ENERGY EFFICIENT RETROFIT OPTIONS FOR INSTITUTIONAL BUILDINGS IN INDIA

A DISSERTATION

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

MASTER OF ARCHITECTURE

By

BHASKAR DE

DEPARTMENT OF ARCHITECTURE AND PLANNING
INDIAN INSTITUTE OF TECHNOLOGY ROORKEE
ROORKEE - 247 667 (INDIA)

JUNE, 2012

CERTIFICATE

Certified that report entitled **"ENERGY EFFICIENT RETROFIT OPTIONS FOR INSTITUTIONAL BUILDINGS IN INDIA"** which has been submitted by **Mr BHASKAR DE,** for partial fulfillment of the requirement for the award of the degree of **Master of Architecture**, submitted in Department of Architecture and Planning, Indian Institute of Technology, Roorkee, is the student own work by him under my supervision and guidance. The matter embodied in this dissertation has not been submitted by him for the award of any other degree of this or any other institute.

Date:

Place: Roorkee

Dr. Mahua Mukherjee

Faculty of Architecture
Department of Architecture and Planning
Indian Institute of Technology- Roorkee
Roorkee, Uttrakhand, India

CANDIDATES DECLARATION

I hereby certify that this report entitled **"ENERGY EFFICIENT RETROFIT OPTIONS FOR INSTITUTIONAL BUILDINGS IN INDIA"** which has been submitted in partial fulfillment of the requirement for the award of the degree of **Master of Architecture,** submitted in Department of Architecture and Planning, Indian Institute of Technology- Roorkee, is an authentic record of my own work carried out during the period from July 2011 to June 2012, under supervision and guidance of **DR. Mahua Mukherjee** , Department of Architecture and Planning, Indian Institute of Technology, 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: 12.06.2012.

Place: Roorkee

(BHASKAR DE)

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

Dr. Mahua Mukherjee

Faculty of Architecture
Department of Architecture and Planning
Indian Institute of Technology- Roorkee
Roorkee, Uttrakhand, India

EXECUTIVE SUMMARY

Considering present day energy crisis and rising fuel prices, it can be predicted that in near future several existing buildings would outrun its working life span and be considered as wasteful and uneconomic to maintain and operate businesses despite being functionally and structurally sound. The energy bill to run the existing facilities may be so high that construction of a new building abandoning the existing one may seem preferable. Knocking down the old structure and constructing new ones in busy urban areas is not very easy; it causes environmental hazards, cripples the traffic movement, and suspends functions held in the previous building largely until the new one is constructed.

Retrofitting of such building can be a better alternative once the economic and environmental aspects are considered. Retrofit would not only be a solution for reduced energy consumption, it'd also result in curbing direct and indirect greenhouse gas emission. Authorities across the globe have taken a number of measures like solar wind, geothermal, tidal, biofuel etc. to reduce overall environmental impact of buildings. Energy efficient retrofitting is one such potential measure that despite being used extensively in developed nations like USA and UK, India till date shies away from it.

Retrofitting is an instance of modernizing or expanding existing facilities with new or modified parts, devices, systems, or equipment, not in existence or available at the time of original production/ construction/ manufacture. Scope of retrofitting measures varies depending upon the target set by responsible stakeholders for a project. Followings are broad categories for retrofit options:

1. Functional Retrofitting
2. Structural Retrofitting
3. Mechanical retrofitting
4. Green Retrofitting

Energy efficient retrofitting is a part of a much large scenario which is green retrofitting. Green retrofitting consists of three major action areas which are Water management, Solid waste management and Energy efficiency.

Literature review-

Several field studies have been done on energy efficient retrofitting, which have measured and documented the energy savings and demand reduction of residential office retail and school buildings. The work mostly conducted in the USA and UK includes Akbari et al. (2007) Akbari and Rainer (2000) Akridge (2008) Boutwell and Salinas (1999) Hildebrandt et al. (1998) Konopacki et al. (1998) and Parker et al (1997, 1998a, 1998b & 1999). All of them shows an annual reduction of energy demand ranging from 40-80% approximately.

Case studies-

Case study is very useful method to look into the paradox of energy efficient retrofitting in India. Due to its capacity to explain causal links and proper analysis of the case in its real life context, not only it helps to identify the problems, but also helps to find a solution. Multiple case study strategy has been chosen to use multiple sources of information from various retrofit projects and analyze their strengths and weaknesses.

The case studies assorted here are unique in their characteristics. The in depth study of the strategy and technique used in the retrofit of the Empire State Building provides a clear idea on technical and financial aspects. The Helmus building retrofit shows that the will and enthusiasm of the client. The case of Clinton Presidential Centre depicts some typical problems of wrong orientation of buildings can be retrofitted with advanced technology.

Objective and research process-

The aim of this dissertation was to analyze the potential of energy efficient retrofitting to reduce the energy demand of the institutional buildings, which are expected to serve for many years in the future. A process was devised that incorporated the following steps-

1. *Identification of a building with significant potential*
   The selected building should be in a condition to serve a long span of time in future to maximize the benefits and properly utilize the investment on it.

2. *Instrument handling and collection of data*

Instruments measured the weather conditions (dry bulb temperature, relative humidity) outside the building, temperature humidity and illumination level inside the building. The total power consumption data was collected from the electrical engineering division, but monthly energy consumption data was not available.

3. *Analysis of data and development of simulation model*
   The data from the field survey was then analyzed and the simulation model was developed. The results of the simulation of the base case was then cross checked with the data which was acquired from the field survey.

4. *Finding out the scope of improvement of energy efficiency of the building*
   After the selection of the base case, the objective was to find out the areas of improvement of the energy performance of the building by studying the building physically and and using the simulation tools like Ecotect, VisDOE, etc.

5. *Selection of individual strategies which have potential to be implemented in the particular case*
   The further step was to explore the available feasible solutions for the areas of improvement. This includes literature survey, market survey and study of successful retrofits done earlier. It is basically to decide which strategies to be chosen from the large number of available solutions. The conversation with some professionals was important to decide which solutions suits the best for the particular project

6. *Deciding the areas of intervention*
   There were three main areas of intervention that was decided according to the travel path of heat from outside to the user inside. They are *1. The Building Surrounding, 2. The Building Skin* and *3. The Building Interior, equipment and fixtures.*

7. *Making of packages*
   After the selection of individual strategies, the grouping or packaging of the strategies was done to analyze their cumulative potential regarding the Lecture Hall Complex building using the simulation tools.
   First package consists of most inexpensive yet effective strategies which can reduce the energy consumption to a substantial amount. This package is named as package A.
   The next package is another step towards the energy efficiency combining some more strategies with package A and termed as package B. Package B can be addressed as the optimum solution for the energy efficiency maintaining a balance between cost and energy efficiency.
   The next step is the ultimate level of energy efficient retrofit. This package combines all the effective solution to reduce the energy demand with package B. This package is addressed as package C.

8. *Development of scenarios*
   To analyze the efficiency and applicability of packages four scenarios have been developed. Each scenario will tell about the monthly heat gain, Total electricity load and estimated savings.
   Scenario 1- stands for the existing situation of the building i.e. the base case.
   Scenario 2- Application of package A over the base case.
   Scenario 3- Application of package B over the base case.
   Scenario 4- Application of package C over the base case.

9. *Analysis of the energy consumption for the retrofitted case and comparison with base case.*
   The packages are picked to be implemented on the model of base case and simulated to analyze how much potential they really posses to increase the energy efficiency of the building. After the analysis it was evident that retrofitting of this building can be a very good option to reduce the operational cost as well as reducing the carbon footprint of the building.

10. *Conclusion and recommendations*
The literature review, case studies and the analysis of retrofit options of the lecture hall complex gives an opportunity to make some recommendations for retrofitting the institutional building in India which are discussed in the last chapter.

Benefits of energy efficient retrofit-

- Environmental Benefits:
  Buildings contribute almost 50% of Greenhouse gas emission outnumbering Industrial and Transportation sectors. So, improving building energy efficiency has top priority. The cost-per-ton of reduced carbon emissions associated with energy efficiency measures is well below that of other strategies such as wind and solar energy production. It is identified retrofit measures like energy-efficient lighting upgrades and shell improvements for residential and commercial buildings as most cost-effective actions; payback period for such investments is relatively short.

- Economic Benefits-
  Effective action to increase buildings' energy efficiency can result in savings with increasing energy price. Moreover local and regional economy can enjoy impact of green investments as dependency on external energy supply would reduce Large scale building retrofit programs will open new career pathways and new jobs opportunity.

- Social Benefits:
  They can play a crucial role in making communities green. Retrofit is especially effective in economically less advanced countries, where development could barely stress on environmental externalities.
  Investments in energy efficient retrofit can yield a wide gamut of profits well beyond the value of saved energy and reduced GHG emissions. If co-benefits of the various mitigation options are included in economic analysis, their economic appeal may rise significantly.

In a world where the energy price is rising and alternative energy is still a costly alternative, reduction of energy consumption is the best option to save resource and money. In spite of several advantages, energy efficient retrofit is not common in India till date due to many reasons like lack of awareness about retrofit concept and benefits, inappropriate government policies and various complications.
Though there is knowledge and technology, surprisingly, there is very less number of takers for retrofitting. Primarily, buildings located in busy urban areas where demolition and reconstruction is not easy as the activity may disturb traffic movement, and pollute the environment, are being retrofitted. And alternative new building may have reduced floor area which is of prime concern for the owner. Landmark images are also some times considered while retrofitting. The world is looking forward to bridge the gap for a better and greener tomorrow and retrofit would be a good strategy to give another chance to existing building to live with elegance and yet perform efficiently.

ACKNOWLEDGEMENT

A dissertation of this scope would not have been possible without the active and passive support of my guide, many teachers, friends and scholars who have contributed greatly on my thinking and insights during the entire work, and who were instrumental in crystallization and formulation of my thoughts on many of the subjects and issues discussed within. To them I am heavily indebted, as I am to the innumerable people and a few organizations that have contributed ideas, comments, drawings, illustrations and other items that have helped to make this work a reality.

*I express my immense **Gratitude** to my guide, my supervisor, Dr. Mahua Mukherjee who extended all facilities and for her guidance help and motivation. Apart from the subject of research I have learned a lot from her which, I am sure, will be useful in different stages of my life. I deem it my privilege to work under her able guidance.*

I would like to express my gratitude to Prof. and Head of the Department Dr. Pushplata, who had kind concern and consideration regarding my all academic requirements. I would also like to thank Prof. Rita Ahuja, the M. Arch thesis coordinator, for her unfailing and unselfish support. I am grateful to all the faculties of the department of architecture, IIT Roorkee and the Jury members for their useful comments and advice.

I would like to acknowledge the financial, technical and academic support of Indian Institute of Technology, Roorkee and MHRD particularly in the award of scholarship that provided support for the research.

I am thankful to my friend Vandana, for her help and support during the period of dissertation. I also wish to thank all my M. Arch and MURP batchmates for the fun time I have had at IIT Roorkee campus.

I am immensely indebted to Ar. Nitish Poonia and Ar. Soumitree Devdutt of TERI who always encouraged me and extended their support to me for the analysis and simulation part of the dissertation.

This dissertation would not have been possible without the confidence endurance and support of my beloved family. My family has always been a source of inspiration and encouragement. I wish to thank my parents, Mr. Santi Kumar De and Mrs. Krishna De whose love, teaching, spiritual and moral support have brought me this far. I wish to thank my brother Mr. Partha De for his love and support.

And finally but most importantly from the core of my heart I express profound gratitude to the omnipresent Almighty for the Blessings He had bestowed upon me to do this work to the best of my abilities.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1 INTRODUCTION

1.1 GENERAL

The ever-growing demand of energy and its crisis is a burning problem of the present millennium. The buildings consume almost 50% of energy generated and so it is the major contributor for the rise of carbon di-oxide and other greenhouse gases (GHG) in the atmosphere. The newer green buildings performing outstandingly regarding use of less operational energy, less embodied energy and lesser carbon di-oxide emission no doubt, but they constitutes only a meager part of our whole building stock which is not green at all, rather they are power hungry.

This solution of energy efficient retrofitting reduces the chances of demolition of older energy inefficient buildings and this is a real boon to the environment because the embodied energy of the building remains within. At the same time the reduction in the energy consumption after the retrofit is so that the retrofitting cost is paid back within three to four years or even less. Two of the world's most famous skyscrapers- Sears Tower (now Willis Tower) and Empire State Building, are undergoing energy efficient retrofitting.

Not only the operational cost, but energy efficient retrofit reduces the carbon di-oxide emission which is far more important than monitory profit for an organization or institution. In spite of the fact that the per capita CO2 emission of India is far less than the first world countries like USA or UK, but this is our global responsibility to make our mother earth more sustainable and habitable for our future generation by reducing the emission. Visionary policies and its wise implementation can avoid some menacing crisis like energy crunch and air pollution and make our nation proudly saying echoing Mahatma Gandhi,

"Be the change that you want to see in this world"

1.2 IDENTIFICATION OF THE PROBLEM

Nowadays planet earth is undergoing a number of critical problems due to our indiscriminant use of non-renewable natural resources and mass destruction of green cover. Excessive use of fossil fuels has resulted in emission of greenhouse gases which is responsible for global warming and climate change. Rise of sea level, melting of polar ice caps and ozone hole has worsened the situation much more. Now this is the high time to learn from mistakes and find a way out to get rid of the menacing problems.

The graphics below shows the current and projected GHG emission in various parts of the world from which it can be concluded that if a restriction is not imposed on the use of fossil fuel and reduction of energy demand, human civilization will face an acute energy crisis.

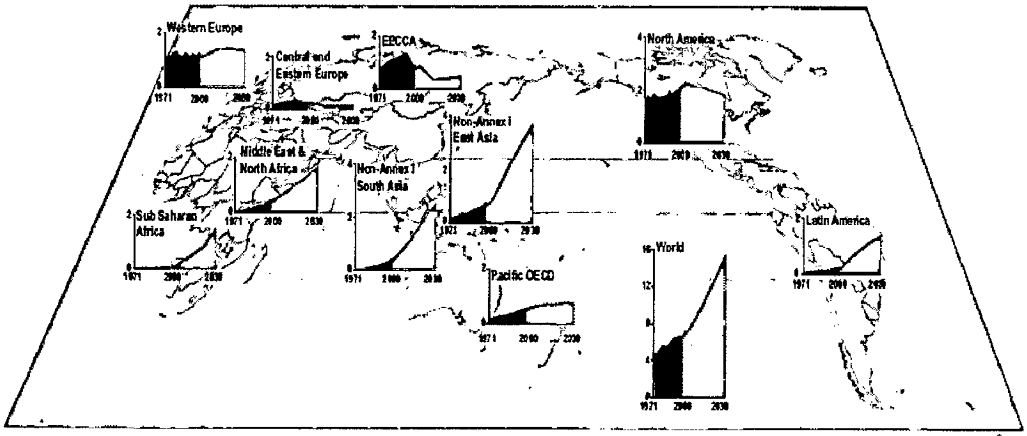


Figure 1.1- Projected global carbon emission

Note: Dark red – historic emissions 1971–2000 based on Price et al. (2006) modifications of IEA data. Light red – projections 2001–2030 data based on Price et al.(2006) disaggregation of SRES data; 2000–2010 data adjusted to actual 2000 carbon dioxide emissions. EECCA = Countries of Eastern Europe, the Caucasus and Central Asia.

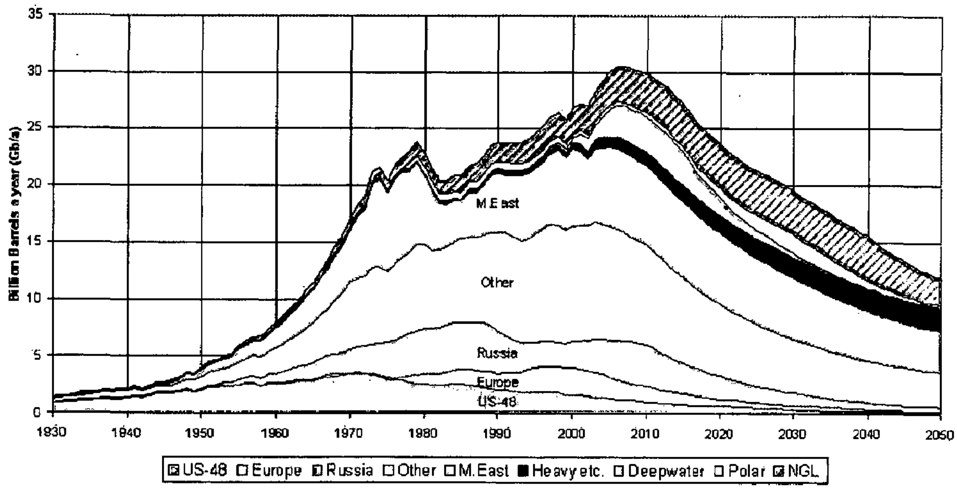


Figure 1.2- Oil and gas liquids 2004 scenario

The world seems to be running out of the cheap sources of energy in near future. So there is a need to refocus the attention to the more practical solution of reducing the energy demand and shifting towards renewable sources of energy.

It is very evident that the buildings consume almost half of the energy produced. If the energy consumption of buildings can be controlled, GHG emission can be reduced to a great extent.

Our existing buildings, which are neither green nor energy efficient poses the greatest problem to reduce the emission of GHG. If their energy consumption can be reduced, the emission (direct and indirect) can be cut down to a great extent.

Today, the technology is available to retrofit these buildings to green buildings and there are number of benefits apart from the environmental benefit. So, energy efficient retrofitting can be a very good solution to conserve the earth's finite resources and reduce the environmental impact of buildings for a better tomorrow.

1.3 NEED FOR THE STUDY

- Apart from new green buildings, existing buildings are major source to energy consumption.
- Retrofitting an existing buildings is a more effective strategy to reduce emission.
- Renewable energy targets can be met more effectively in old retrofitted buildings as compared new green buildings.
- In India, government has passed Energy conservation act 2001 -An Act for efficient use of energy and its conservation.
- Real estate groups looking at cuts in energy bills for their national /International leasing customers.
- The concept of constructing new green buildings is fairly established , retrofitting existing buildings is comparatively a new concept.
- In India, this energy efficient retrofitting concept is comparatively new and has a number of aspects to be explored to make a retrofit project successful.

1.4 AIM AND OBJECTIVES

1.4.1 Aim

Formulation of options for energy efficient retrofit of institutional buildings in India.

1.4.2 Objectives

1. To explore the need and scope of energy efficient retrofitting.
2. To Understand the challenges and strategies to solve them.
3. Finding out the technological options available for energy efficient retrofitting.
4. Virtual implementation of retrofitting strategies on some existing building.
5. Analyzing the comparative benefits after implementation of retrofit strategies.
6. Recommendations for proper implementation of energy efficient retrofitting.

1.5 SCOPE

1.5.1 Scope

The scope is to explore the feasibility of conversion of a non- energy efficient building to an energy efficient one, which is expected to serve for several years in future. It also wants to discuss how modern innovative building technology can be fitted into the buildings, which may be constructed before the invention of the technology or may not be implemented during construction, in a drive to attain operational cost savings and reducing the energy demand to mitigate the environmental impact. Lastly it will attempt to propose some recommendations and find out some possible solutions of the paradox through the implementation of retrofit strategies in a building and assessment of benefits after retrofitting.

1.5.2 Limitations

Retrofitting can be done to existing buildings in various aspects like structural, functional, seismic etc. However, here the spotlight will be only on "Energy Efficient Retrofitting" of Institutional Buildings in India in individual building level, which means reduction in energy consumption of that particular building only.

1.6 RESEARCH METHODOLOGY

1.6.1 Research design

Among various research strategies like qualitative research, correlational research, experimental research, logical argumentation research or simulation research, it is very hard to find a particular strategy to be sufficient enough for this topic of energy efficient retrofit because each type of research strategies has their own strengths and weaknesses. A combined strategy is more suitable as it has the potential to maximize strength and minimize weaknesses of each design. In this particular research, is will be checked whether there is any correlation between the factors which are affecting the energy efficient retrofit in composite climate in Institutional buildings by the help of survey questionnaire. Then it will be tried to propose some way out for the existing paradox of retrofit scenario by the method of multiple case study strategy. Foreign cases as well as successful Indian cases will be studied to find out the problems and deficiencies. Then, a live case, the new by built a lecture hall complex will be taken in consideration to build a baseline simulation model. After analyzing the base case, the findings from the case studies done previously, will be incorporated in the simulation model to find out the increase in energy efficiency of the building.

Lastly, a model will be proposed which will be helpful for energy efficient retrofit of Institutional buildings in composite climatic zones of India.

