTRODUCTION

1.1 IDENTIFICATION OF THE PROBLEM:

World over, Today the major thrust and focus is on constructing environment friendly buildings. The concept is slowly spreading across various other countries around the globe, including India.

- Construction sector is growing at 13% and real estate at the rate of 30% (Source : CII Green Buildings)

- Potential of energy saving in domestic / commercial building sector is estimated at 20% (Source: BEE, Govt. of India)

- Existing buildings have Higher energy consumption than new buildings

- The potential for savings in buildings is very large:
  50 % is feasible in existing buildings already today
  = reduction of total energy consumption on 20 % rate (Source: TERI and BEE, Govt. of India)

- Water - another vital resource for the occupants, which gets consumed continuously during building construction and operation

- Several building processes and occupant functions generate large amounts of waste

Thus there is need to design and develop the new buildings on sound concepts of sustainable efficient use of energy and also apply suitable retrofit options to existing buildings that could substantially improve the energy efficiency.

The **aim** of this thesis project is to retrofit an Existing Building as a Green Building as per LEED-EB Rating System.

1.2 INTRODUCTION TO GREEN BUILDINGS:

Green building is the practice of increasing the efficiency with which buildings use resources — energy, water, and materials — while reducing building impacts on human health and the environment during the building's lifecycle, through better siting, design, construction, operation, maintenance, and removal.

A green building is the one that makes the greatest possible use of natural light and air and least possible utilization of energy and water. It uses industrial byproducts, emphasizes on recycling of waste water, harvesting of rain water, least use of air-conditioning, less production of carbon dioxide and tries to safeguard the environment in every possible way. Making a building green begins at the planning stage. Secondly, safety is paramount in case of a green building.

The appearance of a Green Building will be similar to any other building. However, the difference is in the approach, which revolves round a concern for extending the life span of natural resources; provide human comfort, safety and productivity. This approach results in reduction in operating costs like energy and water, besides several intangible benefits.

1.2.1 SALIENT FEATURES OF GREEN BUILDINGS:

- Minimal disturbance to landscapes and site condition
- Use of Recycled and Environmental Friendly Building Materials

- Use of Non-Toxic and recycled/recyclable Materials
- Efficient use of Water and Water Recycling
- Use of Energy Efficient and Eco-Friendly Equipment
- Use of Renewable Energy
- Indoor Air Quality for Human Safety and Comfort
- Effective Controls and Building Management Systems

1.2.2 TYPICAL FEATURES OF GREEN BUILDINGS:

Sustainable sites

Measures to prevent soil erosion

Rainwater harvesting

Landscapes to reduce heat by islands

Water efficiency

25 to 30 per cent reduction in usage of portable water

100 per cent recycling of waste water

Water efficient landscaping

Energy and atmosphere

Use of world class energy efficient practices

30 per cent reduction in energy over normal buildings

Use of on-site renewable energy

1.2.3 BENEFITS OF GREEN BUILDINGS:

Operational Savings:

Green buildings consume at least 40-50 % less energy and 20-30 % less water vis-à-vis a conventional building. This comes at an incremental cost of about 5-8 %. The incremental cost gets paid back in 3-5 years time.

Daylights & Views:

Working in environment with access to daylight and views provides connection to the exterior environment. This has a soothing effect on the mind. Various studies prove that the productivity of people who have access to day lighting and views is at least 12-15 % higher.

Air Quality:

Green buildings are always fresh and healthy. Every green building will have to purge continuous fresh air. The green buildings use interior materials with low volatile organic compound (VOC) emissions. A typical office building would require purging of fresh air of about 15 cfm/person which provides a fresh ambience inside the building.

(source – USGBC document)

1.2.4 GREEN BUILDING VS CONVENTIONAL BUILDINGS:

The benefits:

Externally, a Green Building and a conventional building look alike. In terms of functionality too, a Green Building is as much functional as a normal building. However the difference is in the benefits that a green building can provide.

Tangible benefits:

- A Green Building consumes 30-40% less water than a conventional building
- Energy consumption lesser by 40-50%
- Enhanced productivity of occupants, 10-15% more than a conventional building Reduction in initial investments on equipment and systems

Intangible Benefits:

- Green corporate image
- Health and safety of occupants
- Enhanced occupant comfort
- Imbibe best operational practices from day one
- Incremental cost of constructing a Green building gets paid back in 3-5 years.

(source – USGBC document)

1.2.5 NEED FOR GREEN BUILDINGS:

World over, today the major thrust and Focus is on constructing environment friendly buildings. The concept is slowly spreading across various other countries across the globe, including India.

Construction Industry in India is growing at a stunning 30 %. If this growth is to be sustainable, adoption of energy efficient housing sector is a necessity. This would go a long way in addressing the national priorities of water conservation and energy efficiency.

Boom in Real Estate in our Energy starving country is again imposing high power and energy requirements threats, to over come this threat we need to design energy efficient buildings, selection and use of energy efficient equipments to be installed inside the building as Major chunk of power is shared by high rise commercial complexes, institutional buildings and malls which are flourishing all around now a days.

Power Scenario:

The present power scenario of the country shows a total energy shortage of roughly 8% of the total demand and the peak shortage is about 13% of the peak demand. The peak shortage normally occurs at a time when the residential and commercial sector consumes the maximum power.

The Need:

- The gross built-up area added to commercial and residential spaces is increasing @ 10% annually.
- Energy demand increasing 25% of total electricity consumption is in residential/commercial sector)
- Projected annual increase in energy demand is 5.4 billion kWh in residential and commercial buildings
- Domestic water consumption is 30 billion m3and projected increase to 111 billion m3by 2050
- Construction and building wastes pose serious environmental threat

(source – IGBC document)

Need for Energy Saving in Buildings:

The residential and commercial sector consumes more than 25% of the total electrical supply usage of the country and major portion of this is utilized in the buildings. Hence saving in energy is building is an important strategy to combat the problem of energy crisis in the country.

The present day buildings that are designed and used, symbolize un-restrained consumption of energy, be it a five start hotel, commercial establishment, Govt buildings or a residence complex. Thus there is need to design and develop the new buildings on sound concepts of sustainable efficient use of energy and also apply suitable retrofit options to existing buildings that could substantially improve the energy efficiency.

1.3 LEED RATING SYSTEMS:

The Leadership in Energy and Environmental Design (LEED) Green Building Rating System™ encourages and accelerates global adoption of sustainable green building and development practices through the creation and implementation of universally understood and accepted tools and performance criteria.

LEED is a third-party certification program and the nationally accepted benchmark for the design, construction and operation of high performance green buildings. LEED gives building owners and operators the tools they need to have an immediate and measurable impact on their buildings' performance. LEED promotes a whole-building approach to sustainability by recognizing performance in five key areas of human and environmental health: sustainable site development, water savings, energy efficiency, materials selection and indoor environmental quality.

Buildings fundamentally impact people's lives and the health of the planet. Since the LEED Green Building Rating System for New Construction was first published in 1999, it has been helping professionals across the country to improve the quality of buildings and their environmental impact.

As the green building sector grows exponentially, more and more building professionals, owners, and operators are seeing the benefits of green building and LEED certification. Green design not only makes a positive impact on public health and the environment, it also reduces operating costs, enhances building and organizational marketability, potentially increases occupant productivity, and helps create a sustainable community.

LEED fits into this market by providing rating systems that are voluntary, consensus-based, market-driven, based on accepted energy and environmental principles, and they strike a balance between established practices and emerging concepts.

The LEED rating systems are developed by USGBC committees, in adherence with USGBC policies and procedures guiding the development and maintenance of rating systems. LEED-EB is one of a growing portfolio of rating system products serving specific market sectors.

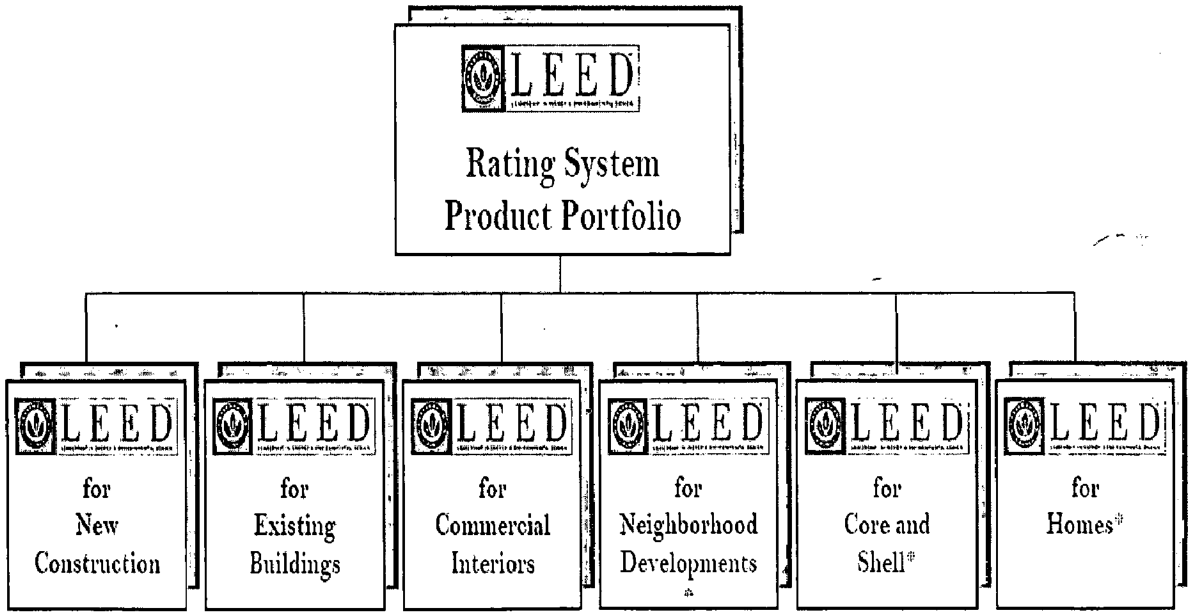

***Fig 1.1:** LEED rating systems for different market sectors.*

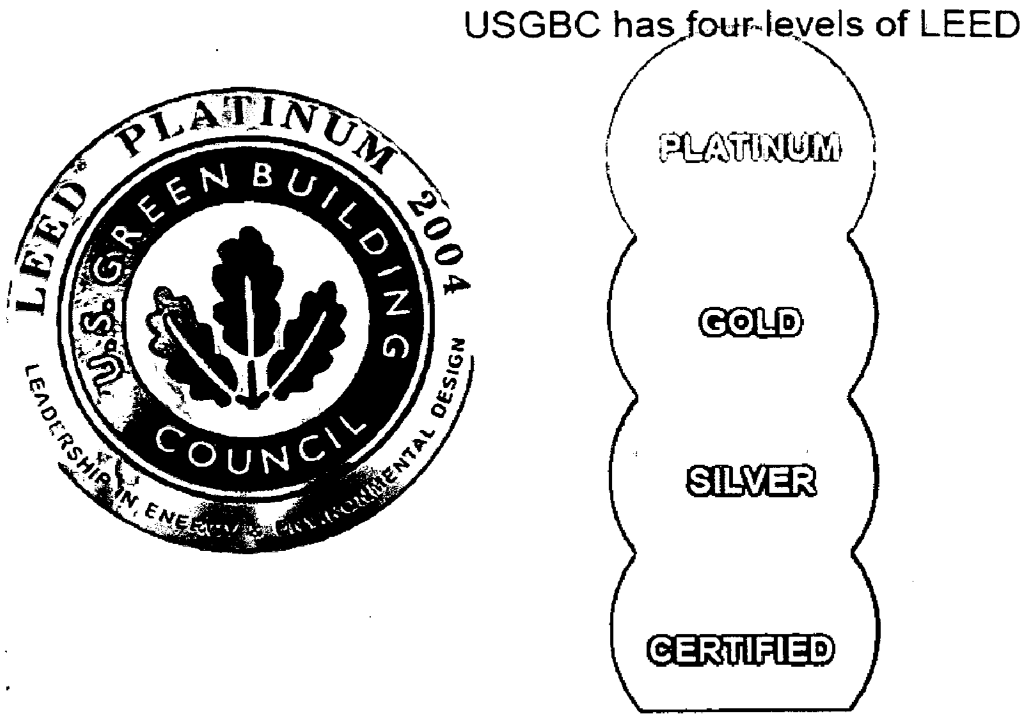

Fig 1.2: Levels of LEED Ratings

1.3.1 LEED FOR EXISTING BUILDINGS (LEED-EB):

The LEED for Existing Buildings Rating System helps building owners and operators measure operations, improvements and maintenance on a consistent scale, with the goal of maximizing operational efficiency while minimizing environmental impacts. LEED for Existing Buildings addresses whole-building cleaning and maintenance issues (including chemical use), recycling programs, exterior maintenance programs, and systems upgrades. It can be applied both to existing buildings seeking LEED certification for the first time and to projects previously certified under LEED for New Construction, Schools, or Core & Shell.

The LEED for Existing Buildings (LEED-EB) green building rating system is specifically designed for retrofit and upgrade projects. LEED-EB provides a recognized, performance-based benchmark for owners and operators to consistently measure operations, facility improvements and maintenance.

Although LEED-EB has not yet been widely adopted in the marketplace, buildings certified under the LEED-NC system can only hold that status for five years - after that they must use the LEED-EB standards to maintain their certification.

Table 1.1: *LEED-EB credit point distribution*

LEED-EB credit category	**Total points**	**% of points**
Sustainable sites	14	16%
Water efficiency	5	6%
Energy and atmosphere	23	27%
Material and resources	16	19%
Indoor environmental quality	22	26%
Innovation and design process	5	6%
TOTAL POINTS	85	100%

(Source: Green Building Rating System for Existing Buildings- LEED-EB)

Table 1.2: *Certification level point requirement*

Certification level points required	
LEED Certified	32 – 39
LEED Silver	40 – 47
LEED Gold	48 – 63
LEED Platinum	64 - 85

(Source: Green Building Rating System for Existing Buildings- LEED-EB)

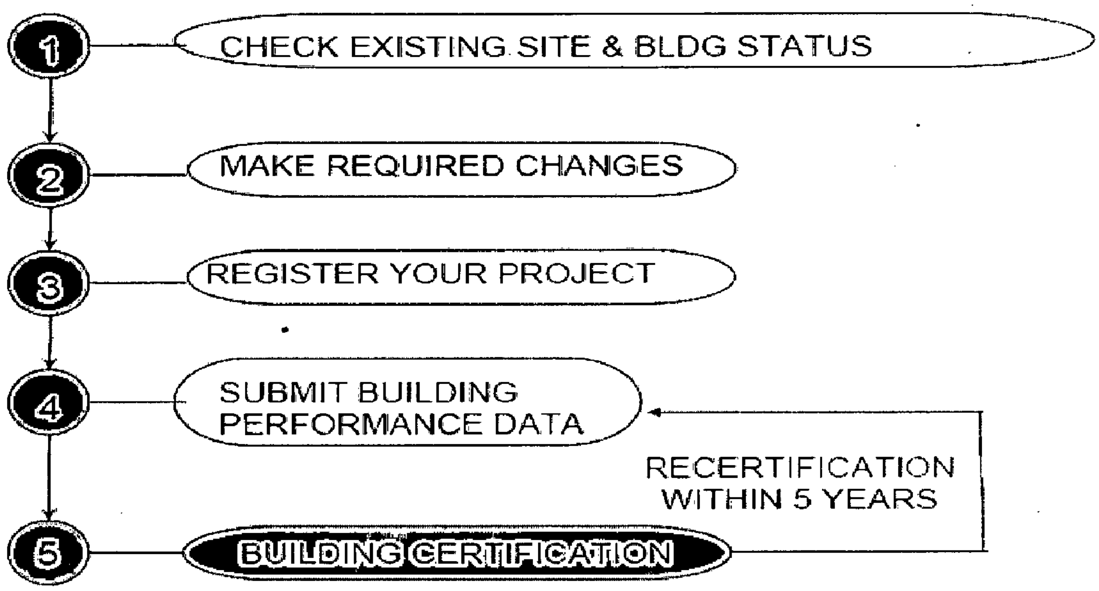

Fig 1.3: *Steps for LEED-EB Certification*

1.4 OBJECTIVES:

- To study Green Building Rating System for Existing Buildings (LEED-EB)
- To study Green Retrofit in Existing Buildings.
- To carry out energy simulation auditing on identified Existing Buildings.
- To develop a Pilot Retrofit Model for the Existing Building on the basis of LEED-EB guidelines.
- To carry out auditing for the Pilot Retrofit Model with respect to energy consumption, water consumption and the quality of indoor environment.

1.5 SCOPE:

This project is limited to the IIT Roorkee campus. The scope of the project is to develop a Pilot Retrofit Model which will be a baseline for Green Retrofitting of all the Existing Buildings within the campus in an effort to make the campus Green.

BUILDING FOR STUDY:

Central Library, IIT Roorkee.
(compact planning and centrally air conditioned building)

1.6 METHODOLOGY:

- **Literature study:**
  Data collection from -
  ·Books
  Journals
  Internet
  And other source

- Carry out literature case studies on Green Retrofitted Existing Buildings.

- Analyze the literature study and case studies and draw inferences.

- Carry out energy simulation auditing on the identified Existing Buildings.

- Prepare energy performance report.

- Propose Update for building systems and make energy efficient changes with reference to inferences drawn case studies to develop a Pilot Retrofit Model as per the LEED-EB guidelines.

- Carry out simulation auditing on the Pilot Retrofit Model to observe its performance.

1.7 LITERATURE CASE STUDIES:

1. Two relevant literature case studies on LEED-EB Certified Buildings from western countries.

2. Energy Auditing Reports for
   Shram Shakti Bhawan and Transport Bhawan, Delhi

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CHAPTER 2

CASE STUDIES

2.1 LEED-EB GUIDELINES:

The LEED-EB Rating System addresses operations, maintenance and systems retrofit. It is the only LEED rating system that projects can use after the design and construction phases, for ongoing certification of building performance.

LEED-EB provides guidelines for following points:

- Sustainable site
- Water efficiency
- Energy and atmosphere
- Material and resources
- Indoor environment quality

2.1.1 SUSTAINABLE SITE:

Table 2.1: *Credit criteria for sustainable sites*

Credit criteria	Intend
1. Erosion and Sedimentation Control	Control erosion to reduce negative impacts on water and air quality.
2. Age of Building	Provide a distinction between buildings that are eligible to apply for LEED-NC and LEED-EB certification.
3. Plan for Green Site and Building Exterior Management	Encourage site management practices that have the lowest environmental impact and preserve ecological integrity, enhance diversity and protect wildlife.

4. High Development Density Building and Area	Channel development to urban areas with existing infrastructure, protect green fields and preserve habitat and natural resources.
5. Alternative Transportation: • Public Transportation Access • Bicycle Storage & Changing Rooms • Alternative Fuel Vehicles • Car Pooling and Telecommuting	Reduce pollution and land development impacts from single-occupancy vehicle use.
6. Reduced Site Disturbance	Conserve existing natural areas and restore damaged areas to provide habitat and promote biodiversity.
7. Stormwater Management: Rate and Quantity Reduction	Limit disruption and pollution of natural water flows by managing stormwater runoff.
8. Heat Island Reduction	Reduce heat islands to minimize impact on microclimate and human and wildlife habitat.

(Source: Green Building Rating System for Existing Buildings- LEED-EB)

2.1.2 WATER EFFICIENCY:

Table 2.2: Credit criteria for water efficiency

Credit criteria	Intend
1. Minimum Water Efficiency	Maximize fixture water efficiency within buildings to reduce the burden on potable water supply and wastewater systems.
2. Discharge Water Compliance	Protect natural habitat, waterways and water supply from pollutants carried by building discharge water.
3. Water Efficient Landscaping	Limit or eliminate the use of potable water for landscape irrigation.
4. Innovative Wastewater Technologies	Reduce generation of wastewater and potable water demand, while increasing the local aquifer recharge.
5. Water Use Reduction	Maximize fixture water efficiency within buildings to reduce the burden on potable water supply and wastewater systems.

(Source: Green Building Rating System for Existing Buildings- LEED-EB)

2.1.3 ENERGY AND ENVIRONMENT:

Table 2.3: *Credit criteria for energy and environment*

Credit criteria	Intend
1. Existing Building Commissioning	Verify that fundamental building systems and assemblies are performing as intended to meet current needs and sustainability requirements.
2. Minimum Energy Performance	Establish the minimum level of energy efficiency for the building and systems.
4. Optimize Energy Performance	Achieve increasing levels of energy performance above the standard to reduce environmental impacts associated with excessive energy use.
5. On-Site and Off-Site Renewable Energy	Encourage and recognize increasing levels of on-site and off-site renewable energy in order to reduce environmental impacts.
6. Building Operations and Maintenance	Support appropriate operations and maintenance of buildings and building systems so that they continue to deliver target building performance goals over the long term.
7. Performance Measurement	Demonstrate the ongoing accountability and optimization of building energy and water consumption performance over time.

8. Documenting Sustainable Building Cost Impacts	Document sustainable building cost impacts.

(Source: Green Building Rating System for Existing Buildings- LEED-EB)

2.1.4 Material and Resources:

Table 2.4: *Credit criteria for materials and resources*

Credit criteria	**Intend**
1. Source Reduction and Waste Management	Establish minimum source reduction and recycling program elements and quantify current waste stream production volume.
2. Toxic Material Source Reduction	Establish and maintain a toxic material source reduction program to reduce the amount of mercury brought into buildings through purchases of light bulbs.
3. Construction, Demolition and Renovation Waste Management	Divert construction, demolition and land-clearing debris from landfill and incineration disposal. Redirect recyclable recovered resources and reusable materials to appropriate sites.
4. Optimize Use of Alternative Materials	Reduce the environmental impacts of the materials acquired for use in the operations and maintenance of buildings and in the upgrading of building services.

5. Optimize Use of IAQ Compliant Products	Reduce IAQ impacts of the materials acquired for use in the operations and maintenance of buildings and in the upgrading of building services.
6. Sustainable Cleaning Products and Materials	Reduce the environmental impacts of cleaning products, disposable janitorial paper products and trash bags.
7. Occupant Recycling	Facilitate the reduction of waste and toxins generated by building occupants and building operations that is hauled to and disposed of in landfills.

(Source: Green Building Rating System for Existing Buildings- LEED-EB)

2.1.5 INDOOR AIR QUALITY:

Table 2.5: *Credit criteria for indoor air quality*

Credit criteria	**Intend**
1. Outside Air Introduction and Exhaust Systems	Establish IAQ performance to enhance indoor air quality in buildings, thus contributing to the health and well-being of the occupants.
2. Environmental Tobacco Smoke (ETS) Control	Prevent or minimize exposure of building occupants, indoor surfaces and systems to Environmental Tobacco Smoke (ETS).
3. Asbestos Removal or Encapsulation	Reduce the potential exposure of building occupants to asbestos and prevent

	associated harmful effects of asbestos in existing buildings.
4. Outdoor Air Delivery Monitoring	Provide capacity for ventilation system monitoring to help sustain long-term occupant comfort and wellbeing.
5. Increased Ventilation	Provide additional outdoor air ventilation to improve indoor air quality for improved occupant comfort, wellbeing and productivity.
6. Construction IAQ Management Plan	Prevent indoor air quality problems resulting from any construction/renovation projects in order to help sustain the comfort and well-being of construction workers and building occupants.
7. Indoor Chemical and Pollutant Source Control	Reduce exposure of building occupants and maintenance personnel to potentially hazardous particle
8. Controllability of Systems	Provide a high level of temperature, ventilation and lighting control by individual occupants or specific groups in multi-occupant spaces

(Source: Green Building Rating System for Existing Buildings- LEED-EB)

2.2 CASE STUDY 1

JOHNSONDIVERSEY'S GLOBAL HEADQUARTERS

2.2.1 INTRODUCTION:

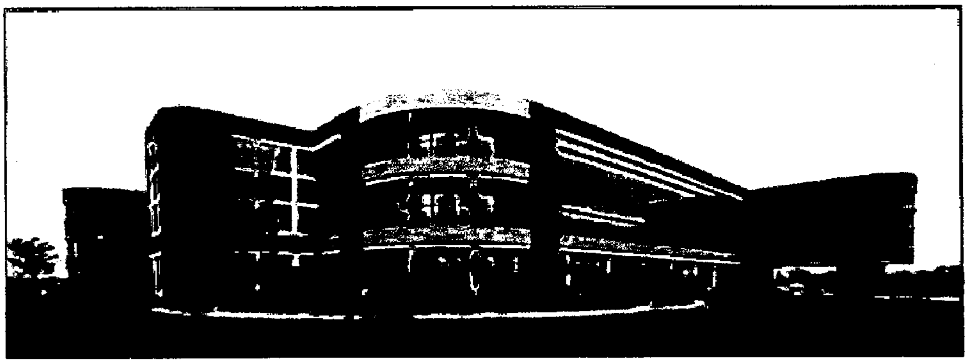


Fig 2.1: *View of JohnsonDiversey Headquarters*

JohnsonDiversey is a privately held, family-managed company that produces commercial cleaning and hygiene products. Founded in 1886 by Samuel Curtis Johnson, the company was initially in the business of installing wood parquet flooring. In response to customers' questions about caring for their new wood floors, Samuel Johnson's company developed Johnson's Wax. The company continued to expand and now produces a number of household products. It operates in 60 countries around the world.

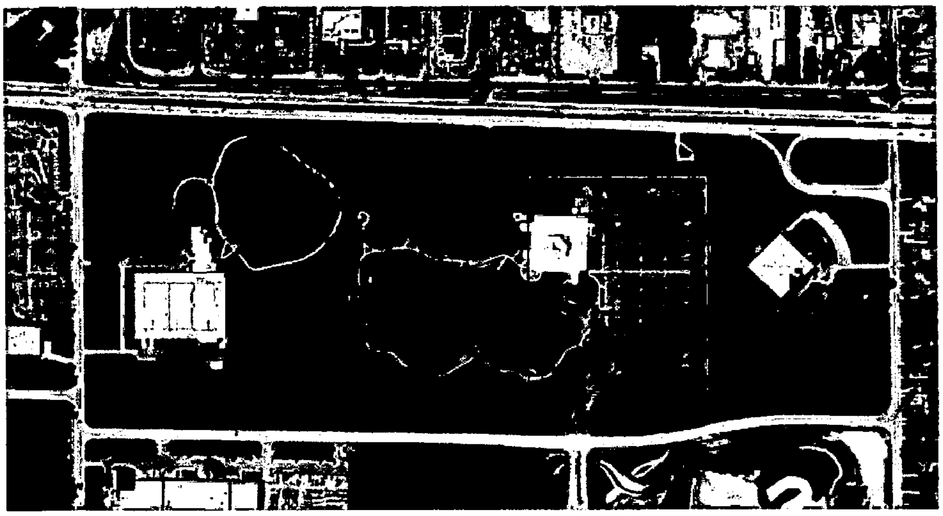


Fig 2.2:
Site image of the JohnsonDiversey

LEED-EB Certified Building:

JohnsonDiversey's global headquarters, located in Sturtevant, Wisconsin, is a three story mixed-use facility constructed in 1997. The building floor area is 277,440 square feet, of which 70% is office space and 30% is research laboratories. The building was designed based on green-building principles, including high-energy efficiency, extensive use of natural lighting, and individual control of workspace environments. Because it was built with sustainability in mind, applying LEED-EB to the building was primarily a matter of fine-tuning the building's operations practices and improving the documentation of existing sustainable practices. The JohnsonDiversey Global Headquarters was certified LEED-EB Gold in March, 2004.

2.2.2 SUSTAINABLE SITES

Erosion & Sedimentation Control:

JohnsonDiversey has adopted a site sedimentation and erosion control plan that confirms to best management practices in the EPA's Storm Water Management for Construction Activities. As part of their efforts to prevent soil loss from the site caused by storm water runoff and/or wind erosion during landscaping or building improvements, JohnsonDiversey has committed to adherence to the policy for all construction projects in the building and on the site.

The plan summarizes the critical elements necessary to effectively minimize erosion during building site projects. These elements include specifications for strategies, materials, work plans, and inspections of the site. The plan includes extensive details on each item that is to be employed, designating the specific materials, sizes, types, etc.