1.6.2 Methodology

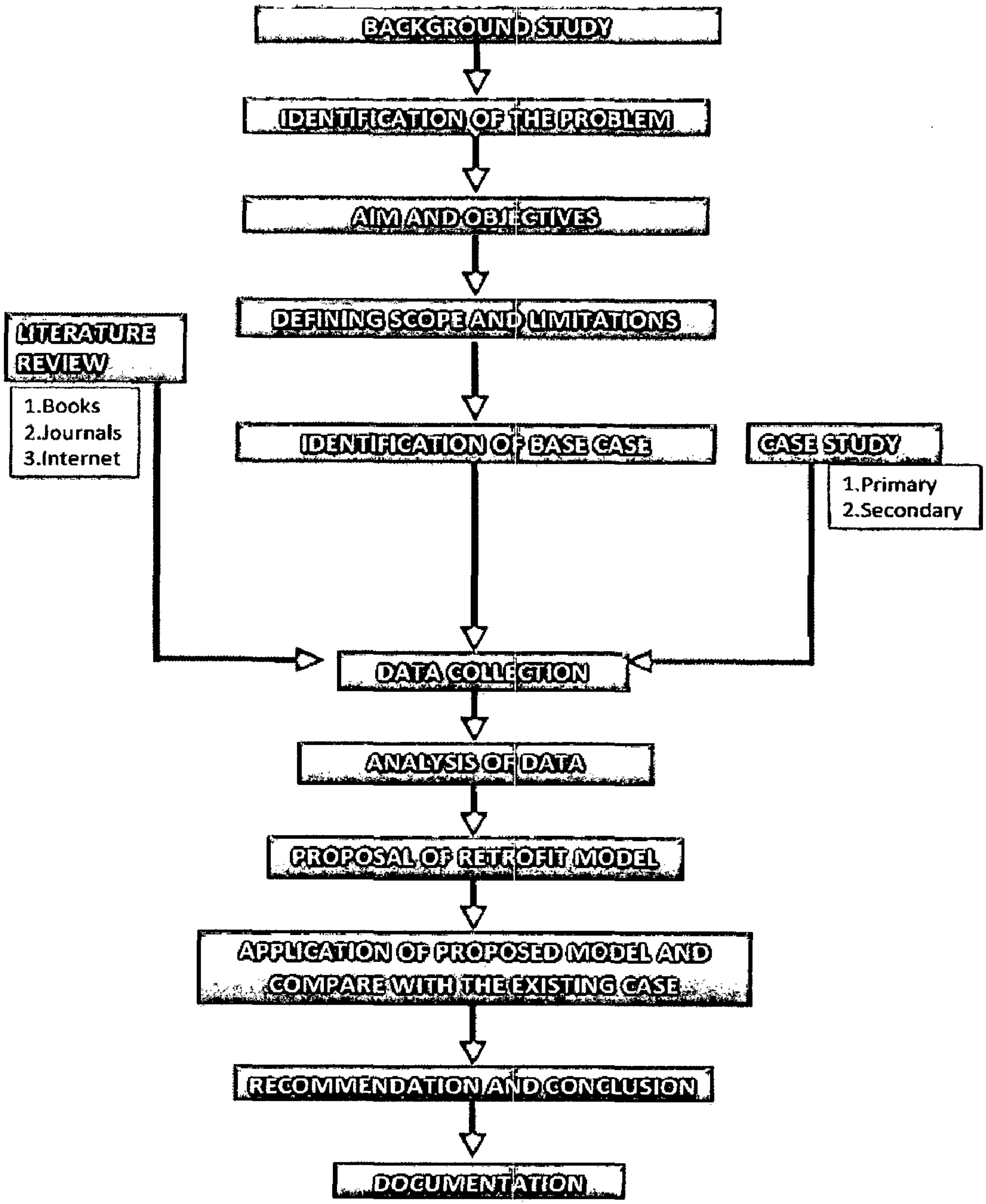


Figure 1.3- Flow chart of research methodology

1.7 SUMMARY

This chapter discussed about the project brief and the aim, objectives, scope, and methodology of the dissertation. The next chapter reviews some literature relevant to the project.

2 LITERATURE REVIEW

2.1 GENERAL

Firstly it has been tried to find out what works have already been done on this ground of Energy efficient retrofitting by architects and researchers around the world. It is helpful to understand the problems and their solutions of this type of work.

It has been found that most of the retrofitting projects have been carried out in the developed countries which are mainly in cold climatic zones and indoor heating consumes a lot of energy in winters. But there is no such notable work carried out in the composite climate zones where cooling and dehumidification consumes the largest amount of resources irrespective of all types of buildings-institutional commercial or in a campus.

The energy efficient retrofit strategies has been very much successful in developed countries in cold climate but not successful in developing nations which are in composite or tropical climate. Here it will be tried to find out the reasons for which energy efficient retrofitting has not widely been adopted in spite of having the toolkits of retrofitting and certain benefits.

2.2 RETROFITTING

A. An instance of modernizing or expanding with new or modified parts, devices, systems, or equipment, not in existence or available at the time of original manufacture.
   http://www.thefreedictionary.com/retrofitting

B. To furnish (as a computer, airplane, or building) with new or modified parts or equipment not available or considered necessary at the time of manufacture.
C. : To install (new or modified parts or equipment) in something previously manufactured or constructed.
D. : To adapt to a new purpose or need : modify <retrofit the story for a new audience>.
   http://www.merriam-webster.com/dictionary/retrofit

2.2.1 Functional retrofitting

Adaptive reuse is the process of adapting old structures for purposes other than those initially intended. When the original use of a structure changes or is no longer required, as with older buildings from the industrial revolution, architects have the opportunity to change the primary function of the structure, while retaining some of the existing architectural details that make the building unique. In local communities, unused schools or Post Office buildings have been adapted for reuse as retail stores or offices. Adaptive reuse covers a wide range of urban areas and building types.

Adaptive reuse, along with brownfield reclamation, is seen by many as a key factor in land conservation and reducing the amount of sprawl. For those who prescribe to the smart growth concept, it is more efficient and environmentally responsible to redevelop older buildings closer to urban cores than it is to build new construction on faraway greenfield sites. Adaptive reuse is also related to the field of historic preservation.

2.2.2 Structural retrofitting

In structural retrofitting, necessary measures are adopted to make a building safe from failure, which has shown some symptoms of failure in near future. Basically, this type of retrofitting is very expensive and applied to the buildings which are being used 365 days in the year or have some conservation aspects attached with it.

2.2.3 Seismic retrofitting

Seismic retrofitting is the modification of existing structures to make them more resistant to seismic activity, ground motion, or soil failure due to earthquakes. With better understanding of seismic demand on structures and with our recent experiences with large earthquakes near urban centers, the need of seismic retrofitting is well acknowledged. Prior to the introduction of modern seismic codes in the late 1960s for developed countries (US, Japan etc.) and late 1970s for many other parts of the world (Turkey, China etc.), many structures were designed without adequate detailing and reinforcement for seismic protection. In view of the imminent problem, various research work has been carried out. Furthermore, state-of-the-art technical guidelines for seismic assessment, retrofit and rehabilitation have been published around the world - such as the ASCE-SEI 41 and the New Zealand Society for Earthquake Engineering (NZSEE)'s guidelines.

The retrofit techniques outlined here are also applicable for other natural hazards such as tropical cyclones, tornadoes, and severe winds from thunderstorms. Whilst current practice of seismic retrofitting is predominantly concerned with structural improvements to reduce the seismic hazard of using the structures, it is similarly essential to reduce the hazards and losses from non-structural elements. It is also important to keep in mind that there is no such thing as an earthquake-proof structure, although seismic performance can be greatly enhanced through proper initial design or subsequent modifications.

2.2.4 Mechanical retrofitting

Mechanical retrofitting is applied mainly in cars, factories and sometimes in chiller plants of HVAC units if the demand from the device has been changed over a period of time.

2.2.5 Green Retrofitting

Green Retrofitting is the addition of new technology or equipment to an existing property in order to reduce operational costs, improve occupant health and productivity, and reduce adverse effects on the environment. Commercial property owners are pursuing green retrofitting projects to reduce utility costs and differentiate themselves in order to fulfill increasing tenant demands for sustainable properties. In addition to operational efficiency and environmental concerns, government officials are supporting retrofitting programs to create jobs and restore economic growth. The current momentum in green building and retrofitting, however, took a very long time to develop, evolving over nearly 40 years to what it is today.

Green retrofitting can be subdivided in there broad categories described below.

- Water Management
- Solid-waste Management
- Energy Efficient Retrofitting

2.3 ENERGY EFFICIENT RETROFITTING

2.3.1 Generation of energy

- Photovoltaic panels.
- Wind turbines

2.3.2 Reduction in consumption

2.3.2.1 The building surrounding

- Surface transformation
- Urban Heat island.

2.3.2.2 Building envelope

- Natural light and ventilation
- Insulation

2.3.2.3 The building interior, equipment and fixtures

- Efficient equipment
- Direct digital control
- Separate the heat generating and non-conditioned space from conditional space.
- Passive strategies(earth air tunnel etc.)

2.4 CLASSIFICATION OF ENERGY EFFICIENT RETROFITTING

The realm of energy efficient retrofitting can be categorized in four different categories according to the scale of implementation. They are

- Individual House Retrofit
- Group Housing Or Apartment Building Retrofit
- Commercial Tower Retrofit
- City Level Retrofit

2.4.1 Retrofitting an individual house

Cost-effective measures that can be undertaken without a major renovation of residential buildings include: sealing points of air leakage around baseboards, electrical outlets and fixtures, plumbing, the clothes dryer vent, door joists and window joists; weather stripping of windows and doors; and adding insulation in attics, to walls or wall cavities.

A Canadian study found that the cost-effective energy savings potential ranges from 25–30% for houses built before the 1940s, to about 12% for houses built in the 1990s

(Parker et al., 2000). In a carefully documented retrofit of four representative houses in the York region of the UK, installation of new window and wooden door frames, sealing of suspended timber ground floors and repair of cracks in plaster reduced the rate of air leakage by a factor of 2.5–3.0 (Bell and Lowe, 2000). This, combined with improved insulation, doors and windows, reduced the heating energy required by an average of 35%. Bell and Lowe (2000) believe that a reduction of 50% could be achieved at modest cost using well-proven (early 1980s) technologies, with a further 30–40% reduction through additional measures. Studies summarized by Francisco et al. (1998) indicate that air-sealing retrofits alone can save an average of 15–20% of annual heating and air conditioning energy use in US houses.

Additional energy savings would arise by insulating pipework and ductwork, particularly in unconditioned spaces. Rosenfeld (1999) refers to an 'AeroSeal' technique that he estimates is already saving three billion US$/yr in energy costs in the USA. Without proper sealing, homes in the USA lose, on average, about one-quarter of the heating and cooling energy through duct leaks in unconditioned spaces – attics, crawl spaces, basements. In a retrofit of 4003 homes in Louisiana, the heating, cooling and water heating systems were replaced with a ground-source heat pump system. Other measures were installation of attic insulation and use of compact fluorescent lighting and water saving showerheads. Space and hot water heating previously provided by natural gas was supplied instead by electricity (through the heat pump), but total electricity use still decreased by one third (Hughes and Shonder, 1998).

External Insulation and Finishing Systems (EIFSs) provide an excellent opportunity for upgrading the insulation and improving the air-tightness of single- and multi-unit residential buildings, as well as institutional and commercial buildings. This is because of the wide range of external finishes that can be applied, ranging from stone-like to a finish resembling aged plaster. A German company manufacturing some of the components used in EIFSs undertook a major renovation of some of its own 1930s multi-unit residential buildings. The EIFSs in combination with other measures achieved a factor of eight measured reduction in heating energy use (see www.3lh.de). An envelope upgrade of an apartment block in Switzerland reduced the heating requirement by a factor of two, while replacing an oil-fired boiler at 85% seasonal average efficiency with an electric heat pump having a seasonal average COP of 3.2 led to a further large decrease in energy use. The total primary energy requirement decreased by about 75% (Humm, 2000).

2.4.2 Group housing or apartment

Retrofitting of housing consists of various strategies taken form individual house retrofit, but some policy level activities are also carried out to serve the residents.

In general, energy efficient retrofitting of housing aims to:

1. Reduce energy consumption by 50%, and thus to improve the environmental value.

2. Increase the market value of dwellings.

3. Improve the condition of buildings and prolong their lifetime (for about 30–40 years) as well as preserve housing resources.

4. Raise the level of comfort in apartment blocks.

5. Avoid maintenance expenses and investments in buildings which would otherwise be needed in the future.

6. Improve the architectural appearance of the facades of apartment houses as well as harmonize them with the environment.

7. Make residential areas more attractive to their residents; improve the residential quality of a building.

8. Attract more middle-class residents to these areas.

2.4.3 Commercial towers

The High Rise building is central to any modern cityscape, attracting the attention of all who view a skyline. In just over one century buildings have grown vertically from 20 stories to over 100 stories and are now have office, hotel and residential uses.

Table 2.1- World's most active cities in building activity on completed high-rise buildings.

#	City	Buildings
1.	Hong Kong	7,650
2.	New York City	5,765
3.	São Paulo	5,644
4.	Singapore	4,327
5.	Seoul	2,875
6.	Tokyo	2,689
7.	Rio de Janeiro	2,466
8.	Istanbul	2,139
9.	Moscow	2,030
10.	Toronto	1,763
11.	Buenos Aires	1,681
12.	Kyiv	1,528
13.	London	1,433
14.	Mexico City	1,279
15.	Osaka	1,180
16.	Madrid	1,162
17.	Caracas	1,109
18.	Chicago	1,096
19.	Santiago	1,092
20.	Recife	1,031
21.	Shanghai	982
22.	Mumbai	955
23.	Campinas	931
24.	Beijing	898
25.	Sydney	828

Source: http://www.emporis.com/en/bu/sk/st/ma/ci/

2.4.3.1 Changing Influence on Design

The design of each high rise reflected a balance between high capital costs of construction and forecast (generally) low costs of energy consumption that were applied during their design and construction. Many issues arise from changes to that paradigm.

First, the use of high rise buildings is changing. On the tallest 100 buildings lists from 1930 to 2000 the percentage of office towers was never below 86%. By 2010 it will be down to just 46%.` (*CTBUH Journal, Issue 2, 2008. pp.40 – 41)*

Secondly, the cost of energy has demonstrated significant transitions in recent times.

Thirdly, Governments are considering active measures to control carbon emissions that will motivate or require reduced energy consumption in existing buildings. The challenge, then, is to address the needs of existing high rise building owners to reduce the costs of energy consumption in their buildings at least cost.

2.4.3.2 Stakeholders

The array of potentially interested parties is wide. They include

1. Architects
2. Builders
3. Bankers & Financiers
4. Developers
5. Engineers
6. Owners
7. Policy Makers in Government
8. Regulators
9. Tenants

Each user group has a particular interest in the challenge of refitting an existing building to reduce energy consumption while maintaining or increasing its value in use. User groups may be broadly separated into two potential target markets: Public Sector (Govt, Municipalities, Universities & Colleges, School Boards and Hospitals) and the Private Sector (Offices and Residential). Each sector differs in the type and range of buildings they own/operate and their methods of decision making.

2.4.3.3 Issues

The interests of one group may be in conflict with another. The tenants will want to reduce their energy costs but will not want to suffer inconvenience during a remodeling process. The owners will not want to invest in additional capital expenditure with no economic return. The policy makers will want to balance tax benefits with taxes to motivate beneficial changes in behaviour.

2.4.4 City level retrofit

Cities and states across the country are ramping up their efforts to boost the energy efficiency of the residential, commercial and public buildings in their communities. They are motivated by the urgency of challenges such as escalating energy costs to their home- and business-owners, rising unemployment, and global climate disruption—and by the enormous opportunities they see to save money and create high-quality jobs and career pathways, especially for lower-income people, while at the same time reducing air and climate pollution and improving indoor air quality.

In other words, investment in building energy efficiency, through retrofitting and other strategies, is emerging as a high priority in a growing number of cities and states throughout the country because it simultaneously meets environmental protection, economic development, and social goals: the quintessential "triple bottom line" solution.

2.5 THE GLOBAL SCENARIO OF ENERGY EFFICIENT RETROFIT

Green, green and more green. The color of sustainability, a color of nature and, of course, the color of money. Green frenzy has permeated most every sector of business, including real estate. The greening of buildings has been occurring since the 1970s, when building owners began to realize that more efficient building systems and upgrades translated into lower costs and higher revenues.

Buildings in the world are responsible for the production of millions of metric tons of greenhouse gas emissions annually. Energy consumption in a building represents more than 25 percent of its operating expenses. A building implementing environmentally sound practices can substantially reduce its emissions and cut operating costs. These lower operating costs can make a project more competitive for leasing and sale and also increase an owner's return on its investment (Ueno et al., 2006).

The USA and the UK has done the most amount of successful energy efficient retrofitting but there are some basic differences in the characteristics of the retrofitting policy, which has been described below.

2.5.1 The retrofit scenario in the U.S.A-

Energy efficient retrofitting of existing buildings makes sound economic and environmental sense. There are many standards today attempting to define what makes a building green. The most widely recognized is LEED certification offered by the U.S. Green Building Council. The greenness of a building is measured in points awarded for implementation of sustainable construction, design and systems. LEED certification is available not only to new construction but also to existing buildings (EB) and commercial interiors (CI).

The Denver Place Towers Complex, a retrofitted 25-year-old office building, has earned a LEED-EB Gold certification by using infrared faucets for water conservation, green housekeeping, green purchasing policies and establishing a reserved parking program for hybrid and alternative fuel vehicles. The upgrades paid for themselves in just three years with help from Xcel Energy rebates. The building now saves its owners more than $300,000 per year in energy costs. Also in Denver, the Alliance Center, built in 1908, was retrofitted with dual-flush toilets and other devices that have reduced the building's water consumption by 84 percent. Further, light sensors and other energy reducing features have reduced electrical consumption by more than 50 percent. The Alliance Center is certified LEED-EB Gold and LEED-CI Silver (IEA, 2006e).

Colorado State University has mandated that all new CSU construction be built to nationally accepted LEED Gold standards. CSU's new residence hall complex features low-flow water fixtures to conserve water use and is landscaped with low-water, native plants. Also, the new dining hall contains a pulper, combining and compacting water and food waste, and then recirculating the water for conservation. CSU is dedicated to making not only its new facilities sustainable, but also its existing buildings. For example, one of CSU's oldest buildings features energy-saving light fixtures, display boards with recycled fibers, waterless urinals and nontoxic paints. The University of Colorado has expanded and renovated its student union bookstore, offices and conference rooms. The renovation included the use of sustainable materials such as bamboo flooring and energy efficient techniques such as daylighting and above-average insulation to earn a LEED-EB Silver certification.

While LEED certification is the widely recognized standard of green building principles, building owners can go green without pursuing LEED certification. An owner can choose among a menu of green building options, each varying widely in price, effort and benefit. These options range from installing compact fluorescent light bulbs, using low volatile organic compounds materials, sealing pipe and air leaks, and window glazing, to installing solar (photovoltaic systems). Solar PV systems for small business typically cost from $10,000 to $35,000.

Government and private funds are available to assist a building owner with the cost of green upgrades. The Federal Energy Policy Act provides a 30 percent federal tax credit for solar water heating and PV systems installed on businesses until Dec. 31. A tax deduction of up to $1.80 per square foot is available to owners or designers of new or existing commercial buildings saving at least 50 percent of the heating and cooling energy meeting ASHRAE Standard 90.1-2001. Partial deductions of up to 60 cents per sf are available for measures affecting any of the building envelope, lighting, or heating and cooling systems. These deductions are available for systems "placed in service" from Jan. 1, 2006, through Dec. 31, 2008. There also is accelerated depreciation on solar equipment through the modified acceleration cost recovery system. Municipal sales and use tax rebates also may be available to business owners who install renewable energy systems (Laitner et al., 2008).

In 2004, Colorado voters approved Amendment 37, which requires Colorado's investor-owned utilities, including Xcel Energy, to generate or purchase enough renewable energy to supply 20 percent of their retail electricity sales in Colorado by 2020. Under the initiative, utilities offer customers a minimum rebate of $2 per watt of installed PV capacity. Of the electricity generated each year from eligible renewable, at least 4 percent must come from solar-electric technologies and at least one-half of the solar requirement must be generated by systems located at customers' facilities. Xcel has implemented the Solar Rewards Program to comply with Amendment 37. The program provides a rebate and payment incentive for small (grid-connected PV systems ranging from 0.5 kilowatts (kW) to 10 kW-DC) and medium-sized customers (10 kW to 100 kW) (IEA, 2006e).

The time is ripe to implement green changes in existing buildings whether through a formal LEED certification or through individual modifications. Society has embraced these high-performance buildings, the government has incentivized the retrofitting and the market justifies it through a recoupment of costs.

2.5.2 The retrofit scenario in the UK

The scenario of energy efficient retrofit is totally different in UK if compared to USA. In UK, the major focus is on home energy retrofit where the focus in USA is mainly on commercial buildings. The local administration and government of UK have initiated a number of lucrative interest-less loan schemes for the house owners who want to retrofit their homes. The awareness of people and the effort of the government have made this possible and it can be a very inspiring model for the whole world. The methodology of retrofit is almost the same, but as this is implemented in a mass scale, the outcome is much apprehensive.

For an example, The PAYS (Pay As You Save) scheme amounts to a homeowner is provided with the funds (loan) to make retrofitting of their house. This increases the efficiency of the house an so the energy bills fall. Given this reduction on their bill, a repayment rate is calculated that can be added to each bill over a period of years to pay for the financing of the investment. The consumer is also benefitted from the lower bill as the scale of repayment is not as great as the saving.

2.5.3 Retrofitting initiatives in India

In India, Energy efficient retrofitting is not so popular if compared to the developed countries like USA and UK. But some private organizations are doing retrofits to only to increase the efficiency and reduce the operational cost of their project which reduces the carbon di-oxide emission.

Some Indian example of Energy efficient retrofit:-

1. Inorbit Mall, Malad, Mumbai
2. ITC Mouriya Hotel, New Delhi.

And some commercial buildings in Hyderabad and Pune.

2.6 CALCULATING RETROFITTING POTENTIAL

When buildings do not meet the residents' needs, or the operational and maintainance cost is greater than its earning, the question arises of whether they should be retrofitted or demolished. A consensus is growing that it is easier and less expensive to slow down building deterioration by investing in proper maintenance and, thereby, prolonging its service life before reconstruction.

To compare reconstruction to renovation in mathematical terms, the following formula (Rosenfeld Y, Shohet I.M, 1999) was proposed:

$$C \geq R + M\left(\frac{1-(1+i)^{-n}}{i}\right) + \frac{C}{(1+i)^{n}}$$

where C is the cost of new construction, R the cost of renovation, M denotes the savings in annual maintenance costs in the case of new construction, n the expected prolonged service life (in years) of the renovated building, and i is the interest rate per year. The right-hand side of this formula is the sum of the renovation costs plus the current value of higher maintenance cost and the discounted current value of the new construction which might be delayed by n years. This basic formula has several logical flaws. Some researchers believe that the value of the existing building should also be added to the renovation cost. Others argue the opposite, namely, that reconstruction should bear as an extra cost the waste of demolishing a valuable (though old and ill-functioning) existing building, while the renovation option utilizes the existing value of the old building and just adds to it.

In order to achieve the goals of an optimal retrofit strategy, it is essential that any given capital investment be directed to the most cost-effective group of energy-saving measures. This can be achieved by ranking the measures in order of decreasing savings—to investment ratio (SIR), where (Gorgolewski, M. 1995)

If a measure has a SIR greater than 1, the predicted savings exceed the investment,

$$\text{SIR} = \frac{\text{current value of the total lifetime energy saving}}{\text{investment cost}}$$

$$\text{PV}_{\text{c}} = C\left[\frac{1-(1+r)^{-n}}{r}\right]$$

and the measure can be regarded as cost effective. The higher the SIR, the larger the return on the investment. To calculate the SIR, the current value of the total energy saved must be found. Finding this value requires the discounting of all future savings to their equivalent current value, using the following equation:

This gives the current value, PVc, for an annual saving C, occurring for n number of years (lifetime of measure), with a real discount rate of r.

Retrofitting aimed to increase building value for users has not only technical, ecological, and economic aspects but also a social dimension that should be considered. Renovation will be made only if there is a demand and acceptance among the users. The cost of a market-oriented retrofit is not simply the market value. There exists some difference between them, known as the acceptance of the market. If economic function of a building is fulfilled, the added value can increase its acceptance among the users and so increase the demand. The increase in price depends on the cost of the retrofit scenario. From the perspective of real estate market value, an effective retrofit may be described by the following market value ratio (MVR):

$$\mathrm{MVR} = \frac{M_{\mathrm{va}} - M_{\mathrm{vb}}}{C_{\mathrm{r}}}$$

where Mva is the market value of the building after retrofit, Mvb the market value of the building before retrofit, Cr denotes the retrofit costs of the building (Zavadskas, Kaklauskas, E.K. A., Raslanas S. 2004). If the package of investments in retrofit has an MVR greater than 1, the package can be regarded as cost-effective from the perspective of real estate market value.

In general, when energy savings and the increase in market value are taken into account, a package k of retrofit measures is effective when

$$\mathrm{SIR}_k > 1, \qquad \mathrm{MVR}_k > 1$$

The following criteria in particular are relevant in the “Retrofitting or Reconstruction” discussion:

costs (taking into account the construction of a new building, the costs of demolition, relocating tenants, renovation costs, operating costs of a new building (as compared to the renovated building)), defects and drawbacks of the building (associated with heat insulation, concrete quality, humidity, ground water, soundproofing, the condition of the living environment, ventilation, parking space), architecture of the building (aesthetics, types of layout), urban planning aspects (nature of the development in the area, availability of public transport system, engineering infrastructure) and social infrastructure (building status, tenant satisfaction). When considering renovation, the major factors, such as social infrastructure and some problems, relating to urban development, in particular, should be considered.

2.7 CHALLENGES OF ENERGY EFFICIENT RETROFIT

Numerous barriers prevent building owners from pursuing opportunities to invest in making their buildings more green. These barriers are sometimes complex and are often interrelated. They extend far beyond the difficulty—although not insignificant—of paying for efficiency investments even when they will "pay for themselves" in the long-term. Chief among them are:

2.7.1 Lack of information or awareness:

This barrier has many dimensions. To begin with, few homeowners or even business owners have a good sense of how efficient or inefficient their buildings are. Nor do they know which efficiency measures will provide the biggest bang for the buck. In fact, efficiency initiatives typically need to overcome important myths in the market. For example, contrary to conventional wisdom caulking and weather-stripping around doors and windows usually accomplishes very minimal reductions in energy use. Window replacements usually provide only very modest savings at fairly high cost. Many of these myths are perpetuated by retailers and contractors—either because they lack understanding or they want to advance their own business interests.

2.7.2 Inadequate access to capital:

Many homeowners—particularly in big cities that have proportionally higher numbers of low-income households—do not have access to the capital necessary to make substantial efficiency investments. That is also true of many small businesses. Even larger, more sophisticated businesses might have limited capital budgets; thus, even if there is an advocate for efficiency improvements in the business, they must compete with others in the company to access that capital.

2.7.3 High transaction costs:

Decisions about how to pursue opportunities for increasing energy efficiency are often a casualty of busy family lives. Homeowners juggling long work hours and multiple jobs, household maintenance needs, and family responsibilities have little time to undertake time-consuming research on what efficiency measures might make sense or which contractors to call. Even assuming they find the time to identify a desirable project, the time requirements for organizing and participating in the development of estimates for efficiency work, negotiating a scope of work and price, and arranging to be at the home to let in and "keep an eye on" the contractor as the work is being done are often enough to stop a homeowner in his or her tracks. The problem is further exacerbated by the current dearth of contractors who perform a full-service set of retrofitting services. These same transactional barriers affect business owners too, particularly small businesses owners. Business owners have the added problem of potentially having their business itself interrupted if contractors need to do work in a retail space during normal business hours.

2.7.4 Short planning horizons:

For a homeowner who is focused on getting food on the table, or a business owner trying to keep the doors to the store open, it is often simply impossible to plan and finance cost-effective efficiency investments, even when they know and understand that there will be net energy savings down the road. This applies equally to efficiency investments that have a pay-back horizon of eight to ten years and those that are swiftly paid back in just a year or two. The difficulty of planning for the long term when funds are extremely tight remains a steep barrier for many families and small business owners.

2.7.5 Split incentives:

This occurs when the individual responsible for making investment decisions is not the customer paying the energy bills. For example, owners of apartment buildings have little incentive to improve the efficiency of the building or individual apartments if the tenants are the

ones paying the bills and benefitting from future energy savings. Similarly, builders or developers have little incentive to design or construct new buildings to be more efficient because they will never pay the bills for energy consumption. This lack of consumer sensitivity is exacerbated by the fact that renters and buyers of new buildings usually have no way of gauging the relative efficiency of different buildings, so owners or builders cannot effectively market their buildings as cheaper to occupy.

2.7.6 Uncertainty

About whom to trust: Consumers also typically have no way of sorting out retailers' or contractors' claims of knowledge, expertise, or projected energy savings. This is a barrier that renders stand-alone energy audits largely unsuccessful in prompting significant numbers of building owners to follow through once they understand the nature and magnitude of investments they could pursue.

2.7.7 Efficiency isn't "sleek":

Many consumers who want to do the "right thing" and have the resources to do it are attracted first to energy investments such as solar panels on their roof. While such investments in renewable energy are admirable and desirable from a societal perspective, they are much more expensive than many efficiency measures. Ideally, one would make all cost-effective efficiency investments first and then think about how to reduce energy needs with renewable energy. However, efficiency investments are not very glamorous. Compare the lure of being able to announce to a colleague or neighbor that you are overhauling your roof to heat your home with the sun's rays, with announcing that you are fixing some old insulation in your attic. In addition, efficiency measures are largely invisible to neighboring households and businesses; unlike renewable energy, they do not serve as a tangible badge of one's environmental stewardship. For better or worse, issues like these do influence the decisions of many would-be consumers of energy improvements.

2.8 THE WAY OUT

Though the myriad barriers to prompting investments in efficiency are fairly well known and understood, they are not easily overcome. To be sure, there have been some successes. Both utility programs and government policies have achieved significant energy savings in some markets, particularly new construction and appliance markets (e.g., purchases of new refrigerators, clothes washers and air conditioners). Success in reaching similar levels of savings in residential and commercial building retrofit initiatives—e.g. by reducing air leakage and increasing insulation levels in homes—has generally been more elusive because it is more complicated (it does not lend itself to off-the-shelf solutions) and discretionary (adding insulation is not perceived as urgent, compared to replacing a broken refrigerator), and because the cost tends to be much higher (it is always cheaper in the long run to build something well at the outset than come back and fix it later). That said, the lessons learned from the vigorous efforts of retrofit programs to date, and the thinking behind some innovative ideas that have not yet been fully tested, offer invaluable guidance for municipalities and their partners as they contemplate how to ramp up delivery systems and ensure participation across all building sectors. Getting onto a more fruitful path will require careful attention to the follow lessons:

2.8.1 Substantial funding and/or regulation

The most successful utility programs have required substantial funding commitments. The leading electricity rate-payer funded programs have needed an investment of $20 to $40 per capita per year to achieve a 1% to 2% level of energy savings. For a city of 1 million people, that would translate to spending levels of $40 to $80 million per year. As future energy savings and climate protection goals become more aggressive, the required level of spending across all types of fuel will be many times greater than these per capita levels. Federal and state policies have demonstrated real success in achieving significant efficiency with regulated funding. Key examples are federal minimum efficiency standards for new appliances and the California energy codes for construction of new residential and commercial buildings. Municipal policy options—discussed below—also have the potential to be very successful.

2.8.2 Must be in it for the long haul:

The "per year" notation in the funding discussion above is particularly important. One of the other key lessons from all successful efficiency initiatives is that they require sustained effort over at least several years to overcome the barriers described above. Moreover, the programs that have achieved high participation rates in only three to five years are those that have been targeted to either new construction markets or equipment replacement markets (e.g. increasing market share for sales of high efficiency clothes washers). Overcoming the barriers to success in residential or commercial retrofit initiatives will likely require a sustained effort over at least a decade and probably two.

2.8.3 Aim high:

Success in reaching the ultimate goal—substantial reductions in energy use and greenhouse gas emissions—requires not only triggering investments by large numbers of building owners, but also getting those building owners to implement the kinds of investments that result in "deep" energy savings in each building. Unfortunately many of the policies used by municipalities as levers for driving retrofitting have not set a high enough bar to achieve substantial improvements in energy efficiency. For example, the handful of municipal rental energy codes in use by municipalities have not yet achieved noteworthy results because the efficiency improvements they mandate are simply not aggressive enough.

2.8.4 Segment and understand markets:

The most successful programs evaluate the specific barriers that prevent participation among different types of customers, and then develop tailored program designs for reaching each of those different customer groups. For example, many utilities have had success offering well-subsidized (i.e. 80% or more) direct installation of efficiency measures to small business customers. This approach minimizes transaction costs, addresses their short planning horizons, assures the businesses that the work is being overseen by a trusted source (the utility), and addresses a range of financial constraints. The federal low-income weatherization program and many utility programs have also found that the only way to achieve significant savings for low-income customers is to

(1) offer all efficiency investments for free; and

(2) deliver those services through an organization that the customers trust (e.g., local non-profit social service agencies).

In contrast, programs targeted to larger, more sophisticated commercial and industrial customers have often found that technical support in assessing the opportunities and assistance in making the internal financial case for investments are often more important than financial incentives.

2.8.5 Show the owner the benefits:-

Homeowners and small business owners are unlikely to participate in multiple efficiency initiatives, both because the transaction costs are daunting and because they will assume they have addressed all key opportunities for improving the efficiency of their buildings the first time they get involved with a retrofit program. Thus, efficiency initiatives should aim to provide a comprehensive set of services when they first interact with an interested building owner. Rather than narrowly focusing on a particular type of improvement that might be made (e.g. increasing insulation, or replacing a furnace), they should help the owners identify and plan for as many cost-effective investments as possible, and then provide assistance to the building owner to follow through with the identified projects.

2.8.6 Make it as simple as possible:

One cannot overstate the importance of making investment in energy efficient retrofitting as easy as possible. Minimal paperwork requirements, services that help building owners locate and choose contractors to do the work, and services that actually arrange the work are all effective and important features of successful programs. This particular success factor applies to many categories of potential consumers of retrofit services, including wealthy and low-income homeowners, small commercial property owners or managers, and owners of multi-family residences. "One stop shops" that provide comprehensive information all in one place about steps for improving efficiency, financial loans and incentives to defray or reduce upfront costs, and services for assessing buildings and getting the work done can be effective in addressing this barrier.

2.8.7 Utilize the power of social motivators:

Conventional wisdom used to hold that programs wishing to stir people to action should just load them up with compelling information. But decades of experience with efficiency and other environmental outreach programs have shown that information does little by itself to motivate behaviour change. In recent years, much more attention has been devoted to understanding how to market behaviour change to would-be change agents. For example, several innovative retrofit programs have built their design around the premise that people respond to competition among their peers or neighbours to be the best environmental steward. Others have concluded that the key to motivating people is to give them a means of showing their neighbours the commitment they have made, by making their investments visible in some way. Still others seek to foster a feeling of belonging to a community with shared values and norms. In sum, outreach programs must do much more than disseminate information. They must connect their target audiences with a whole range of social benefits that serve as powerful motivators for action.

The retrofit community has already learned a great deal about the kinds of approaches and program designs that are most likely to overcome barriers to participation. But there is much yet to learn. No program or initiative anywhere in the country has yet been able to achieve widespread participation across an entire city, or even an entire neighbourhood. The next generation of efforts to expand and accelerate participation should adopt a commitment to experimentation. As noted above, there is no single successful approach to getting homeowners and businesses involved in energy efficient retrofit programs. The unique characteristics of cities and the specificity of barriers affecting different types of building owners means that tailored approaches will always work best. Thus, cities will need to be creative. They will also need to measure and evaluate the patterns of participation that result from the strategies they choose. Only with continuous invention, regular analysis of market feedback and a willingness to change course when strategies fail will cities be able to create a true wave of retrofit projects.

2.9 ENERGY EFFICIENT RETROFIT PRINCIPLES

Design strategies for energy-efficient buildings include reducing loads, selecting systems that make the most effective use of ambient energy sources and heat sinks and using efficient equipment and effective control strategies. An integrated design approach is required to ensure that the architectural elements and the engineering systems work effectively together.

2.9.1 Reduce Heating, Cooling And Lighting Loads

A simple strategy for reducing heating and cooling loads is to isolate the building from the environment by using high levels of insulation, optimizing the glazing area and minimizing the infiltration of outside air. This approach is most appropriate for cold, overcast climates. A more Effective strategy in tropical, sub tropical and composite climates is to use the building envelope as a filter, selectively accepting or rejecting solar radiation and outside air, depending on the need for heating, cooling, ventilation and lighting at that time and using the heat capacity of the building structure to shift thermal loads on a time scale of hours to days.(Taylor et al, 2006).

2.9.2 Utilize Active Solar Energy And Other Heat Sources

Active solar energy systems can provide electricity generation, hot water and space conditioning. The ground, ground water, aquifers and open bodies of water, and less so air, can be used selectively as heat sources or sinks, either directly or by using heat pumps. Space cooling methods that dissipate heat directly to natural heat sinks without the use of refrigeration cycles (evaporative cooling, radiative cooling to the night sky, earth-pipe cooling) can be used.

2.9.3 Increase Efficiency Of Appliances, HVAC equipment

The efficiency of equipment in buildings continues to increase in most industrialized and many developing countries, as it has over the past quarter-century. Increasing the efficiency – and where possible reducing the number and size – of appliances, lighting and other equipment within conditioned spaces reduces energy consumption directly and also reduces cooling loads but increases heating loads, although usually by lesser amounts and possibly for different fuel types.

2.9.4 Improvement of Operations And Maintenance

The actual performance of a building depends as much on the quality of construction as on the quality of the design itself. Building commissioning is a quality control process that includes design review, functional testing of energy-consuming systems and components, and clear documentation for the owner and operators. Actual building energy performance also depends critically on how well the building is operated and maintained. Continuous performance monitoring, automated diagnostics and improved operator training are complementary approaches to improving the operation of commercial buildings in particular.

2.9.5 Change In Behaviour

The energy use of a building also depends on the behavior and decisions of occupants and owners. Classic studies at Princeton University showed energy use variations of more than a factor of two between houses that were identical but had different occupants (Socolow, 1978). Levermore (1985) found a variation of 40% gas consumption and 54% electricity consumption in nine identical children's homes in a small area of London. When those in charge of the homes knew that their consumption was being monitored, the electricity consumption fell. Behaviour of the occupants of non-residential buildings also has a substantial impact on energy use, especially when the lighting, heating and ventilation are controlled manually (Ueno et al., 2006).

2.9.6 Utilize System Approaches To Building Design

Evaluation of the opportunities to reduce energy use in buildings can be done at the level of individual energy-using devices or at the level of building 'systems' (including building energy management systems and human behaviour). Energy efficient retrofit strategies focused on individual energy-using devices or design features are often limited to incremental improvements. Examining the building as an entire system can lead to entirely different design solutions. This can result in new buildings that use much less energy but are no more expensive than conventional buildings.

2.9.7 Consider Building Form, Orientation And Related Attributes

At the early design stages, key decisions – usually made by the architect – can greatly influence the subsequent opportunities to reduce building energy use. These include building form, orientation, self-shading, height-to-floor-area ratio and decisions affecting the opportunities for and effectiveness of passive ventilation and cooling. Many elements of traditional building designs in both developed and developing countries have been effective in reducing heating and cooling loads. Urban design, including the clustering of buildings and mixing of different building types within a given area greatly affect the opportunities for and cost of district heating and cooling systems as well as transport energy demand and the shares of different transport modes.

2.9.8 Minimize Halocarbon Emissions

Many building components – notably air conditioning and refrigeration systems, foam products used for insulation and other purposes and fire protection systems – may emit greenhouse gases with relatively high global-warming potentials. These chemicals include chlorofluorocarbons, hydrochlorofluorocarbons, halons (bromine-containing fluorocarbons) and hydrofluorocarbons (HFCs). While the consumption of the first three is being eliminated through the Montreal Protocol and various national and regional regulations, their on-going emission is still the subject of strategies discussed in the IPCC special report (IPCC/TEAP, 2005). Meanwhile, the use and emissions of HFCs, mostly as replacements for the three ozone-depleting substances, are increasing worldwide.

2.9.9 Insulation

The choice of insulation material needs to maximize long-term thermal performance of the building element overall. As mentioned previously, this involves consideration of remaining thermal bridges and any water ingress, or other factor, which could result in deterioration of performance over time. For existing buildings, space may be at a premium and the most efficient insulation materials may be needed to minimize thicknesses required. Where upgrading of existing elements is essentially voluntary, minimization of cost and disturbance is equally important and a range of post-applied technologies can be considered, including cavity wall insulation, spray foams and rolled loft insulation. Only a few specific applications with effective control of end-of life emissions have been identified in which foams containing high GWP blowing agents will lead to lower overall climate impacts than hydrocarbon or CO2 solutions. However, where this is the case, care should still be taken to optimize life-cycle management techniques in order to minimize blowing agent emissions.

2.9.10 Windows

The thermal performance of windows has improved greatly through the use of multiple glazing layers, low-conductivity gases (argon in particular) between glazing layers, low-emissivity coatings on one or more glazing surfaces and use of framing materials (such as extruded fibre-glass) with very low conductivity. Operable (openable) windows are available with heat flows that have only 25–35% of the heat loss of standard non-coated double-glazed (15 to 20% of single-glazed) windows. Glazing that reflects or absorbs a large fraction of the incident solar radiation reduces solar heat gain by up to 75%, thus reducing cooling loads. In spite of these technical improvements, the costs of glazing and windows has remained constant or even dropped in real terms (Jakob and Madlener, 2004). A major U.S. Department of Energy program is developing electrochromic and gasochromic windows which can dynamically respond to heating and cooling in different seasons.

2.9.11 Minimizing Air leakage

In cold climates, uncontrolled exchange of air between the inside and outside of a building can be responsible for up to half of the total heat loss. In hot-humid climates, air leakage can be a significant source of indoor humidity. In residential construction, installation in walls of a continuous impermeable barrier, combined with other measures such as weatherstripping, can reduce rates of air leakage by a factor of five to ten compared to standard practice in most jurisdictions in North America, Europe and the cold-climate regions of Asia (Harvey, 2006).

2.9.12 Passive solar heating

Passive solar heating can involve extensive sun-facing glazing, various wall- or roof-mounted solar air collectors, double-façade wall construction, airflow windows, thermally massive walls behind glazing and preheating or pre-cooling of ventilation air through buried pipes. Technical details concerning conventional and more advanced passive solar heating techniques, real-world examples and data on energy savings are provided in books by Hastings (1994), Hestnes et al. (2003) and Hastings (2004). Aggressive envelope measures combined with optimisation of passive solar heating opportunities, as exemplified by the European Passive House Standard, have achieved reductions in purchased heating energy by factors of five to thirty (i.e., achieving heating levels less than 15 kWh/ m2/yr even in moderately cold climates, compared to 220 and 250–400 kWh/m2/yr for the average of existing buildings in Germany and Central/Eastern Europe, respectively (Krapmeier and Drössler, 2001; Gauzin-Müller, 2002; Kostengünstige Passivhäuser als europäische Standards, 2005).

2.9.13 Reducing the cooling load

Reducing the cooling load depends on the building shape and orientation, the choice of building materials and a whole host of other decisions that are made in the early design stage by the architect and are highly sensitive to climate. In general, recently constructed buildings are no longer adapted to prevailing climate; the same building forms and designs are now seen in Stockholm, New York, Houston, Hong Kong, Singapore and Kuwait. However, the principles of design to reduce cooling load for any climate are well known

In most climates, they include:

(i) orienting a building to minimize the wall area facing east or west;
(ii) clustering buildings to provide some degree of self shading (as in many traditional communities in hot climates);
(iii) using high-reflectivity building materials;
(iv) increasing insulation;
(v) providing fixed or adjustable shading;
(vi) using selective glazing on windows with a low solar heat gain and a high daylight transmission factor and avoiding excessive window area (particularly on east- and west-facing walls); and
(vii) utilizing thermal mass to minimize daytime interior temperature peaks. As well, internal heat loads from appliances and lighting can be reduced through the use of efficient equipment and controls.

Increasing the solar reflectivity of roofs and horizontal or near-horizontal surfaces around buildings and planting shade trees can yield dramatic energy savings. The benefits of trees arise both from direct shading and from cooling the ambient air. Rosenfeld et al. (1998) computed that a very large-scale, citywide program of increasing roof and road albedo and planting trees in Los Angeles could yield a total savings in residential cooling energy of 50–60%, with a 24–33% reduction in peak air conditioning loads.

2.9.14 Passive And Low-Energy Cooling Techniques

Purely passive cooling techniques require no mechanical energy input, but can often be greatly enhanced through small amounts of energy to power fans or pumps. A detailed discussion of passive and low-energy cooling techniques can be found in

(i) Natural and night-time ventilation
(ii) Evaporative cooling
(iii) Other passive cooling techniques

Underground earth-pipe cooling consists of cooling ventilation air by drawing outside air through a buried air duct. Good performance depends on the climate having a substantial annual temperature range. Desiccant dehumidification and cooling involves using a material (desiccant) that removes moisture from air and is regenerated using heat. Solid desiccants are a commercially available technology. The energy used for dehumidification can be reduced by 30 to 50% compared to a conventional overcooling/reheat scheme (50 to 75% savings of conventional sources if solar energy is used to regenerate the desiccant) (Fischer et al., 2002; Niu et al., 2002). In hot-humid climates, desiccant systems can be combined with indirect evaporative cooling, providing an alternative to refrigerationbased air conditioning systems (Belding and Delmas, 1997).