Plan for Green Site and Building Exterior Management:

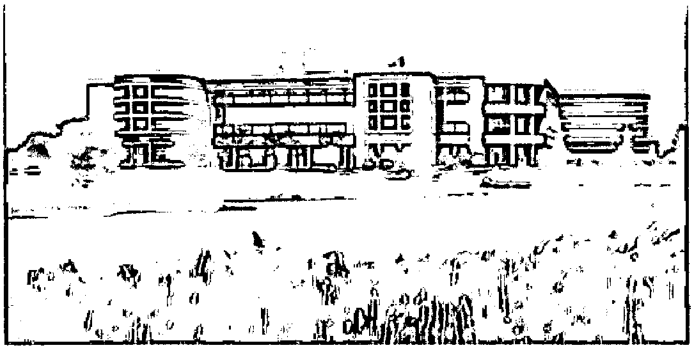


Fig 2.3: Vegetation ground and pond-JohnsonDiversey headquarters

JohnsonDiversey's facility has maintained a significant amount of open space, vegetation ground, native ground, and adapted ground cover that provides viable habitats for local wildlife. Ponds and wetlands totally 15 acres provide habitat for a variety of waterfowl and marine life. The health and growth of the prairie grasses, wild flowers, and native landscape on the site, are monitored regularly. In addition, JohnsonDiversey has developed and adopted a low impact site and building exterior chemical/fertilizer/pest management program in summer and low impact snow removal and management program in winter.

Alternative Transportation - Bicycle Storage & Changing Rooms:

Fig 2.4: Cycle parking facility-JohnsonDiversey headquarters

JohnsonDiversey maintains facilities to securely house at least 30 bicycles in 3 racks located at ground level of the West Side of the 655-person facility. Convenient changing and shower facilities are located nearby and next to the fitness center for cyclists' use. Monthly checks of the number of building occupants and quarterly checks of the facilities are conducted and documented to verify that the bike securing apparatus and changing and shower facilities are sufficient to serve at least 5% of the buildings' occupants.

Alternative Transportation - Alternative Fuel Vehicles:

JohnsonDiversey's parking facility has a total vehicle capacity of 580 cars. JohnsonDiversey provides up to 58 spaces of preferred parking for hybrid or alternative vehicles, accounting for 10% of total vehicle parking capacity. Monthly checks are conducted and documented to verify that the hybrid and alternative fuel vehicle preferred parking represents at least 10% of the parking capacity.

Fig 2.5: Hybrid fuel pumps- JohnsonDiversey headquarters

Reduced Site Disturbance - Protect or Restore Open Space:

Building 200 is located on a rural site measuring 2,501,943 ft2. Total vegetated area of the site including turf grass, prairie grass, and ponds equals 2,081,688 sq. ft. or 93% of the total open space. If ponds are excluded from this calculation, total vegetated area equals 1,732,022 sq. ft. or 77% of total open space. A minimum assessment along with improvement recommendations is to be provided annually.

Stormwater Management - Rate and Quantity Reduction:

JohnsonDiversey has a storm water management program currently in place at the Building 200 site, where 34% of the site defined as impervious area. Detention ponds collect 100% of storm water runoff from the site, as well as runoff from neighboring sites and roadways. The ponds and surrounding wetlands provide sediment, pollution and flood control.

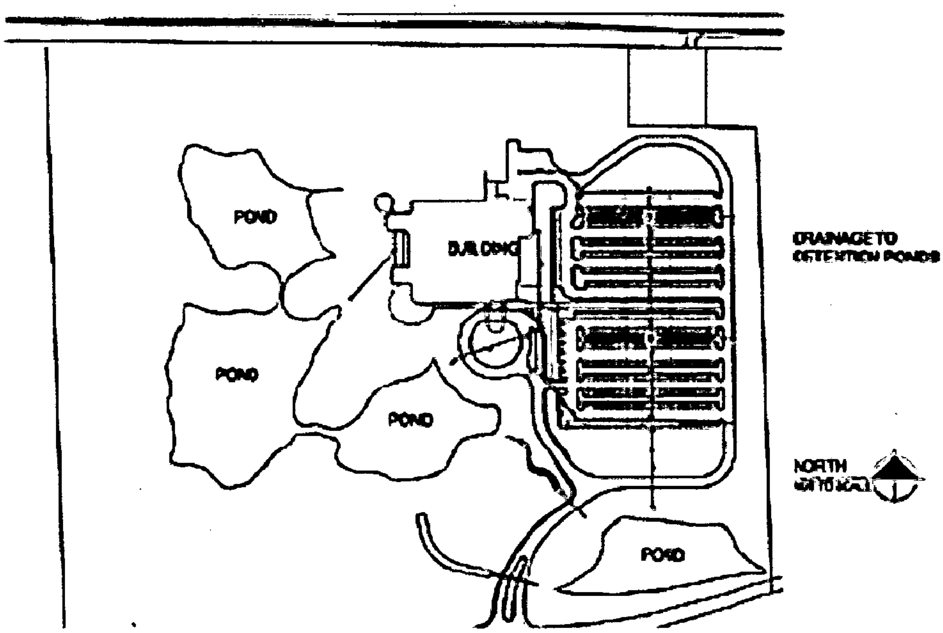


Fig 2.6: Strom water management plan- JohnsonDiversey headquarters

2.2.3 WATER EICIENCY

Minimum Water Efficiency:

JohnsonDiversey maintains a water use fixture performance baseline that is 32% below the usage that would result from outfitting 90% of the total building fixture count with plumbing fixtures that meet the EPA Policy act of 1992 (EPACT92) fixture performance requirements. JohnsonDiversey has completed the conversion from 2.5 gpm to 0.5 gpm by installing aerators in all lavatory faucet fixtures and has completed the conversion from 2.5 gpm to 1.8 gpm by installing aerators in all shower facilities. The toilets and urinals have replacement Sloan Valve Co. valve diaphragms rated at 1.6 gpf for toilets and .5 gpf for urinals.

Water Efficient Landscaping:

The irrigation system serving the JohnsonDiversey building operates solely on captured rain and runoff from surrounding areas, using no potable water in any application. The current system used for irrigation of the grounds pumps irrigation water from the detention pond, which is supplied by captured rain and storm water runoff. The sprinkler system is automated with a timer, which can be enabled or disabled based on a moisture content analyzer reading for ground soil moisture content.

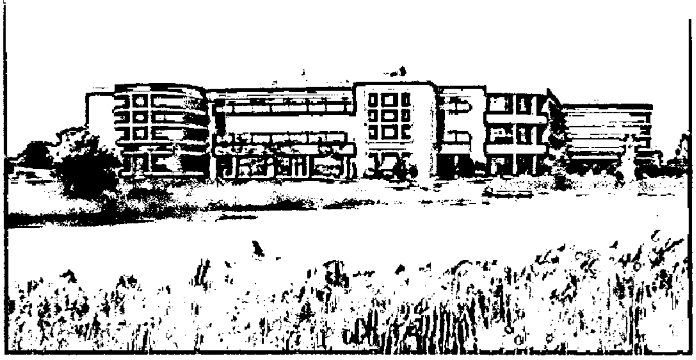


Fig 2.7: *Detention pond- JohnsonDiversey headquarters*

Water Use Reduction:

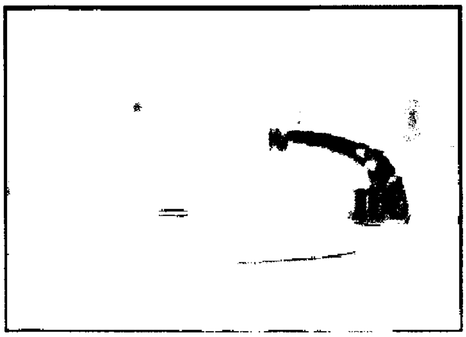


Fig 2.8: *Water efficient lavatory faucet fixtures- JohnsonDiversey headquarters*

JohnsonDiversey has achieved water use performance that is 32% below the baseline standards as designated by LEED-EB by installing aerators in all lavatory faucet fixtures and shower fixtures and Sloan Valve Company valve diaphragms in toilets and urinals. JohnsonDiversey's total actual annual meter usage for 2002 was 21,032,264 gallons. The actual plumbing fixture load (1,641,900 gallons) was calculated by subtracting the process loads, the irrigation load, and the cooling tower from the meter use, and represents a reduction from a baseline of 32%.

2.2.4 ENERGY AND ATMOSPHERE

Existing Building Commissioning:

The JohnsonDiversey Global Headquarters building has a comprehensive building operation plan that includes constant monitoring and scheduled inspections of the heating system, cooling system, humidity control system, lighting system, safety systems, water system, and building automation system. The operational plan consists of written operating procedures for the building systems and equipment, programmed logic that operates and monitors the building and safety systems, and the Measurement and Verification plan for monitoring and ensuring the performance of energy and water systems in the building.

JohnsonDiversey maintains written versions of maintenance procedures and employs a preventive maintenance schedule with a computerized maintenance management system. This system also generates work orders for maintenance and serves as a tracking system to ensure that the work is completed as mandated. The preventive maintenance programs act as a retro-commissioning plan and program and the Facility Project Manager is the commissioning authority on site.

Minimum Energy Performance:

The entire building was built to meet or exceed all applicable codes, with high efficiency ratings on the lighting and building envelope systems. Beyond these initial measures, JohnsonDiversey has enhanced the energy efficiency of the lab's mechanical systems. These measures include a heat wheel with latent and sensible energy recovery, Variable Air Volume (VAV) control for the supply fans in labs, and a common ducted exhaust system that stages and modulates six exhaust fans as required by the lab activities.

Ozone Protection:

JohnsonDiversey has zero use of CFC-based refrigerants in HVAC&R base building systems.

Building Operation & Maintenance: Building Systems Maintenance:

The building has an on-site facility engineering staff of 2 electricians and 2 HVAC technicians and as many as 45 different contractors that are dedicated to the continuous commissioning, maintenance, efficient and safe operation of the facility. JohnsonDiversey has in place planned service contracts to maintain major equipment and complex systems such as chillers, boilers, building automation controls, etc. Routine inspections of the building and the equipment are used to determine maintenance repair requirements. This system provides a scheduled preventive maintenance program that ensures that all of the building systems and equipment are functioning properly and catalogs inspections of the equipment in the system.

Continuous Existing Building Commissioning and Maintenance: IEQ Monitoring in LEED-EB Pilot Draft:

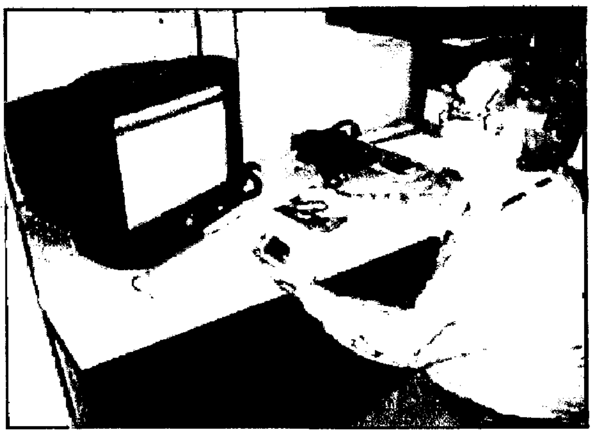


***Fig 2.9**: Monitoring system-JohnsonDiversey headquarters*

JohnsonDiversey uses Johnson Controls, a computerized building automation system, to monitor and control all building HVAC equipment. The automation system includes controls and sensors for the heating, cooling, humidity control, lighting, and safety systems. These points are continuously monitored, and alarm parameters have been established to indicate when conditions are beyond their normal operating limits. Trend and tantalization logs are used to determine when equipment is in need of adjustment or repair and to keep operating conditions at their peak.

Performance Measurement: Enhanced Metering:

JohnsonDiversey, Inc. Global Headquarters employs a building automation system that monitors and measures building electric use, cooling tower water use, air distribution static pressures and ventilation air volumes, chiller efficiency, cooling load, variable frequency drives operation, and with recently installed CO2 sensors, the CO2 levels within the building.

2.2.5 MATERIAL AND RESOURCES

Source Reduction and Waste Management -Waste Stream Audit:

JohnsonDiversey has established an extensive waste management program that integrates employee awareness, waste management staff involvement, and building interior design/redesign to promote and facilitate recycling.

Waste Audit Results (Annual Waste Generation)

Waste - Landfill	
Garbage	208,000 lbs.
Waste - Recycled	
Cardboard	74,800 lbs
Paper	116,480 lbs
Commingle	5,200 lbs
Total Waste Stream	**404,480 lbs**
Total Recycled	**196,480 lbs**
% Recycled	**49%**

Source Reduction and Waste Management - Storage & Collection of Recyclables:

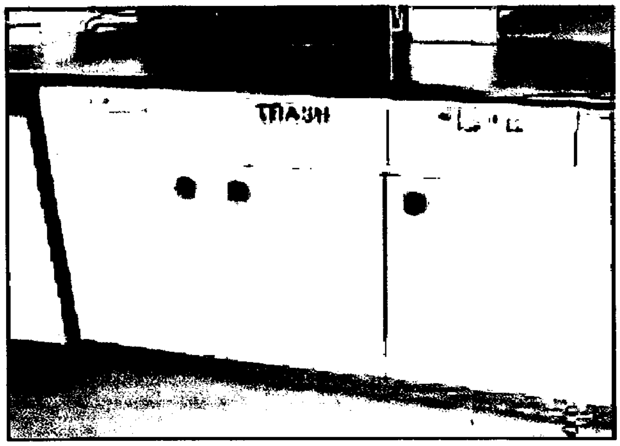


***Fig 2.10:** Storage and collection of recyclables- JohnsonDiversey headquarters*

JohnsonDiversey has developed recycling information and instructional forms for employees. The recycling policy lists the materials to be recycled by employees in the Headquarters building. A recycling card was created and distributed to all employees in the building. This card provides information on what to recycle, what not to recycle, where to take recyclables, and whom to contact with questions. There are 24 recycling areas for recycling commingles (cans, glass, and plastic) and paper located throughout the facility. The custodial staff collects the recycled items from all 24 recycling areas and places it all in larger main recycling bins in a loading dock area. There is a paper recycling bin in every workstation in the facility.

Construction, Demolition and Renovation Waste Management:

JohnsonDiversey has adopted a construction waste management policy that requires that staff or contractors recycle and/or salvage at least 30% (by weight) of any construction, demolition and land clearing waste (if applicable). This policy is considered to be in effect for all construction projects within the building.

Optimize Use of Alternative Materials:

JohnsonDiversey has established and adopted purchasing policies that target the use of alternative materials. For all construction projects within the building where materials needs could be met with alternative materials, JohnsonDiversey has specified the percentage of the total materials that must be met by alternative materials. The policies cover salvaged materials use, recycled content, local/regional materials, and certified wood. These policies are adhered to on all construction projects.

2.2.6 INDOOR AIR QUALITY IMPROVEMENT

Environmental Tobacco Smoke (ETS) Control:

JohnsonDiversey maintains a designated smoking room in the facility that has exhaust ventilation dedicated to serving only the smoking room and labs. The system is supplied with 100% outside air, and there is no recirculation. There is a minimum of 1600 cubic feet per minute of exhaust from the smoking room, resulting in 48 air changes per hour.

Outdoor Air Delivery Monitoring:

JohnsonDiversey has included the installation of CO2 sensors in the mixed air plenums at all major air handling systems, as well as in select occupied spaces in the buildings. The occupied spaces monitored are representative of areas in the building that may experience fresh air delivery or ventilation mixing difficulties during certain occupancy patterns and/or periods of the year. The CO2 sensors are tied into the building automation system and have initially been set at 530 ppm above ambient. When sensors exceed the allowable set point, the building automation systems alarm alerts building operators so that they can address the conditions.

Increased Ventilation:

The JohnsonDiversey Global Headquarters was designed with an under-floor HV.AC system that supplies ventilation air to the employee's desk surface. This is accomplished with a Module that takes supply air from the raised floor space and moves it to the work surface for maximum benefit to the employee.

Indoor Chemical and Pollutant Source Control: Isolation of High Volume Copying/Print Rooms/Fax Stations:

High volume copying, print rooms and fax stations are required to have special ventilation system features to mitigate the risks that chemicals or other agents from those areas might contaminate the ventilation and supply air distribution system. JohnsonDiversey facilities have a dedicated exhaust air management system for venting high volume copying, print rooms and fax stations.

Controllability of Systems: Lighting, Temperature & Ventilation:

Personal environment modules (PEMs) are installed in 93% of the total building office areas. These modules provide individual control of temperature, air flow, lighting, and acoustics at each workstation.

Thermal Comfort- Compliance:

The JohnsonDiversey Global Headquarters building is equipped with temperature and humidity sensors in the discharge air plenums at all major air handling systems as well as in select occupied spaces in the building. The occupied spaces monitored are representative of areas in the building that may experience temperature and/or humidity difficulties during certain occupancy patterns and/or periods of the year. The temperature and humidity sensors are tied into the building automation system, are monitored constantly, and compared to pre-determined set points. When sensors exceed the allowable set point, the building automation system alarm alerts building operators so that they can address the conditions.

Daylighting & Views: Daylighting:

The JohnsonDiversey Global Headquarters building was designed to provide a connection between indoor occupied spaces and the outdoor environment through the introduction of indirect and direct sunlight. The building uses south and west exposure window walls for the open office area along with light shelves to enable the natural light to penetrate deeper into the space. There is also a central atrium with a skylight and light scopes that provide natural light to the inner portions of the open office area.

Daylighting & Views:

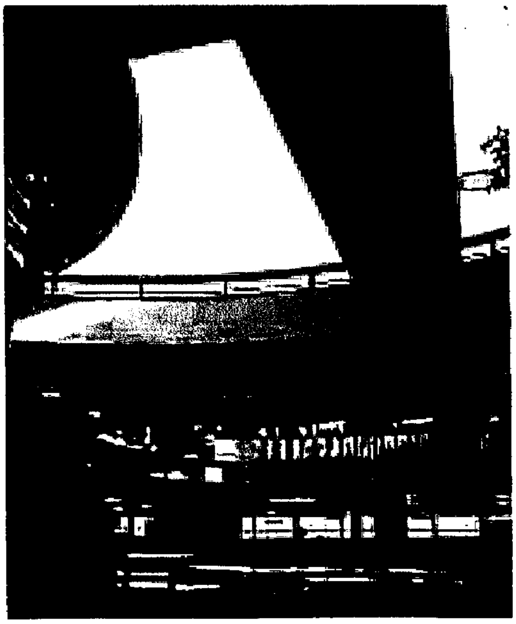


Fig 2.11: Daylighting & Views – Views

The JohnsonDiversey building was designed to maximize the line of sight to windows. The existing configuration provides line of sight from occupied areas for 81% of the building area.

Green Cleaning: Isolation of Janitorial Closets:

Water and chemical concentrate mixing areas are required to have special ventilation system features to mitigate the risk that chemicals or other agents from those areas might contaminate the ventilation and supply air distribution system. JohnsonDiversey facilities have a dedicated exhaust air management system for venting water and chemical concentrate mixing areas.

2.2.7 SUMMARY OF BENEFITS

Participating in LEED-EB and achieving LEED-EB certification has produced a number of benefits for Company:

- Energy savings exceed $90,000 per year, relative to a similar building designed without integrated design approach and energy efficiency measures.

- Use of collected stormwater for turfgrass irrigation reduces potable water use by 2-4 million gallons per year.

- For the first time, we have documented that over 50% of site generated solid waste is recycled.

- Participation in the LEED-EB program has renewed focus on integrated pest management, cleaning worker training, certified cleaning chemicals, systems approach to cleaning, and cleaning equipment, and has allowed JohnsonDiversey to construct an integrated cleaning program in alignment with LEED requirements.

- CO2 monitoring has confirmed adequate airflow design in occupied building areas, and allows us to respond to unusual incidents or conditions.

- Individual/personal environment controls (air flow, temp, acoustics and lighting) significantly increase occupant comfort, virtually eliminate hot/cold calls to maintenance, and allow for general building zone temperature range to exceed normal building comfort ranges thereby resulting in additional energy savings.

- Occupant interest and involvement in environmental aspects of building operation have increased.

2.2.8 ECONOMIC SUMMARY OF BENEFITS:

Table 2.6: *Summery of economic benefits- JohnsonDiversey headquarters*

Building floor space	277,440 ft2
Initial Implementation Cost	$73,800
Initial Implementation Cost per ft2	$0.27
Annual Net Savings	$137,320
Annual Net Savings per ft2	$0.49
Life Cycle Net Present Value	$1,351,535
Life Cycle Net Savings per ft2	$4.87
ROI	0.5 years

(Source: USGBC- LEED- EB project case study: JohnsonDiversey headquarters)

2.3 CASE STUDY 2
THE FRANKLIN BUILDING,
UC OFFICE OF THE PRESIDENT

2.3.1 INTRODUCTION

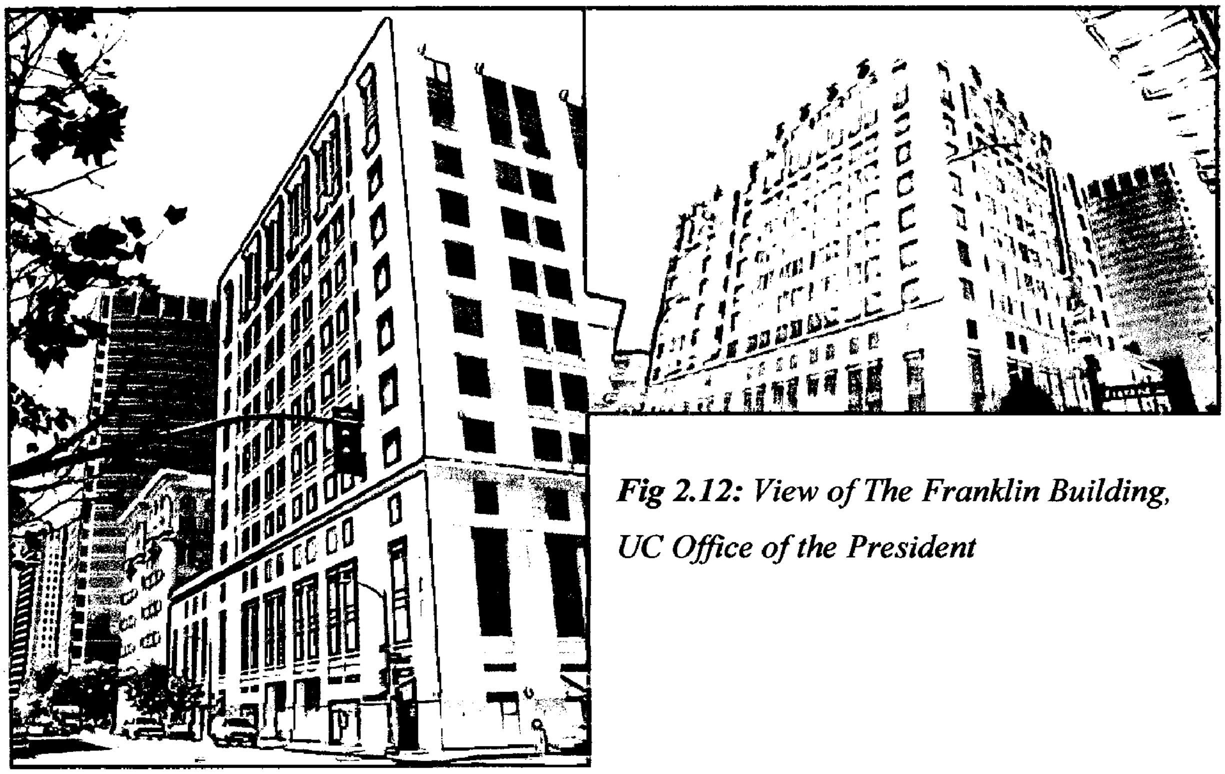


Fig 2.12: View of The Franklin Building, UC Office of the President

In recognition of the widespread environmental, economic and health benefits of sustainably maintained facilities, the University Of California President issued a Policy on Sustainable Practices in March 2007. The policy requires all UC campuses to begin adopting sustainable operations and maintenance practices and submit one pilot building for LEED-EB certification.

Before adopting this policy for the entire university system, the UC Office of the President (UCOP) performed a pilot LEED-EB project on its own headquarters. The Franklin Building, located in downtown Oakland, was selected to undergo operational changes and provide UCOP with hands-on understanding of the LEED-EB compliance, documentation and certification process. This case study details the actions UCOP took to improve the building's performance, and offers guidance to help other campuses complete a successful LEED-EB project.

2.3.2 SUSTAINABLE SITES:

THE FRANKLIN Building was built in Oakland's dense urban center in 1998. The building is conveniently located just one block from a BART station, the Bay Area's high-speed rail service. BART public transit facilitates commuting to and from several major cities including San Francisco and Berkeley, and also provides services to the San Francisco and Oakland International Airports. An extensive network of bus lines also serves the area. To further encourage the use of alternative transportation, bicycle parking and showers are available for occupants. Given the dense downtown location and the availability of established public transportation, underground parking is provided for under one third of building occupants.

The Franklin building has no green areas along the building-street border to maintain, however there is a small rooftop garden over the fifth floor. Employees can step outside for lunch or host small meetings in the garden, which is positioned away from the street to reduce exposure to noise and exhaust.

LEED-EB Actions

Due to its auspicious location, many of the Sustainable Sites credits were achieved by documenting the existing building and site conditions, and did not require any operational changes. The garden, however, provided an ideal opportunity to incorporate sustainability into the management of the grounds through the implementation of a Green Site Management Plan.

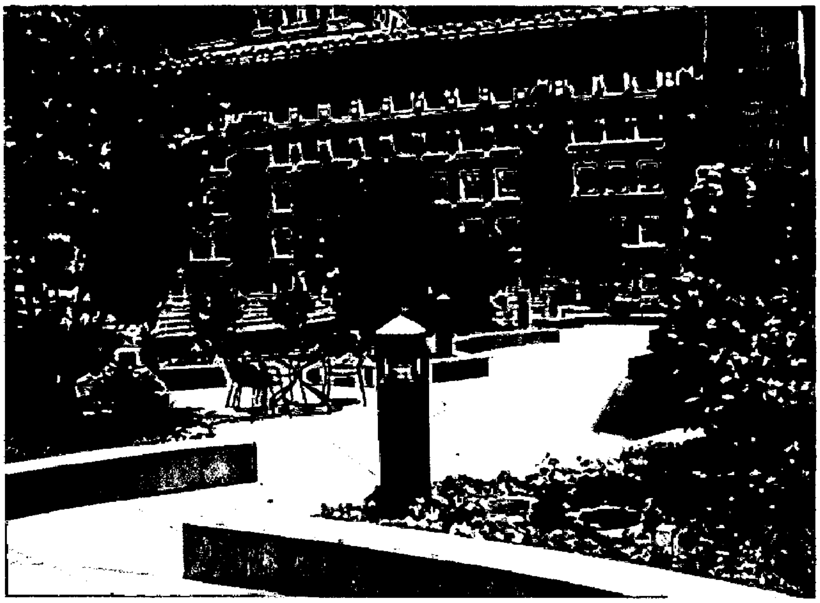


Fig 2.13: Green roof for optimizing the heat gain of the building- The Franklin Building.

All conventional fertilizers are now banned from the garden. Instead, compost and mulch are applied once each year, followed by the release of earth worms. Roundup and other forms of chemical weed control have been exchanged for least-toxic pesticides. All green waste generated by the garden, about two cubic yards per year, was already composted under the terms of the original contract and will continue to be sent to Biofuel Systems in Livermore, California.

Cost & Savings

The only cost associated with the Sustainable Sites credits pursued by the Franklin Building is $800 annually for switching from fertilizer to a compost application.

2.3.3 WATER EFFICIENCY:

ALL RESTROOM and kitchen fixtures in the Franklin Building meet the water conservation requirements established by the Federal Energy Policy Act of 1992. Relatively little water is applied to landscaping as the building has no lawn or exterior vegetation and only a small rooftop garden. The irrigation schedule for the garden is monitored and adjusted depending on levels of seasonal rainfall.

LEED-EB Actions

Given the Franklin Building's low landscape irrigation requirements, UCOP found the greatest water savings could be achieved by focusing conservation efforts inside the building. UCOP replaced the 2.2 gpm restroom sink faucet aerators with very low-flow 0.5 gpm faucet aerators. These devices effectively maintain water pressure and reduce the flow by mixing air into the water stream. By simply replacing faucet aerators in its restrooms, the Franklin Building's overall water consumption has dropped by over 20 percent according to the LEED-EB template calculator.

Cost & Savings

The water savings achieved at the Franklin Building required no capital investment. EBMUD's Conservation and Recycling Department provided sixty-four aerators at no charge. There have been no complaints from building occupants and no problems with the faucet aerators since the replacement.

2.3.4 ENERGY AND ATMOSPHERE:

The program has the goal of reducing electricity use by 5 percent and gas use by 3 percent. Enhanced metering will capture utility data at regular intervals throughout the day, giving staff immediate feedback on the building's energy consumption. This feedback will enable staff to maintain the building's energy conservation goals.

The Franklin Building was able to increase its energy efficiency by making a few simple changes during the LEED-EB performance period. First, the building engineer optimized the HVAC schedule and eliminated one hour of operation daily without negatively impacting the building's indoor air quality. Second, the engineer eliminated the use of the building's second boiler. Third, the Sustainability Coordinators worked with their departments to encourage employees to turn off their computers and monitors every evening.

The Franklin Building increased its purchase of Green-e energy from 17 percent to 45 percent in support of the clean energy and climate protection goals in the UC Policy on Sustainable Practices.

Cost & Savings

It cost $4,368 to increase UCOP's renewable energy purchases from 17 percent to 45 percent for one year plus the three month LEED-EB performance period. The MBCx project cost $69,680 to implement. The annual utility cost savings are anticipated at roughly $26,500, giving the project a simple payback of less than three years.

2.3.5 MATERIAL AND RESOURCES:

THE FRANKLIN Building had a healthy recycling rate of 54 percent prior to the LEED-EB project. Each occupant was equipped with a personal desk-side recycling can and a smaller, hanging trash bin that attached to the side. Some departments purchased 30 percent post-consumer recycled content paper, however this effort was not uniform throughout the building. A rigorous furniture reuse program has been in place at UCOP for several years. UCOP's unwanted computers, monitors, phones and other equipment are sold, donated or recycled.

LEED-EB Actions

The Franklin Building's new waste management policy stipulates that 75 percent of all construction waste must be diverted from landfills and incinerators through re-use or recycling.

A new purchasing policy was implemented at the Franklin Building to address the sustainable procurement of office paper, office equipment and supplies, and furniture. Sixty-eight percent of the building's total purchases now qualify as green under the criteria set by the LEED-EB letter template. However, this number under reflects the true level of green purchasing. Some departments procure copy machine paper from University of California Printing.

Services, all of which is 30 percent recycled content. The LEED-EB implementation team performed extensive paper testing to encourage the departments purchasing virgin office paper to switch to recycled-content paper. Product testing was important to help the departments find an acceptable alternative, thereby ensuring they would continue to purchase recycled content paper. The 30 percent recycled-content paper was ultimately selected as the most feasible alternative by nearly all participating departments.

The waste stream audit performed revealed that paper towels constitute 30 percent of the Franklin Building's garbage by volume. A new composting program was developed to capture this material, as well as other soiled paper items and food scraps, to reduce UCOP's landfill contribution. Implementing the new program required not only the addition of composting bins, but a change in the building's approach to waste disposal.

Recycling and composting bins outfitted with clear signage were placed beside the trashcan. In addition to composting kitchen waste, paper towels generated in the bathrooms and pre-consumer waste from the café are included in the program. To reinvigorate the building's occupant recycling program and facilitate proper sorting, all black desk-side recycling bins were replaced with blue bins. Color coding the bins gives an immediate visual signal differentiating the recycling bin from the trashcan. The bins are stamped with "Please Recycle Paper, Bottles, Cans" and the traditional recycling logo to eliminate any lingering confusion. The old bins were collected by the UC Berkeley's Recycling and Refuse Department for reuse in another building.

A necessary component of the Franklin Building's successful composting and recycling program was investing time in reeducating employees to stimulate a cultural change within the building.

The building's new low-mercury fluorescent lighting policy requires that interior and exterior bulbs have an average mercury content of less than 80 picograms per lumen hour. This policy allows some purchasing flexibility, because individual bulbs can exceed 80 picograms per lumen hour as long as the building's average remains below that rate.

Cost & Savings

The new recycling and compost bins required a capital expenditure of $4,086. The Franklin Building pays $280 each month to have its composting materials collected. There is no cost increase associated with purchasing 30 percent recycled content paper, switching to indoor air compliant products, or requiring vendors to recycle construction and demolition waste. UCOP saves over $5,000 each year.

2.3.6 INDOOR AIR QUALITY:

UCOP RECOGNIZES that significant benefits for occupant health and comfort are attainable through indoor air quality protection. Prior to the LEED-EB project the Franklin Building had many procedures in place to safeguard indoor environmental quality (IEQ). For example, painting projects are scheduled for after hours on Friday to minimize occupant contact with fumes. In addition to operational precautions such as this, UCOP takes reports of discomfort seriously and immediately investigates complaints made by building occupants.

The Franklin Building uses a web-based building management system called iRequest to track requests and complaints regarding indoor environmental quality. The iRequest process creates a direct and efficient line of communication between occupants and facilities management. Additionally, the system maintains long-term documentation of issues and resolution strategies.

A new green cleaning program has been welcomed into the Franklin Building with great success. The low-toxicity products now being used are a healthier choice for the environment, occupants, and maintenance staff.

The majority of products in the Franklin Building's green cleaning program are certified products. In addition to specifying sustainable cleaning products, the new green cleaning program requires that there are no antimicrobial agents in the building's hand soap and all floor stripping products must be zinc free. A significant component of this credit was selecting and testing new products.

Cost & Savings

UCOP hired an engineering consultant to confirm that the Franklin Building was in compliance with IEQ Prerequisite. The consultant inspected the outside air ventilation and exhaust systems to verify that the equipment was operating properly and maintaining a minimum airflow rate. This service cost $3,620. High efficiency MERV 13 filters were installed in the building's HVAC system to reduce the quantity of particulates that enter in the air system. These filters are replaced once each year at a total annual cost of $250.

2.3.7 CONCLUSION:

Certifying the Franklin Building at a LEED-EB Silver level required 1500 staff and consultant hours and $37,200 in capital investments. Operational changes that maintain the building with greater sensitivity to environmental and human health concerns cost $1,330 annually. This cost is far outweighed by savings of $30,700 achieved each year through various operational improvements.

2.4 ENERGY AUDIT FOR BUILDINGS

2.4.1 INTRODUCTION

The energy audit in a building is a feasibility study. For it not only serves to identify energy use among the various services and to identify opportunities for energy conservation, but it is also a crucial first step in establishing an energy management program. The audit will produce the data on which such a program is based. The study should reveal to the owner, manager, or management team of the building the options available for reducing energy waste, the costs involved, and the benefits achievable from implementing those energy-conserving opportunities (ECOs).

The energy management program is a systematic on-going strategy for controlling a building's energy consumption pattern. It is to reduce waste of energy and money to the minimum permitted by the climate the building is located, its functions, occupancy schedules, and other factors. It establishes and maintains an efficient balance between a building's annual functional energy requirements and its annual actual energy consumption.

2.4.2 WHY ENERGY AUDITING IS NECESSARY?

- ***Record and attribute energy consumption and costs.***

Energy costs depend on the amount consumed and its price. In an organization with many facilities, energy accounting makes it possible to compare energy use and cost among facilities and to monitor how energy use changes over time.

➢ ***Troubleshoot energy problems and billing errors.***

By consistently tracking energy use, you can identify problems. A sudden unexplained increase in consumption, for instance, means it's time to investigate the site for the cause.

➢ ***Provide a basis for prioritizing energy capital investments.***

Find out which facilities have the highest energy costs, and consider targeting them for energy retrofits or other energy management efforts.

➢ ***Evaluate energy program success and communicate results.***

Once you determine the results of energy management activities, it's important to communicate this information to decision makers and implementers who were responsible for the activities. Energy accounting reports and graphs are the tools for this important feedback.

➢ ***Create incentives for energy management.***

It's often difficult to get anyone in an organization to take the time and responsibility required for carrying out energy management activities because there is little incentive to take on the task. A maintenance director or site manager may not see much benefit in reducing energy costs if all of the savings revert to the general fund, or if lower energy bills only result in smaller allocations for utility costs in next year's budget.

➢ ***Budget more accurately.***

Energy accounting gives a historical look at costs that will help you budget more realistically for the future.

2.4.3 GOALS

- Manage energy costs
- Promote energy/environmental awareness
- Manage water and other resource costs

2.4.4 OBJECTIVES

- Verify savings from energy retrofits
- Motivate staff to manage energy costs
- Set energy cost savings goals and monetary incentives
- Prioritize sites for energy retrofits
- Troubleshoot unusual consumption increases
- Find billing errors
- Prepare to negotiate for price and service as electricity undergoes deregulation

2.4.5 STAGES IN ENERGY PROGRAMME

The energy audit may range from a simple walk-through survey at one extreme to one that may span several phases. These phases include a simple walk-through survey, followed by monitoring of energy use in the building services, and then model analysis using computer simulation of building operation. The complexity of the audit is therefore directly related to the stages or degree of sophistication of the energy management program and the cost of the audit exercise.

The first stage is to reduce energy use in areas where energy is wasted and reductions will not cause disruptions to the various functions. The level of service must not be compromised by the reduction in energy consumed. It begins with a detailed, step-by-step analysis of the building's energy use factors and costs, such as insulation values, occupancy schedules, chiller efficiencies, lighting levels, and records of utility and fuel expenditures. It includes the identification of specific ECOs, along with the cost-effective benefits of each one. The completed study would provide the building owner with a thorough and detailed basis for deciding which ECOs to implement, the magnitude of savings to be expected, and the energy conservation goals to be established and achieved in the energy management program. However, the ECOs may yield modest gains.

The second stage is to improve efficiency of energy conversion equipment and to reduce energy use by proper operations and maintenance. For this reason, it is necessary to reduce the number of operating machines and operating hours according to the demands of the load, and fully optimize equipment operations. Hence the ECOs would include the following:

- Building equipment operation,
- Building envelope,
- Air-conditioning and mechanical ventilation equipment and systems,
- Lighting systems,

• Power systems, and

• Miscellaneous services.

The first two stages can be can be implemented without remodeling buildings and existing facilities. The third stage would require changes to the underlying functions of buildings by remodeling, rebuilding, or introducing further control upgrades to the building. This requires some investment.

The last stage is to carry out large-scale energy reducing measures when existing facilities have past their useful life, or require extensive repairs or replacement because of obsolescence. In this case higher energy savings may be achieved. For these last two stages, the audit may be more extensive in order to identify more ECOs for evaluation, but at an increased need for heavier capital expenditure to realize these opportunities.

2.4.6 SURVEYING THE BUILDING

A walk-through survey of a building may reveal several ECOs to the experienced eye of the auditor. The survey could be divided into three parts.

Primary survey

Prior to the walk-through survey, the auditor may need to know the building and the way it is used. The information can be obtained from:

• architectural blueprints,

• air-conditioning blueprints,

- electrical lighting and power blueprints,
- utility bills and operation logs for the year preceding the audit,
- air-conditioning manuals **Preliminary survey** and system data, and
- Building and plant operation schedules.

Walk-through

Thus having familiarized with the building, the walk-through process could be relatively straightforward, if the blueprints and other preliminary information available describes the building and its operation accurately. The process could begin with a walk around the building to study the building envelope. Building features such as building wall colour, external sun-shading devices, window screens and tint, and so on are noted as possible ECOs.

If a model analysis is included in the study, the building must be divided into zones of analysis. The survey inside the building would include confirmation that the air-conditioning system is as indicated on plans. Additions and alterations would be noted. The type and condition of the windows, effectiveness of window seals, typical lighting and power requirements, occupancy and space usage are noted. This information could be compared against the recommendations in the relevant Codes of Practices.

System and plant data could be obtained by a visit to the mechanical rooms and plant room. Nameplate data could be compared against those in the building's documents, and spot readings of the current indicating panels for pumps and chillers recorded for estimating the load on the system.

Operator's input

The auditor may discuss with the building maintenance staff further on the operating schedules and seek clarification on any unusual pattern in the trend of the utility bills. Unusual patterns such as sudden increase or decrease in utility bills could be caused by changes in occupancy in the building, or change in use by existing tenants. It is not uncommon for tenants to expand their computing operations that may increase the energy use significantly.

Report

At this stage, ECOs could be found in measures such as:

- Reduce system operating hours,
- Adjust space temperature and humidity,
- Reduce building envelope gain
- Adjust space ventilation rates and building exfiltration,
- Review system air and water distribution,
- Adjust chiller water temperatures, and
- Review chiller operations

The benefit from adopting each ECO should be compared against cost of implementation. Caution should be exercised in the cost-benefit analysis given the wider range of certainty of the projections made. However, a survey at this level may be sufficient for small buildings.

2.4.7 MEASUREMENTS

The capability of the energy auditor and the scope of an audit could be extended by the use of in place instrumentation and temporary monitoring equipment. In-place instrumentation refers to existing utility metering, air-conditioning control instrumentation and energy management systems (EMS). The use of in-place utility metering and temporary monitoring equipment in energy auditing can yield valuable information about the building systems such as:

- Energy signature and end-use consumption analysis,
- Discovery and identification of ECOs,
- Quantification of energy use and misuse,
- Establishing bounds for potential energy reduction, and
- Data acquisition for further calculation and analysis.

Existing information

Existing instrumentation such as utility meter readings, and energy billings could be used to establish energy consumption patterns for the building. The regularity of consumption pattern is an indicator that no significant change in consumption occurred prior to the audit. This can also be used to check the validity of projections based on extrapolated short-term monitored data. Utility data could be used to establish useful indices such as kWh/m2/year to compare relative energy performance of buildings.

Air-conditioning control instrumentation such as chilled water temperature probes, water flow meters could be used to estimate cooling load demand and plant operation. For example, chilled water temperature outside the designed range may indicate that cooling coils may be operating under offdesign conditions.

Short term monitoring

The building may not be equipped for monitoring energy consumption and it may be necessary to install temporary measurement devices such as instantaneous recorders (strip chart, data loggers, etc) and totalizing recorders (kWH meters) to obtain data over the period of a week for the study. Monitored data is also useful for completing the energy model of a building for use in some building energy simulation software. For example the total building energy consumption would include energy used in the vertical transportation system and potable water pumps which are not modelled in the software.

An estimate for annual consumption is extrapolated from the typical week consumption profile. Regularity of the weekly consumption profile means that the annual consumption could be estimated with confidence and the value used to cross check with the annual energy bills.

2.4.8 MODEL ANALYSIS

Building energy consumption in simplest terms is just the product of rate of consumption of a system and the period of operation. In lighting systems, its energy consumption could be determined manually with precision as it does not interact with other consumption variables. Energy consumption of cooling systems, however, is many times more complicated as it is affected by the internal heat gain within a building as well as weather variables, which varies in a complex manner over time.

Building model analysis using computers offers several improvements over manual calculations. These include:

- Precise schedule of building parameters,
- Precise determination of weather impact,
- Specification of part load performance of plant and equipment, and
- Consideration of parameter interactions such as lighting load on air-conditioning consumption.

Software

Some software permit hour-by-hour calculations of building consumption for the entire 8760 hours of the year, but require thorough knowledge of the software to carry out accurate and meaningful analysis. Simplified software based on consumption analysis on characteristic days may also be considered. However, the improvements in computational power of the desktop PC have introduced several powerful features and user-friendly graphical interface possible in more recent versions of such software making it more accessible to the practicing engineer.

Analysis

The general procedure for an analysis would be to establish a model giving an annual consumption within 10% of the measured data. This establishes the base model. The impact of ECOs on energy consumption would be compared against the base model. ECOs could be considered singly or in combinations to determine interactions between them. The results of the energy savings in each analysis should not be taken as absolute but rather taken to be relative to the base run so as to give an indication of the order of magnitude of savings. Thus those ECOs which shows significant gains would be implemented.

2.4.9 SUMMARY

The objective of energy audit is to identify the end use of energy in building and its ECOs; and as a feasibility study leading to implementation of an energy management programme. The audit procedures can be expanded as needed in the various phases of the energy programme, with the application of each succeeding phase yielding more information on energy use, and more opportunities for raising energy efficiency.

2.5 CASE STUDY 3

Shram Shakti Bhawan and Transport Bhawan

2.5.1 PROJECT DESCRIPTION

Project Host

CPWD, Ministry of Urban Development, Government of India

Project Facility

Shram Shakti Bhawan and Transport Bhawan, New Delhi.

Project

Reduction of Energy Consumption in the Buildings under performance contracting.

Project Specifications

Retrofit of building envelope, lighting system, HVAC system, water pumping system, and Canteen Heating System.

Project Objective

To reduce the energy consumption in the building by 30%.

2.5.2 PROJECT BASELINE

Baseline

The baseline establishment is worked out from the energy bills for last 3 years, the current inventory of energy consuming appliances, sample testing of equipment, and operating conditions of building. (Rational for taking three years energy period)

Inputs for Baseline

Following are inputs for establishing baseline:

Utility electricity bills for year 2000, 2001, and 2002

Inventory of all energy consuming devices in the building

Building operating conditions

Sample testing of selected equipment and systems

Outputs

The baseline fixing results in following:

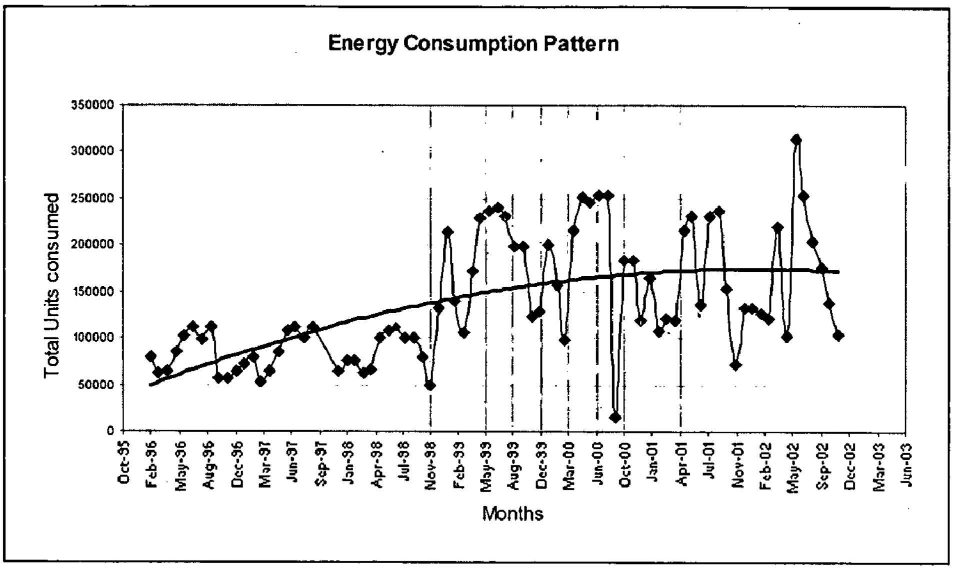
Month-wise baseline energy consumption

Model for estimating the adjustments

Utility Energy Bills

In the fiscal year 2001-02, SSB and TB together incurred an energy bill of Rs 1.27 Crores at a single part tariff of Rs 6.37 per kWh. The team analyzed the historical energy consumption data of the facilities to establish the energy consumption pattern in the buildings. The facilities combined have a monthly average consumption of 0.17 mn kWh and for last three years average yearly consumption was 2.04 mn kWh

A detailed analysis of the energy consumption pattern of the facility over the last 8 years was conducted. The graph below depicts this pattern at the facility between the years 1995-2003, taken on a quarterly basis. It is clear from the graph that the facility has a trend of increasing power consumption over the years.

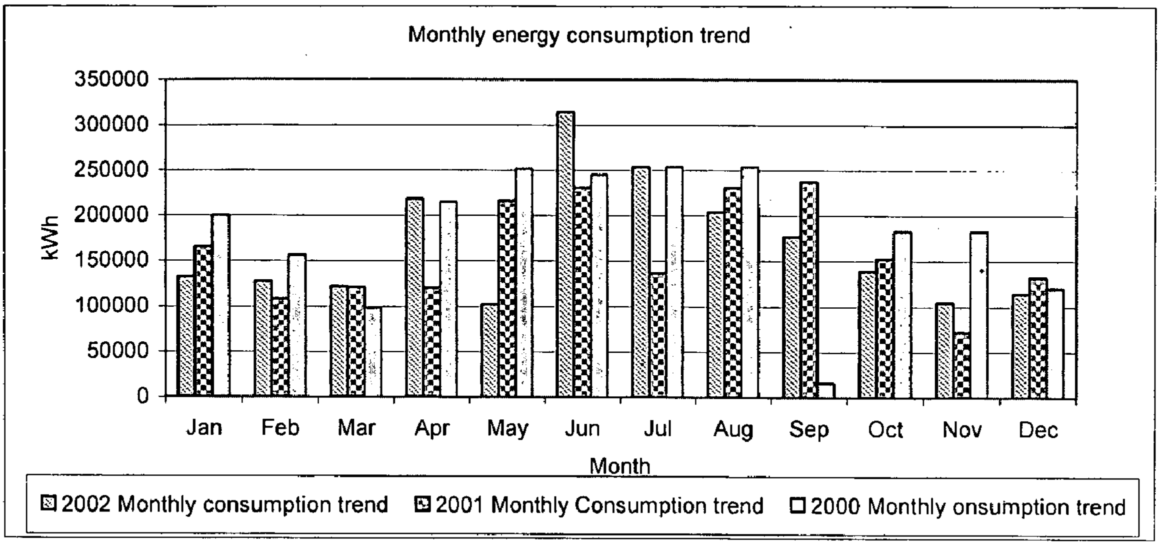


Graph 2.1: *Monthly energy consumption 1995 – 2003- SSB and TB*

Subsequent to this, the average growth rate in power consumption is plotted to see the trend in energy consumption as can be seen from the graph below. The power consumption in 1999 has suddenly increased by more than 100%. The maintenance personnel informed the team that new power meters were installed at the facility during the year 1999. The power consumption after 1999 has remained stable.

Monthly Power Consumption

The monthly power consumption of electricity in SSB and TB is shown in Figure below. The readings were collected from the records being maintained building JE office. The overall trends show high power consumption from Apr to Sep and lower power consumption in Feb, Mar and Dec. This clearly represents co-relation with the weather i.e. in summers there is higher power consumption due to air conditioning load and in winters especially in Jan there is higher load due to heating.



Graph 2.2: Monthly Energy Consumption for 2000, 2001, and 2002

However, monthly bill for the same months (for some of the months) in the different years show some abnormal deviations.

The reasons for these variations can be attributed to:

- Heavy load shedding
- Operation of DG sets for which records are not available and also supply from the DG sets is not metered
- Inaccurate recording of meter readings and faulty meter conditions
- Date of taking meter readings
- Abnormal utilisation behaviour pattern e.g. large number of staff going on leave at the same time.

The data for the months, when the deviation of power consumption from the average power consumption of the same month is least is considered as baseline. Based on this logic the following table describes base line energy consumption for different months.

Table 2.7: Baseline Energy Consumption- SSB and TB

Month	Actual Energy Bills, kWh			Deviation from Average			Baseline, monthly Power Consumption, kWh
	2000	2001	2002				
Jan	200,200.00	165,390.00	131,640.00	21%	**0%**	-21%	**165,390.00**
Feb	156,400.00	107,990.00	127,480.00	20%	-17%	**-2%**	**127,480.00**
Mar	98,480.00	120,570.00	121,180.00	-13%	**6%**	7%	120,570.00
Apr	214,800.00	119,760.00	218,690.00	**16%**	-35%	19%	**214,800.00**
May	251,460.00	216,090.00	102,320.00	32%	**14%**	-46%	**216,090.00**
Jun	245,320.00	231,360.00	314,528.00	**-7%**	-12%	19%	**245,320.00**
Jul	253,720.00	136,190.00	253,742.00	18%	-37%	**18%**	**253,742.00**
Aug	253,720.00	231,330.00	203,734.00	11%	**1%**	-11%	**231,330.00**
Sep	-	237,320.00	176,477.00	-100%	72%	**28%**	**176,477.00**
Oct	183,100.00	152,870.00	138,593.00	16%	**-3%**	-12%	**152,870.00**
Nov	183,100.00	71,400.00	104,506.00	53%	-40%	**-13%**	**104,506.00**
Dec	119,970.00	131,640.00	114,035.00	**-2%**	8%	-6%	**119,970.00**
Yearly	**2,160,270.00**	**1,921,910.00**	**2,006,925.00**				2,128,545.00

(Source: Project report by BEE, Delhi)

All these variations can be captured by recording the load behavior pattern. The present system of metering for the facility requires some technical modification for connecting load-monitoring system. Such a system has to be installed by the successful bidder while determining the baseline prior to undertaking project implementation.

Many factors affect the performance of equipment and achievement of savings. The parameters that are predictable and measurable can be used for routine adjustments. Such adjustments reduce the variability in reported savings, or provide a greater degree of certainty in reported savings. Unpredictable parameters within the boundaries of a savings determination may require future non-routine Baseline Adjustments (e.g. change in usage pattern, reduction of staff).

Parameters affecting Baseline

SN	Parameter
1	Schedule (office timings)
2	Weather
3	Installed equipment intensity, schedule
4	Occupancy level
5	Occupant or user demand for services (e.g. space temperature, plant throughput)
8	Occupant or operator cooperation in using EEM related equipment in accordance with direction
9	Occupant or operator cooperation in using non-EEM related equipment in accordance with direction
10	Equipment deterioration, both ECM related equipment and non-ECM related
11	Equipment life, both ECM and non-ECM related

2.5.3 BUILDING OPERATING CONDITIONS

Lighting

The lighting levels at different places in Shram Shakti and Transport Bhawan is as under:

Table 2.8: *Building Lighting-BBB & TB*

SN	Building	Lux Level As Per IS Codes	Lux Level Actual Measured during Energy Audit
1	Entrance halls and reception area	150	73

2	Conference rooms, executive offices	300	263
3	General offices	300	197
4	Corridors and lift cars	70	69
5	Stairs	100	87

(Source: Project report by BEE, Delhi)

Air Conditioning

The current room conditions of temperature and humidity as measured in sample rooms (30 rooms) on 6 May 2003 is as under:

Table 2.9: *Building Air Conditioning-BBS & TB*

Room Dry Bulb Temperature	Humidity	Air Conditioned Area (Sq M)	Comfort Conditions (more than 70% comfort level)
25 Deg C to 26 Deg C	67% to 71%	1575	Air Temperature - 26 Deg C Air Speed (mean) - 0.20 M/Sec Humidity - 10% to 50%
26 Deg C to 28 Deg C	70% to 90%	2457	Air Temperature – 27 Deg C Air Speed (mean) - 0.25 M/Sec Humidity - 10% to 35%
28 Deg C to 30 Deg C	64% to 84%	1575	Air Temperature – 29 Deg C Air Speed (mean) - 0.35 M/Sec Humidity - 10% to 25%

30 Deg C to 35 Deg C	60% to 85%	4950	Air Temperature – 31 Deg C Air Speed - Not Available Humidity - 10%

(Source: Project report by BEE, Delhi)

The average outside air temperature on 6 May 2003 was 40 Deg C and average humidity was 65.2%. The weighted average room temperature was 29.88 Deg C and humidity 73.94%.

2.5.4 TECHNO-ECONOMIC FEASIBILITY

Brief Description

Shram Shakti Bhawan (SSB) and Transportation Bhawan (TB) are located in New Delhi and come under NDMC territory. SSB is a six-storied building with a total floor area of 2356 Sq.m. TB is a five-storied building with a total floor area of 2280 Sq.m. New Delhi Municipal Council (NDMC) provides the power supply to these buildings. The facility has a sanctioned load of 1.8 MW. Power comes through a common sub-station located in the SSB premises. The substation receives supply at 11 kV, which is stepped down through three transformers of 1000 kVA rating to 440 V. Refer to Annexure for more details on distribution system. Three DG sets – one at TB and Two at SSB meet the contingencies. The DG sets at SSB are rated 125 kVA and 250 kVA.

As a part of the baseline establishment exercise, the following activities were undertaken at SSB & TB.

- Recording the historical energy data (energy bills year-wise and month-wise for the previous years)
- Establishing inventory
- Recording the Maintenance information and expenditure details
- Establishing system-wise power consumption

During the fiscal year 2001-2002, the buildings incurred a total energy bill of Rs 1.27 Crores at a single part tariff of Rs 6.37 per unit. It was observed that the facilities have a monthly average consumption of 1.7 lac kWh. HVAC system, lighting, water pumping system form the major load in the building. The canteen heating system also consumes substantial amount of energy. Office equipment forms the rest of the loads. The graph below shows the kWh consumption in percentage by each of the utility. As can be observed AC is the major contributor to the energy bill.