2.9.15 Building Energy Management Systems (BEMS)

BEMSs are control systems for individual buildings or groups of buildings that use computers and distributed microprocessors for monitoring, data storage and communication (Levermore, 2000). The BEMS can be centrally located and communicate over telephone or Internet links with remote buildings having 'outstations' so that one energy manager can manage many buildings remotely. With energy meters and temperature, occupancy and lighting sensors connected to a BEMS, faults can be detected manually or using automated fault detection software (Katipamula et al., 1999), which helps avoid energy waste (Burch et al., 1990). With the advent of inexpensive, wireless sensors and advances in information technology, extensive monitoring via the Internet is possible. Estimates of BEMS energy savings vary considerably: up to 27% (Birtles and John, 1984); between 5% and 40% (Hyvarinen, 1991; Brandemuehl and Bradford, 1999; Brandemuehl and Braun, 1999; Levermore, 2000); up to 20% in space heating energy consumption and 10% for lighting and ventilation; and 5% to 20% overall (Roth et al., 2005).

2.9.16 Building-Integrated PV (Bipv)

Building-integrated PV (BiPV) consists of PV modules that function as part of the building envelope (curtain walls, roof panels or shingles, shading devices, skylights). BiPV systems are sometimes installed in new 'showcase' buildings even before the systems are generally cost-effective. These early applications will increase the rate at which the cost of BiPVs comes down and the technical performance improves. A recent report presents data on the cost of PV modules and the installed-cost of PV systems in IEA countries (IEA, 2003b). Electricity costs from BiPV at present are in the range of 0.30–0.40 US$/kWh in good locations, but can drop considerably with mass production of PV modules (Payne et al., 2001). Gutschner et al. (2001) have estimated the potential for power production from BiPV in IEA member countries. Estimates of the percentage of present total national electricity demand that could be provided by BiPV range from about 15% (Japan) to almost 60% (USA).

2.9.17 Solar Thermal Energy For Heating And Hot Water

Most solar thermal collectors used in buildings are either flat-plate or evacuated-tube collectors. Integrated PV/thermal collectors (in which the PV panel serves as the outer part of a thermal solar collector) are also commercially available (Bazilian et al., 2001; IEA, 2002). 'Combisystems' are solar systems that provide both space and water heating. Depending on the size of panels and storage tanks, and the building thermal envelope performance, 10 to 60% of the combined hot water and heating demand can be met by solar thermal systems at central and northern European locations. Costs of solar heat have been 0.09–0.13 €/kWh for large domestic hot water systems and 0.40–0.50 €/kWh for combisystems with diurnal storage (Peuser et al., 2002).

Worldwide, over 132 million m2 of solar collector surface for space heating and hot water were in place by the end of 2003. China accounts for almost 40% of the total (51.4 million m2), followed by Japan (12.7 million m2) and Turkey (9.5 million m2) (Weiss et al., 2005).

2.9.18 High efficiency electric lighting

Presently 1.9 $GtCO_2$ are emitted by electric lighting worldwide, equivalent to 70% of the emissions from light passenger vehicles (IEA, 2006b). Continuous improvements in the efficacy of electric lighting devices have occurred during the past decades and can be expected to continue. Advances in lamps have been accompanied by improvements in occupancy sensors and reductions in cost (Garg and Bansal, 2000; McCowan et al., 2002). A reduction in residential lighting energy use of a factor of four to five can be achieved compared to incandescent/halogen lighting.

2.9.19 Daylighting

Daylighting systems involve the use of natural lighting for the perimeter areas of a building. Such systems have light sensors and actuators to control artificial lighting. Opportunities for daylighting are strongly influenced by architectural decisions early in the design process, such as building form; the provision of inner atria, skylights and clerestories (glazed vertical steps in the roof); and the size, shape and position of windows. IEA (2000) provides a comprehensive sourcebook of conventional and less conventional techniques and technologies for daylighting.

2.9.20 Household appliances, electronics and office equipment

Energy use by household appliances, office equipment and consumer electronics, from now on referred to as 'appliances', is an important fraction of total electricity use in both households and workplaces (Kawamoto et al., 2001; Roth et al., 2002). This equipment is more than 40% of total residential primary energy demand in 11 large OECD nations (IEA, 2004f). The largest growth in electricity demand has been in miscellaneous equipment (home electronics, entertainment, communications, office equipment and small kitchen equipment), which has been evident in all industrialized countries since the early 1980s. Such miscellaneous equipment now accounts for 70% of all residential appliance electricity use in the 11 large OECD nations (IEA, 2004f). Appliances in some developing countries constitute a smaller fraction of residential energy demand. However, the rapid increase in their saturation in many dynamically developing countries such as China, especially in urban areas, demonstrates the expected rise in importance of appliances in the developing world as economies grow (Lawrence Berkeley National Laboratory, 2004)

2.10 INFERENCES

This is very much agreed upon fact that buildings are the largest contributor for GHG emission, climate change and environmental degradation. The energy inefficient buildings, that were built previously when there was no such technology available to mitigate the direct and indirect emission problem, ranges from a single storied detached house to supertall commercial towers. But they all can easily be retrofitted to become an green building with the help of technology available at present. The method of retrofitting not only brings down the direct and indirect GHG emission but also curbs down the power bill to a great extent. Apart from all these, direct benefits, it also creates new job opportunity, better living environment and many more indirect co benefits.

In spite of all these advantages, energy efficient retrofit is not so much popular till date due to many reasons like lack of awareness, inappropriate government policies and various complications. There is knowledge and technology, there are benefits, but surprisingly, the retrofitting is not very much popular in common mass level. The world is looking forward to bridge the gap for a better and greener tomorrow.

3 CASE STUDIES

3.1 SELECTION OF CASE STUDIES

Case study is very useful method to look into the paradox of energy efficient retrofitting in India. Due to its capacity to explain causal links and proper analysis of the case in its real life context, not only it helps to identify the problems, but also helps to find a solution.

In this research, multiple case study strategy has been chosen to use multiple sources of information from various retrofit projects and analyze their strengths and weaknesses.

The case studies assorted here are unique in their characteristics. The in depth study of the strategy and technique used in the retrofit of the Empire State Building provides a clear idea on technical and financial aspects. The Helmus building retrofit shows that the will and enthusiasm of the client. The case of Clinton Presidential Centre depicts some typical problems of wrong orientation of buildings can be retrofitted with advanced technology.

Apart from the above, some more interesting retrofitting cases have been studied and they are provided in a condensed matrix format at the end of this chapter.

The main selection criteria were the following

- Implementation of new and innovative strategies.
- The building should be a detached building.
- Almost similar climatic condition(except ESB.)

3.2 HELMUS BUILDING, GRAND RAPIDS, MICHIGAN

3.2.1 Project details:-

Table 3.1- Project details of Helmus Building

Helmus Building, Grand Rapids, Michigan	
Project type	Commercial
Project scale	Individual Building
Project context	Urban
Construction type	Retrofitting
Date completed	July 2002
Address	959 Wealthy SE, Grand Rapids MI 49506
Subjects	Energy Efficiency
	Materials Use
	Social Benefits
Total project costs	$1,042,800 (soft costs)
	$249,000 (building acquisition)
Building	9,480 sq. ft.

3.2.2 History:-

Built in 1918, the Helmus Building in Grand Rapids, Michigan, was a dry storage warehouse for most of its life. After going vacant and falling into a state of disrepair, much like the surrounding neighborhood, Guy Bazzani purchased the building in 1999. Bazzani bought the Helmus Building not only for its redevelopment potential, but because of his commitment to the local community.

For over a decade, Bazzani has been active in real estate development in the area, and sustainable building design and development are at the core of his business practices. Intending to locate his offices in the Helmus Building, he sought to demonstrate the economic, social, and environmental value of sustainable design with this project; the Helmus renovation project is an historic rehabilitation that salvaged 100% of the original shell, and more than 50% of the non-shell materials. The super-insulated and super-efficient building pays dividends in many ways: utility and water bills are significantly lower than comparables, and the improved insulation of the building envelope have enabled Bazzani to downsize the HVAC systems, reducing construction costs as well as future replacement costs.

The Helmus Building is more than just energy and water efficient. Under its one roof, the building mixes residential, commercial, and retail uses. Sustainable materials –

including low-VOC paints, recycled carpeting, and recycled content ceiling pads – were used throughout the renovation. Most important, this project affected more than Bazzani Associates and its customers; the renovation of the Helmus Building sparked the revitalization of the surrounding community.

3.2.3 Energy Efficiency:-

Initially, the exterior walls of the Helmus Building consisted of only brick. Upon renovation, all exterior walls were super-insulated using the Icynene Insulation System, an open-cell foam insulation with an R21 rating. Additionally, the energy efficiency of the walls was increased through the use of thermal breaks, vapor barriers, and low-E glass in all the windows. The building was built to ASHRAE/IESNA 90.1-1999 energy efficiency standards, and Bazzani estimates that his super-insulated building saves him roughly $2,444 annually in gas and electric utility costs.

In addition to super-insulating the walls, several energy efficient devices were installed throughout the building, including dimmable compact fluorescent lights, timers for all light fixtures, and occupancy sensors. ENERGY STAR-rated appliances and equipment also were installed throughout the building. One of the most innovative approaches to conserving energy was the design of the building's awnings, positioned at an angle to shade the storefront windows in the summer and to allow maximum sunlight penetration in the winter to optimize passive solar gain.

To complete the energy-efficient envelope of the building, Bazzani installed a Carlisle-Syntec 2,511-square foot green roof. Using plants that require little water and maintenance, the green roof helps release moisture, cool the building in the summer, and reduce storm water runoff, in addition to conserving energy and prolonging the life of the roof. Additionally, the green roof was designed as a usable rooftop garden providing additional green space for occupants of the building to enjoy.

Figure 3.1- Green roof at Helmus Bulding

Bazzani's investments in efficiency created immediate and long-term savings. The improved insulation of the building allowed them to downsize HVAC equipment, reducing construction costs. They selected a Bryant 350MAV Furnace and a Bryant 533A central air conditioner. The downsized HVAC equipment coupled with the building's energy efficient envelope offer significantly reduced annual energy costs at $0.68 per square foot per year.

In addition to cooling the building in the summer, reducing water runoff, improving energy efficiency, and prolonging the life of the roof, this green roof creates new usable space for occupants.


Figure 3.2- The Building offers nice workspace with ample daylight.

3.2.4 Materials Use:-

Reuse is always the optimal choice for any material that reaches the end of its intended life, and Bazzani Associates wholeheartedly embraced the reuse concept when renovating Helmus. In fact, Bazzani reused 100% of the building's existing frame and more than 50% of the "non-shell." One of the most unique reuses was the loading dock, which originally was two feet higher than the rest of the first floor to accommodate delivery trucks. Rather than sending all the concrete from the loading dock to a landfill, Bazzani disconnected it from the walls and lowered it to ground level, providing a perfectly surfaced floor for what is now the building's new garage.

Finishing materials were selected to maximize sustainability. Interface carpeting with recycled nylon and backing material was used on the floors throughout the Helmus Building as were Armstrong Cirrus ceiling tiles containing 72% recycled content. All paints, stains, and sealants were low-VOC products. As a result of the carefully developed and implemented waste management plan, the renovation project generated less than 25% of the waste normally generated by new construction of a similar building.

3.2.5 Social Benefits-

Incorporating multiple uses into one facility ensures that the capital and energy invested in the project are used to a higher potential while delivering social benefits, such as reducing transportation demands and creating a more vibrant community. Bazzani Associates' core staff of five and Clean Water Action, a local non-profit, inhabit the office space on the first floor of the Helmus Building. Guy Bazzani and his wife reside on the second floor, where two additional residential units are nearing completion. Finally, local individuals and businesses rent storage units in the basement.

Guy Bazzani has a proven track record of personal involvement in the community, including his work with local non-profits and his involvement with the West Michigan Sustainable Business Forum and EDGE2 advisory committee (Economic Development and Growth through Environmental Efficiency). The Bazzani's Helmus Building project has extraordinarily impacted the surrounding community. When Bazzani bought the building in 1999, the neighbourhood was plagued with drugs and prostitution. In fact, the police often used the Helmus Building for stakeouts.

After years of decay, Bazzani's redevelopment catalyzed the revitalization of the surrounding area. As a result of the renovation, the city invested in new street lighting, paved the main street with recycled bricks, and implemented a program to curb graffiti that has plagued the area. Just after the completion of the building, several new and local businesses moved into the neighbourhood.

3.2.6 Lessons Learnt:-

According to Guy Bazzani, the historic preservation and renovation of the Helmus Building in Grand Rapids went fairly smoothly, although the project hit a snag when Bazzani wanted the state's Historic Commission to approve new low-E glass windows for the building. The Commission originally rejected the permit request because of the building's "historic" designation and the Historic Commission's concern that the low-E glass would not match the reflective properties of other historic windows in the area. After several presentations to the Commission, Bazzani's request for the new windows was approved.

This step of the owner can be a lesson to be learnt for other developers and owners apart from the technologies and strategies used to retrofit the building.

The Helmus Building illustrates what can be accomplished despite the limitations of a retrofit project and a historic rehab. Bazzani's investments in energy efficiency resulted in reduced capital requirements (downsizing HVAC equipment, for example) and will pay future dividends through reduced utility bills. Furthermore, his pursuit of a mixed-use structure insures that his investments will be fully utilized while also delivering social benefits to society and the building's occupants.

Figure 3.3- Staircase located inside Bazzani's apartment,

3.3 IHM MOTHERHOUSE, MONROE, MICHIGAN

3.3.1 Project Details

Table 3.2- Project details of IHM Motherhouse

Project type	Residential
Project scale	Building
Construction type	Retrofit
context	Urban
Date completed	January 2003
Subjects	Energy Efficiency
	Water Efficiency
	Materials Use
	Social Benefits
Building square footage	376,000 sq. ft.
Cost/square foot	$150/sq. ft.

3.3.2 History

In 1845, the Sisters, Servants of the Immaculate Heart of Mary (IHM), founded a ministry of education in Monroe, Michigan. The 280-acre campus in Monroe remains the “home office” of the IHM community. After the destruction of the previous structure by fire, the existing Motherhouse was constructed in the early 1930s. Despite the hardships of the Great Depression, the community was able to fund reconstruction and employ builders who took great pride in their craftsmanship. The 18-inch-thick brick and concrete walls and the interior spaces of the Motherhouse, finished with terrazzo, Flint Faience tiles, and period chandeliers, convey a sense of elegant permanence. Estimates of the life of the structure extend into the 23rd century.

In the 1990s, the Sisters determined that the Motherhouse no longer met the changing needs of the IHM community. The utility systems throughout the building were outdated and failing; a complete reinstallation of plumbing, electrical, and HVAC systems was required. Faced with the option of building a completely new structure, the Sisters instead chose to renovate the Motherhouse, reusing the site and building shell but replacing most of the interior. By sustainably renovating the Motherhouse, the IHM community emphasized their strong belief in responsible stewardship and educated the construction industry and the general public about the principles of green living.

3.3.3 Energy Efficiency

At the Motherhouse,

- lighting fixtures were adapted to use compact fluorescent bulbs, reducing energy costs and requiring less maintenance.
- The appropriate lighting was carefully selected for each space, reducing the amount of over-lighting. The large number of windows throughout the Motherhouse allows the residents to take full advantage of natural daylight.
- The installation of both occupancy sensors and light meters allows the lights to be turned on only when needed.
- As part of the renovation, 800 windows were removed, refurbished (instead of purchasing new windows), and reinstalled with high-efficiency glass and operating sashes that allow the residents to control fresh air, heating, and cooling in their rooms.
- In addition to the windows, individual thermostats were installed in each room to minimize unnecessary heating and cooling of large spaces.
- A heat recovery system was installed on the ductwork to prevent warmed air from escaping the building.
- A closed-loop geothermal energy system circulates water through the building and into the earth, providing heat in the winter and removing heat in the summer. In addition to the thermal mass of the building structure, which evens out the indoor temperature, the geothermal system allows supplemental heating and cooling systems to work less often than typically needed in Michigan. The system, which effectively "uses the Earth as a giant radiator," is the largest residential geothermal field in the USA.

  The Geothermal System
  232 holes, 450 feet deep
  54 miles of closed-loop pipe
  Underground temperature: 55 degree F
  Temperature of water when entering building: 72 degree F (due to friction)

3.3.4 Materials Use

New Interface tiled carpets have the dual benefits of not off-gassing after installation and of being easily replaceable if necessary: a single 12"x12" tile can be replaced instead of an entire room. Cork flooring, used throughout the building, is sustainably harvested, provides superior sound-absorption capacity, and lasts for decades without an appreciable loss in quality. Cork was one of the original flooring materials in the 1932 Motherhouse and the tiles that remain today cannot be distinguished from the newly installed cork floors.

Building Materials in the Motherhouse-

- Cork and linoleum flooring
- Interface carpeting
- Benjamin Moore low-VOC paints
- Trex recycled plastic and wood product on veranda
- Natural gypsum wallboard
- Mineral wool insulation

Figure 3.4- Refurbished 800 original windows, saved costs Social Benefits

The retrofit project of the IHM Motherhouse succeeded in having a minimal impact on the environment but a profound impact on everyone involved. The IHM community, architects, construction company, and its subcontractors learned together how sustainable renovation and restoration can have a beneficial environmental impact. The contractors and subcontractors who worked on this project are now, in turn, implementing earth-friendly practices on other projects, thus changing the marketplace of the future.

3.3.5 Lessons Learnt

Motherhouse renovation is an example of how Earth-friendly retrofit can be accomplished in an old building, and [accomplished] cost effectively. While its sheer magnitude places the project in a unique class, the opportunities for demonstrating innovative sustainable systems makes the Motherhouse retrofit an extraordinary example for developers throughout the state. A truly sustainable practice propagates itself by demonstrating its benefits and educating others; by that measure, the IHM Motherhouse will positively impact the environment and the community for generations to come.

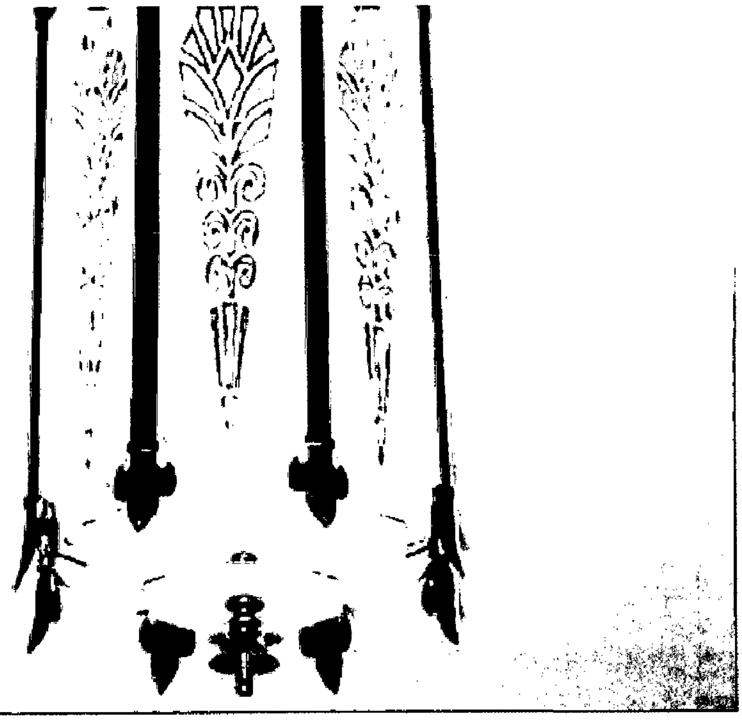


Figure 3.5- Cleaned and updated the lights to use CFL.

3.4 WILLIAM J. CLINTON PRESIDENTIAL CENTER

Location: Little Rock, Arizona, USA.

Climate Region: Warm – Humid(3A)

Table 3.3- Project details of WJC Presidential Centre

Project type	Assembly,Library
Project scale	Building
Construction type	Retrofit
context	Urban
Date completed	November 2004
Subjects	Energy Efficiency
	Water Efficiency
	Materials Use
	Social Benefits
Building square footage	167,000 sq. ft.
Cost/square foot	$169/sq. ft.

Project Details

3.4.1 Context

The Clinton Presidential Center, located east of downtown Little Rock, is partially elevated, its bridge-like form both a reference to Little Rock's distinctive "Six Bridges". Inside, a large, daylit exhibition space teaches visitors about the Clinton administration's initiatives.

Figure 3.6- A view from one of the bridges

3.4.2 Finance & Cost

This was a privately funded project. Funding was coordinated through a supporting foundation.

Although payback was not modelled as part of the energy analysis, the team estimated that the incremental cost of the project's energy-efficient measures—including variable-air-volume boxes; variable fan drives; efficient fans, pumps, and motors; and low-emissivity glazing—would be repaid through energy cost savings within two to five years.

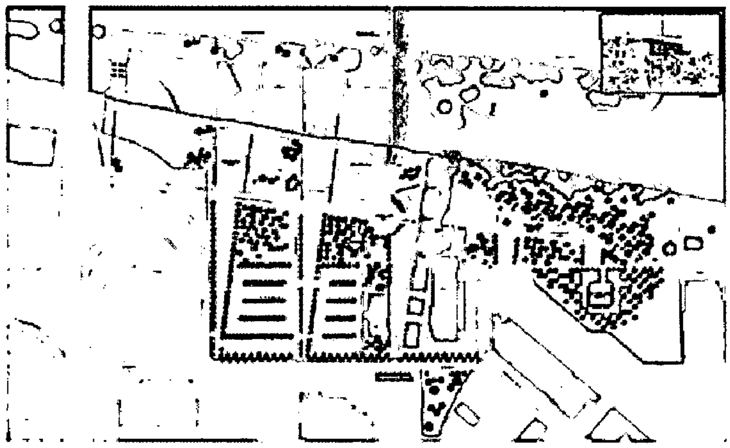


Figure 3.7- Site plan- WJCP centre

3.4.3 Site lev

By replacing the existing paved areas with plantings, the project reduced the site's rate and quantity of stormwater runoff by more than 20%. Currently, more than 60% of the site is planted or otherwise porous, allowing for 45% of all stormwater to percolate into the ground and reducing the urban heat island effect at the same time which actually results in reduction of temperature in the microclimate. Reduction of parking area gradually and converting them into landscape is a strategy adapted to reduce the paved area.