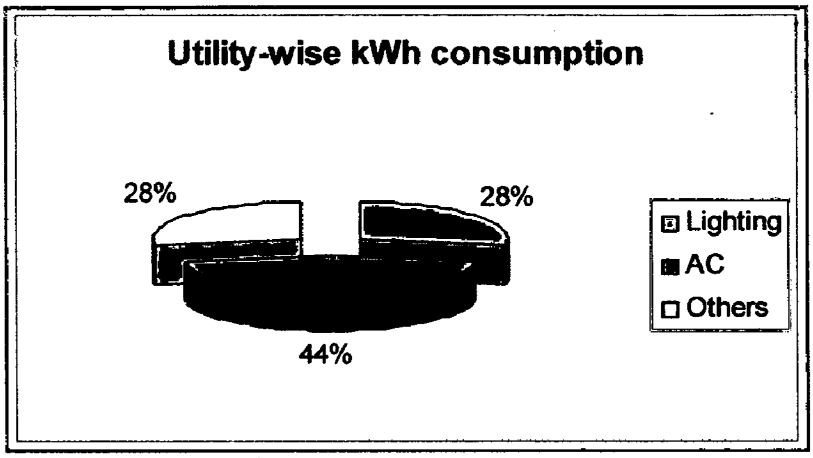
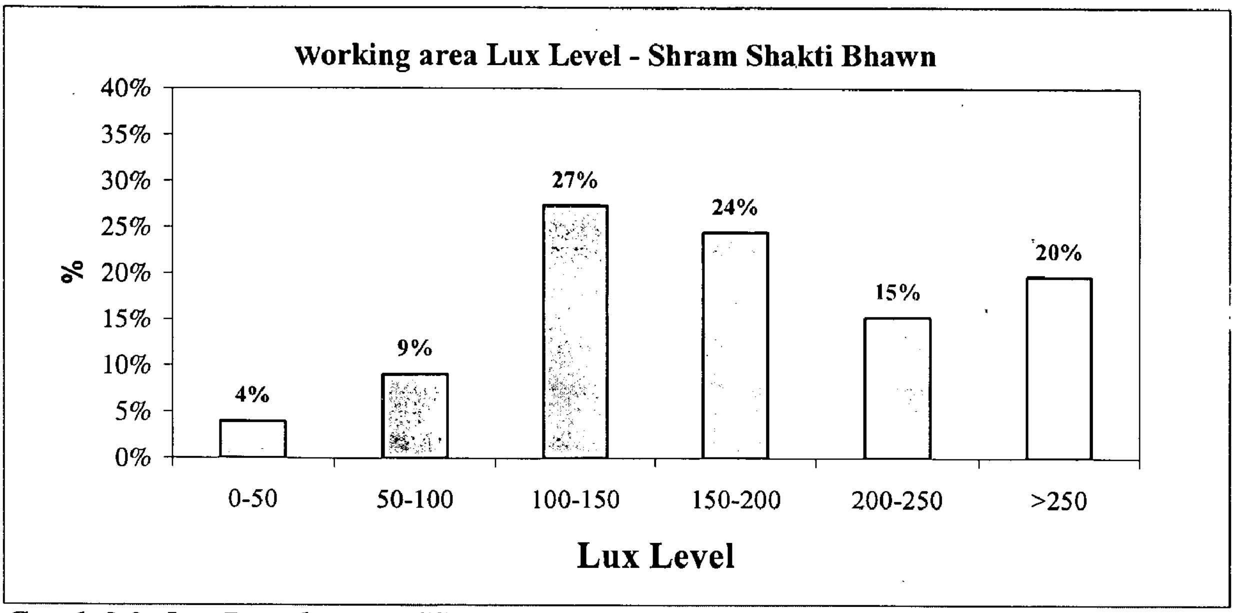


Fig 2.14: Energy usage distribution

Project 1: Lighting

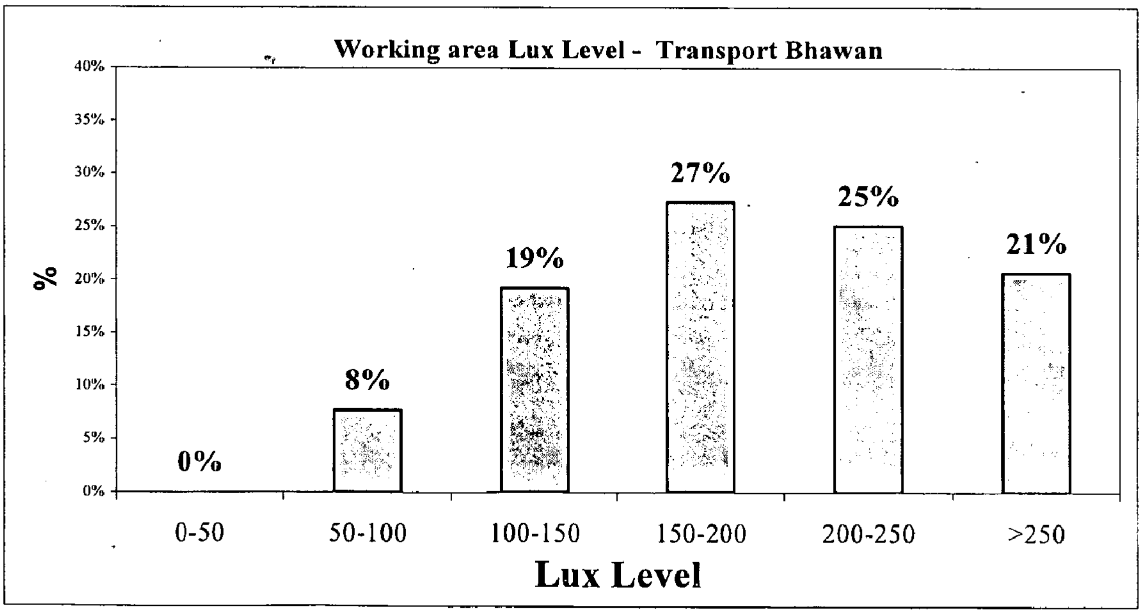
Lighting system

Detailed analysis shows that 13% of the measurement points have lux levels less than 100 lux, while 65% have below 200 lux. According to the standards, 87% of the working area is well illuminated. The figure below demonstrates these details.



Graph 2.3: Lux Distribution - SSB

The analysis of illumination data recorded from Transport Bhawan shows that 92% of the working area is well illuminated.



Graph 2. 4: Lux Distribution – TB

In some of the areas the illumination levels are low due to the following reasons:

Poor reflectors or no reflector installed for tube lights

Distance range between the installed fittings and working plane more than needed

Reduction in lumen due to ageing of the lights

Improper selection of furniture

Improper design of seating arrangement

The system performance would be enhanced by redesigning is some of the areas and also use of more efficient fittings / luminaires. Further some of the lighting circuits in individual offices would be rationalized for inducing habit-oriented savings. The design would include the task level lighting system.

With the improved system, the possible savings are calculated as shown in the table below.

Table 2.10: *Cost benefit- lighting- SSB & TB*

SN	Description	Value
1	Electrical savings	131,000 kWh/yr
2	Monetary Savings	8.34 Rs Lacs /yr
3	Estimated Project Cost	11.80 Rs Lacs
4	Project ROI	70 %

(Source: Project report by BEE, Delhi)

Project 2: HVAC system

Presently about 20% of the total area is covered by air-conditioning comprising of window and split AC units as shown in the figure below.

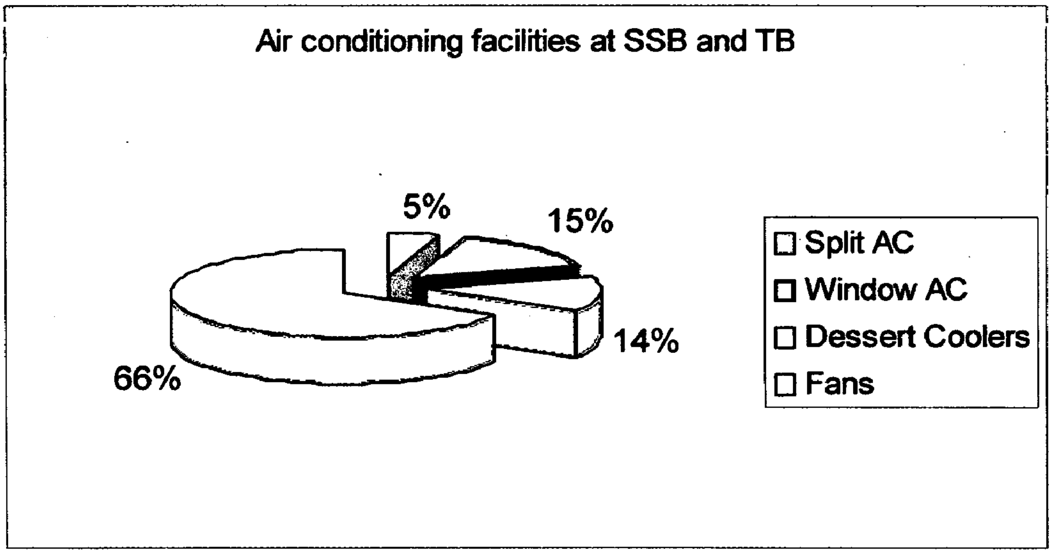


Fig 2.15: Air conditioning facilities at SSB and TB

A Central Air conditioning plant was in operation till the year 1998. But it was removed in 1999.

The relative merits and demerits of package system and central system have been evaluated, considering higher energy performance and also savings in maintenance cost, central system has been selected. The central system would also be equipped with control system to give optimum energy performance at varying ambient conditions. The system design consideration has been based on the following assumptions

- Outside Air Dry Bulb Temperature: 40.00 Deg C
- Room Air Dry Bulb Temperature: 29.88 Deg C on weighted average basis.

Actual temperature would be lower due to occupancy diversity factor. 450 TR chillers are proposed to be installed to derive the optimum cooling conditions and cost benefit from the retrofit project. The AHU system has been designed at higher value of 600 TR to provide for enhanced comfort conditions.

Table 2.11: *Cost benefit- HVAC system- SSB & TB*

SN	Description	Value
1	Electrical savings	421,000 kWh/yr
2	Monetary Savings	26.80 Rs Lacs /yr
3	Estimated Project Cost	122 Rs Lacs
4	Project ROI	22 %

(Source: Project report by BEE, Delhi)

Project 3: Water pumping system

Two submersible pumps of 10 HP capacity each are operated for five hours for both the buildings. The efficiency of the system and individual pumps are 26% and 29% respectively. It is proposed to replace the same more efficient pumps and system improvement to achieve the efficiency at 65%.

Table 2.12: *Cost benefit- water pumping system*

SN	**Description**	**Value**
1	Electrical savings	12,210 kWh/yr
2	Monetary Savings	0.71 Rs Lacs

3	Estimated Project Cost	0.30 Rs Lacs
4	Project ROI	233 %

(Source: Project report by BEE, Delhi)

Project 4: Canteen Heating

It is proposed to replace the electrical heating system by LPG.

Table 2.13: *Cost benefits- canteen heating- SSB & TB*

SN	Description	Value
1	Electrical savings	36,680 kWh/yr
3	Fuel Expenses	1.00 Rs Lacs/yr
2	Monetary Savings	2.34 Rs Lacs/yr
3	Estimated Project Cost	1.00 Rs Lacs
4	Project ROI	233 %

(Source: Project report by BEE, Delhi)

Project 5: Winter Heating System

There are 116 room heaters and 329 blowers combined in both the buildings. These are used for winter heating. The system operates for around 8 hrs in the day, during the winter for four months. Out of the total, 240 heaters and blowers are installed in the air-conditioned rooms. This corresponds to 480 kW load. The team advocated that the electrical consumption can be reduced by installing a Light diesel oil (LDO) fired boiler. Cost analysis of electrical energy against the LDO usage has been evaluated to validate the recommendation. The project has an attractive ROI of 175% With the availability of infrastructure for cooling water system circulation, the same can be used for hot water circulation. The room heating would be carried over by circulating hot water through Fan Coil Units.

Table 2.14: *Cost benefits- winter heating system*

SN	Description	Value
1	Electrical savings	246,900 kWh/yr
3	Fuel Expenses	9.70 Rs Lacs /yr
2	Monetary Savings	6.00 Rs Lacs/yr
3	Estimated Project Cost	6.00 Rs Lacs
4	Project ROI	100 %

(Source: Project report by BEE, Delhi)

2.5.5 PROJECT IMPACT ANALYSIS

Table 2.15: *EEM Impact Analysis- SSB & TB*

SN	Area	Brief Description	Infrastructure	Utilities	Operating Conditions
1.	Lighting	Retrofit based on Design and Technology for task lighting	No effect	No effect	20% increase in Lux Levels Task level lighting

2.	Air Conditioning	Replacement of Window and Split ACs with Centrifugal Chiller based Central AC System	Space required for central AC plant: 100 M2	Increase in water consumption by 12 Cu.M/hr	Improvement in comfort condition by improving air movement More cooling available due to favorable impact of usage diversity
3	Winter Heating	With the infrastructure available for central cooling distribution system it is possible to retrofit the same system at marginal cost can provide building with Central Heating System	Space required for central heating plant: 100 M2 Fuel handling system	2 kW increase	
4.	Pumping System	Replacement of existing pumps with the more efficient pumps and piping modification for more efficient pumping	No change	No Change	No Change
5.	Canteen Heating	Replacing Electrical heating with LPG heating	Safety requirement		

(Source: Project report by BEE, Delhi)

2.5.6 PERFORMANCE MEASUREMENT AND VERIFICATION PROTOCOL

We have selected Whole Facility performance verification for the following reasons:

Present metering system is for common for both SSB and TB.

The entire distribution system is not segregated for power and lighting devices separately and it would be very expensive to do segregation

Providing metering system for individual circuits would be too expensive to cover both the facilities.

The disadvantage of whole facility verification system primarily on account of month wise variation in the energy bill as has been explained under the baseline chapter. The billing adjustment factor is proposed as under:

Adjustments would be done at two levels (Quarterly and Annual)

All variations from the guaranteed saving with in +/- 5% would be ignored

Variations upto +/- 10% would be factored at 50%.

All variations above 10% would be investigated and resolved to the satisfaction of both the parties

Any disputes arising out of PMV protocol and system would be referred to dispute resolution mechanism given Performance Contract

The formula used for determination of energy savings for the purpose of payment under shared savings would be:

Energy Savings = Base year energy consumption (as shown by facility meters/utility energy bill) – Current Energy Bill (as per meter / utility energy bill) +/- Adjustments

2.5.7 OPERATION AND MAINTENANCE

The maintenance practices shall be established and followed in the following manner:

Predictive maintenance

Preventive maintenance

Repair

Periodic overhauling

Predictive maintenance

The purpose of predictive maintenance is to take early action in setting right equipments based on condition and at the same time avoid unnecessary expenses in preventive maintenance and overhauling. The subsequent section shows the organization structure for the O&M. Log books shall be maintained for all the equipment and trend analysis shall be carried out once a month to diagnose any deterioration. Based on these diagnoses, corrective steps shall be taken.

Preventive maintenance

This would include operation maintenance as well as some periodic equipment maintenance. Pressure drop in pipelines, checking the foundation, cleaning of the electrical contacts and systems and also testing of protective devices are some of the activities undertaken as a part of the preventive maintenance

Repair

Periodic repair shall be required for sealing of leakages, breakdown maintenance of equipments, fuel transportation and handling equipments. Electrical repair would include repair of cable faults, motor burnout and lighting system.

Overhauling

Periodic overhauling of Air conditioning equipment, Pumps and Lights is necessary to maintain the system in good running conditions.

2.5.8 ENERGY AWARENESS AND TRAINING

In order to create the most advantageous situation for the operations and maintenance staff and for those who work in and use the facilities on a regular basis, a comprehensive training and awareness program will be developed and implemented within this project, Facility Owner would co-operate in this and encourage development of habit oriented savings.

2.5.9 ENVIRONMENT ANALYSIS

Environmental analysis is very critical to understand the impact of energy savings on the environment. DSCL Energy services made an effort to study this impact. The power supply characteristics and composition in India is obtained as summarized underneath.

Table 2.16: *Indian Power Supply Composition & CO2 emissions*

Generation Displaced By Project (% Of Total)	Value
Thermal (Coal (sub-bit))	50%
Hydro (Hydro)	13%
Thermal (Natural Gas)	37%

(Source: Project report by BEE, Delhi)

Software called Proform-V is used to calculate the Green House Gas emissions reduction. The software makes the following assumptions for calculating the CO2 emissions.

Table 2.17: *Carbon Coefficients*

Fuel	Ton-C/GJ000
Coal (sub-bit)	26.20
Natural Gas	15.30

(Source: Project report by BEE, Delhi)

27.47 lac kWh of electrical energy would be saved after the implementation of project. This means 374 tons of CO2 emission reduction annually. But the project recommends the usage of LPG in canteen heating which would increase the GHG emissions to a certain extent. Thus implementation of this project brings GHG savings anything about 300tons, which is beneficial to reduce pollutants.

CHAPTER 3

PROJECT AREA STUDIES / ANALYSIS

3.1 ROORKEE CITY:

*Roorkee is located at 29.87°N 77.88°E. It has an average elevation of 268 metres (879 feet). Roorkee is 172 km north of the Indian capital New Delhi and located between the rivers Ganga and Yamuna, close to the foot hills of Himalayas. Before the creation of Uttarakhand on 9th November 2000 , Roorkee was a part of the state of Uttar Pradesh.

3.1.1 CLIMATE:

Due to its location away from any major water body and its close proximity to the Himalayas, Roorkee has an extreme and erratic continental climate. Summers start in late March and go on until early July, with average temperatures around 28°C (83°F). The monsoon season starts in July and goes on until October, with torrential rainfall, due to the blocking of the monsoon clouds by the Himalayas. The post monsoon season starts in October and goes on until late November, with average temperatures sliding from 21°C (70°F) to 15°C (58°F). Winters start in December, with lows close to freezing and frequent cold waves due to the cold katabatic winds blowing from the Himalayas. The total annual rainfall is about 2600 mm (102 in).

In the beginning of 19th century, Roorkee was chosen for the location of a cantonment by the then, British rulers. Roorkee was a very modest mud-built hamlet at that time having a population of 5511 (in 1847). It was resurrected from this non-descript position by the construction of the Upper Ganges Canal (1842-1854) and the concomitant establishment of Thomason Collage of Civil Engineering (in 1847).

* Data for Roorkee City is taken from *en.wikipedia.org*

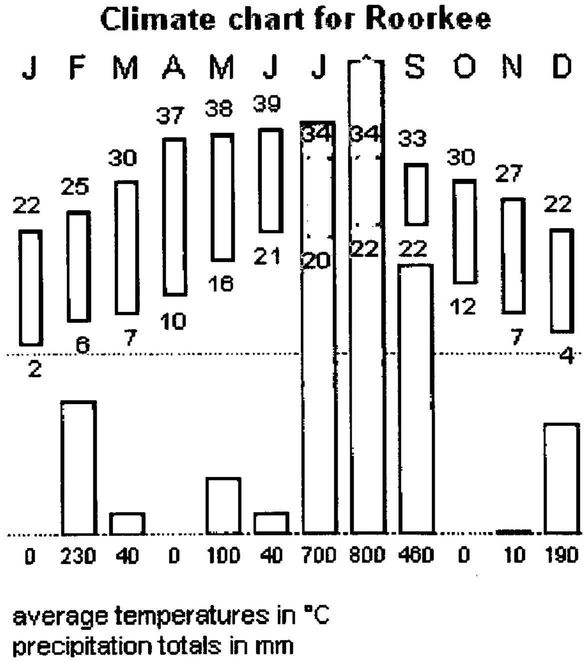


Fig 3.1: Climate chart for Roorkee

Thomson Collage was raised to the status of a university and known as University of Roorkee. By and By Roorkee became known in academic circles. The University of Roorkee is not only the first engineering university of Asia but also third in the world. As the university was a catalyst in the establishment of other R&D institutions of national importance, Roorkee rapidly became one of the foremost educational and research centers in India. This event stimulated the urbanization of Roorkee as several new institution came to be established in the proximity of the university.

3.1.2 URBAN STRUCTURE:

During the initial years of development, the urban structure of Roorkee was 'open-grained-single-nuclei' type, which gradually got transformed to' compact-grained-multiple nuclei' type. This was accompanied with a high rate of increase in population density.

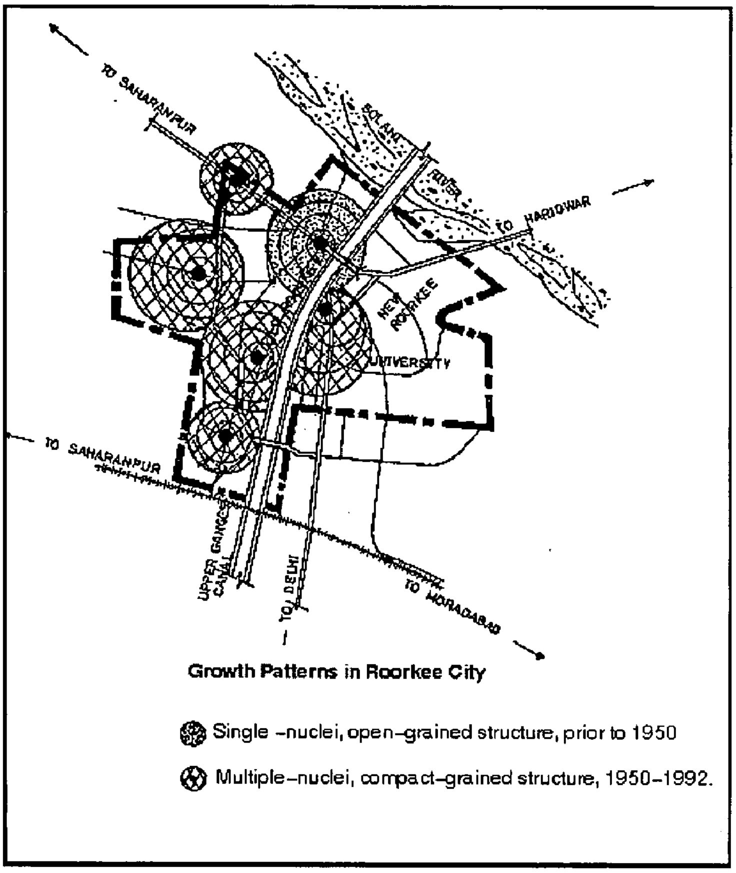


Fig 3.2: Growth patterns in Roorkee city

3.1.3 ENVIRONMENTAL IMPACTS:

The developing urban structure of Roorkee has made environmental impacts on the city:

- ***Temperatures***

  The maximum ambient temperatures have steadily increased and the minimum ambient temperatures have steadily decreased over the years.

- ***Precipitation***

  The statistical trend line shows a visible decrease in annual rainfall though the trend is not yet highly significant

- ***Changing Land Use***

  The impact of rapid urbanisation is seen in the changing land use pattern during the years 1961 through 1991. The percentage of built-up area has increased has increased from 45% (in 1961) to 72% (in 1991), causing a 27% decrease in the productive agricultural land of the town and its surroundings.

- ***Run-off and Recharge pattern***

  There is a 17% increase in run-off over the last two decades; causing diminished recharging of groundwater.

- ***Ground Water***

  The water table displays a visibly decreasing trend. The decreasing recharge rate is likely to be due to a combination of these factors :

1. Decrease in rainfall during 1975-1991;
2. Continuously increasing built-up area

- ***Non-scientifically designed waste dumping site***

  The present disposal site for the roughly 200 tones per day garbage as also the town's sewage, is situated upstream of the aquifer serving the town's water supply. There is thus very strong possibility of the present waste disposal site causing contamination of the entire aquifer thereby adversely affecting the town's water supply.

3.2 INDIAN INSTITUTE OF TECHNOLOGY, ROORKEE:

The Institute has two campuses. The main campus is at Roorkee in Uttarakhand and the other campus is 50 km away at Saharanpur in Uttar Pradesh. The campus at Roorkee is spread over 356 acres of landscaped lush greenery. Nestled within this are several heritage buildings, modern academic departments, Central library, twelve hostels, messes, hospital, school, banks, community centers, indoor and outdoor sports facilities, students' clubs and several activity centers and other buildings.

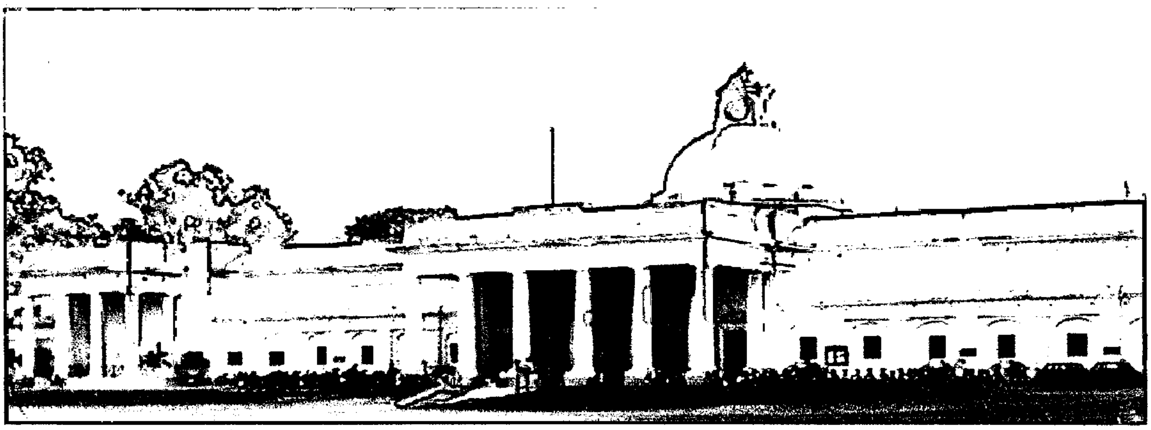


Fig 3.3: *View of the Main Administrative block, IIT Roorkee*

3.3 CENTRAL LIBRARY:

Library services in IIT Roorkee are the core of academic services, and therefore, Central Library of the Institute finds a unique place in Academic Service centers. The Central Library of the Institute is one of the best academic libraries in the country.

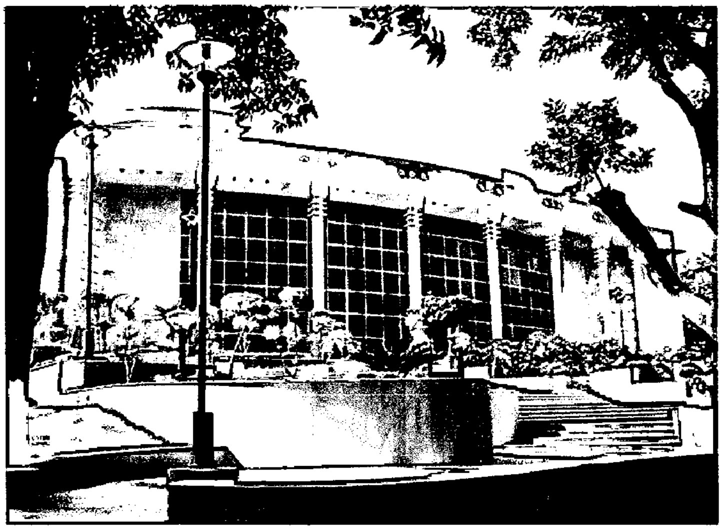


Fig 3.4: Front façade of the Central Library

With its collection of more than 3,20,000 documents it provides the world class information support to its users. Besides printed books and journals, its collection contains all forms of documents in on-line databases, audio-video material, standards, specifications, theses, reports etc. The main emphasis of the central library is on providing digital information support which is provided through its five servers and more than 70 user terminals.

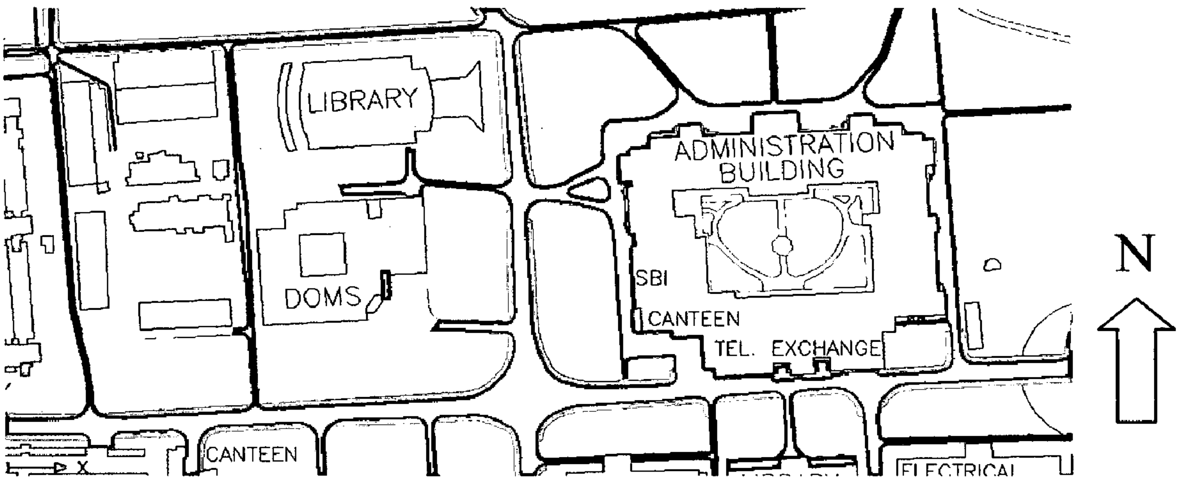


Fig 3.5: Location plan for the library building

The central library is a three storied building and with a basement floor, constructed in year 2007. The building floor area is approximately 6735 sq m, of which 70% is reading and books stacking space, while rest 30% is office and circulation space. The building is designed for energy efficiency with extensive use of natural lighting. Since the building is designed for energy efficiency green retrofitting the building is a matter of fine tuning the building's operation practice and improving the existing practices.