3.4.4 Energy

The project uses 25% less energy than a comparable building designed in minimal compliance with ASHRAE 90.1-1999.

A solar screen on the building's west elevation reduces solar heat gain by 50%. The

Figure 3.8- Reduced light pollution

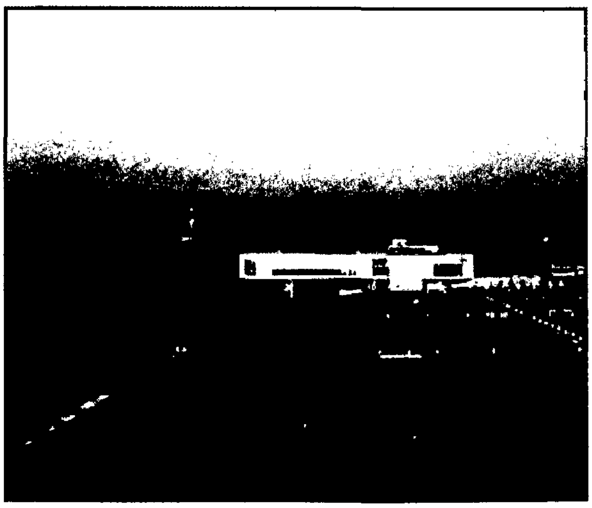


Figure 3.9- Regreening the site

research and archive wing uses perforated metal sunscreens to reduce heat gain and glare. Low-emissivity glass was used throughout the project. Air-handling equipment enclosed in unconditioned interstitial spaces underneath the building provides insulation for the conditioned museum spaces. Much of the archive storage and support areas are embedded in the ground, providing additional insulation.

Displacement cooling in the museum space reduces the cooling load for that space by 40%, and radiant-floor heating and cooling reduces fan energy for the museum. Variable-frequency drives and pumps were used. Ventilation is supplied on demand, as determined by carbon dioxide monitoring.

A direct digital control (DDC) system controls the chiller, the boiler, and all water and air systems. All areas of the building are programmed for occupancy, including times of special events. Reporting to the DDC system is a fully integrated, computer-controlled lighting system for all public areas, also programmed for occupancy and special events. Archive areas are not automated due to the light sensitivity of some items. Occupancy sensors control lighting in restrooms and areas that receive infrequent use.

A 66,000 kWh photovoltaic array located on the archive roof provides 4% of the project's electricity needs, and the library has contracted for 100% green power for two years.

3.4.4.1 Energy security

Both the museum and the office areas have generous glazing to provide daylighting when available. In addition, battery-powered emergency lighting is supplied for all areas except archival storage, and an emergency generator would supply power to critical zones in the event of an outage.

3.4.4.2 Green Strategies

3.4.4.2.1 Daylighting for Energy Efficiency

Use large exterior windows and high ceilings to increase daylighting

3.4.4.2.2 Interior Design for Light

Use light colors for surfaces and finishes

3.4.4.2.3 Photovoltaics

Use a photovoltaic (PV) system to generate electricity on-site

3.4.4.2.4 Heating Systems

Use hot water heat distribution

3.4.4.2.5 Ventilation Systems

Use demand-controlled ventilation

3.4.4.2.6 Lighting Controls

Use occupancy sensors

3.4.4.2.7 HVAC Distribution Systems

Use variable frequency drives for fans

3.4.4.2.8 HVAC Controls and Zoning

Provide sufficient sensors and control logic and use direct digital control (DDC) systems

3.4.5 Indoor Environment

The project design features extensive daylighting, and views to the exterior are provided from all museum and archive office spaces. Programmatic requirements for archival storage and support facilities prohibited daylighting in those areas. The same requirements prohibited operable windows for ventilation.

Carbon dioxide monitors integrated with the building-management system ensure that adequate ventilation is supplied. Desiccant dehumidifiers and humidifiers integrated with the building-management system and controlled with humidistats, thermostats, and fan coils ensure thermal comfort in all administrative, museum, and support spaces. Radiant-floor heating and cooling is used in the museum.

Recessed walk-off mats at every major building entrance reduce the amount of dirt and other pollutants tracked into the building. Deck-to-deck partitioning, dedicated exhaust, and appropriate plumbing are provided for all areas where chemical mixing was anticipated.

During construction, the project team protected ductwork and reduced contamination that could reduce indoor air quality once the building was occupied.

3.4.5.1.1 Entry of Pollutants

Design entry to facilitate removal of dirt before entering building

Avoid carpet and other hard-to-clean floor surfaces near entry to reduce the clogging of HVAC systems which results in decreased efficiency.

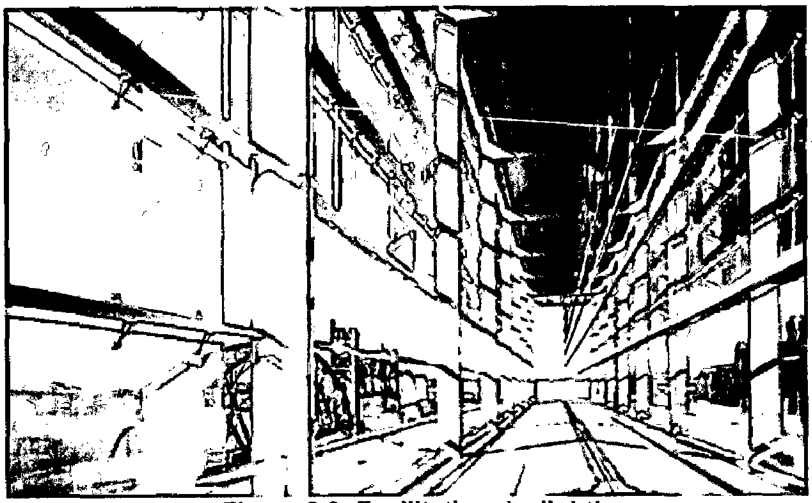


Figure 3.8- Facilitating daylighting

3.4.5.1.2 Visual Comfort and The Building Envelope

Use large exterior windows and high ceilings to increase daylighting

3.4.5.1.3 Direct Exhaust from High-source Locations

Provide local exhaust ventilation for rooms with high-emitting sources

3.4.5.1.4 Reduction of Indoor Pollutants

Use only very low or no-VOC paints
Avoid wood products made with urea-formaldehyde binder

3.4.6 Lessons Learnt

The key challenge in this project was the cantilevered glass museum building. Its transparency and orientation posed the difficulty of overcoming the sun's heat on the building's west elevation and the greater thermal exposure of its underside. To respond to these conditions, a solar screen of transparent and tinted glass was incorporated, reducing solar heat gain by 50%.

Figure 3.9- Solar screen to reduce heat gain

3.5 THE EMPIRE STATE BUILDING

Overview

The Empire State Building

Building owner: Empire State Building Company, LLC, Malkin Holdings

Location: New York City, The USA

Climatic Zone-Humid Continental

3.5.1 Project details

Table 3.4- Project details of Empire State Building

Project type	Commercial
Project scale	Skyscraper
Construction type	Retrofit
context	Urban
Proposed Compleation	December, 2013
Subjects	Energy Efficiency
	Water Efficiency
	Materials Use
	Environmental Benefits
Building Size	2,700,000 square feet

3.5.2 Retrofit Design Project Team

Owner: Empire State Building Company, LLC, Malkin Holdings

Program Manager: Jones Lang LaSalle

Energy Service Company: Johnson Controls, Inc.

Design Partner & Peer Reviewer: Rocky Mountain Institute

Facilitator: Clinton Climate Initiative

The retrofit of the iconic Empire State Building is now underway, with the most innovative undertaking—the remanufacturing of its 6,514 windows onsite into super-windows—completed in September 2010. Cutting winter heat loss by at least two-thirds and summer heat gain by half, the advanced glazing along with improved lighting and office equipment will cut the building's peak cooling load by one-third.

The old chiller plant will then be renovated rather than replaced and expanded—saving more than $17 million of budgeted capital expenditure. That capital cost savings helps pay for other projects and cuts the overall incremental simple payback for the energy retrofit to three years. The expected 38 percent energy savings is several times the savings commonly achieved from a typical retrofit.

The energy efficiency retrofit of the Empire State Building is a great story—one that illustrates the results possible through leveraging the deep retrofit process. Anthony Malkin, the owner of the Empire State Building, spearheaded the project, along with the Clinton Climate Initiative, a non-profit that works with partners to help dramatically reduce global greenhouse gas emissions. The project also involved the property manager (Jones Lang Lasalle) and a large Energy Service Company (Johnson Controls Inc.) who is seeking to build greater market demand and associated service offerings for deep retrofits. Rocky Mountain Institute served as a design partner and peer reviewer, pushing the integrative design process to achieve deep energy reductions.

3.5.3 Financial

Several measures helped to ensure a sound fi nancial decision making process and outcome for the project:

- The use of Life Cycle Cost Analysis (LCCA)
- Piggybacking energy upgrades on planned improvements
- Incorporating energy modeling into the design process to identify options of energy efficiency measures
- Using a hybrid of the ESCO model and owner investments to finance the upgrades
- Incorporating tenant energy reduction measures.

Taking advantage of an already planned retrofit enabled the building owners to make improving the energy performance of the building not only financially viable, but profitable. This project prompted cascading energy savings from several energy efficiency measures including: the reduced solar heat gain coefficient and increased r-value of the rebuilt windows; the radiative barriers on the perimeter heating units; and the daylighting/ lighting controls.

The original budget for energy related projects (projects that may somehow affect energy use) was approximately $93 million. This energy budget included a project to replace the chiller plant to increase cooling capacity, which would have required tearing up Fifth Avenue to bring the new chillers into the building. However, by first implementing strategies that reduced the buildings cooling demand, it was possible to reduce the cooling capacity by 1,600 tons allowing the chillers to be retrofit rather than replaced for a capital savings of $17.3 million.

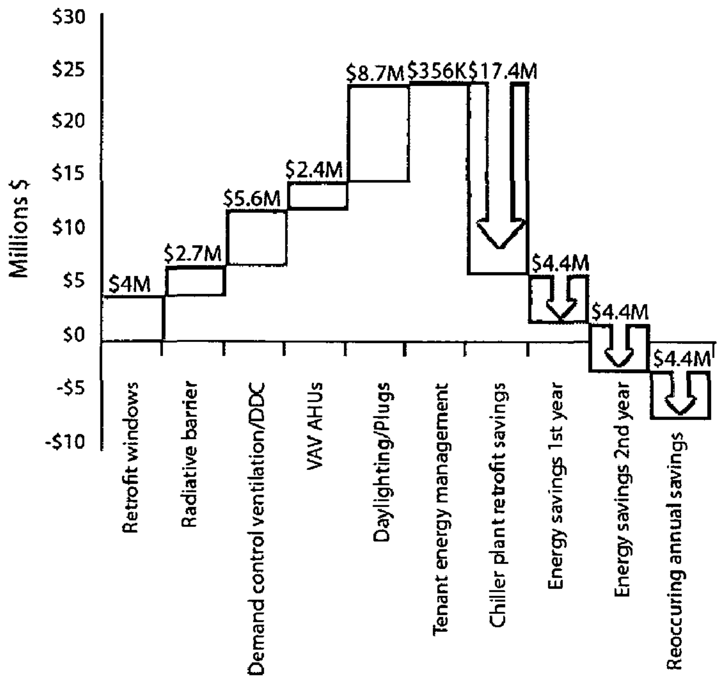


Figure 3.10- *Measures and expenses of retrofitting options*

Efficiency measures implemented on the Empire State Building (shown in red) and the subsequent capital cost reductions (shown in blue) and the annual energy savings (shown in green) demonstrate the concept of 'tunneling through the cost barrier'
The annual utility costs before the retrofi t were $11 million (~$4.00/sf/year). After the retrofi t is fully implemented, the anticipated annual energy costs will be around $6.6 million (~$2.50/sf/year).

By packaging measures that had positive individual net present value, the team created the "NPV (Net Present Value)Max" package. Similarly, the team created the "Max CO2" package by placing all the measures into one package that optimized CO2 savings. With these two packages, the team bounded the NPV extremes of the project. The team recognized that neither the "NPV Max" nor the "Max CO2" packages put forth the best solution for the client. This led to the creation of two more packages, the "NPV Neutral" and "NPV Mid" package, which provides a better balance between economics and CO2 savings.

Building ownership selected the NPV "Mid" package of measures as a solution to meet CO2 saving goals balanced with fi nance constraints.

Retrofits not only affect the building owners' net operating income but they also have an impact on tenants. Proposed green pre-built spaces (office spaces that are finished out by the owner and ready for tenants to move in) will save $0.70–0.90

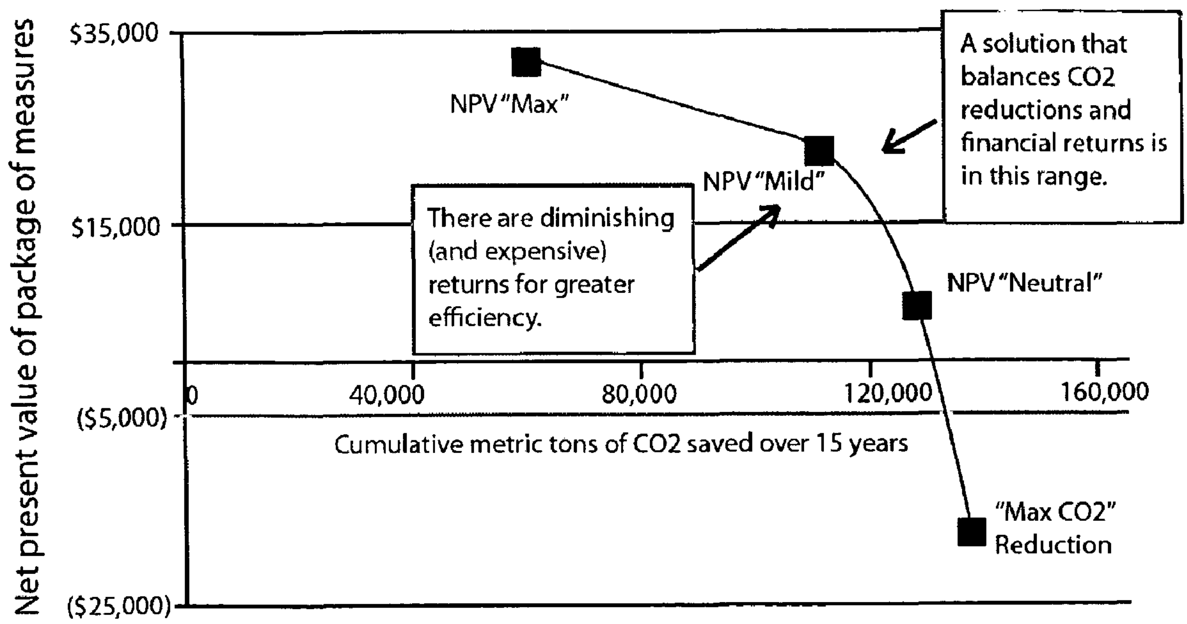


Figure 3.11- Cost and CO^2 reduction comperison

The 15-year Net Present Value of various bundles of energy efficiency measures. Individual energy efficiency measures (EEMs) were packaged together in bundles to determine their integrative effects on the overall energy use and carbon emissions.

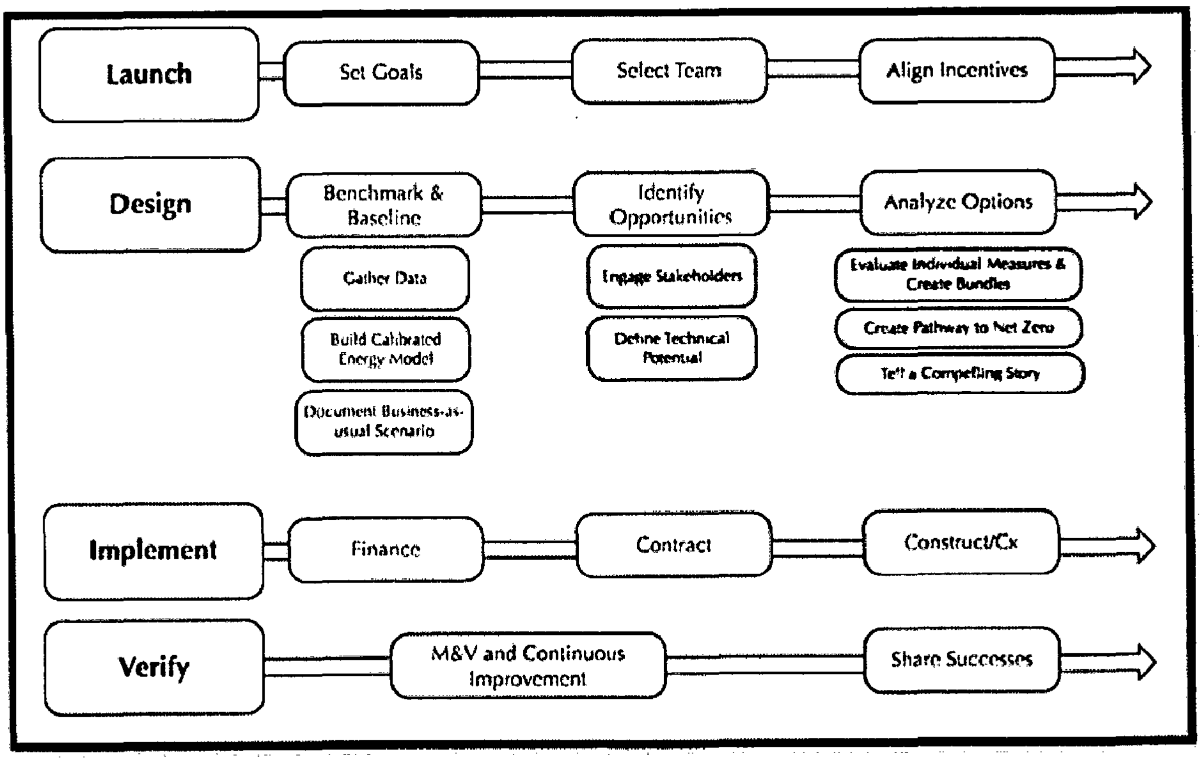


Figure 3.12- Retrofit Process diagram

The process followed in the Empire State Building retrofit. Orange boxes indicate steps that were particularly strong in this project and went above and beyond a typical retrofit process, which enabled significant energy savings.

3.5.4 Project Development Process

Typically, improvements to buildings are made on an ad hoc basis determined by sudden equipment failure or tenant complaints. Not surprisingly, greater energy savings occur when building owners plan for investment and deliberately incorporate energy efficiency. At the Empire State Building, the project team developed a long-term plan coordinated with planned equipment turnover to maximize energy savings with minimal additional investment.

3.5.4.1 Process Overview

The process for the Empire State Building retrofit roughly follows the main steps for a deep retrofit (shown in the diagram above). In this case study, we focus on two key steps— "Identify Opportunities" and "Analyze Options."

3.5.4.1.1 Identify Opportunities:

Engage Stakeholders

A key part of "Identifying Opportunities" is to engage with building tenants. To this end, the team identified three key programs to reduce tenant energy use: the tenant pre-built program; tenant design guidelines; and a tenant energy management program. The proposed green prebuilt design will save $0.70–0.90 per square foot in operating costs annually and the design reflects the tenant design guidelines.

Nearly 40 percent of tenant space will turnover between now and 2015, so aggressive guidelines are needed immediately. For the tenant energy management program, each tenant space will be sub-metered and a feedback/ reporting system will be put into place to inform tenants about their energy use. This program will also help tenants with their own carbon reporting efforts. The team designed a space on the 42nd floor (now complete) for the Empire State Building to use in marketing space to prospective tenants.

Key tenant space design features include a highly responsive HVAC system, an indirect layered lighting system (to provide individual control over ambient, task and accent lighting), new high-performance glazing that provides better thermal comfort, and local, high-recycled content construction materials.

Define Technical Potential

To define the technical potential, the design team collected and brainstormed a long list of ideas for individual energy efficiency measures from in-house experts, outside consultants, and core design team members. This exercise was called a Technical Potential Workshop.

Out of this workshop, the team generated more than 70 energy efficiency ideas to estimate the theoretical minimum amount of energy the building could save, which in this case was 68 percent. This represents the maximum potential opportunity based on today's technology alone, not limited by cost, time, materials or other impediments.

A key approach the team used in identifying opportunities for the technical potential was to leverage the concept of the "right steps in the right order." This approach helps to ensure the team considers all options to reduce the need for lighting, heating, and cooling before considering efficient equipment to meet these needs. Ultimately, the energy efficiency measures for the Empire State Building retrofit aligned with three key pieces that ensured the right steps happened in the right order:

Reduce Loads:

First, the team looked at design solutions that could reduce the thermal loads on the building, thus reducing the need for heating and cooling. The energy efficiency measures that contributed to heating and cooling load reduction strategies included the following:

1. Window Retrofit:

Windows were remanufactured on site to reduce the solar heat gain and conduction.

2. Radiant Barriers:

Radiant barriers were placed behind the perimeter heating units to direct more heat into the building rather than losing it through the wall to the outside.

3. Tenant Loads:

More efficient electric lighting was installed with controls that will help tenant spaces maximize daylight. Individual workstation energy use (plug loads) will be reduced through occupancy sensors and tenant education and feedback.