CHAPTER 4

BASELINE MODEL

4.1 BUILDING FORM AND ENVELOPE:

The library building form is rectangular having the dimensions 48m x 45m. The library building is facing east. The service cores are placed at the four corners and the center of the building. The building also has an atrium at the entrance hall.

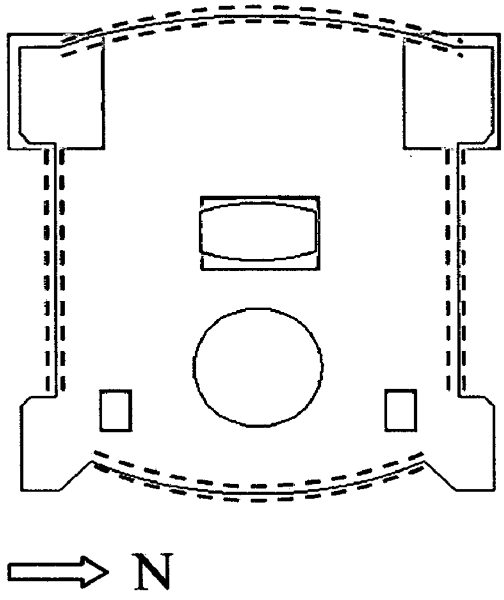


Fig 4.1: Building form and envelop

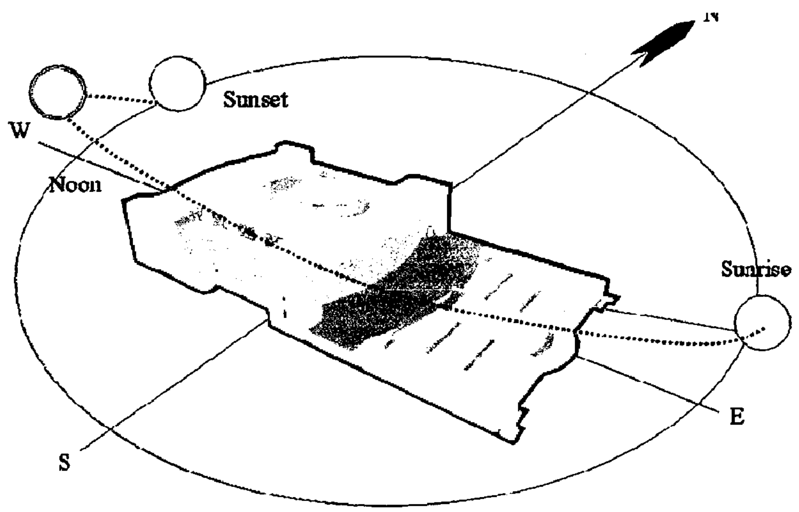


Fig 4.2: Sun diagram- Summer sun altitude

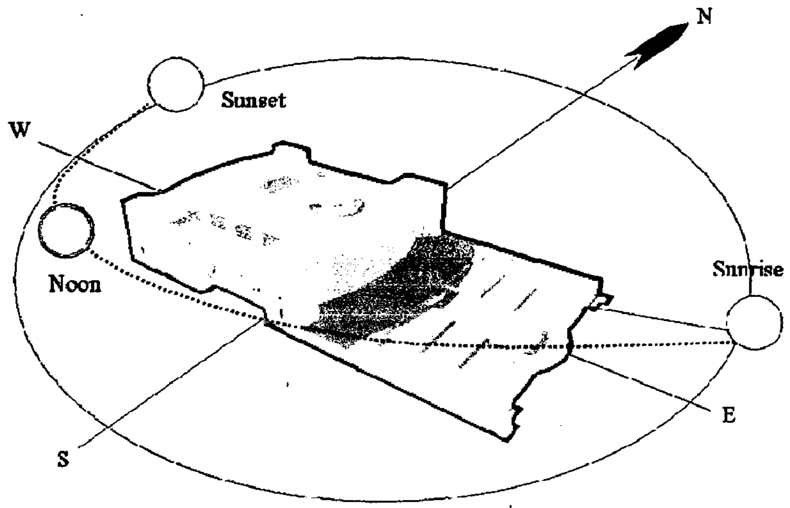


Fig 4.3: Sun diagram- Winter sun altitude

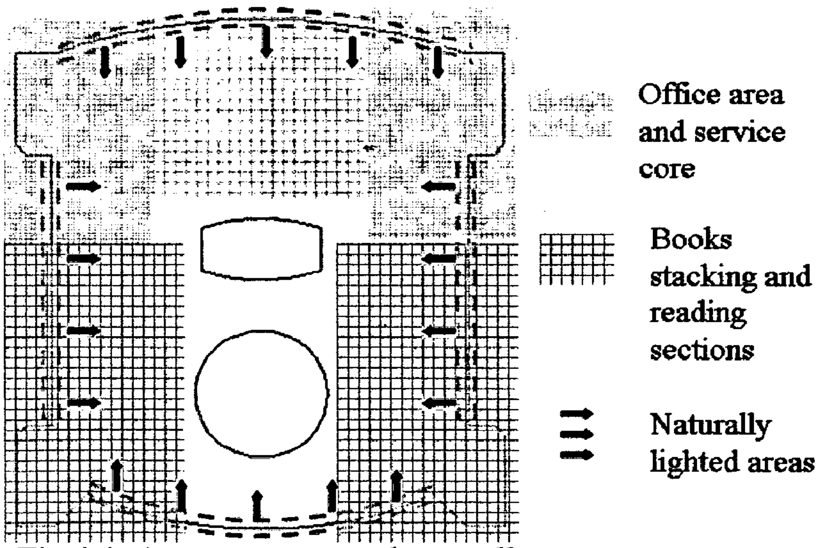


Fig 4.4: Activity zoning and naturally lighted areas in the library building

The building has tinted double glazing on all sides of the building which allows most of the natural light and heat into the building. Reading and books stacking being the most integral activities of a library, the reading sections are placed mostly in these naturally lighted zones. Rest of the zones are dedicated for offices and service cores. The external wall has sandstone cladding of 25 cm thickness which reduces the U – value of the wall as compared to the normal plastered wall.

4.2 SITE:

Most of the area around the library is paved with few small plantations and a water body. The building is surrounded by tarred road on all sides. Tough the library building do not have landscaped area on its site it faces the vast lawn area in front of the administrative block. Since most of the site area is paved the site is impervious to the rain water and the rain water runoff is carried away through underground drains.

4.3 ENERGY USE OF THE BUILDING:

4.3.1 ACTUAL ENERGY CONSUNPTION OF THE BUILDING:

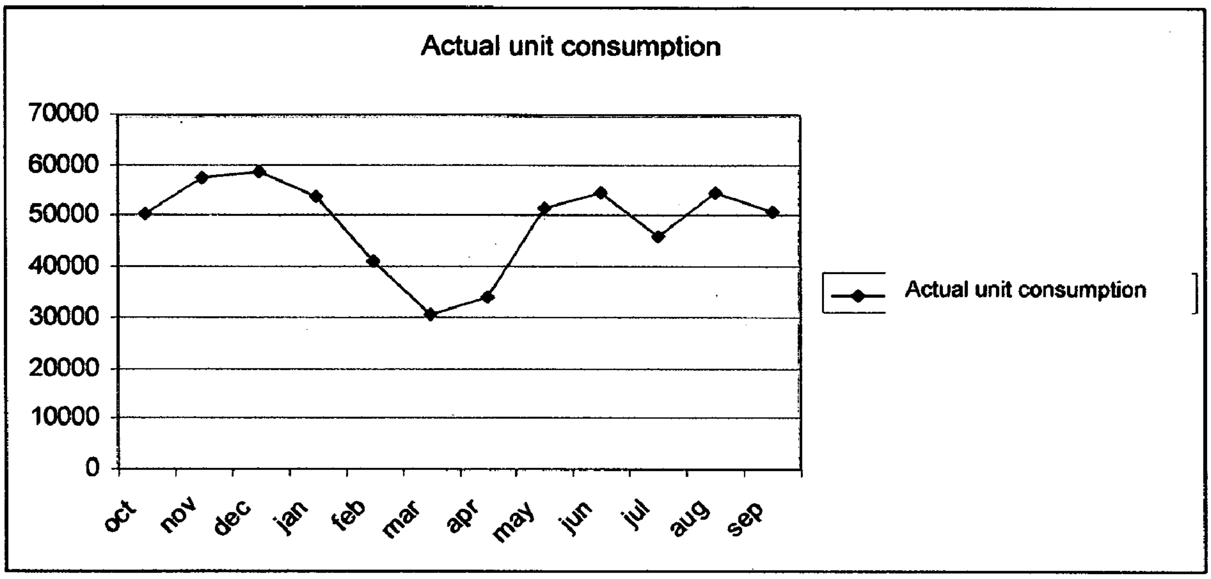
The use of the library building starts from morning 9:00 AM to night 9:00 PM. The electric consumption of the building during this period is approximately 585315 units per year. The meter has been installed at the library from 18th September '07. Monthly consumption units of the building from October '07 to September '08 are as follows:

Table 4.1: Simulation model: *Actual unit energy consumption by the library building*

Month	Actual units consumption
October '07	50592
November '07	57680
December '07	58864
January '08	53920
February '08	41184
March '08	30762
April '08	34233
May '08	51520
June '08	54720

July '08	46080
August '08	54720
September '08	51040
Total	**585315**

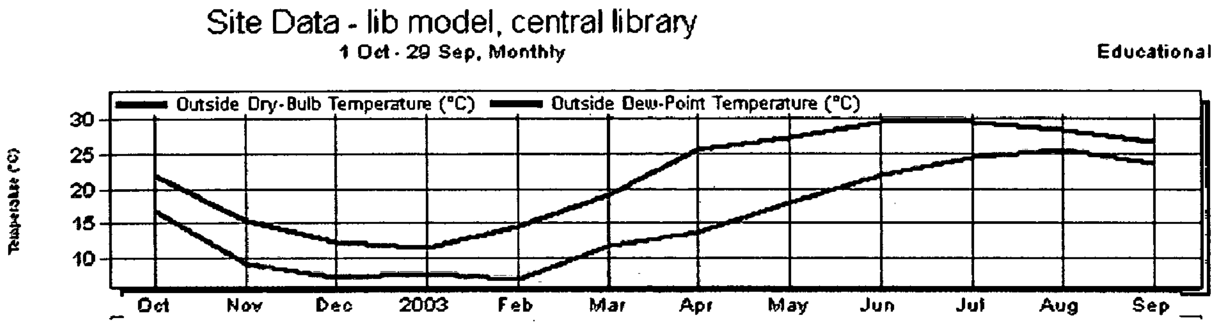
(Source: Data acquired from the college electricity Consumption records in the Administrative Block)



***Graph 4.1: simulation model:** Actual unit energy consumption by the library building*

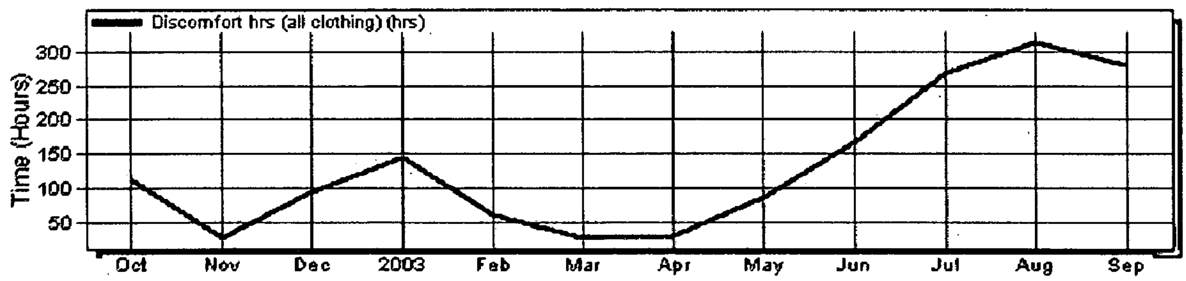
Energy use of the library building is mainly for:

1. HVAC system
2. Lighting
3. Various other equipments like computers, printers, Xerox machine etc.



***Graph 4.2: Simulated Model:** Maximum and minimum temperature graph for Roorkee*

The climatic graph establishes the fact that the site experiences both extreme conditions i.e. the temperature during months November to January may fall below 5 degree C and the temperature during months June to August may rise to 30 degree C. Thus these two periods during a year results to most of the discomfort hours as compared to the rest of the months.



***Graph 4.3: Simulated Model:** Discomfort hours for all types of clothing*

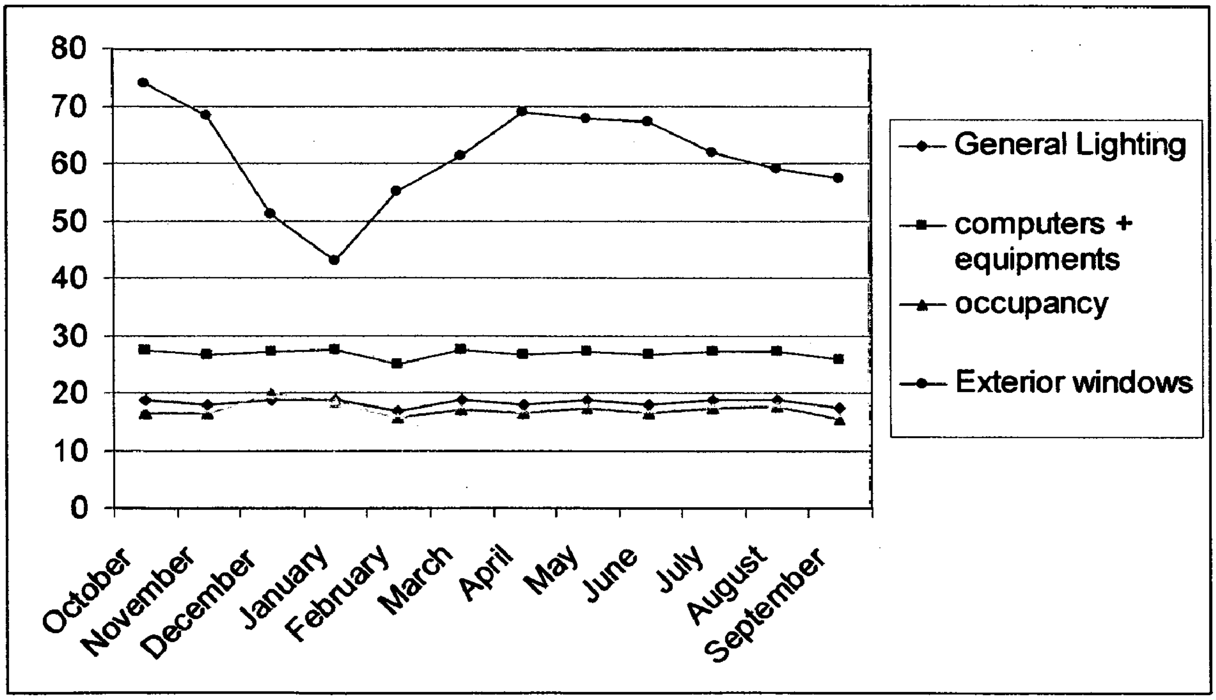
The graph 4.3 shows that most of the discomfort hours occur at the hotter months.

Apart from the climatic extremes of this area the heat gain from various components like lighting, computers, other equipments, and occupancy can also have remarkable effect on the comfort level of the users of the library. These conditions give rise to the need for HVAC system.

Table 4.2: Simulated Modeling: *Heat gain through lighting, computers, other equipments, occupancy and external windows*

Month	General lighting MWh	Computers + Equipments MWh	Occupancy MWh	Exterior windows MWh
October	18.75	26.59	16.74	74.00
November	18.15	26.68	16.67	68.58
December	18.74	27.28	20.19	51.39
January	18.75	27.58	18.69	43.09
February	16.94	24.93	15.83	55.13
March	18.75	27.53	17.33	61.52
April	18.14	26.62	16.65	68.97
May	18.75	27.4	17.45	67.92
June	18.15	26.62	16.64	67.39
July	18.75	27.46	17.44	61.86
August	18.75	27.4	17.82	59.06
September	17.54	25.83	15.47	57.58

(Source: simulation results for the library building)



Graph 4.4: Simulated Model: *Heat gain through lighting, computers, other equipments, occupancy and external windows*

To provide proper human comfort to the users of the library HVAC system is used.

4.3.2 HVAC SYSTEM AND COMPONENTS:

An HVAC system provides adequate indoor air quality by conditioning the air in the occupied space of a building in order to provide for the comfort of its occupants; diluting and removing contaminants from indoor air through ventilation. The HVAC system is installed for two reasons:

1. process system
2. human comfort

Process system is used where specific amount of temperatures and humidity is required E.g. in a pharmaceutical lab. The purpose of providing HVAC system in the central library is human comfort.

Central type of HVAC system is used here. This system includes an outdoor condenser system, a compressor and an air handling unit. The compressor used in this HVAC system is Reciprocating Air Compressor type.

The working of the system is as follows:

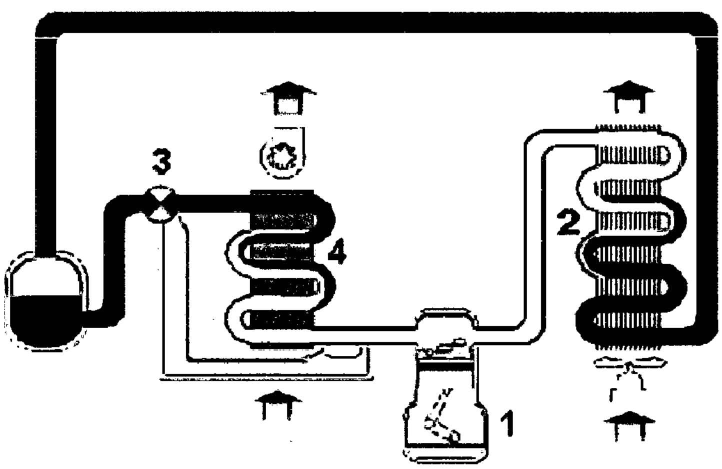


Fig 4.5: Working of the Central type HVAC System

1. The compressor pumps the refrigerant around the system. Before the compressor, the refrigerant is a gas at low pressure. Because of the compressor, the gas becomes high pressure, gets heated and flows towards the condenser.

2. At the condenser, the high temperature, high pressure gas releases its heat to the outdoor air and becomes subcooled high pressure liquid.

3. The high pressure liquid goes through the expansion valve, which reduces the pressure, and thus temperature goes below the temperature of the refrigerated space. This results in cold, low pressure refrigerant liquid.

4. The low pressure refrigerant flows to the air handling unit where it absorbs heat from the indoor air thought evaporation and becomes low pressure gas. The gas flows back to the compressor where the cycle starts all over again. The cooled air from AHU is circulated within the areas to be air conditioned through ducts, while the hot used air returns to the AHU for cooling.

In case of a heat pump the cycle can be reversed.

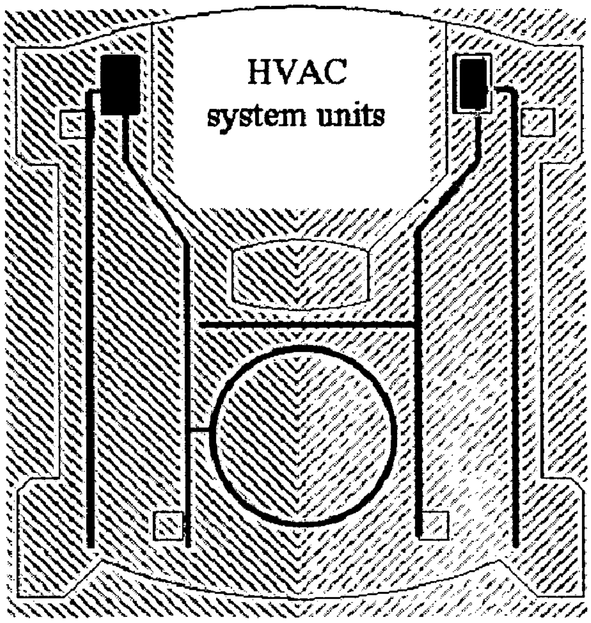
The HVAC system installed in the library has following units:

Table 4.3: *Components of the HVAC System*

UNITS	NO. OF UNITS
Chilled water pumps	3
Condenser water pumps	3
Cooling tower	2
AHU	10

The building floor plans are divided into convenient zones which are provided conditioned air by separate AHU units. This is done for the easy handling and monitoring of the supply air system. Also segregating the zones allow switching on/off the heating/cooling for the particular zone as per the need without affecting other zones.

The 10 AHU units are zoned over the building plan as follows:

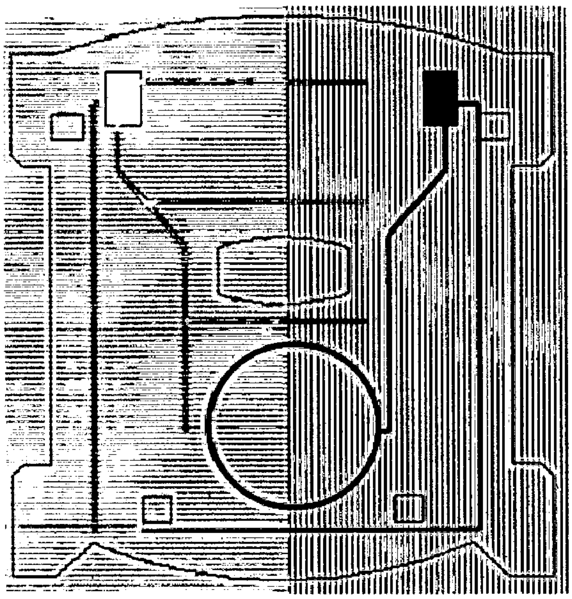


BASEMENT : 2 AHUs

AHU 1

AHU 2

Fig 4.6: Basement plan- HVAC layout



GROUND FLOOR:
2 AHUs

AHU 3

AHU 4

Fig 4.7: Ground floor plan- HVAC layout

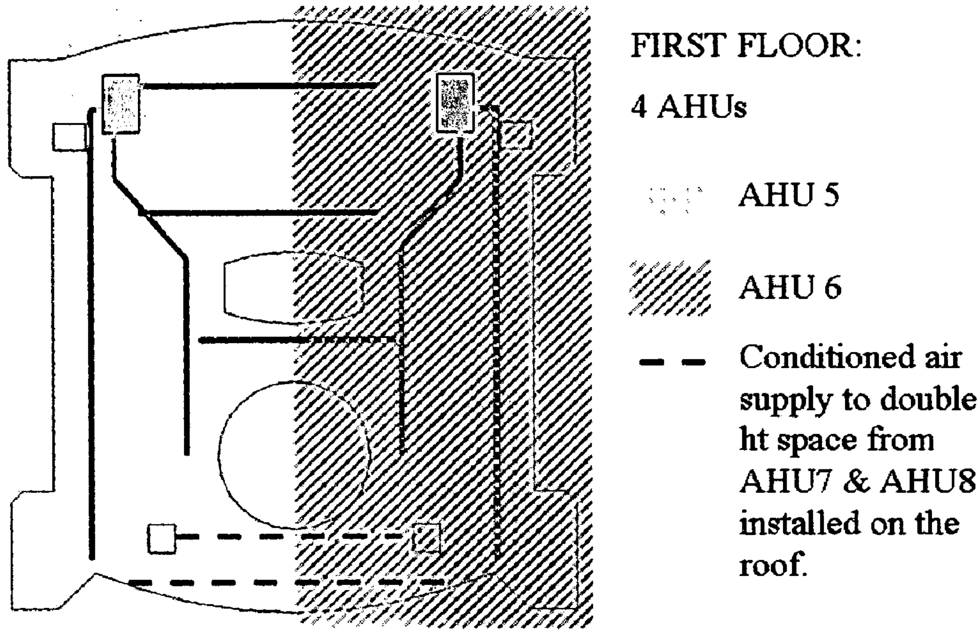


Fig 4.8: *First floor plan- HVAC layout*

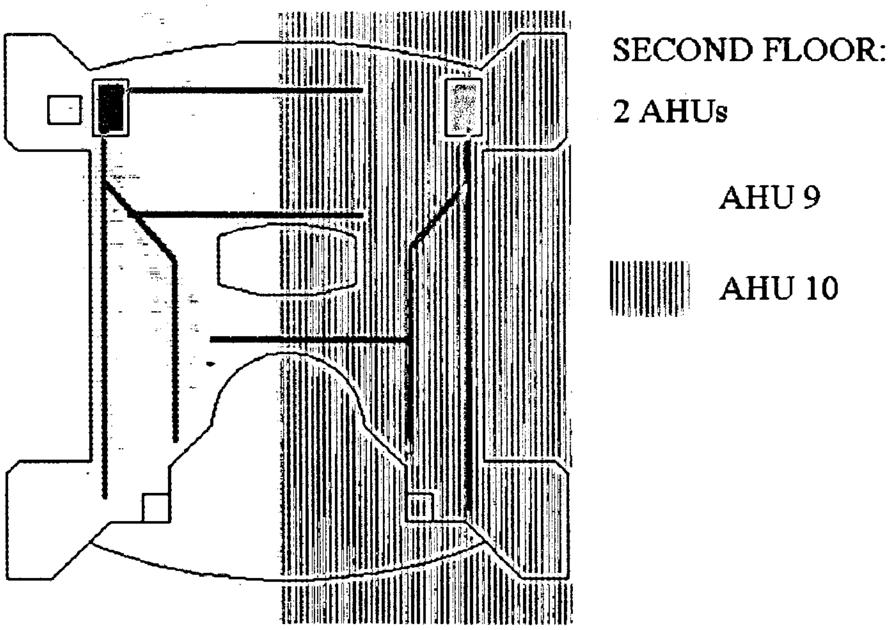


Fig 4.9: *Second floor plan- HVAC layout*

The present HVAC system is using Voltas water cooled chiller (reciprocating compressor). This chiller uses Refrigerant R-22 which has the ozone depletion potential (ODP) of 0.05 and global warming potential (GWP) of 1700.

4.3.3 OPERTATION OF THE HVAC SYSTEM:

The HVAC system is operated manually through a control panel which has on/off options for the:

1. chilled water pumps
2. condenser water pumps
3. cooling tower fans
4. AHUs
5. cooling towers

The system is used according to the climatic condition of the day. Hence the number of hour operation of the system varies every week.

4.3.4 LIGHTING SYSTEM:

The library building is designed for extensive use of natural lighting. Besides that compact florescent lights (CFLs) are used for the lighting systems. *These CFLs have better lighting quality and energy efficiency compared to the regular incandescent and fluorescent tube lights*.

* Data for the CFL properties is taken from "Compact Fluorescent Lamps Information Sheet" by EnergyStar

- ***Efficient:***

CFLs are four times more efficient and last up to 10 times longer than incandescents. A 22 watt CFL has about the same light output as a 100 watt incandescent. CFLs use 50 - 80% less energy than incandescents.

- ***Less Expensive:***

Although initially more expensive, money can be saved in the long run because CFLs use 1/3 the electricity and last up to 10 times as long as incandescents. A single 18 watt CFL used in place of a 75 watt incandescent will save about 570 kWh over its lifetime.

- ***Reduces Air and Water Pollution:***

Saving electricity reduces CO_2 emissions. Replacing a single incandescent bulb with a CFL will keep a half-ton of CO_2 out of the atmosphere over the life of the bulb.

The library areas are divided into zones and the lightings in a zone are controlled by a single on/off control system. The drawbacks of this system are that the major loss of energy is due to lack of energy conservation awareness among the users of the building. Lights in the reading zones and the books stacking zones remain in working condition even if these zones are unoccupied, thus causing considerable amount of loss of energy.

4.4 WATER USE:

The water use in the library building is basically for toilets, drinking, landscaping, and chillers. Presently the flushes used in the toilets and urinals are of Hindware fixtures. 13 numbers of toilets are using cisterns that use 11 lpf. Water used by the toilets cisterns in a day is about 275 liters. Similarly 13 numbers of urinals with flushing capacity of 6 lpf consumes 85 liters of water in a day. The present wash basin consumes 30 liters of water in a day. Thus per day water consumption considering only toilets is about 390 liters. The water use for the toilets by the library building comes to approximately 151632 liters/year.