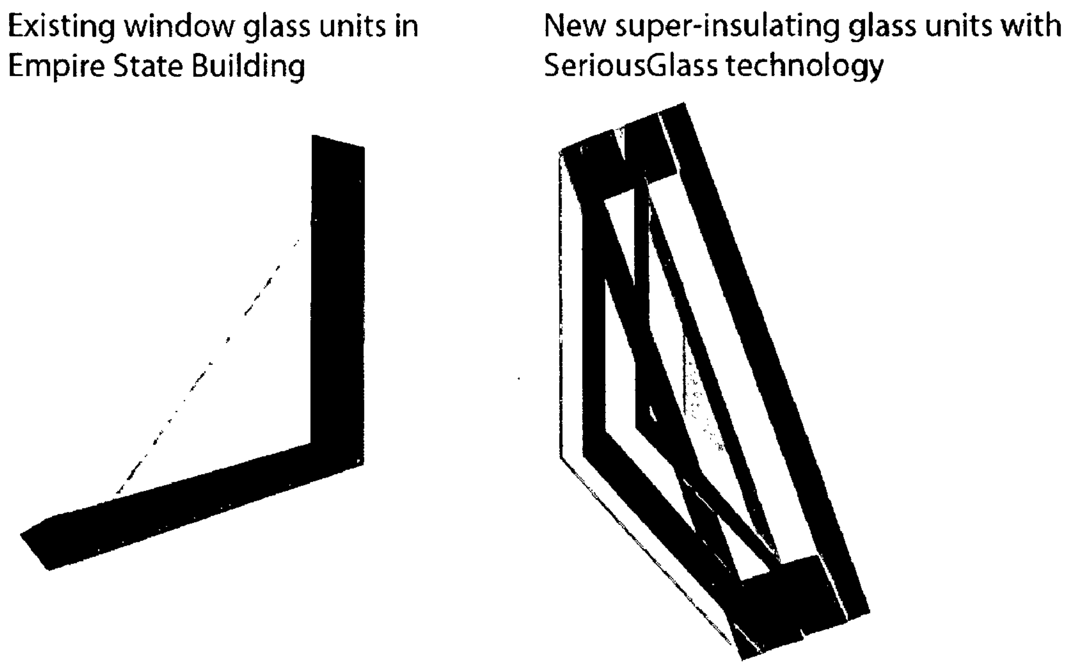


Figure 3.13- Super Insulated Windows by Serious Windows

(Courtesy of Serious Materials)

Figure 3.14- The temporary window refurbishing production line

(Courtesy of Serious Materials)

B. Install Efficient Systems:

To meet the reduced loads of the new spaces, heating and cooling systems were upgraded with the most efficient systems available.

1. Chiller Retrofit:

The team reused the shells of the existing industrial electric chillers and replaced the tubes, valvesand motors with high efficiency equipment.

2. Air Handling Units:

Variable air volume air handling units will replace less efficient constant volume air handlers. These provide greater control and occupant comfort while saving energy.

C. Ongoing Controlling and Monitoring Energy Systems:

1. Tenant Energy Management, Monitoring, and Submetering:

Tenants will receive real-time feedback regarding their energy use and will be able to benchmark their energy use against that of other tenants.

2. . Demand Control Ventilation:

Measuring CO2 concentrations inside the building will determine appropriate levels of outside air to be brought to the building. This will improve air quality while also reducing energy use (by not conditioning unnecessary amounts of outside air).

3. Direct Digital Controls (DDC):

Controls help to optimize HVAC system operation as well as to provide more granular sub-metering of energy use.

Energy, carbon and financial analysis

After identifying an expansive list of opportunities, the design team significantly narrowed the list of over 70+ efficiency measures to ~20 by using decision-making tools such as energy modelling and life cycle cost analysis. Examples of efficiency measures that didn't get implemented included interior wall insulation and building wide LED lighting (though LED lighting was implemented in the observatory).

The team then created bundles of measures to understand the interactive effects of measures on one another and to compare the cumulative energy savings and carbon emissions of various bundles of measures. Ultimately, the team settled on four different bundles that represented a range of investment and savings options to present to building ownership.

3.5.5 The implementation

A. Windows:

The 6,500 existing insulated glass units were remanufactured into super-windows onsite within a dedicated processing space at the Empire State Building. The double-hung windows have been dismantled and rebuilt to include a suspended coated film and gas fill. This more than triples the insulating value of each window. The total capital cost for this measure was $4.5 million and the annual energy savings is projected to be $410,000. Benefits include:

- Increased occupant comfort through warmer winter and cooler-summer glass surfaces
- Blocked winter heat loss three times better than the existing windows
- Greatly reduced heating and cooling HVAC loads
- 99+percent ultraviolet blockage to protect both furnishing and occupants
- Directional "tuning" to enhance north-window daylighting and south-elevation solar heat rejection
- Freedom from glass-surface condensation due to super insulation.

B. Radiative barrier:

More than 6,000 insulated reflective barriers were installed behind radiator units located on the perimeter of the building. Currently approximately half of the heat radiates into the usable space, while the other half helps to heat New York City. This barrier will reflect most of the heat back into the occupied space where it was intended to go. Radiators will also be cleaned and thermostats will be repositioned to the front side of the radiator for easier control. The total capital cost for this measure was $2.7 million and the annual energy savings is projected to be $190,000. Benefits include:

- Reduced heating costs
- Increased occupant comfort

C. Tenant daylighting/Lighting/Plug loads:

This measure involves reducing lighting power density in tenant spaces, installing dimmable ballasts and photosensors for perimeter spaces and providing occupants with a plug load occupancy sensor for their personal workstation. This will be implemented within the green pre-built spaces and will appear as recommendations within the tenant design guidelines. The total capital cost for this measure was $24.5 million and the annual energy savings is projected to be $941,000. Benefi ts of these measures include:

- Lower cooling demand due to less heat from electric lights and equipment
- Reduced utility costs for tenants
- Improved visual quality

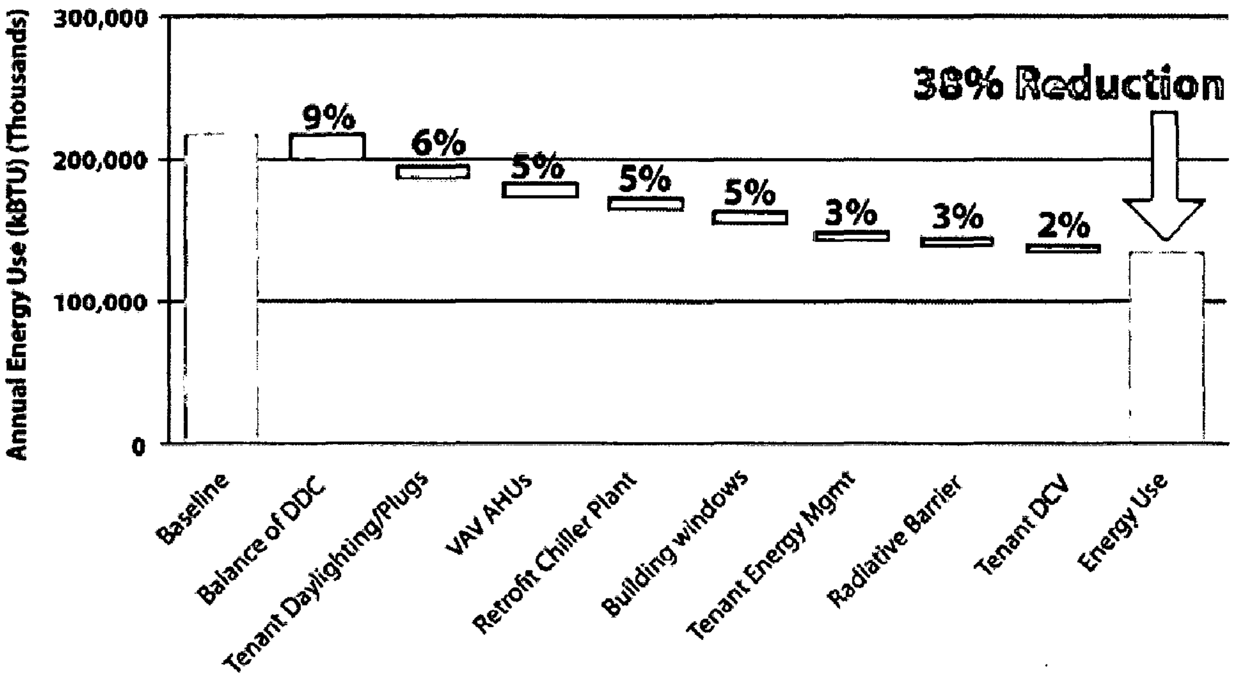


Figure 3.15- Energy and CO2 savings from the 8 key projects.

D. Chiller plant retrofit:

The chiller plant retrofit project includes the retrofit of four industrial electric chillers in addition to upgrades to controls, variable speed drives, and primary loop bypasses. The total capital cost for this measure was $5.1 million and the annual energy savings is projected to be $675,000.

E. VAV Air handling units:

When tenant turnover occurs, existing constant volume units will be replaced with variable air volume units using a new air handling layout (two floor-mounted units per floor instead of four ceiling-hung units). VAV air handlers are more intelligent than constant volume units providing greater control. The total capital cost for this measure was $47.2 million and the annual energy savings is projected to be $702,000. Benefits include:

- Greater occupant comfort and control
- Lower utility bills
- Reduced electricity demand

F. Direct digital controls upgrade:

The measure involves upgrading the existing, piecemeal and primarily pneumatic control systems at the Empire State Building to comprehensive, consistent digital controls. The total capital cost for this measure was $7.6 million and the annual energy savings is projected to be $741,000. This measure involves control upgrades for the following building systems:

- Refrigeration Plant Building Management System
- Condenser Water System Upgrades
- Chiller Water Air Handling
- DX Air Handling Units
- Exhaust Fans
- Stand Alone Chiller Monitoring
- Misc. Room Temperature Sensors
- Electrical Service Monitoring
- The benefits include:
- Providing greater flexibility
- More intelligence built into the systems
- Increased occupant comfort and control
- Lower utility bills

G. Demand control ventilation:

This project involves the installation of CO2 sensors for control of outside air introduction to the air handling units. Capital costs for this measure was included in the cost for the direct digital controls and the annual energy savings is projected to be $117,000. Benefits include:

- Reduced cooling and heating demand
- Monitoring of indoor air quality
- Increased occupant comfort
- Reduced energy bills

H. Tenant energy management:

This project will provide tenants with access to online energy and benchmarking information as well as sustainability tips and updates. Tenants will have access to a digital dashboard showing energy use in real time and comparing it to past use and other tenants. The total capital cost for this measure was $365,000 and the annual energy savings is projected to be $396,000. Benefi ts include:

- Live energy use feedback
- Comparison charts can encourage reduction of energy use

3.5.6 Tools

Extensive energy and financial modelling supported the financial case for the energy retrofit measures. The team ran energy analyses using DOE-2.2 (eQUEST interface), a building energy simulation tool that allows for the comparative analysis of building designs and technologies.

After climatic, building geometry, material properties, equipment schedules, and system components information have been input, the program computes building loads and outputs annual building energy use and cost.

Once the team generated preliminary energy savings estimates for individual measures, the team turned to a large custom-built excel financial model to determine how to create packages of measures that maximized greenhouse gas savings while providing sound economic benefits. Iterations between the energy and financial models helped the design team make final recommendations to Empire State Building ownership regarding specific short-term and long-term projects and programs they could implement.

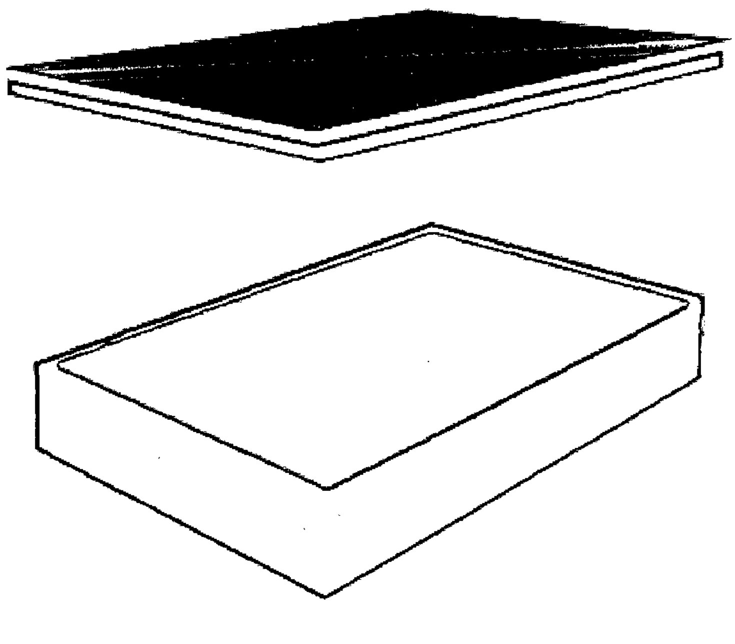


Figure 3.16- eQuest model of typical floorplate, as modeled.

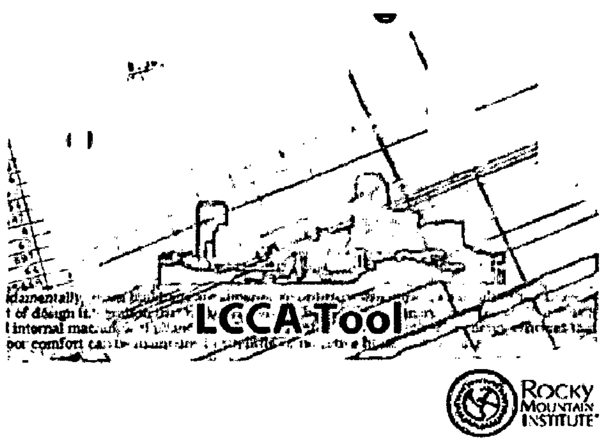


Figure 3.17- Cover page of LCCA tool developed by RMI.

3.5.6.1 eQuest: www.doe2.com/equest

An hourly energy simulation tool that uses weather and building data to predict energy use with various efficiency strategies.

3.5.6.2 LCCA Tool

This tool simplifies the interface between architects, engineers, energy modelers and cost estimators to make life cycle costing faster and more comprehensive so the right decisions can be made.

3.5.6.3 LEED: usgbc.org

An internationally recognized green building certification system provides third-party verification that a building or community was designed and built using strategies aimed at improving performance across all the metrics that matter most: energy savings, water efficiency, CO2 emissions reduction, improved indoor environmental quality, and stewardship of resources and sensitivity to their impacts. The Empire State Building is on track to receive LEED for Existing Buildings: Operations & Maintenance and some tenants are pursuing LEED for Commercial Interiors.

3.5.6.4 Energy Star: energystar.gov

An ENERGY STAR qualified facility meets strict energy performance standards set by EPA and uses less energy, is less expensive to operate, and causes fewer greenhouse gas emissions than its peers. Energy use in commercial buildings and manufacturing plants accounts for nearly half of all energy consumption in the U.S. at a cost of more than $200 billion per year, greater than any other sector of the economy. Commercial and industrial facilities are also responsible for nearly half of U.S. greenhouse gas emissions that contribute to global warming.

Empire State Building received an Energy Star score of 90 out of a possible 100. This places the pre-war building in the top 10 percent of all buildings for energy efficiency. It is possible the building will score higher once all of the retrofits have been completed in 2013.

Energy Use Operating Data

The Empire State Building retrofit is expected to be fully completed by 2013. Modelled data indicates an expected 38 percent energy use reduction over the pre-retrofit building. As tenants turn over and their spaces are remodelled under the new tenant guidelines, the remodels will account for a substantial portion of the savings.

3.5.7 Opportunities for Improvement

Given that few cost-effective deep retrofits have been completed in the U.S., the team learned numerous lessons over the course of the project. Some opportunities for others to consider as they embark on this process include:

3.5.7.1 Navigating multiple stakeholders:

Key stakeholders included building ownership, Jones Lange LaSalle (property management/ tenant engagements), Clinton Climate Foundation (convening body), Johnson Controls (engineering and execution, some measures were implanted under performance contracts), and Rocky Mountain Institute (energy efficiency consultant). Keeping the team aligned throughout the project was a challenge.

To overcome this common barrier, the design team purposefully worked very closely together communicating every day as well as via 'imbed' sessions where key team members would dedicate time to work together in the same room, wholly devoted to the project. This process enabled better team building and integration than typical 'distance-designed' projects. Also, multiple workshops conducted at key points (inception, at the conclusion of analysis, and prior to the final decision making point) included all five key stakeholders and allowed for robust discussion around key decisions. Documentation of the key decisions and outcomes was also helpful throughout the process, as it enabled all players to tell a consistent story.

3.5.7.2 Time:

The process took eight months from the inception, through goal setting, energy modelling, and presentation of recommendations to ownership. Beyond this work, the team spent additional time on detailed engineering and developing the performance contract documents. This process could have been shortened and streamlined if the team had more experience working together, had more dedicated staff and had a clearer vision of what outputs they were shooting for.

3.5.7.3 Tenant engagement:

As with any multi-tenant building, investments in energy efficiency measures can be confusing as the benefits often accrue to multiple parties. This challenge was overcome at ESB through the development of the pre-built spaces (where utilities are paid for by ESB) and through the tenant guidelines (where investments and savings are reaped by tenants).

3.5.7.4 • Financing:

The financing of this retrofit was simplified due to coordination with already large planned capital investments. Had this project not been coordinated, financing certainly would have been a challenge.

3.5.8 Other Benefits

The Empire State Building energy efficiency retrofit is just one component of a huge capital investment aimed at repositioning this iconic skyscraper as a Class A, state-of-the-art office building. The energy efficiency retrofit has created great public relations and is now serving as inspiration and a model for other multi-tenant, multi-story retrofits.

In addition to energy savings, the retrofit measures also improve indoor environmental quality for tenants by way of enhanced thermal comfort from better windows, radiative barriers and superior controls; they improve indoor air quality through tenant demand-controlled ventilation; and they create better lighting conditions that coordinate ambient and task lighting.

3.5.9 Lessons Learnt

The Empire State Building teaches that no matter how committed a company is to green design, Energy Efficiency cannot be accomplished without the assistance and guidance of others. Successful energy efficient design depends on the commitment of all the members of the team, including the architect, client, and contractor.

By incorporating integrated design from the beginning, the developer, client, and design team realized even greater long-term savings and benefits than initially projected.

The Empire State Building will be among the country's best buildings defined by environmental responsibility, construction, and operating costs, and as a healthy place to live and work.

Figure 3.18- Retrofitting of radiative heating system

3.6 ITC GRAND CENTRAL, MUMBAI

3.6.1 Project details:

Client - ITC Grand Central

Total Score: 560,000 Sq. Ft.

Location: Mumbai (India)

Architect : Hafeez Contractor

Hotel ITC Grand Central, the 30 storied super luxury hotel with 280 rooms and five specialty restaurants is a south Mumbai landmark.

ITC Hotels limited initiated action to reduce overall energy consumption in all ITC hotels to achieve reduction of CO2 emission & Energy Conservation from the present levels- Accordingly ITC Hotels have engaged M/s UVK Associates as energy consultant to submit project report for reduction of energy consumption and reduce CO2 emission- preliminary survey was conducted and they proposed huge energy saving potential from the present operating level by various replacement and retrofitting projects. Detailed descriptions for the all projects suggested have been comprehensively given in the report.

Few of the green features of ITC Grand Central are :-

- 22% energy savings
- 48% water savings
- Reflective heat paint and terrace garden
- 100% water reuse for landscaping, air-conditioning and flushing
- Integrated BMS and SCADA metering for optimized energy use
- Replacement of halogens with LEDs
- Organic waste converter to convert food waste to manure
- Green housekeeping and pest control

3.6.2 Project development process

The services provided by the energy consultant include :-

- Stormwater inspection and audit
- Waste stream audit
- Energy audit services
- Indoor air quality audit
- Water efficiency audit

- Acoustic quality audit
- Daylight effectiveness audit
- Hardscape management

3.6.3 The implementation

Following are the Energy Conservation Proposals given by U.V.K. Rao and Associates, after the Energy Audit was carried out by them. There are total six Energy Conservation Projects, which are as follows:

- Implementation of green roof and heat reflective paint on hard surfaces.
- Replacement and re-engineering of the chiller plant and auxiliary system
- Re-engineering and retrofit of HVAC system to reduce overall thermal load.
- Water & waste system improvements for energy load reduction
- Replacement and retrofitting in Electrical & Lighting
- Revamping Laundry with energy efficient Machinery and utilities
- Reengineering and retrofit of boiler and steam system to reduce overall thermal load.

3.6.3.1 Retrofitting the Chiller plant (Project A).

Previous System

Three Trane Screw chillers each of 350 TR capacity are installed in the hotel for catering to the entire air conditioning load for which 3 primary chilled water pumps of 11 kW each are installed for positive circulation of water in chiller and 4 pairs of chilled water pumps are installed for circulating chilled water to AHUs, TFAs & FCUs. Each pair is dedicated for each of the 4 zones segregated on the basis of usage as per details below:

Zone A : Guest Rooms (10-20th Floor)

Zone A1 : Guest Rooms (21-28th Floor)

Zone B : Lobby Lounge, Mezz. Floor, kitchen spot cooling coffee shop

Zone C : Ground floor, main kitchen.

Also, 3 condenser water pumps, one for each chiller, are installed.

- One chiller is operated for continuous requirement and second chiller is operated during peak load requirements (including summer) and one primary pump is operated for each chiller operation and each secondary zone is connected with one pair of pump (working + standby) and one pump per zone is operated continuously for which VFDs are installed.

- Average present plant load is around 500 TR. Specific power consumption of screw chiller is around 0.72 kW/TR at 44oF chilled water outlet set point at full load and increases up to 1.0 kW/TR during part load. Presently chilled water set point out let temperature is maintained at 44oF for most of the year and is varied manually by engineering staff depending upon lower ambient conditions.

- Primary pump is operated on constant speed to circulate fixed flow of water across chiller irrespective of load and cooling load in chilled water system increases with higher circulation of water.

- Variable Frequency Drives (VFDs) are installed for all secondary chilled water pumps.

- Presently the cooling water flow in condenser remains constant irrespective of tonnage of load. The condenser pumps take a load of 40-46 amps (22.8 – 26.5 kW).

Proposal

- While procuring the chiller, a new pump is also to be procured that would precisely match the known head and flow of the primary chilled water pump as well as enhanced efficiency levels.

- Install remote microprocessor based control in the BMS room and operate chillers with set point of 10oC as a standard operating practice.

- Increase set point to 11oC during favorable ambient conditions and nights (12 PM to 6 AM).

- Reduce set point to 8oC during high humid period (Rainy season) and peak summer.

- The COP of refrigeration system increases and compression work decreases as the evaporator temperature is raised.

- Operating chillers at higher set point reduces specific power (kW/TR) consumption besides reduction in thermal loss.

- Install on line data logger to monitor specific power consumption of chillers.

- Install 350 TR screw chiller with waste heat recovery VFD along with heat recovery system.

- Total specific power consumption of proposed screw compressor with suitable pumps is less than 0.75 kW /TR (including Condenser pump& cooling tower fan).

- Also hot water at 40-45oC can be supplied from the system for the required applications.

- There will substantial reduction in pumping power as the new chiller requires lower water circulation (Condenser and evaporator).

- Besides power saving demand (kVA) also will reduce drastically.

- Operate existing 350 TR chiller only during peak load requirements.
- Replace existing primary pump with energy efficient pump matching system head and flow.
- New pump may be selected with mechanical seal and energy efficient Motor.
- The VFDs will measure load on chiller by measuring differential temperature and vary the pump flow (frequency and speed) accordingly.Hence the pump flow will be altered to match the actual system requirement.
- This will reduce wastage of pumping power.
- However care should be taken to maintain minimum water flow across evaporator irrespective of reduced load conditions.
- Procure new condenser pumps and matching VFD.
- New pumps will have specs of 1050 gpm (380 m_3/hr) and 62 ft head (19 m), 35 hp.
- Expected average power consumption with VFD & new pump will be 18 – 19 kW (savings 10 – 15% on existing power) giving a savings of 4-5 kW/pump.

3.6.3.2Retrofit of HVAC system to reduce load (Project B).

Previous System

At Grand Central, outside air is drawn into a TFA unit, cooled, dehumidified and saturated air (100 % RH) at 18oC is supplied to guest rooms and corridors in each floor in. The purpose of TFA is to ensure that outside air does not impose additional load on fan coil units which are not designed for such duties Even though air is cooled to 18oC in separate TFAs, this air supplied to guest rooms is not adequately dehumidified

- Fan coil units (FCUs) are installed in all guest rooms for air conditioning.
- All FCUs are operated at maximum speed during non-occupancy period. There is no appreciable thermal load in the guest rooms during non-occupancy period and hence high-speed operation during such periods adds avoidable electrical load and thus thermal load to the air-conditioning system.
- Two 500 TR induced draft cooling towers are installed for condenser water cooling. Two cooling towers are operated continuously.
- The condenser heat load varies with chiller load.
- Also ambient temperature plays vital role in cooling tower load.
- Presently the total power consumption for all cooling tower fans is around 22 kW.

Proposal

Pre-cool before the air enters the cooling coil and reheat after the air leaves the cooling coil by installing Heat Pipes. The recommended Heat Pipe for TFAs needs to be "U-framed" as a single equipment, enveloping the cooling coil, with a pre-cool section on up-stream side and a re-heat section on down-stream side. Pre-cool section cools incoming ambient air by about 10oC. Due to this, the cooling coil is able to de-humidify FROM A LOWER temperature than it was doing before and thus saving chiller power .In re-heat section, saturated, overcooled air coming out of cooling coil is heated up by about 10oC, thus maintaining less than ASHRAE recommended of not more than 70% RH for air leaving the cooling coil. Overcooling and reheating is achieved this way without any additional running cost

- Install electronic speed varying controls in the room to change over FCU to lowest speed whenever guest room key card is removed (when unoccupied). This will reduce electrical and thermal load to the air conditioning system.
- Install enthalpy based cooling tower (CT)control and operate CT fans based on actual condenser load and ambient conditions.
- Cooling tower outlet water temperature will be measured and fan speed will be controlled accordingly. Ambient temperature also will be measured to obtain best system efficiency.

3.6.3.3 Water & Waste system retrofit (Project C).

3.6.3.4 Retrofitting in Electrical & Lighting (Project D).

Previous System

- Operating voltage in rising mains circuit is above 230 V i.e. 230 to 250 Volts.
- Lamps & lighting luminaries are designed to operate between 180 - 230 V.
- Operating lighting system at higher voltage leads to excess energy consumption, in addition to reduced life of lamps and accessories.
- Widely, twin tube light fittings with T8 lamps are catering the requirement in plant room, car parking, kitchen, back of offices, etc.
- 40 W tubes, 36 W slim tubes and 36 W energy efficient lamps (such as Trulite of Philips make) are in service.
- Electronic chokes are also in service in fittings.
- Auto power factor control panels are installed in both Transformers.
- 7 W CFL lamps are installed in guest rooms as night lamps.
- Existing motors are standard motors.
- Motor capacity range (typical) : 1 kW to 20 kW.

Proposal

- Operate lighting circuit in 200–210 V range by use of Energy Saver in lighting circuit that helps in power saving by reducing applied voltage without a proportionate reduction in illumination level.

- In general practice, the three-phase voltage is maintained at 415 Volts as per requirement which means the voltage across phase and neutral will be 239 Volts. This is far above the rated voltage of lamps. Lot of energy is wasted, as the corresponding benefit in terms of illumination is not obtained. Life of the lamps also gets reduced.

- Energy savings are possible by optimizing the voltage applied to the lamps to 200 to 210 Volts.

- Savings in excess of 20% is common with Energy Savers on a sustained basis and trials and installations amongst ITC hotels have confirmed the same.

- Such type of energy savers supplied by M/s. Servomax India Ltd., Hyderabad is already in service in Plant Room, Dakshin Kitchen Lighting Circuits and working satisfactorily in ITC Kakatiya, Hyderabad.

- Replace conventional FTL with energy efficient T5 – OSRAM make – PICOSTAR-R ; FH 28 W Combi.

- The consumption of T5 fitting is 28 W & these are direct matching with the existing fixtures.

- Electronic ballast of T5 consumes power of 2 W and operates at PF of above 0.95.

- This improved PF helps in reduction of current and hence losses in the lighting circuits.

- T5 lamps give more Illumination i.e. around 100 lm/watt, compared to 65 lm/watt of T8. i.e. 50 % more illumination with 25 % lesser power consumption.

- This can be applicable in B1 & B2 car parking areas and back of offices. Illumination in car parking is in the range of 30 to 120 Lux. This is much on the higher side and illumination in the range of around 50 lux is sufficient.

- In this case, using of one FTL of T5 in place of twin T8 FTLs will reduce the energy consumption further to the tune of 40 % without suffering the minimum Illumination requirement.

- Osram make T5 fittings are installed in Marriott Welcom Hotel, New Delhi in car parking, back offices, etc. and these are working satisfactorily.

- These are applicable in all locations leaving a few tasks specific locations such as offices, stores, control rooms, etc.

- It is recommended to connect capacitor to certain identified feeders.

- This helps in correcting the PF in the respective circuits.

- Reduce the maximum demand proportionately; Reduce the line losses.
- Saving of energy through reduced losses.
- Replace 7 W CFL with LED based night lamp. LED night lamps consumes 1 W power and life is more than 50,000 working hours.
- Replace select motors with energy efficient 1 (eff1) motors.
- This is a proven energy saving proposal and must be encouraged even if the payback is higher since it gives perennial saving beyond the payback period
- New motors are also with same frame size and suit same foundation.

3.6.3.5 Revamping with energy efficient machinery (Project E).

3.6.3.6 Retrofit of Boiler & Steam System (Project F).

3.6.4 Total savings

Table 3.5- Estimated cost savings in ITC Grand Central

Project	Cost Saving per Year (Lacs)	Energy saved per year (KWH)	Capital Cost (Rs. Lacs)	Life of Equipment
Project (A)	38,00,000	2,55,000.00	78,00,000.00	
Project (B)	20,00,000.00	4,83,000.00	49,00,000.00	
Project (C)	1,74,000.00	42,000.00	6,00,000.00	
Project (D)	27,00,000.00	3,24,000.00	64,00,000.00	
Project (E)	3,25,000.00		5,10,000.00	
Project (F)	80,000.00		3,00,000.00	

3.7 INFERENCES

Interest of stakeholders

Almost all the case studies discussed above shows that there is a great interest of the owner or the user. If interest is there, retrofitting is not at all a great problem.

Teamwork

Success of retrofitting lies entirely on teamwork. Team members are the client himself, project manager, Consultant and financer. Their synchronization usually results in great success.

Social Benefits

Economic Benefits

Environmental Benefits

Design Phases

A streamlined design programme is very essential for retrofitting an old building. A more or less generalised strategies and hierarchy of workflow has been followed in all projects. Though the steps can be modified as each and every case is different but there must be a predetermined phasing of work. They can be subdivided as following.

Generation of energy

- Photovoltaic panels.
- Wind turbines

Reduction in consumption

The building Surrounding

- Surface transformation
- Urban Heat island.

The building envelope

- Natural light and ventilation
- Insulation

The building interior, equipment and fixtures

- Efficient equipment
- Direct digital control
- Separate the heat generating and non-conditioned space from conditional space.
- Passive strategies(earth air tunnel)

3.8 CASE STUDY MATRIX

Table 3.6- Case Study Matrix

CASE STUDY MATRIX		COMMERCIAL		EDUCATIONAL		RESIDENTIAL		INSTITUTIONAL	
		Helmus Building	Empire State building	Zeeland West High School	Forest Hills Eastern High School	Green Built Demonstration Home	IHM Motherhouse	Ann Arbor District Library	William J. Clinton Presidential Center
Key Topics	Brownfield Redevelopment								*
	Materials Use	*	*		*	*	*	*	*
	Energy Efficiency	*	*	*	*	*	*	*	*
	Social Benefits	*	*		*		*	*	
	Development Processes		*		*	*	*	*	*
	Cost-Benefit Analysis		*		*	*			
	Funding Sources		*	*				*	
Benefits of Retrofit Development	Reduced Capital Costs	*		*	*				*
	Lower Operating Costs	*	*	*	*	*	*	*	*
	Reduced Risks & Liabilities		*			*			
	Less Environmental Impact	*	*	*	*	*	*	*	*
	Healthier Indoor Environment and Improved Productivity	*	*		*	*	*	*	*
	Stronger Social Networks	*			*		*	*	
	Increased Environmental Awareness				*		*	*	*
Costs	Under $1 million					*			
	$1 million - $10 million	*						*	
	$10 million - $50 million			*	*				
	Over $50 million		*				*		

4 LECTURE HALL COMPLEX, IIT ROORKEE- THE BASE CASE

This chapter will discuss about the present situation of the case taken for study which is the newly built lecture hall complex of IIT Roorkee.

The simulation model will be made in the virtual environment to find out the energy performance index an at last it will focus on the possible opportunities of improvement of the energy efficiency of the building.

4.1 SELECTION OF BASE CASE

Retrofitting is only done to those buildings which have the potential to serve many years in the future and use much amount of energy due to wrong design. The lecture hall complex at IIT Roorkee has been newly built and uses lot more energy than any conventional building. The orientation of the building is also wrong. So this building has the potential to be retrofitted to reduce the energy demand of it. So this building has been adopted to implement the retrofitting strategies and calculate the energy savings by simulating the situation in virtual environment with the help of simulation software.

4.2 TOOLS AND TECHNIQUES

4.2.1 Instruments

These instruments are basically used to collect some data from the site which are used as input parameters when simulating the model in Ecotect.

4.2.1.1 Anemometer

An anemometer is a device for measuring wind speed, and is a common weather station instrument. Anemometers can be divided into two classes: those that measure the wind's speed, and those that measure the wind's pressure; but as there is a close connection between the pressure and the speed, an anemometer designed for one will give information about both.

4.2.1.2 Thermohygrometer

Thermohygrometer measures the relative air humidity and indoor temperature. A memory feature allows to check the minimum and maximum temperature and humidity readings across any period of time, by simply pressing the "MAX/MIN" button and it will display the minimum and maximum readings since the thermohygrometer was last reset.

The temperature can be displayed in °C and °F which can be easily changed by the flick of a switch on the front of the unit.

It has two receiving antenna. One for the humidity measurement and other for the measurement of temperature which are connected to the instrument body directly by wire connections.

This measurement device usually relies on measurements of some other quantity such as mass or a mechanical or electrical change in the sensor as moisture is absorbed. From calculations based on physical principles these measured quantities leads to a measurement of humidity which is displayed in the screen.

4.2.1.3 Lux meter

A lux meter is a device for measuring brightness. It specifically measures the intensity with which the brightness appears to the human eye. This is different than measurements of the actual light energy produced by or reflected from an object or light source.

The lux is a unit of measurement of brightness, or more accurately, illuminance. A lux meter works by using a photo cell to capture light. The meter then converts this light to an electrical current. Measuring this current allows the device to calculate the lux value of the light it captured.

4.2.1.4 Infrared thermometer

This instrument is used to measure the surface temperature of various surfaces with different material in and around the building. This gives a clear idea of heat absorption potential of various materials.

4.2.2 Building Information Modeling and Simulation Software

Building energy simulation is the science of estimating the energy interactions within a building. These interactions include the direct purchase of energy. Such as electricity for lighting or natural gas for heating, but also the exchange of energy due to such things as the infiltration of air a building or the heat generated by a building's occupants. Simulation attempts to account for these factors, plus many more, in determining the heating. cooling and ventilation loads within a building, the equipment types and sizes needed to meet these load, and the cost to operate this equipment plus other non-HVAC (heating, ventilating and air-conditioning) equipment.

"Simulation is the process of developing a simplified model of a complex system and using the model to analyze and predict the behaviour of the original system. Why simulate? The key reasons are that real-life systems are often difficult or impossible to analyse in all their complexity, and it is usually unnecessary to do so anyway. By carefully extracting from the real system the elements relevant to the stated requirements and ignoring the relatively insignificant ones (which is not as easy as it sounds), its is generally possible to develop a model than can be used to predict the behaviour of the real system accurately". Aburdene, M.F. Computer Simulation of Dynamic System.

Building energy simulation is used as a tool in the design of building for determining compliance to building standards and for the economic optimization of building components. It can be used on building of any size, from one zone residential houses to multi-zone commercial building, or any occupancy, such as schools, offices, hospitals, supermarkets, etc.

4.2.2.1 Building Information Modeling (BIM) Software

Revit Architecture

Autodesk Revit Architecture often referred to as simply Revit is a Building Information Modeling software developed by Autodesk. It allows the user to design with both parametric 3D modeling and 2D drafting elements. Building Information Modeling is a Computer Aided Design (CAD) paradigm that employs intelligent 3D objects to represent real physical building components such as walls and doors.

Revit uses .RVT files for storing BIM models. Typically, a building is made using 3D objects to create walls, floors, roofs, structure, windows, doors and other objects as needed. These parametric objects — 3D building objects (such as windows or doors) or 2D drafting objects (such as surface patterns) — are called "families" and are saved in .RFA files, and imported into the RVT database as needed.

A Revit model is a single database file represented in the various ways which are useful for design work. Such representations can be plans, sections, elevations, legends, and schedules. Because changes to each representation of the database model are made to one central model, changes made in one representation of the model (for example a plan) are propagated to other representations of the model (for example elevations). Thus, Revit drawings and schedules are always fully coordinated in terms of the building objects shown in drawings.

Here, Revit is used to model the existing building and applying the changes in the proposed case in virtual environment. The main reason of using revit as modeling tool is its precision of modeling which is very essential to perform a good realistic analysis. Then the models are exported to Ecotect analysis as GBXML file format to simulate the cases and doing the analysis.

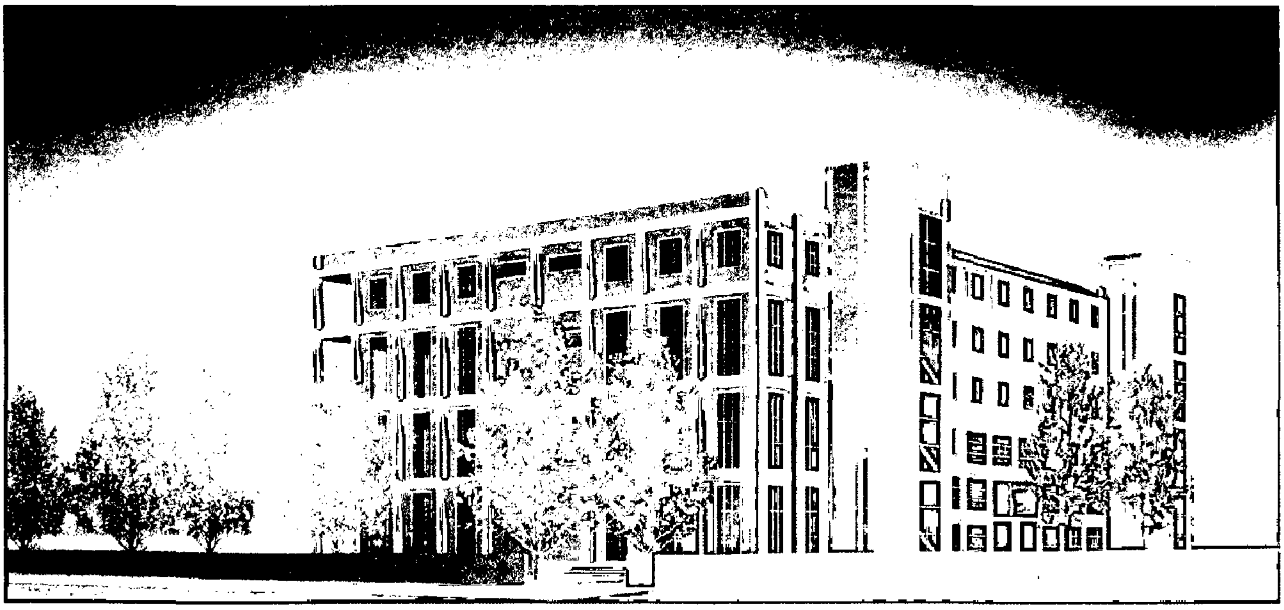


Figure 4.1- Model generated in Revit Architecture

4.2.2.2 Simulation Software

A number of Building Energy Simulation Software like, RADIANCE, DAYSIM, DIAUX, equest, IES Environment, Autodesk ECOTECT, etc, are available in the market, The list of such simulation software would be endless. The salient features of some of these simulation softwares are listed below:

4.2.2.2.1 Radiance

RADIANCE is freeware software used for calculation the interior lighting both due to artificial lighting as well as daylighting.

4.2.2.2.2 DAYSIM

It is software similar to RADIANCE, It is used for analyzing the interior lighting.

4.2.2.2.3 DIALux

Dialux is an advanced yet easy to use lighting analysis package available free. One of the major features is the ability of DIALux to use the catalogues of different from luminaire manufacturers.

4.2.2.2.4 eQuest

eQUEST is a easy to use, freeware building energy use analysis tool that provides professional-level results with an affordable level of effort.

4.2.2.2.5 IES Virtual Environment:-

Integrated Environmental Solution (IES) is building simulation software, but is not available free.

4.2.2.2.6 Ecotect Analysis

4.2.2.2.7 Visual DOE

Visual DOE is a Windows application that enables architects, engineers, energy analysts and utility personnel to quickly evaluate the energy savings of building design options. The program covers all major building components, including building envelope, lighting, daylighting, water heating, HVAC and central plant. Visual DOE uses the DOE-2.1 E hourly simulation tool as the calculation engine so that energy use and peak demand are accurately evaluated on an hourly basis for a specific period of time

In all the above mentioned softwares except IES Virtual Environmental, one of the major disadvantage is that of making a comprehensive model of the situation. But in addition to energy analysis, ECOTECT has an intuitive modeling tool.

Features of ECOTECT as a design simulation tool:

1. It is easy to use.
2. Large range of material library having almost all building materials.
3. Handy with the application of any material.

4. The rage of analysis performed by ECOTECT is very large.

Hence ECOTECT has been chosen as the analysis tool for the analysis.

4.2.2.3 Ecotect Analysis

Autodesk ECOTECT is an environmental analysis tool that allows designers to simulate building performance right from the earliest stages of conceptual design. It combines a wide array of detailed analysis functions with a highly visual and interactive display that presents analytical results directly within the context of the building model, enabling it to communicate complex concepts and extensive datasets in surprisingly intuitive and effective ways. ECOTECT is a conceptual design analysis tool that features overshadowing, shading design, lighting, acoustic and wind analysis functions as well as thermal.

ECOTECT was acquired by Autodesk in June 2008 adds to an already formidable array of analytical and sustainable design tools that augment the Revit BIM environment. ECOTECT is quite different from other analysis tools in that it specifically targets the earliest stages of design, a time when simple decisions can have farreaching effects on not just energy but almost every aspect of the performance of the final project.

4.2.2.3.1 Modeling

ECOTECT is a complete modeling environment. Feasibly, any model can be constructed within the ECOTECT environment using its own internal drawing commands, extrusions and other modeling features. Each part of a building modeled in ECOTECT is termed as an element. The element type assigned to any building part can be changed. The element types used vary from walls, floors, ceilings, windows, doors, panels, voids, appliances, lights and speakers.