These toilet equipments if replaced by more efficient equipments it can save some part of the present water consumption of the library. The use of aerators to the wash basins can reduce water use by 50%. The aerators mix water into the water stream. This maintains steady pressure so the flow has an even, full shower spray. Thus the daily water consumption through wash basins reduces to 15 liters. Further the cisterns in the library toilets may be changed to duel flush system that use 6/3 lpf. With this retrofit water consumption can be reduced by 187.25 liters/day. Waterless urinals do not need water for flush. Thus installing these fixtures can save all 85 liters of water which is other wise being used in present urinal fixture. Thus total per day water use is reduced by 48%.

Portable water is used for the landscaped area within the site. The irrigation schedule for the small landscaped area is adjusted depending on the levels of seasonal rainfall.

Rainwater harvesting potential

Most of the site area is paved and hence the site is impervious to the rain water and the rain water runoff is carried away through underground drains. This results in low ground water levels. The library building has roof area of approximately 2000 sq m. Roorkee receives the annual rainfall of 833 mm. Considering these factors total amount of water that can be harvested yearly can be calculated.

Rainwater harvesting (RWH) potential calculation formula is:

Roof area x annual rainfall in mm x .9

So for the library building the rainwater collected by the roof is:

2000 x 833 x .9 = 1499400 liters

If a green roof is provided about 75% of this water available is retained by the green roof. Rest of the 25% of water which is 374850 liters of water is available for harvesting in the library building.

4.5 MATERIALS AND RESOURCES:

- Most of the waste form the library constitutes paper and cardboards which are both recyclable materials.

- Another type of waste is the waste water from toilets (black water) and wash basins (grey water). The volume of grey water generated in the library can be used for irrigating the green roof or the surrounding landscape by recycling it through a simple recycling system.

- The lights used in the lighting system of the library are CFLs. These lights use less mercury thus reducing the amount of toxic materials inside the building.

CHAPTER 5

SIMULATION MODEL

To provide an energy efficient retrofit option to a building it is necessary to study the fundamental building systems and assemblies and that whether they are intended to meet current needs and sustainable requirements. This study for the library project is done using energy simulation software – DesignBuilder Simulation.

5.1 ABOUT DESIGNBUILDER SIMULATION SOFTWARE:

DesignBuilder combines rapid building modelling and ease of use with state of the art dynamic energy simulation. DesignBuilder allows building models to be assembled in 3-D space. Data templates allow loading common building constructions, activities, and HVAC & lighting systems into the design. EnergyPlus was selected because it computes building energy use based on the interaction of the climate, building form and fabric, internal gains, HVAC systems, and renewable energy systems.

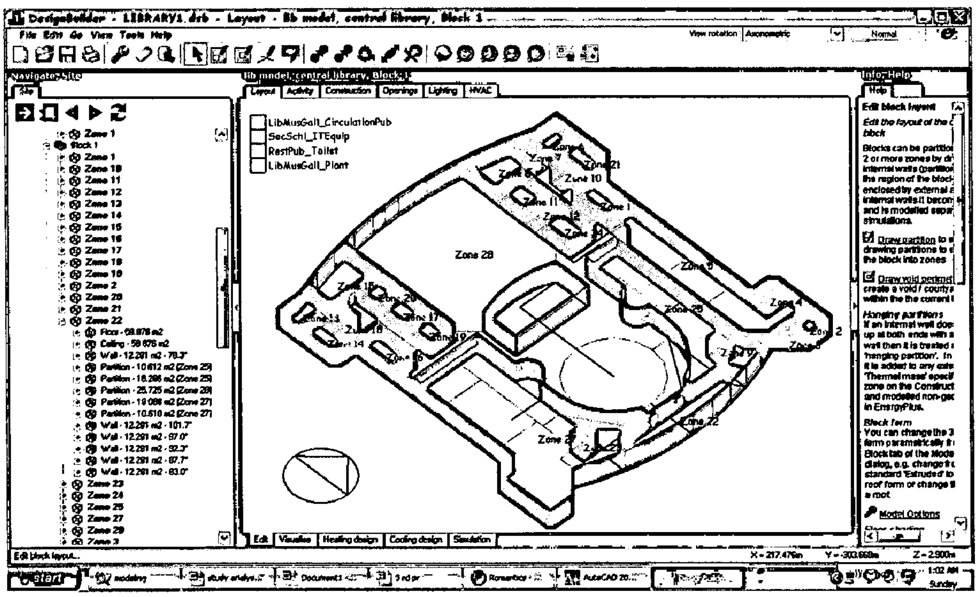


Fig 5.1: *Model building process in DesingBuilder software*

DesignBuilder is a user-friendly modelling environment where you can work with virtual building models. It provides a range of environmental performance data such as: annual energy consumption, maximum summertime temperatures and HVAC component sizes.

Some typical uses are:

- Calculating building energy consumption.
- Evaluating facade options for overheating and visual appearance.
- Thermal simulation of naturally ventilated buildings.
- Day lighting - models lighting control systems and calculates savings in electric lighting.
- Visualization of site layouts and solar shading.
- Calculating heating and cooling equipment sizes.
- Communication aid at design meetings.
- An educational tool.

DesignBuilder uses the EnergyPlus dynamic simulation engine to generate performance data.

5.1.1 ENERGY PLUS

EnergyPlus is the U.S. DOE building energy simulation program for modelling building heating, cooling, lighting, ventilating, and other energy flows. It builds on the most popular features and capabilities of BLAST and DOE-2 but also includes many innovative simulation capabilities such as time steps of less than an hour, modular systems and plant integrated with heat balance-based zone simulation, multizone air flow, thermal comfort, and photovoltaic systems.

EnergyPlus is a stand-alone simulation program without a 'user friendly' graphical interface which is where DesignBuilder comes in. We have integrated EnergyPlus tightly within the DesignBuilder environment to allow you to carry out simulations without any fuss just define your building model, request data and let the EnergyPlus simulation engine take care of the details.

DesignBuilder has been specifically developed around EnergyPlus allowing most of the EnergyPlus fabric and glazing data to be input. Databases of building materials, constructions, window panes, window gas, glazing units and blinds are provided.

HVAC is modelled using the Compact HVAC descriptions. A range of commonly used HVAC system types can be defined parametrically without the need for complex system layouts. These compact descriptions are automatically expanded behind-the-scenes into full HVAC simulation data sets prior to simulation.

5.1.2 CAPABILITIES OF DESIGN BUILDER

- Environmental performance data is displayed without needing to run external modules and import data and any simulations required to generate the data are started automatically.
- EnergyPlus Compact HVAC descriptions provide an easy way into detailed analysis of commonly used heating and cooling systems.
- Natural ventilation can be modeled with the option for windows to open based on a ventilation set point temperature.
- Day lighting - models lighting control systems and calculates savings in electric lighting.
- Shading by louvers, overhangs and side fins as well as internal and mid pane blinds.
- A comprehensive range of simulation data can be shown in annual, monthly, daily, hourly or sub-hourly intervals:
    - Energy consumption broken down by fuel and end-use.
    - Internal temperatures

    - Weather data
    - Heat transmission through building fabric including walls, roofs, infiltration, ventilation etc.
    - Heating and cooling loads.
    - CO_2 generation.
- Heating and cooling plant sizes can be calculated using design weather data.
- Parametric analysis screens allow you to investigate the effect of variations in design parameters on a range of performance criteria.
- Generate EnergyPlus IDF files and work with these outside DesignBuilder to access EnergyPlus system functionality not provided by DesignBuilder.

5.1.3 MODEL DATA HIERARCHY AND DATA INHERITANCE

DesignBuilder models are organized in a simple hierarchy:

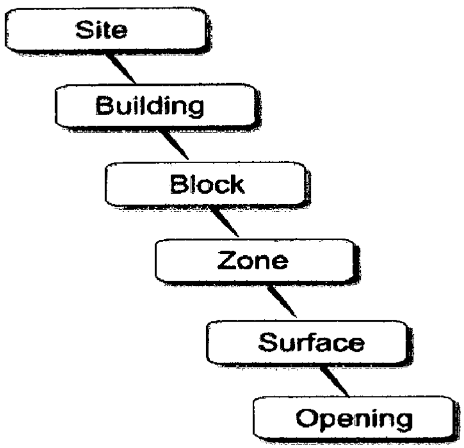


Fig 5.2: Model data hierarchy

Default data is inherited from the level above in the hierarchy, so block data is inherited from building level, zone data is inherited from block data and surface data from zone data. This arrangement allows to you make settings at building level which can becomes active throughout the whole building; or make settings at block level to change data for all zones/surfaces in the block.

The construction and opening defaults are inherited down to surface level where the data is actually used in the calculations.

5.1.4 SIMULATION USING REAL WEATHER DATA

You can generate detailed building energy performance data based on simulations using real weather data.

Simulations using EnergyPlus have the following characteristics:

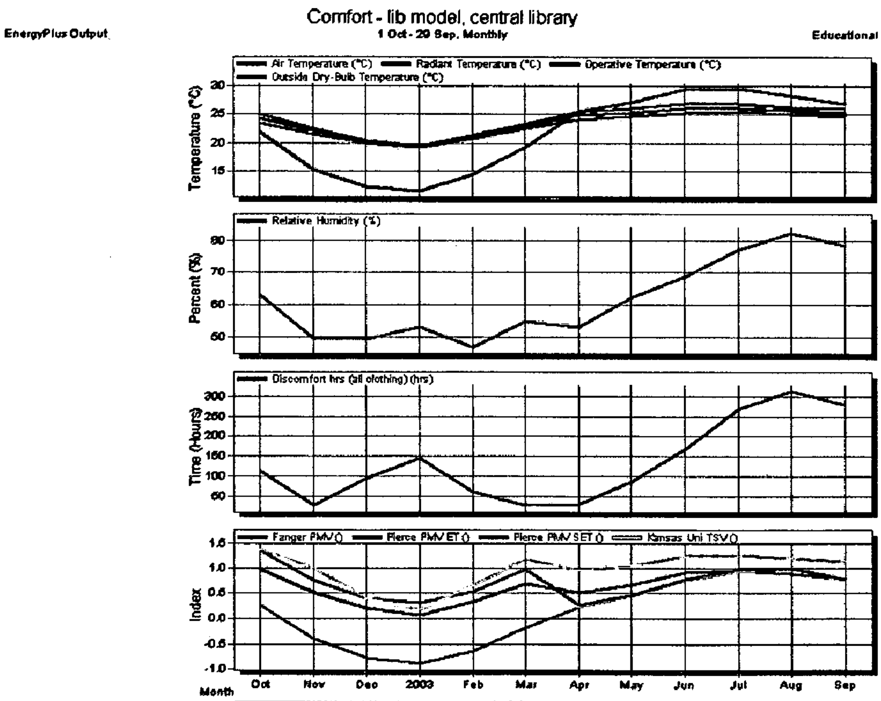
- Weather data comes from Hourly weather data file.
- Includes consideration of heat conduction and convection between zones of different temperatures.
- Includes solar gain through windows.
- Simulation of HVAC equipment (options)
- Includes one or more 'warm-up' days to ensure correct distribution of heat in building thermal mass and the start of the simulation. Warm-up continues until temperatures/heat flows in each zone have converged. If convergence does not occur then simulation continues for the maximum number of days as specified in the calculation options.

Outputs provided by the software:

1. Calculate heating and cooling loads using the ASHRAE-approved 'Heat Balance' method implemented in EnergyPlus. Design weather data is included.
2. Run simulations of the model using real hourly weather data to check how the building would behave under actual operating conditions.
3. Check the effects of design alternatives on the key design parameters such as annual energy consumption, overheating hours, CO2 emissions.
4. A comprehensive range of simulation data can be shown in annual, monthly, daily, hourly or sub-hourly intervals

5. Energy consumption broken down by fuel and end-use.
6. Internal air, mean radiant and operative temperatures and humidity
7. Site weather data
8. Heat transmission through building fabric including walls, roofs, infiltration, ventilation etc.
9. Heating and cooling loads.
10. CO2 generation.

The final outputs are in the form of graphs and tables as shown in the figure on right:



Month	Oct	Nov	Dec	2003	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Air Temperature (°C)	23.54	21.50	19.80	19.27	20.74	22.44	24.12	24.81	25.32	25.38	25.12	24.72
Radiant Temperature (°C)	24.87	22.61	20.38	19.46	21.30	23.29	25.54	26.03	26.85	26.73	26.32	25.86
Operative Temperature (°C)	24.25	22.05	20.14	19.37	21.02	22.86	24.83	25.32	26.08	26.06	25.72	25.34
Outside Dry-Bulb Temperature (°C)	21.85	15.29	12.26	11.57	14.45	19.11	25.48	27.10	29.35	29.54	28.20	26.73
Relative Humidity (%)	63.02	49.80	49.32	53.18	46.72	54.69	53.10	62.07	69.83	77.19	82.43	78.56
Discomfort hrs (all clothing) (hrs)	114.38	26.24	93.63	144.37	59.61	27.00	26.71	86.65	166.65	268.48	314.34	279.25
Fanger PMV ()	0.97	0.52	0.19	0.07	0.33	0.69	0.51	0.66	0.89	0.94	0.89	0.77
Pierce PMV ET ()	0.26	-0.41	-0.78	-0.89	-0.64	-0.17	0.21	0.44	0.74	0.93	0.96	0.75
Pierce PMV SET ()	1.35	0.75	0.40	0.30	0.53	0.98	0.27	0.46	0.77	0.96	0.99	0.78
Kansas Uni TSV ()	1.38	0.98	0.41	0.19	0.66	1.18	0.94	1.03	1.23	1.26	1.19	1.12

Fig 5.3:Output of simulation model in the form of graphs and tables

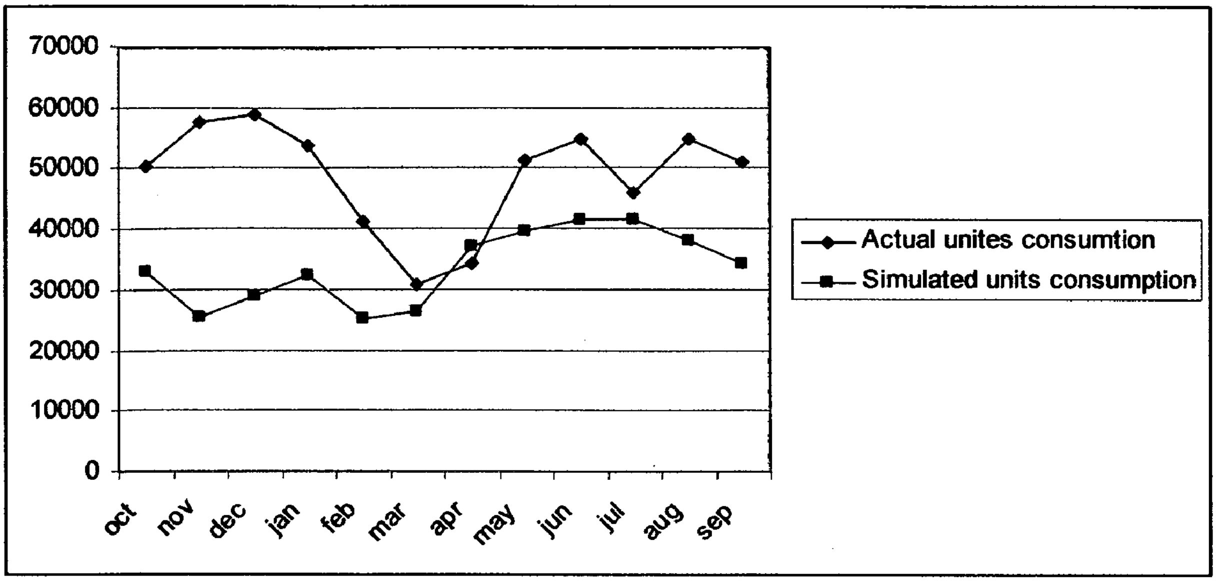
5.2 RESULTS FROM SIMULATION OF THE LIBRARY MODEL:

The actual consumption is considerably different from the energy consumption obtained from the energy simulation of the library model. The table below shows that presently a lot of energy is used by the building than required. The simulated result for energy consumption shows that the total energy consumption should be approximately 411236 kWh yearly as against the total actual consumption of 585315 kWh. These values show that the building is using 29% more energy that that required by the building. The main reason for this difference in results is because the simulation model considers the HVAC system to be controlled by automation system while at present the HVAC system is operated and controlled manually.

Table 5.1:* *Simulation Model: *Reduction in Unit energy consumption of the library building after providing HVAC Controls*

Month	Actual units consumed	Units consumed after HVAC controls	Percent reduction
Oct '07	50592	34455	32%
Nov '07	57680	26328	54%
Dec '07	58864	28165	52%
Jan '08	53920	30990	43%
Feb '08	41184	25156	39%
March '08	30762	27435	11%
April '08	34233	38237	-12%
May '08	51520	40740	21%
June '08	54720	42706	22%
July '08	46080	42535	8%
Aug '08	54720	39205	28%
Sept '08	51040	35284	31%

(Source: Simulation model results for library building)



Graph 5.2: Simulation Model: *Reduction in Unit energy consumption of the library building after providing HVAC Controls*

5.3 SIMULATED CO2 PRODUCTION BECAUSE OF THE ENERGY CONSUMPTION

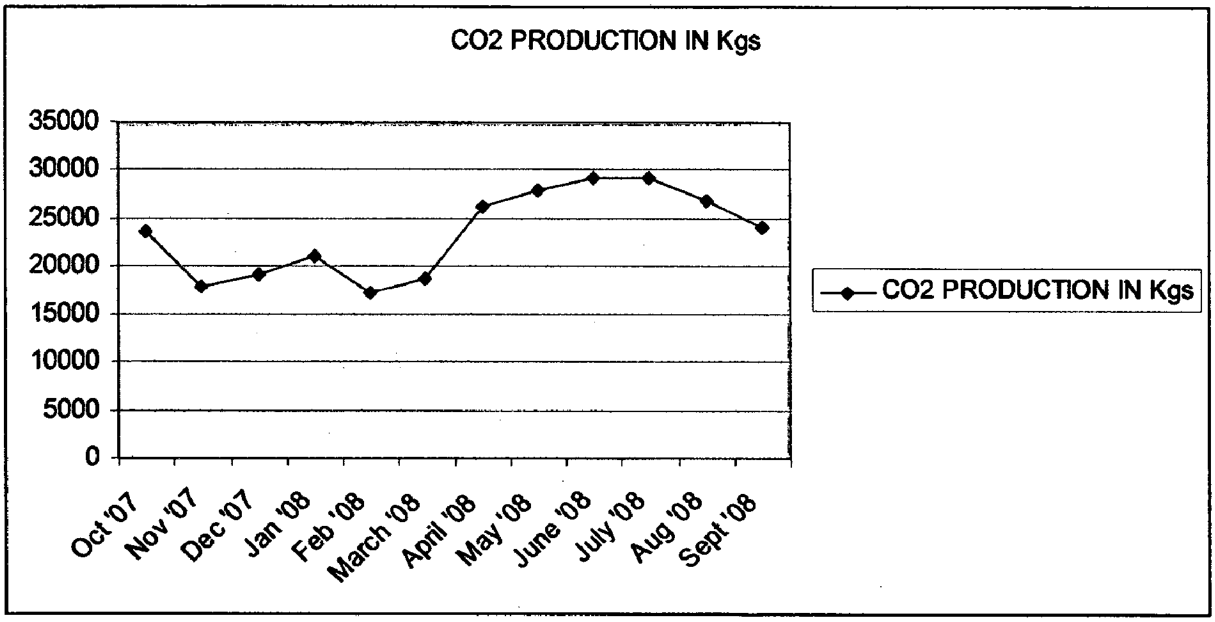
The production of the electricity emits carbon. The present energy requirement of the library – 585315 kWh emits 400928 Kgs of CO2. But the simulated model shows less amount of energy requirement with provision of automation controls for HVAC system. Energy use as per simulation model is 411236 kWh which emits 281688 Kgs of CO2 for production.

Table 5.2: Simulation Model: *CO2 production due to energy consumption by the library according to the simulated model*

MONTH	CO2 PRODUCTION IN Kgs
October	23601
November	18033
December	19293

January	21227
February	17230
March	18793
April	26191
May	27906
June	29253
July	29137
August	26855
September	24169
TOTAL	**281688**

(Source: Simulation model results for library building)



Graph 5.3: Simulation Model: *CO_2 production due to energy consumption by the library according to the simulated model*

5.4 ENERGY USE BREAKUP:

Scope for energy conservation requires the knowledge of the energy usage break up for the energy consuming components of the building. Out of the total energy requirement most of the energy is consumed by HVAC system which is about 46 %, 19% lighting and 35% by other systems like computers, printers, Xerox machines etc.

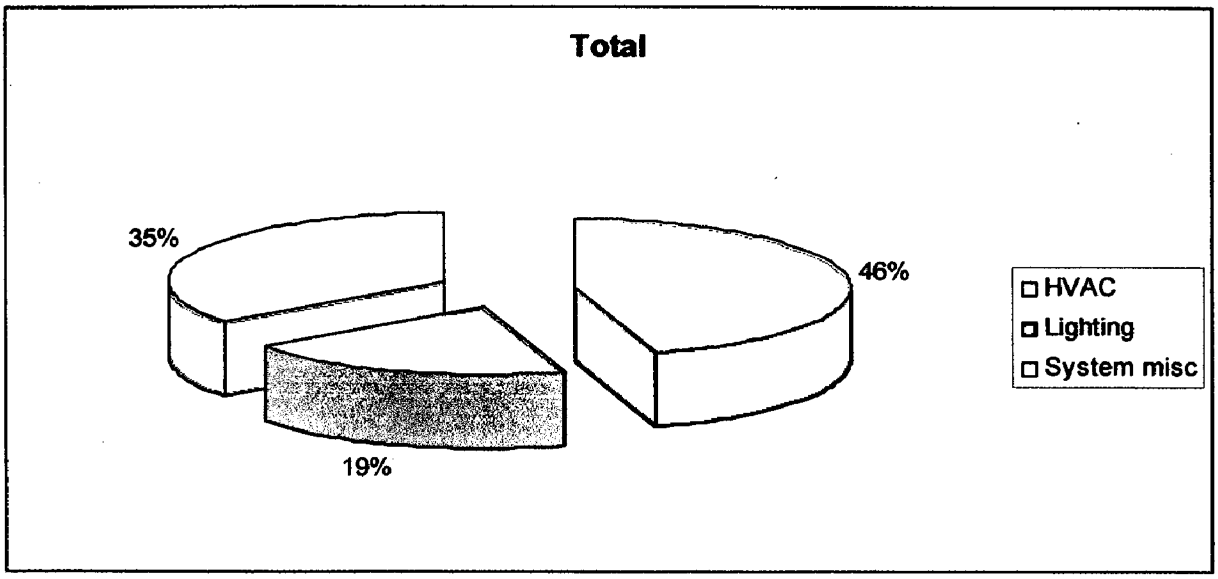


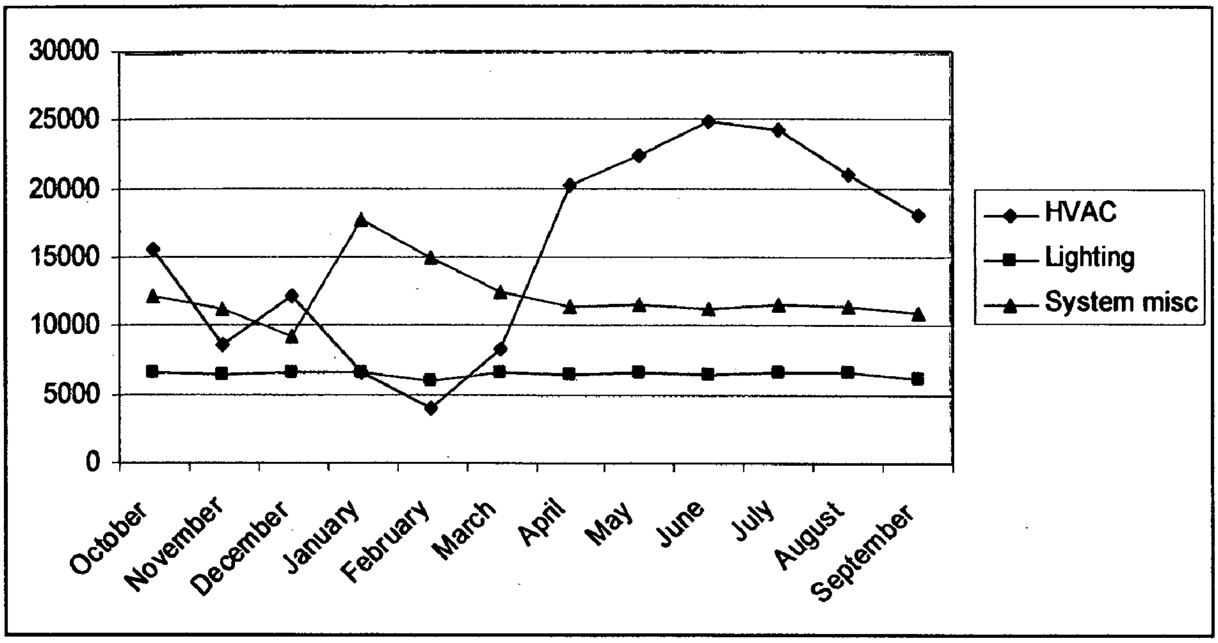
***Fig 5.4: Simulation Model:** Energy use distribution in library*

***Table 5.3: Simulation Model:** Energy use break up for HVAC, lighting and system misc*

Month	HVAC	Lighting	System misc
October	15620	6678	12157
November	8613	6462	11253
December	12246	6674	9245
January	6577	6678	17735
February	4064	6032	15060
March	8284	6678	12473
April	20323	6461	11453
May	22440	6677	11623
June	24968	6462	11276
July	24331	6676	11528
August	21025	6676	11504

September	18046	6247	10991

(Source: Simulation model results for library building)



Graph 5.4: Simulation Model: *Energy use break up for HVAC, lighting and system misc*

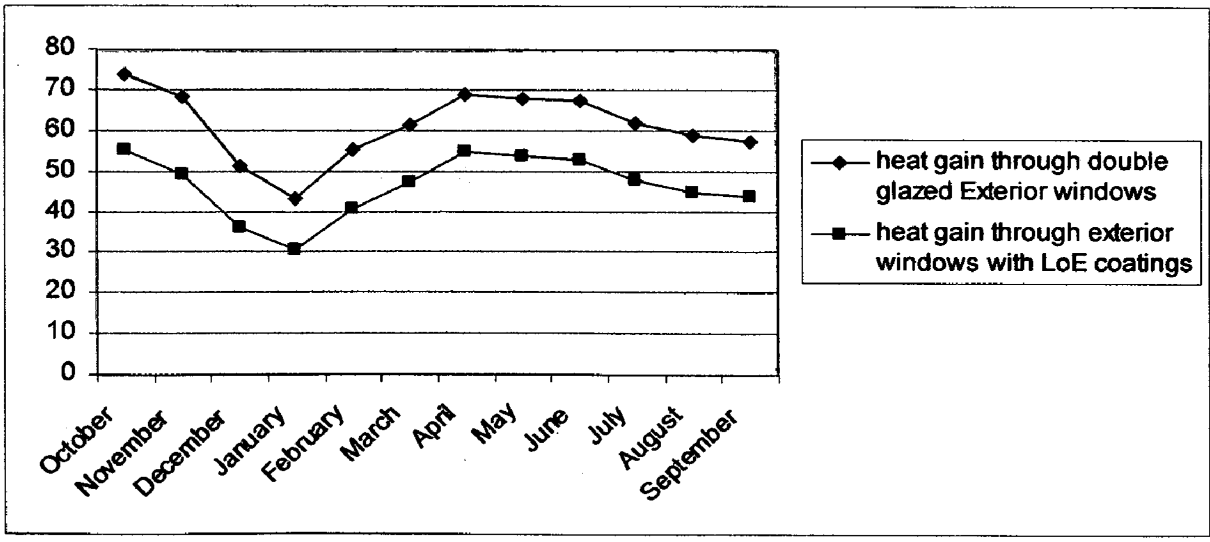
The library model can further be simulated for different settings and options to find out the options that can further reduce the energy use of the library building. Following are the simulation results for these options.

The library model when simulated for the Low Emissive Coating (LoE) coating on both the sides of the double glazed window shows reduction in heat gain of the building. This can be verified through the comparative graph below. The reduction in heat gain reduces the HVAC system load.

Table 5.4: Simulation Model: *Reduction in Heat gain external windows using LoE coatings*

Month	**Heat gain through exterior windows in MWh**	**Heat gain through exterior windows using LoE coatings in MWh**	**Percent reductions in heat gains**
October	74.00	55.40	25%
November	68.58	49.53	28%
December	51.39	36.28	29%
January	43.09	30.79	29%
February	55.13	40.97	26%
March	61.52	47.29	23%
April	68.97	54.66	21%
May	67.92	53.83	21%
June	67.39	52.7	22%
July	61.86	47.99	22%
August	59.06	44.65	24%
September	57.58	43.81	24%

(Source: Simulation model results for library building)



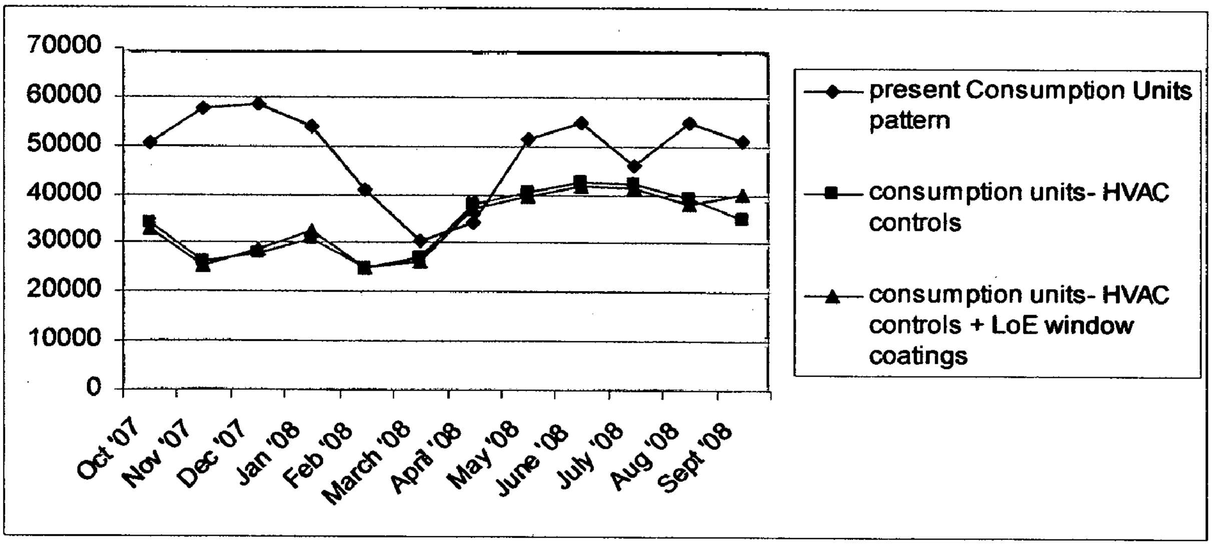
Graph 5.5: Simulation Model: *Heat gain through present double glazed windows and windows with LoE coatings*

The following table shows the reduced energy consumption because of this alteration to the existing building (HVAC control + LoE coated windows). The reduction is about 31% of the present consumption pattern.

Table 5.5: Simulation Model: *Reduction in Unit energy consumption of the library building after providing HVAC Controls + LoE coated windows*

Month	Actual units consumed	Units consumed after HVAC controls + LoE coatings	Percent reduction
Oct '07	50592	32962	35%
Nov '07	57680	25445	56%
Dec '07	58864	29045	51%
Jan '08	53920	32500	40%
Feb '08	41184	25135	39%
March '08	30762	26396	14%
April '08	34233	37158	-9%
May '08	51520	39736	23%
June '08	54720	41777	24%
July '08	46080	41655	10%
Aug '08	54720	38272	30%
Sept '08	51040	40386	21%

(Source: Simulation model results for library building)



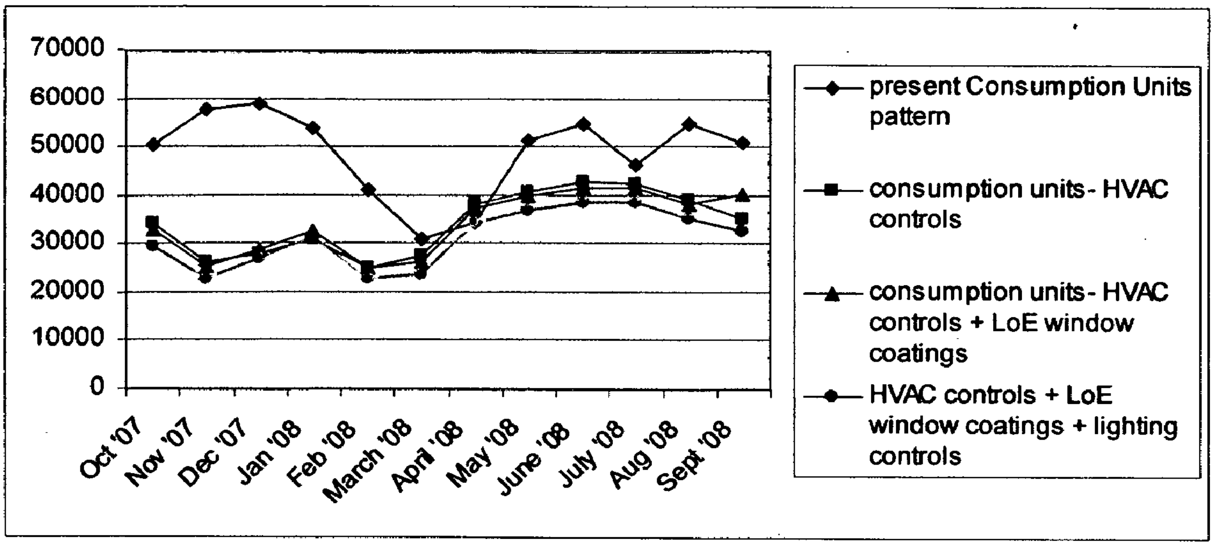
Graph 5.6: Simulated Model: *Reduction in energy consumption through installation of the HVAC control system + LoE coated Windows*

Further the simulation on library model for lighting controls shows further reduction in energy consumption of the library building. The following graph and table shows the reduction in energy consumption after HVAC controls + lighting controls + LoE coated windows. The total reduction is about 36%.

Table 5.6: Simulation Model: *Reduction in Unit energy consumption of the library building after providing HVAC Controls + LoE coated windows + lighting controls*

Month	Actual units consumed	Units consumed after HVAC controls + LoE coatings + lighting controls	Percent reduction
SOct '07	50592	29640	41%
Nov '07	57680	22774	61%
Dec '07	58864	27357	54%
Jan '08	53920	31413	42%
Feb '08	41184	23027	44%
March '08	30762	23596	23%
April '08	34233	34248	0%
May '08	51520	36773	29%
June '08	54720	38806	29%
July '08	46080	38653	16%
Aug '08	54720	35181	36%
Sept '08	51040	32507	36%

(Source: Simulation model results for library building)



Graph 5.7: Simulation Model: *Reduction in energy consumption after HVAC controls + LoE coated windows + lighting controls*

CHAPTER 6

INFERENCES AND RESULTS OF STUDIES

The project area falls into a climatic zone which has extreme conditions and thus experiences heat up to 42 degree C and lowest temperature below 5 degree C. Thus the building design should be according to the heat gain and heat loss of the building during both the extreme periods so that the interiors of the building provides for most of the human comfort possible.

6.1 BUILDING FORM AND ENVELOP:

- The building's longer side is aligned with the North – South axis. This is the most desirable orientation for optimum use of the HVAC system. The reason being that in this orientation comparatively smaller external wall surface area faces west and south west directions which receives most of the total heat gain of the building.

- The major service cores that include toilets, staircase, lifts and AHU are at the rear side of the building which faces the west and thus buffer the internal spaces from harsh western sun.

- The external walls have sandstone slab cladding of 2.5 cm thickness. This reduces the u-factor of the wall i.e. the heat gain of the wall reduces as compared to the U – value of the simple brick wall plastered on both sides.

- Maximum area of the total surface area of the external wall of the building is double glazing. This part of the external wall surface accounts for the most of the heat gain of the building on all sides.

- The huge glazed surfaces provides ample amount of natural light to the building lowering the need for artificial lighting. The best advantage of the present zoning within the building is that the reading areas which are the essential part of the activities carried out in the building falls in this naturally lighted area.

6.2 SITE:

- The paved and the tarred area around the building as well as the roof of the library building radiate back the solar heat it receives during the whole day. These results in formation of heat island effect i.e this area becomes warmer than its surroundings.

The term "heat island" describes built up areas that are hotter than surrounding under developed areas around Roorkee. The annual mean air temperature of a city with 1 million people or more can be 1–3°C warmer than its surroundings. In the evening, the difference can be as high as 12°C. Heat islands can affect communities by increasing summertime peak energy demand, air conditioning costs, air pollution and greenhouse gas emissions, heat-related illness and mortality, and water quality.

Effect of heat islands:

1. **Increased energy consumption:**
   Higher temperatures in summer increase energy demand for cooling and add pressure to the electricity grid during peak periods of demand. Heat island effect is responsible for 5–10% of peak electricity demand for cooling building under study.

2. **Elevated emissions of air pollutants and greenhouse gases:**
   Increasing energy demand results in greater emissions of air pollutants and greenhouse gas emissions, viz. CO_2 gas emissions.

3. **Compromised human health and comfort:**
   Warmer days and nights, along with higher air pollution levels, can contribute to

general discomfort, respiratory difficulties, heat cramps and exhaustion, non-fatal heat stroke, and heat-related mortality.

4. **Impaired water quality:**

   Hot pavement and rooftop surfaces transfer their excess heat to stormwater, which then drains into storm sewers and raises water temperatures as it is released into streams, rivers, ponds, and lakes. Rapid temperature changes can be stressful to aquatic ecosystems.

   The paved surfaces make the site of the library impervious to the water. Thus the rain water from these areas is carried away through storm water drains and finally adds to the further reduction in the level of ground water of the area.

6.3 WATER USE:

- The water use in the toilets and wash basins may be reduced by changing the fixture type or making alterations in them

- The use duel flush system, dry urinals and aerators for the wash basins can save water consumption by 187.25 liters daily as against the present water use which is 390 liters daily. Thus the ware saving can be upto 48% through the mentioned retrofits. After the retrofit the water use is reduced to 202.75 liters/day. Finally annual consumption is 78830 liters.

- The rainwater available for harvesting is 374850 liters/year which is much more than the water used by the toilets in the library. Thus the rainwater can be stored and used for the toilets for the whole year, reducing the load on the portable water use by the toilets totally. The remaining water can be used for landscaping.

6.4 ENERGY USE AND ATMOSPHERE:

- The present energy consumption of the library building is high during the hot months from May to August and during the cold months from November to January because of the heating and the cooling loads.

- The glazed external surface causes the maximum heat gain of the building during summers and causes heat loss during winters.

- The refrigerant used by the chiller in the HVAC system is R - 22 which has the ozone depletion potential (ODP) of 0.05 and global warming potential (GWP) of 1700. These values are high as compared to the refrigerant HCFH used in centrifugal type of chillers. This refrigerant has the ozone depletion potential (ODP) of 0.012 and global warming potential (GWP) of 120*.

- The chilled water in the HVAC system cools the hot internal air and the hot water returns to the chiller to be cooled again. Thus using the same water again and again in a cycle. This proves to be the water efficient feature of the HVAC system being used.

- The HVAC system is managed manually using a control panel. The internal temperatures are set according to outside temperatures. The total time required to run the HVAC system for the day is decided manually. Thus this system does not provide proper human comfort conditions to the users all the time.

- The library building is already using the CFLs which are energy efficient, long lasting and less expensive than the CFL source over a year is 4 milligrams (used

* Data obtained from en.wikipedia.org

in the CFL) and 2.4 milligrams emission from the power plant while mercury emission by incandescent light is 10 milligrams. Thus CFLs are helpful in improving the indoor air quality and also reduce the energy consumptions fluorescent tubes and the incandescent lights. Since they use less energy it reduces the CO2 emission. Mercury emission by a.

- Though CFL lights are used the energy consumption for lighting system is high. This is because of lack of awareness among the users. Lights in unoccupied areas are kept switched on frequently. Most of the times the naturally lighted areas are using artificial lights even when not required and thus causing the increase in lighting loads.

6.5 SIMULATION MODEL RESULTS:

- Applying the HVAC control system to the present library saves 29% energy use of the building, thus saving 174079 unit consumption of energy in a year (Table 6.1).

Table 6.1: *Cost Benefits due to the New Control System Applied to the HVAC*

Sr. No.	Description	Values
1.	Units saved	174079 units#/year
2.	Monetary savings	3,48,200 Rs/year
3.	Estimated cost of additional components	5,56,000 Rs
4.	Payback Period	1.5 years

Unit = kWh

- The LoE coating on both sides of the double glazed windows further saves 6850 units consumption of energy per annum (table 6.2).

Table 6.2: *Cost Benefits due to the LoE Coatings Applied to the windows*

Sr. No.	Description	Values
1.	Units saved	6850 units/year
2.	Monetary savings	Rs 13,700 /year
3.	Estimated cost of additional LoE coatings	Rs 66,150
4.	Payback Period	5 years

- The lighting control applied to the library will save 30411 units on energy consumption per annum (Table 6.3).

Table 6.3: *Cost Benefits due to the New Control System Applied to the Lighting System*

Sr. No.	Description	Values
1.	Units saved	30411 units#/year
2.	Monetary savings	Rs 60,822 /year
3.	Estimated cost of additional components	Rs 1,86,500
4.	Payback Period	3 years

- The approximate 2000 sq mts of roof if converted to green roof have the capability of saving about 25%* of total energy consumption (Table 6.4)

Table 6.4: *Cost Benefits due to the Installation Green Roof*

Sr. No.	Description	Values
1.	Units saved	146300 units/year
2.	Monetary savings	Rs 2,92,600 /year

Unit = kWh

* Data taken from a Cover Story of "Green Roofs- can Greatly Reduce India's Carbon Footprints" by Geoff Wilson

3.	Estimated cost for the Green Roofs	Rs 9,60,000
4.	Payback Period	3.5 years

- The following table shows the total savings made by the energy conservation project along with the pay back period.

Table 6.5: *Total cost benefits due to the Energy Conservation Retrofits*

Sr. No.	Description	Values
1.	Units saved	357640 units/year
2.	Monetary savings	Rs 7,15,280 /year
3.	Estimated cost for the Energy Conservation Retrofits	Rs 17,68,650
4.	Payback Period	2.5 years

- The energy production emits carbon. Reduction in energy use reduces this carbon emission due to the energy use of the building and this reduction in carbon emission gains carbon credits for the building. Any building gets 1 carbon credit for 1 ton reduction of carbon emission. The following table shows the reduction in carbon emission if the energy conservation project is carried out.

Table 6.6: Reduction in Carbon Emission due to the Total Energy Conservation Retrofits

Sr. No.	Project	Reduced Carbon emission in Kgs
1.	HVAC control system	119240
2.	LoE coating for the windows	4693
3.	Lighting controls	20831
4.	Green roof	100232
5.	**Total**	**244996**

- Total carbon emission reduction ~ 245tons
- Carbon credits earned by the Library ~ 245
- In monetary terms one carbon credit trade at Rs 720 – Rs 4330 internationally.

CHAPTER 7

RECOMMENDATIONS

Considering the project area study, the detailed study and the inferences drawn from the studies allow to make the following recommendations to retrofit the existing library building as a green building.

7.1 BUILDING FORM AND ENVELOPE:

The detailed study of the library shows that the external window glazing causes the maximum heat gain of the building. Heat gain through the windows can be reduced by applying LoE coating on the glazing.

A Low-E coating is a microscopically thin, virtually invisible, metal or metallic oxide layer deposited directly on the surface of one or more of the panes of glass. The Low-E coating reduces the infrared radiation from a warm pane of glass to a cooler pane, thereby lowering the U-factor of the window.

To keep the sun's heat out of the library the Low-E coating should be applied to the outside pane of glass. The Low-E coating should also be applied to the inside pane of glass so that during the winter there is no heat loss through the windows and the heat is retained inside the building. The LoE coating can reduce the U- factor of the library window from 0.34 to 0.22. Using the LoE films will be cheaper compared to total window replacements. The coatings last 10–15 years without peeling, save energy and increase comfort.

7.2 SITE:

Although prevailing weather patterns, climate, geography, and topography are beyond the influence of local policy, certain range of energy-saving strategies can generate multiple benefits, including vegetation, landscaping, and improvements to building and road materials.

7.2.1 REDUCED SITE DISTURBANCE:

Green Roof should be installed on the library roof. It will reduce heating and cooling energy use and associated air pollution and greenhouse gas emissions, remove air pollutants, lower the carbon emission, help lower the risk of heat-related illnesses and deaths, lower the heat island effect due roof surface, improve stormwater control and water quality, reduce noise levels, create habitats, improve aesthetic qualities, and increase property values. Native grass and shrubs should be used to reduce the water need for irrigation. The green roof will reduce energy use of the library by 25%. Also the green roof is the most effective way to recover the building footprint.

7.2.2 HEAT ISLAND REDUCTION:

The roads and the pavements can be given the cool coating to lower cooling energy use, peak electricity demand, air pollution and greenhouse gas emissions and heat-related incidents. Cool pavements reduce heat island effect by reducing surface temp. of the pavement. Heat-shield pavements and roads can be made by applying a special coating that reflects near-infrared rays to the pavement surface.

7.2.3 TRANSPORTATION:

Vehicular movements in the campus of IIT Roorkee are less as compared to pedestrians and cycles. To further reduce the use of vehicles to the library the use of cycles should be encouraged. This can be done by providing secured parking facilities for cycles on the library site. This will help in reduction of pollution.

7.3 ENERGY USE AND ATMOSPHERE:

7.3.1 USING CAPACITOR PANEL IN THE SUBSTATION:

Most of the energy used for the building is for the HVAC system. Few alterations in the present system would achieve great energy efficiency. The library receives electricity from a separate substation which serves library and has recently been providing electricity to Department Of Management Studies. Since the supply is from within the campus there is an advantage that a capacitor panel is used for the supply of electricity to the building. This will supply constant voltage to the library. Constant voltage supply uses less current thus reducing the total energy consumption of the building.

7.3.2 USE OF TEMPERATURE CONTROLS:

Presently the HVAC system is operated manually, thus not providing proper comfort to the users. Also the system at the unoccupied spaces also keeps running consuming more energy. Providing the system with proper control system may save lot of energy consumption.

Different zones of the building should be provided with temperature sensors which would detect the temperature of the zone and end this data to the thermostat.

According to the outside climate the thermostat is adjusted set point temperatures :

- for heating temperatures $\pm$ 20 degree C and
- for cooling temperatures $\pm$ 23 degree C.

A thermostat is a device for regulating the temperature of a system so that the system's temperature is maintained near a desired set point temperature. The thermostat does this by controlling the flow of heat energy into or out of the system. That is, the thermostat switches heating or cooling devices on or off as needed to maintain the correct temperature.

A thermostat may be a control unit for a heating or cooling system or a component part of a heater or air conditioner. Thermostats can be constructed in many ways and may use a variety of sensors to measure the temperature. The output of the sensor then controls the heating or cooling apparatus.

For the library project the thermostat may be connect to the chilled water supply valve in the AHU units. The thermostat will thus control the amount of chilled water supply in the AHU unit, finally controlling the temperature requirement of the spaces within the library. When the temperature in the room increases or decreases than the set point temperature the thermostat will trip the AHU unit till it is necessary to start the unit again.

The change in the temperature of the spaces may be due to:

1. change in number of users
2. use of components like computers, printers, etc
3. use of lighting system

Thermostats may also be connected to the occupancy sensors to lower the use of the HVAC system in the spaces which are not being used. Thus the energy used at the AHU unit is saved. When the AHU unit is off the chilled water supply to it also stopped thus using less amount of chilled water for the rest of the system. Finally this will reduce the electric load at the chillers also. Earlier studies shows that providing these alterations to the present system will save about 29% of the energy use. It finally reduces the CO_2 emission by the energy use by same proportion. These alterations also provide exact temperatures required for human comfort.

7.3.3 LIGHTING CONTROLS:

The library building is already using CFL lights which are energy effective and have longer life.

The reading areas in the library are in the areas which are naturally lighted. Lighting in these areas is still switched on even when they are not in use. Same is applicable for the books stacking spaces where lighting is left on even when that space is not occupied. The building zones should be provided with occupancy sensors each so that the lighting of the areas not in use is switched off. Lighting dimmers can be easily fitted for the CFL lights. The dimmers can fitted for the lighting fixtures in the zones which are naturally lighted so that only required amount of lighting load is used. The earlier simulation shows that this retrofit to the library building can reduce its energy use by 5%

High intensity discharge (HID) lamps are more efficient than incandescent flood lights and should be used in their stead. HID lamps are best suited for large interior spaces with a high ceiling such as lobbies and atriums. HID lamps have a longer lifetime than either fluorescent or incandescent bulbs and do not have to be changed as often. In the library the CFL lights only in the double heighted reading room space near the atrium can be changed to HID lamps which will allow tight focusing of light in this reading area where the height of lighting fixture is very high from the table top.

Use of task lighting for reading area can reduce the footcandle levels in a space and reduce the electrical energy demand.

7.3.4 PEAK LOAD SHIFTING:

The peak hours which use maximum load of electricity is the starting of the day i.e. from 9:00 am when the staff members of the library and students arrive. In the evenings after the scheduled classes i.e. from 5:00 pm to 7:00 pm, the library is used maximum by the students for the reading rooms. The HVAC system demand is the most during these periods.

The system's demand may be limited by shifting the building load to off peak hours. One way to do this is to run the chillers during the night to chill water that is stored in large tanks on the premises. Then during the peak building load the following day the chillers are turned off and the ready-made chilled water is circulated to the building loop.

7.3.5 OZONE PROTECTION:

The presently use refrigerant used in the chiller has the ozone depletion potential (ODP) of 0.05 and global warming potential (GWP) of 1700. Changing the refrigerant used in the system may have a positive effect on the environment. The refrigerant HCFC-123 may be used which has the ozone depletion potential (ODP) of 0.012 and global warming potential (GWP) of 120.

7.3.6 ON-SITE RENEWABLE ENERGY:

After achieving energy consumption reduction and ozone protection through various ways, attempt should be for further energy conservation through renewable sources of energy which are environment friendlier. Renewable energy may be produced on the library site. In this case a mixed mode system can be used.

In mixed mode system comfort conditions and components like computers and printers are achieved mostly through regular electric supply. The remaining energy needs in terms of lighting can be made by productive mode system. In productive mode the building will produce its own energy using photovoltaics, which will provide clean, quiet and pollution free energy source.

The photovoltaics can be located on the south façade of the building which receives unobstructed solar gain and also on the terrace of the building. Solar trees also have photovoltaic panels. These panels can generate electricity and store them in batteries for further use. Thus about 20% of energy use load can be reduced from the library building by the use of renewable energy. The energy production will not produce carbon emissions at all. Thus the carbon emissions due to the library will further reduce by 20%S

7.3.7 BUILDING OPERATIONS AND MAINTAINANCE:

Effective energy load management is a two step process, consisting of effective system alterations and system response. Having achieved the first step next step is operation and management of the systems. The management and maintenance is the only ways to optimize the life performance of the system in terms of energy use and comfort. Energy monitoring and control systems should provide energy consumption monitoring using hourly graphs to note the effects of small operational changes and monthly graphs to have a record of historical trends and provide operating information over time.

The building should have on-site facility engineering staff electricians and HVAC technicians that are dedicated to the continuous commissioning, maintenance, efficient and safe operation of the facility. Routine inspections of the library and the equipment are used to determine maintenance repair requirements. This system provides a scheduled preventive maintenance program that ensures that all of the building systems and equipment are functioning properly and catalogs inspections of the equipment in the system.

The library can use a computerized building automation system, to monitor and control all building HVAC equipment. The automation system includes controls and sensors for the occupancy and heating, cooling and lighting systems. These points should be continuously monitored, and alarm parameters can be established to indicate when conditions are beyond their normal operating limits.

7.3.8 PERFORMANCE MEASUREMENT:

Presently the library building has a single meter. Thus if there is any change in energy consumption than the regular trend of energy consumption of the building there is no way to find out the reason for the change. For this purpose separate metering system should be used for HVAC system, lighting system and other misc. systems.

7.4 WATER USE:

7.4.1 USE OF WATER EFFICIENT FIXTURES:

The library building should use aerators for the washbasins which reduce water use by 50%. The present flushing system should be replaced by the duel flush system. This further reduces water use by 31%. Waterless urinals do not use water and hence there is potential of totally reducing the water use by present urinals by replacing them by the waterless urinals.

In the library water is also required for the water coolers for drinking. The consumption amount of the drinking water cannot be reduced but the water wasted while drinking water can be saved by providing use-and-throw plastic glasses. This will avoid the run off of the water while drinking it directly from the water cooler tap

7.4.2 RAIN WATER HARVESTING:

The study for rain water harvesting in previous chapters shows that the library building has a potential of harvesting 374850 liters of rain water annually. The retrofitted toilet fixtures will reduce the water use by 48% so that after the retrofit the water consumption will be 78830 liters. Thus the rainwater harvested can be used for both toilets and the irrigation of the green roofs.

For rainwater harvesting whatever excess water collected by the roof after the green roof retaining about 75% of the rainwater should be brought down to the underground storage tank through conveyance pipes. The water stored this way can be used in flush and washbasin for the whole year. The remaining stored rainwater can be used for irrigating the landscaped area. Thus load on portable water supply to the library building will almost be nil.

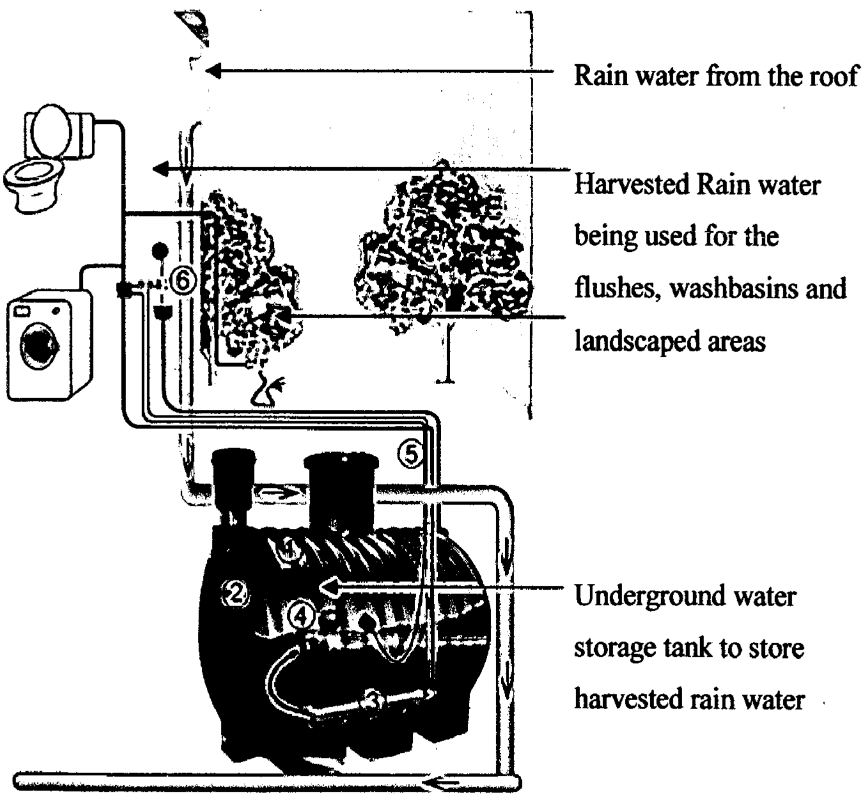


Fig 7.1: Method recommended for rain water harvesting

The site surrounding the library is impervious because of the roads and the pavements. Hence there is surface run off of the rainwater from the roads and pavements. This can be reduced by percolating the run off water to the ground water table through the recharge trench. The library site is slightly sloping to the front side of the building. A continuous trench of 0.5m width and 1m depth should be excavated. Then this trench should be lined with bricks with openings (weep-holes) at regular intervals. The trench should be refilled with porous media like pebbles, boulders or broken bricks. The top area of the pit can be covered with a perforated cover. The run off water from road and pavements will percolate through this trench to the ground water table.

The present pavements may be replaced with grid pavement to further allow the run off rainwater from the pavements to perforate to the ground water table. The grid pavement will keep the grass, ensure adequate drainage, and prevent mud puddles parking lots.

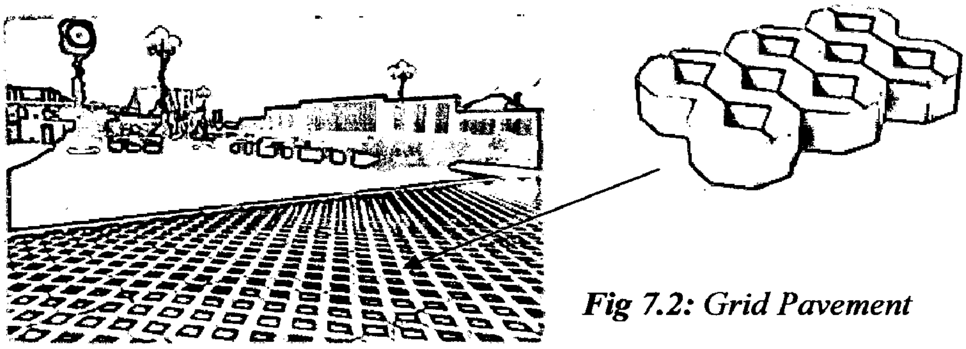


Fig 7.2: Grid Pavement

7.4.3 GREYWATER REUSE:

Greywater is waste water taken from hand basins and water cooler. It can only be used for toilet flushing and garden irrigation. The volume of grey water generated in the library can be used for irrigating the green roof or the surrounding landscape by recycling it through a simple recycling system. The waste water from the washbasins and warecoolers can simply filtered using a sand pit before using it for the irrigation of the landscaped area. Simple filtration process is need for grey water from the library because it has very low amount of soap quantity and low amount of nitrogen content.

7.5 MATERIALS AND RESOURCES:

7.5.1 WASTE MANAGEMENT:

The major waste material from the library is paper and cardboard. The library should establish minimum source reduction and recycling program. The recycling policy for the library building should provide a list of recyclable materials to the users of the building. Separate facilities should be provided for recyclable and non recyclable material so that the reusable waste can be sent for recycling and rest of the garbage can be sent to garbage disposing plants. This will reduce load on the garbage disposing plants and grounds and reduce pollution.

7.5.2. TOXIC MATERIAL SOURCE REDUCTION:

Emission of the toxic material can be reduced by avoiding mercury emitting lighting systems. An incandescent light bulb emits 10 mg toxic mercury in a year. The library building is already using CFL lighting system emits only 4mg mercury in a year and emits 2.4 mg mercury from power plant in a year. This has lead to improved indoor air quality in the library and also reduces pollution at the power plant.

7.5.3 OPTIMISE USE OF ALTERNATIVE MATERIAL:

The library building should establish and adopt purchasing policies that target use of alternative materials. The policy can cover use of salvaged material, material that is recycled or has recycled content and local/regional material. For eg. Use recycled paper or having recycled content for photocopying facilities, printings and bindings etc.

7.6 INDOOR AIR QUALITY:

Establishing indoor air quality improvement program will enhance the ıdoor air quality of the building, thus contributing to the health and the well being of the ·cupants.

Tobacco smoke is prohibited in the library building. The library building ;o uses CFL lighting system which emits less mercury during its life period. The high lume printing/copying rooms, fax stations and computer rooms that release toxic ıterials and heat should be provided with exhaust system to keep the indoor air clean.

The controllability provided to the lighting and HVAC system as ɜntioned in above recommendations will promote the productivity, comfort and well ing off the library users. The huge double glazing provided to the library connects loor spaces and the outdoor environment through introduction of sunlight and views o the occupied areas of the library building.

LEED-EB PROJECT CHECKLIST

The recommendations in the previous chapter are the ways to make the Central Library Building, IIT Roorkee, green. After applying the retrofitting measures to the library building it will get LEED-EB points. Following is the checklist provided by the LEED-EB to check how green the building is after applying retrofitting measures to it to make it green.

Sustainable Sites	**14 Possible Points**
Erosion and Sedimentation Control	Required
Age of Building	Required
Plan for Green Site and Building Exterior Management	
High Development Density Building and Area	
Alternative Transportation: Public Transportation Access	
Alternative Transportation: Bicycle Storage & Changing Rooms	1
Alternative Transportation: Alternative Fuel Vehicles	
Alternative Transportation: Car Pooling & Telecommuting	
Reduced Site Disturbance: Protect or Restore Open Space	2
Stormwater Management: Rate and Quantity Reduction	2
Heat Island Reduction: Non-Roof	1
Heat Island Reduction: Roof	1
Light Pollution Reduction	1

Water Efficiency	**5 Possible Points**
Minimum Water Efficiency	Required
Discharge Water Compliance	Required
Water Efficient Landscaping: Reduce Water Use	2
Innovative Wastewater Technologies	1
Water Use Reduction	2

Energy & Atmosphere	23 Possible Points
Existing Building Commissioning	Required
Minimum Energy Performance	Required
Ozone Protection	Required
Optimize Energy Performance	10
On-site and Off-site Renewable Energy	4
Building Operations and Maintenance: Staff Education	
Building Operations and Maintenance: Building Systems Maintenance	1
Building Operations and Maintenance: Building Systems Monitoring	1
Additional Ozone Protection	1
Performance Measurement: Enhanced Metering	3
Performance Measurement: Emission Reduction Reporting	
Documenting Sustainable Building Cost Impacts	

Materials & Resources	16 Possible Points
Source Reduction and Waste Management: Waste Stream Audit	Required
Source Reduction and Waste Management: Storage & Collection of Recyclables	Required
Toxic Material Source Reduction: Reduced Mercury in Light Bulbs	Required
Construction, Demolition and Renovation Waste Management	
Optimize Use of Alternative Materials	5
Optimize Use of IAQ Compliant Products	
Sustainable Cleaning Products and Materials	
Occupant Recycling	
Additional Toxic Material Source Reduction: Reduced Mercury in Light Bulbs	1

Indoor Environmental Quality	22 Possible Points
Outside Air Introduction and Exhaust Systems	Required
Environmental Tobacco Smoke (ETS) Control	Required
Asbestos Removal or Encapsulation	Required
Outside Air Delivery Monitoring	
Increased Ventilation	1
Construction IAQ Management Plan	

Documenting Productivity Impacts: Absenteeism and Healthcare Cost Impacts	
Documenting Productivity Impacts: Other Impacts	
Indoor Chemical and Pollutant Source Control:	
Non-Cleaning – Reduce Particulates in Air Distribution	
Indoor Chemical and Pollutant Source Control:	
Non-Cleaning –High Volume Copying/Print Rooms/Fax Stations	1
Controllability of Systems: Lighting	1
Controllability of Systems: Temperature & Ventilation	1
Thermal Comfort: Compliance	
Thermal Comfort: Permanent Monitoring System	1
Daylighting and Views: Daylighting for 50% of Spaces	1
Daylighting and Views: Daylighting for 75% of Spaces	
Daylighting and Views: Views for 40% of Spaces	1
Daylighting and Views: Views for 80% of Spaces	
Contemporary IAQ Practice	
Green Cleaning: Entryway systems	
Green Cleaning: Isolation of Janitorial Closets	
Green Cleaning: Low Environmental Impact Cleaning Policy	
Green Cleaning: Low Environmental Impact Pest Management Policy	
Green Cleaning: Low Environmental Impact Cleaning Equipment Policy	

Innovation in Operation, Upgrades and Maintenance **5 Possible Points**

Innovation in Operation & Upgrades 1

Innovation in Operation & Upgrades 1

Innovation in Operation & Upgrades 1

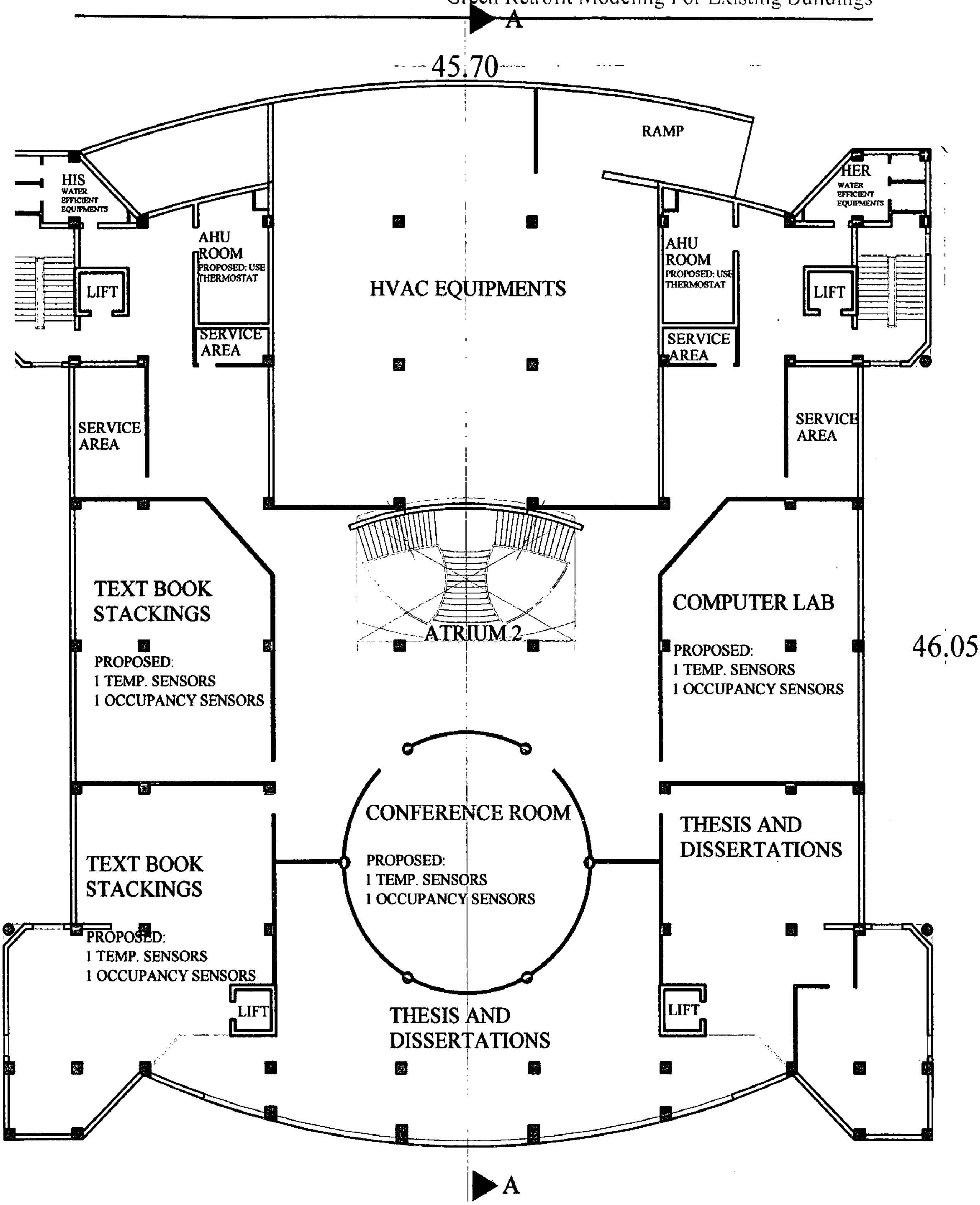
Innovation in Operation & Upgrades 1

LEED Accredited Professional 1

POSSIBLE GREEN BUILDING CERTIFICATION:

Points earned: 46

Certification level: LEED Silver



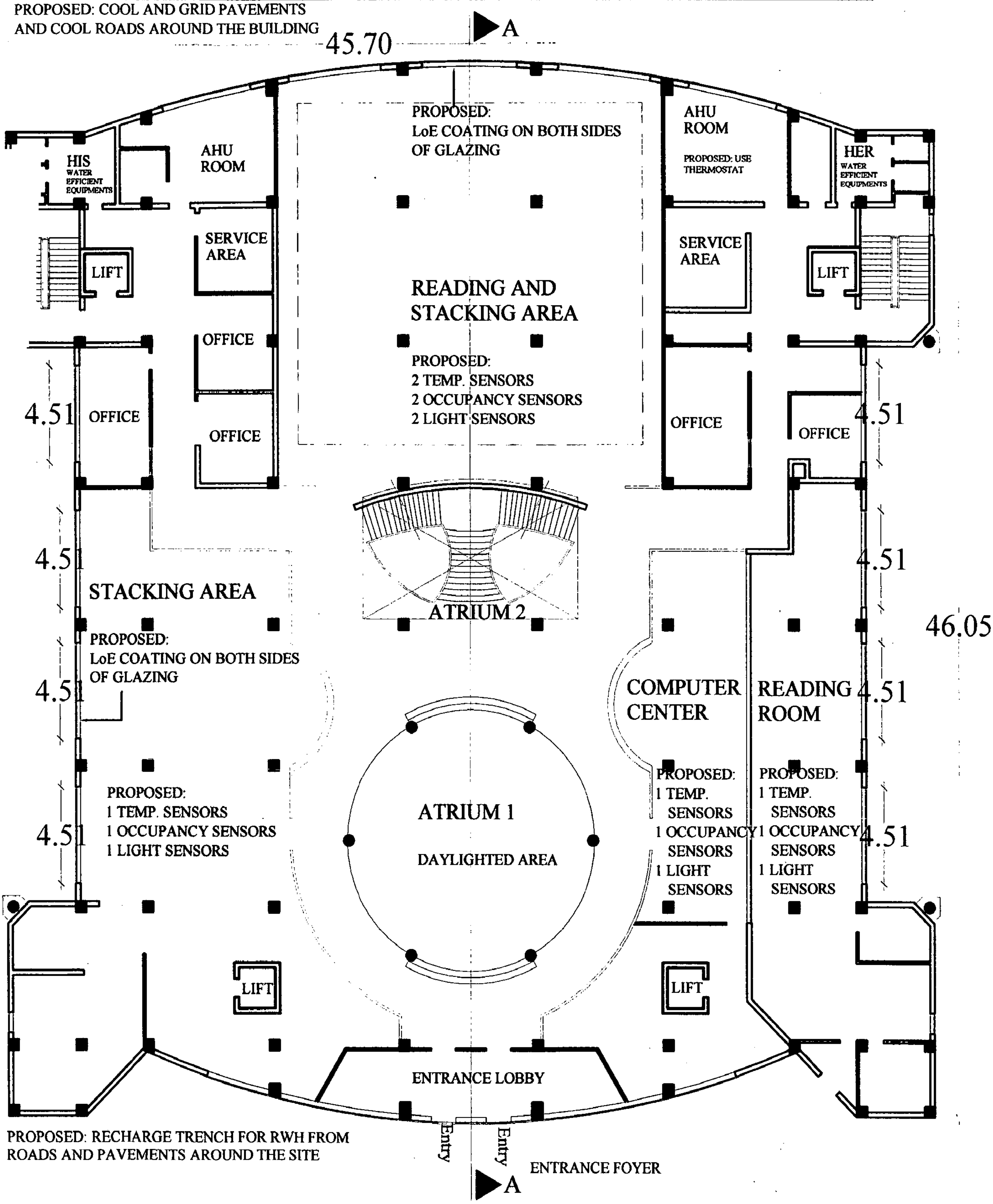
BASEMENT PLAN
CENTRAL LIBRARY
B U I L D I N G

N

PROPOSED GREEN RETROFITS TO THE LIBRARY BUILDING

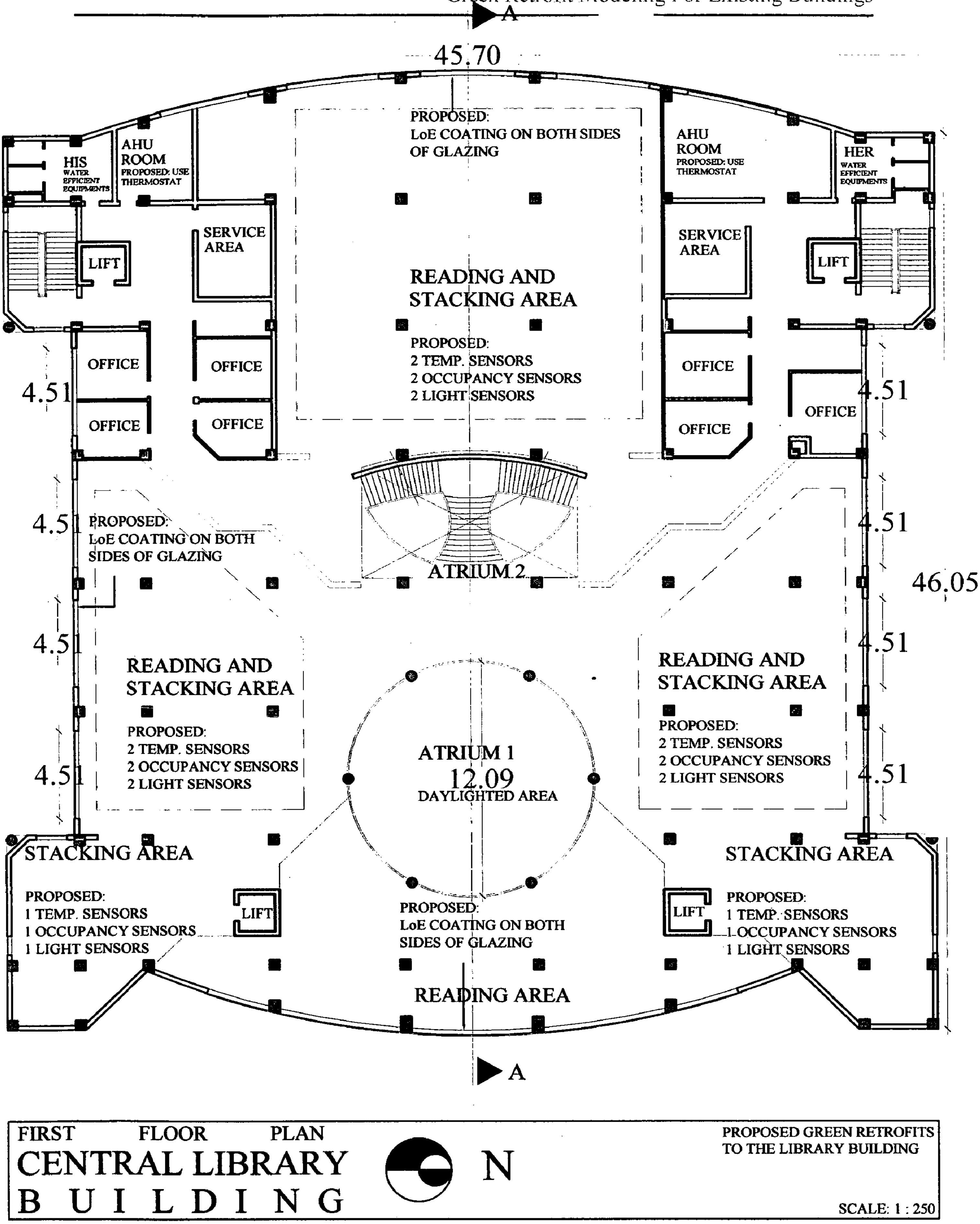
SCALE: 1 : 250

DRAWING 1: BASEMENT PLAN

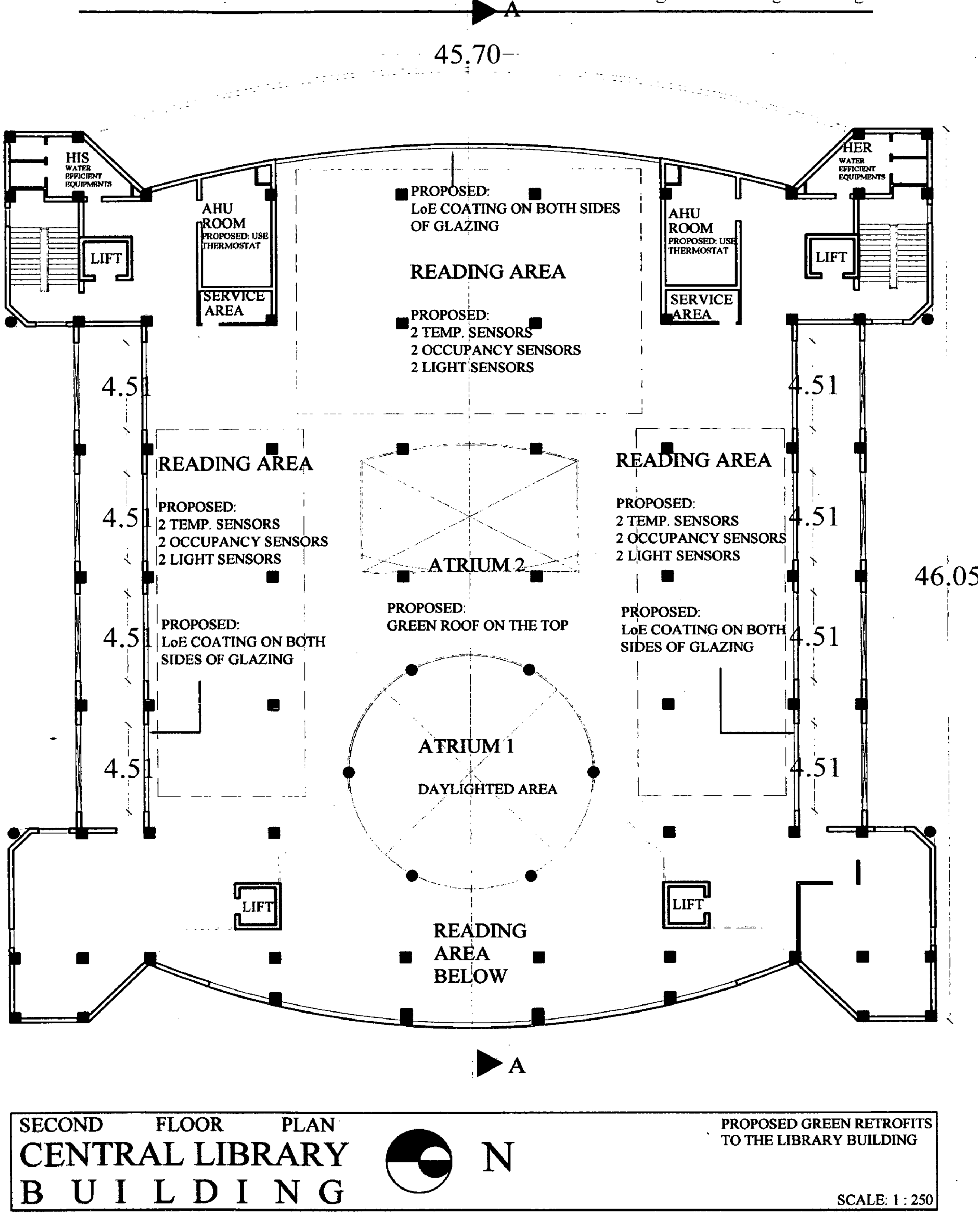


GROUND FLOOR PLAN CENTRAL LIBRARY BUILDING	N	PROPOSED GREEN RETROFITS TO THE LIBRARY BUILDING SCALE: 1 : 250

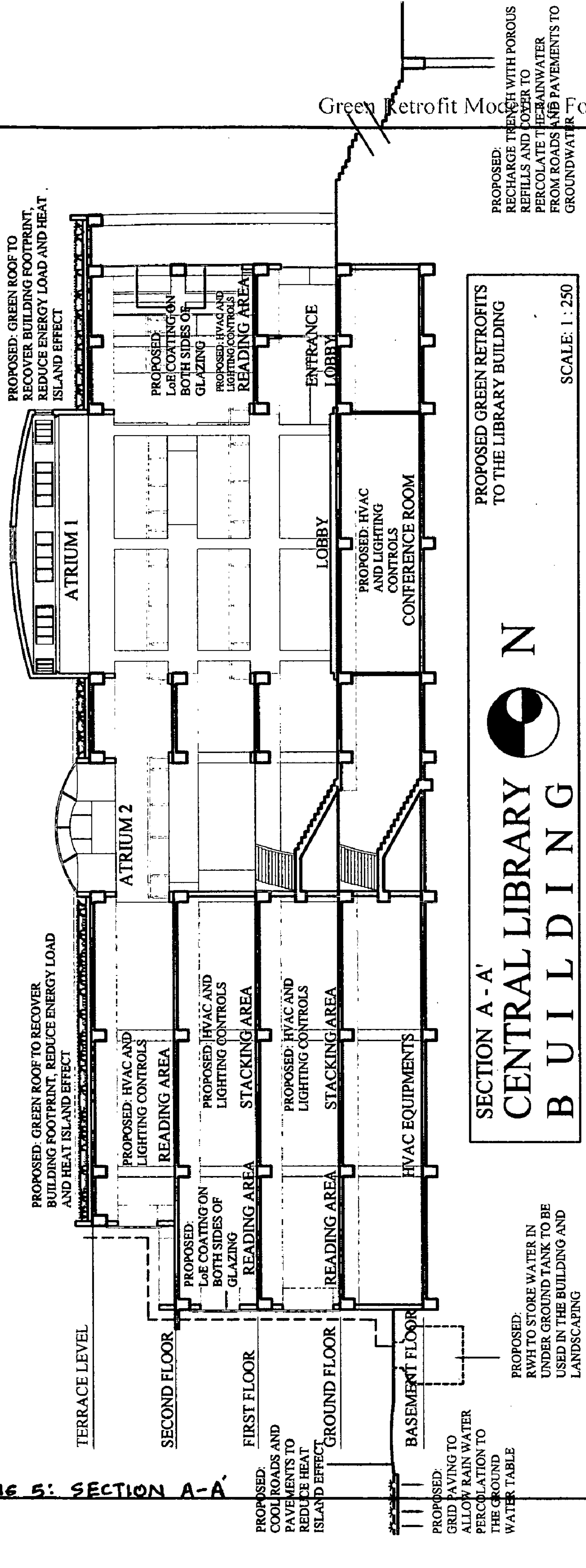
DRAWING 2: GROUND FLOOR PLAN



DRAWING 3: FIRST FLOOR PLAN



DRAWING 4: SECOND FLOOR PLAN



DRAWING 5: SECTION A-A'

BIBLIOGRAPHY

Bhattacharya K.K. and Bhupender Singh, *Energy Efficiency in Buildings And Building Codes.*
Also available on:
http://www.energymanagertraining.com/Presentations/IndiaIEA4_5Oct2006/SessionIIIbyDLF.pdf

Bureau of Energy Efficiency, *Energy Conservation Building Code*, revised version, may 2008.

Carmody John, Selkowitz Stephen, Lee Eleanor S., Arasteh Dariush and Willmert Todd, *Window Systems for High – performance Buildings*, first edition, New York, London: W.W. Norton and Company, 2004.

CII – Sohrabji Godrej Green Business Center, *Energy Efficiency in Building Design and Construction*, Indian Green Building Council.

Department of Energy Information Administration, www.eia.doe.gov

Geoff Wilson, Cover Story- *Green Roof (can greatly reduce India's Carbon Footprint)*

Hale E.T., Macumber D.L., Long N.L., Griffith B.T., Benne K.S., Pless S.D. and Torcellini P.A., *Technical Support Document: Development of The Advanced Enenrgy Guide – 50% Energy Savings,* National Renewable Energy Laboratory, September 2008.
Also available on: http://www.nrel.gov/docs/fy08osti/42829.pdf

Lane Michael, *Advanced Energy Design Guide for Office Buildings*, 2003

Majumdar Mili, *Energy Efficiency in Green Buildings – An Integrated Approach to Building Design*, C II – Godrej GBC.

McQuay International, *Engineering System Solutions – Building Sustainability and HVAC Systems*, Edition No. 16, April 2003.

Marriott Carol, *Three Simple Approaches To Energy Efficiency*, ASHRAE Journal, July 2006

Mobley Phil, Murray Nick, Damon Lorie and Fischer Mark, *The Green Issue*, BOMA.Kingsley Quarterly, 2006

Telkonet SmartEnergy, *Energy Management Thermostat for HVAC Sysytems – Data Sheet*, Energy Star, 2006.

USAID ECO III Project- International Research Group, *Building Envelope*, Version 1, December 2007.

USAID ECO III Project- International Research Group, *Building Lighting Design*, Version 1, February 2008.

USAID ECO III Project- International Research Group, *HVAC System*, Version 1, March 2008.

USAID ECO III Project- International Research Group, *Energy Assessment Guide for Commercial Buildings*, April 2008

U.S. Green Building Council, *transferring The Built Environment.*

U.S. Green Building Council, *Green Building Rating System for Existing Buildings . Upgrades, Operational and Maintenance (LEED-EB),* Version 2, October 2004.

U.S. Green Building Council, *Existing Building Version 2.0 Reference Guide*, 2nd Edition, October 2006.

Wilson and Morrill, The *Consumer Guide to Energy Savings*, 5th Edition, American Council for An Energy Efficient Economy, 1996.

WEBSITES:

en.wikipedia.org

www.greenconcepts.com

www.usgbc.org

www.igbc.in

www.bee-india.nic.in

www.usgbc.org/leed/eb

www.crd.bc.ca