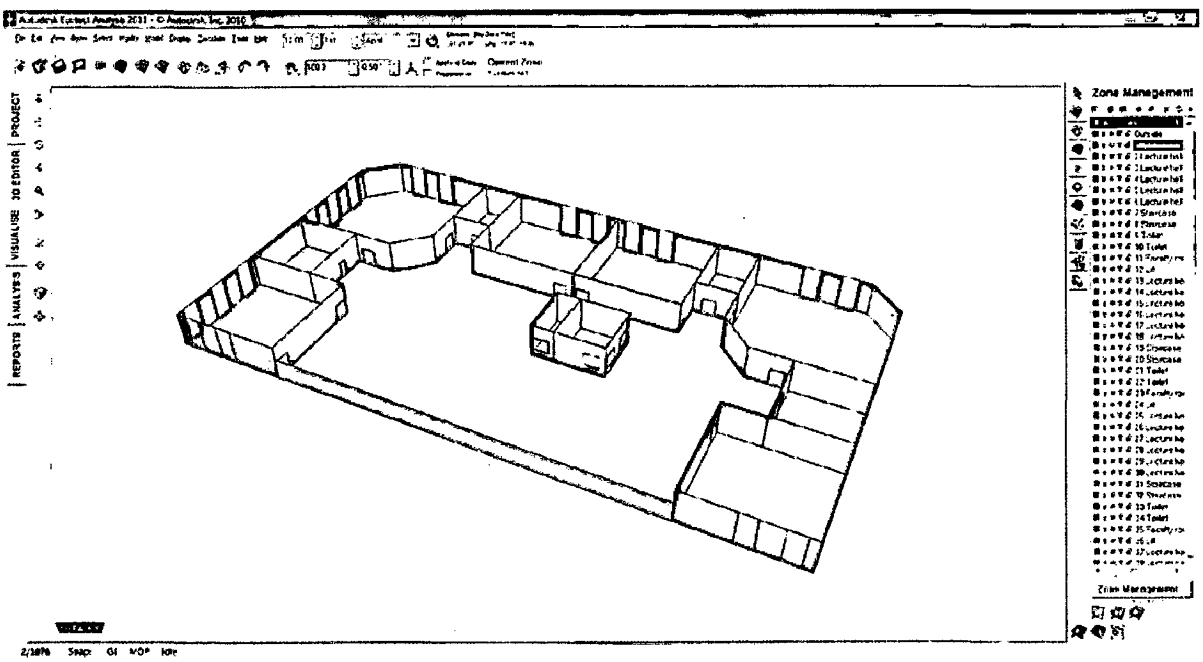


Figure 4.2- Ecotect simulation model of LHC

It should also be noted that, less number of elements in a model decreases the analysis time. So it is always recommended that whenever any model is designed in ECOTECT, the number of elements should be kept to a minimum.

4.2.2.3.2 Zones

Zones in ECOTECT are roughly equivalent to layers in AutoCAD. However, in addition to the normal use of layers to group related objects in a model, a zone in ECOTECT can also be taken to mean a room within a building – more specifically a single enclosed homogeneous volume of air. If a model is being built solely for shadow and lighting analysis, or for export to another analysis application, then its zones really don't need to define enclosed spaces. These zones are referred to as Thermal Zones and are very important concept in ECOTECT when performing thermal analysis.

A Thermal Zone is assumed to be an enclosed space within the building. As such it must be completely enclosed with planar objects forming its floors, walls, ceilings or roofs. There is no restriction on the number of different types of surface, as long as its is completely enclosed on all sides with sufficient geometry to allow its volume to be calculated.

Whilst a model can contain any number of zones, its will always contain an Outside zone. This is automatically created within the model and cannot be removed or renamed. This zone should be used to store external objects such as fences, trees and site boundaries.

4.2.2.3.3 Materials

All objects in the ECOTECT model can be assigned two different materials, referred to as their Primary and Alternate materials. When an object is initially created its material depends on the element type of the object. For objects such as wall, roofs, floors, and ceilings the alternate material is used whenever the object overlaps another belonging to the external surface of another zone. For windows, doors, panels, voids, appliances, lights and speakers the alternate material is used only when the objects is activated. The Primary Material this specifies the material the element is constructed of.

4.2.2.3.4 Schedules and Operational Profiles

It allows one to create operational and cost schedules for application to elements of your model. A schedule consists of a list of 365 days to which hourly profiles are assigned. There can be up to 12 different daily profiles for each schedule, each represented by a different colour when assigned in the day list. Each profile consists of 24 percentage values. Full object scheduling allows definition of all types of elements as on or off, open or closed etc. The resulting thermal analysis using scheduling, takes into account how spaces are used, as well as the use of appliances and equipment within a space.

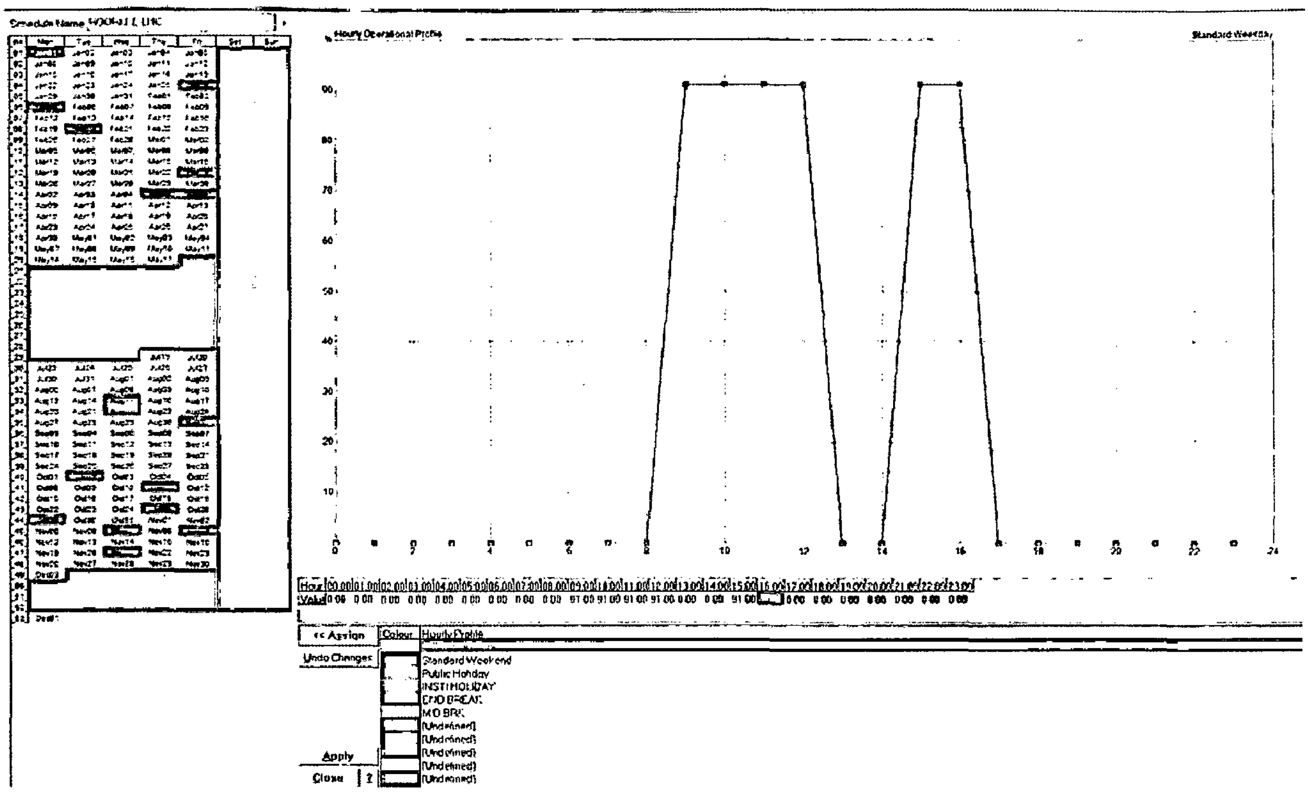


Figure 4.3- Daily operational schedule for simulation

4.2.2.3.5 Analysis

For most of the analysis done in ECOTECT, first of all a analysis grid need to be set up first. Ecotect has the following analysis option.

1. Lighting Analysis
2. Insolation level analysis
3. Thermal Analysis
4. Material Cost analysis
5. Resource Consumption
6. Acoustical Analysis

Of the above mentioned analysis, a few will be discussed here.

Thermal Analysis

Any building for thermal analysis must be formed from one or more fully enclosed thermal zones, with each such zone representing a room or precinct within the building. Being fully enclosed, the walls of adjacent thermal zones should be complainer (or at least very close and parallel) and overlap each other. The thermal Analysis dialog performs the following analysis:

Internal Temperature: Internal hourly temperatures can be shown for any day of the year. Graphs include external temperatures, radiation and wind effects, allowing a full appreciation of the thermal response of any zone.

Temperature Distribution: Statistical analysis is used to provide information on the passive performance of a building. This includes clearly highlighting fabric gains, mass effect and insulation requirements without extensive trial and error.

Heating and Cooling load: Monthly space loads can be calculated using real climate data. With full consideration of direct/indirect solar gains, accurate overshadowing, internal gains, inter-zonal hear flow and comprehensive operational schedules, ECOTECH can calculate the demand on any HVAC systems.

Load Distribution: Heat load distribution graphs are quire different from temperature distribution as they show both the hour and date at which maximum and minimum loads occur. This is especially usefull when looking at the effects of thermal mass in as building.

Heat Gains and Losses

ECOTECT gives detailed analysis of the direct, indirect, fabric heat gain/loss for any model. It also gives the passive heat gain/loss analysis for any duration within a year.

Resource Consumption

Appliances and material within a model can both consume and produce resources based on their operation. ECOTECT can product graphs of cumulative resource usage over the entire year, to compare, to compare, Energy consumption for HVAC, lighting equipments or water consumption and rainfall catchment.

The models generated in revit are analysed with the help of Ecotect and the results are listed in the next part.

4.3 SIMULATION AND ANALYSIS OF BASE CASE.

4.3.1 Assumptions of Simulation

The following assumptions has been made during the analysis of the models developed in ecotect for calculating their performance.

1. The whole analysis has been carried out for the entire building, not for any typical part.
2. All other spaces except the lecture halls are considered as non conditioned space.
3. All spaces except the outside has been considered as thermal zones which means they take active role in thermal exchange during the simulation.
4. The acrylic top of the atrium has been modeled with a U value of 6.
5. The coffer slabs has been replaced with an equivalent flat section for making the simulation less time consuming.
6. The structure has been considered in isolation with no buildings nearby.
7. The non conditioned zones in each model has been assumed to transfer thermal energy to the conditioned space.
8. All windows in the base case has been assumed 90% transparent

4.3.2 Site Details

Location-

The Rooekee city is located at 29.87°N 77.88°E.It is 172 km north of Indian Capital New Delhi and located close to the foothills of the Himalaya.

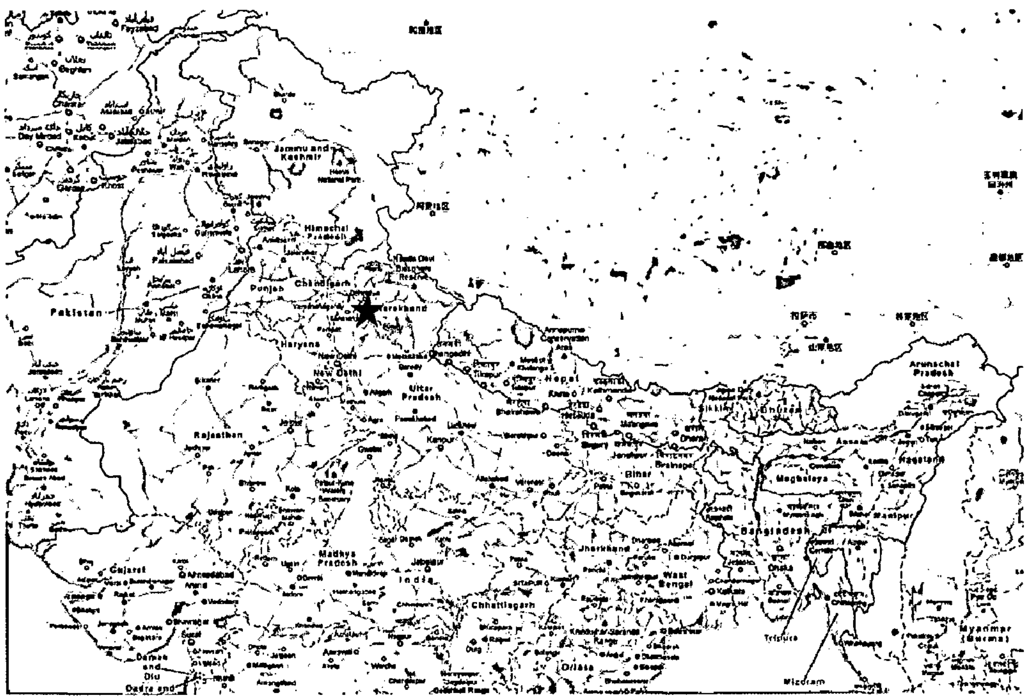


Figure 4.4- Location of Roorkee in India

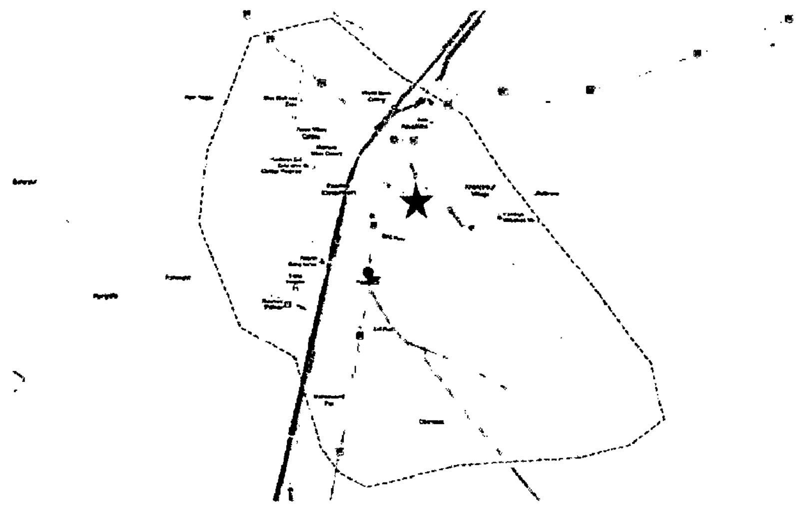


Figure 4.5- Location of IIT in Roorkee town

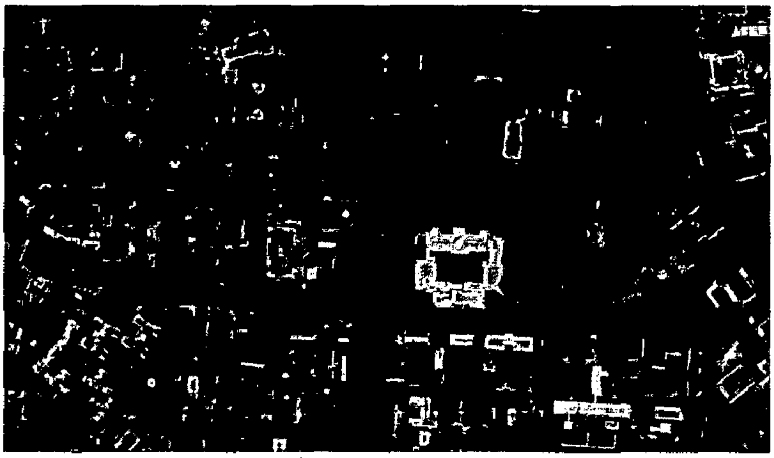


Figure 4.6- Location of Lecture Hall Complex in IIT Roorkee

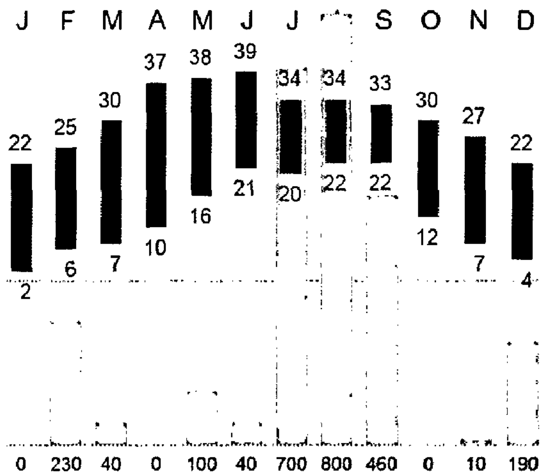
Construction year- 2010

Architect- NBCC limited

Number of floors- 4 (Four)

4.3.2.1 Climate

The climate of Roorkee is typical of north-western India, with very hot summers and very cold winters. In terms of precipitation, Roorkee is semi-arid. The south-west monsoon generally breaks in mid-June and the North-East during November-December. Winters begin from late September and continue through February. The coldest months are generally December and January, when the minimum temperature approaches zero. A rise in temperature is experienced from the beginning of March, which heralds the onset of summer. The day temperature is around 40 C and warm winds blow frequently.



Average max. and min. temperatures in °C

Precipitation totals in mm

Source: GAIA case studies

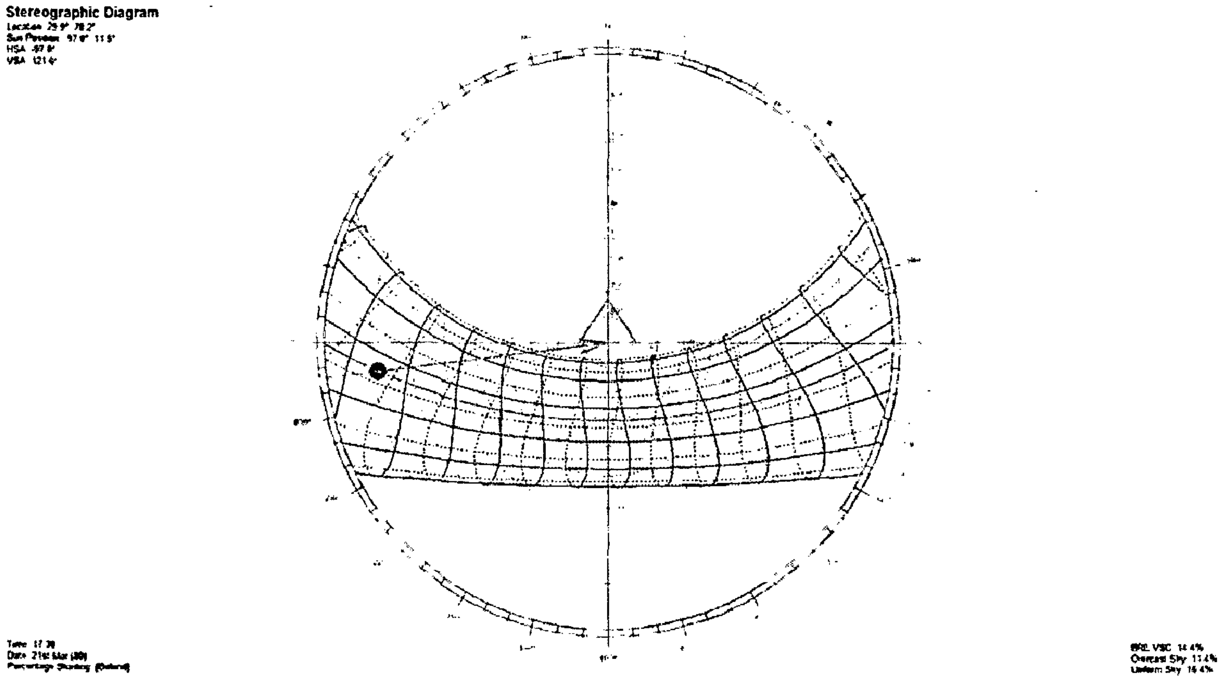


Figure 4.7- Sunpath diagram for Roorkee

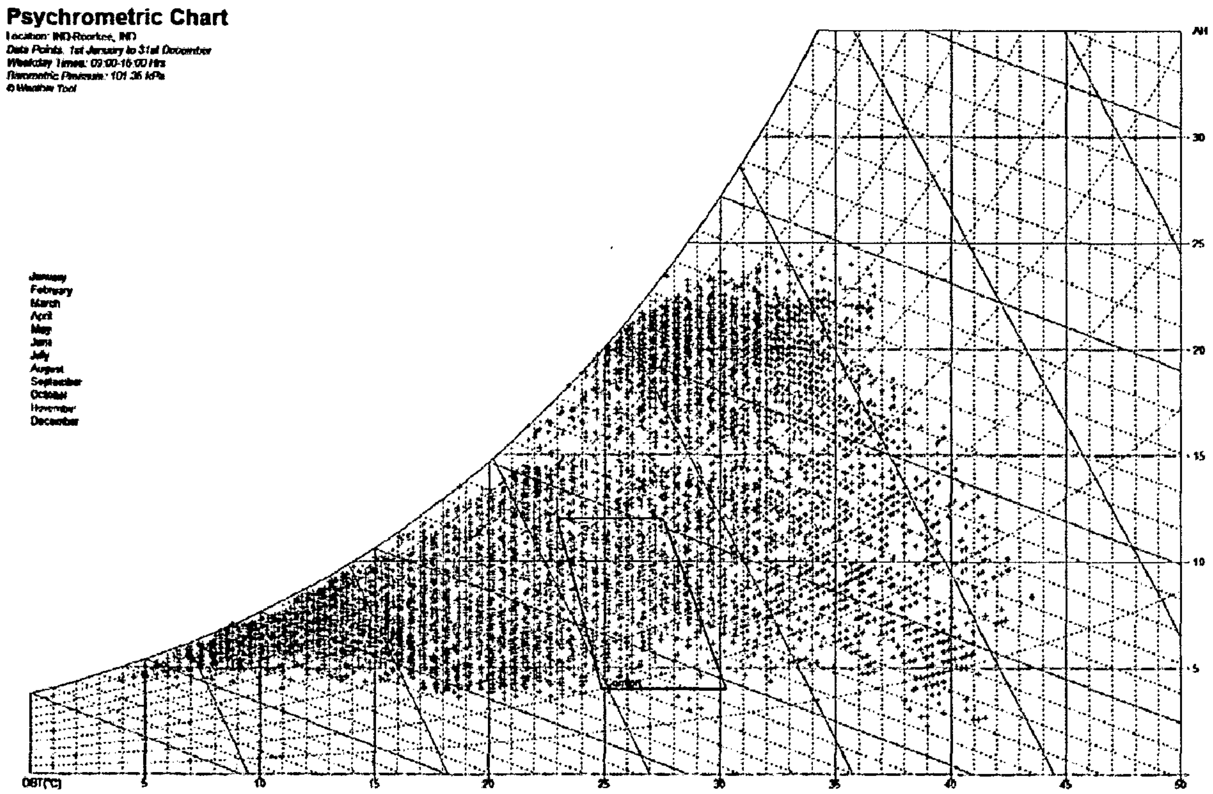


Figure 4.8- Psychometric chart for Roorkee

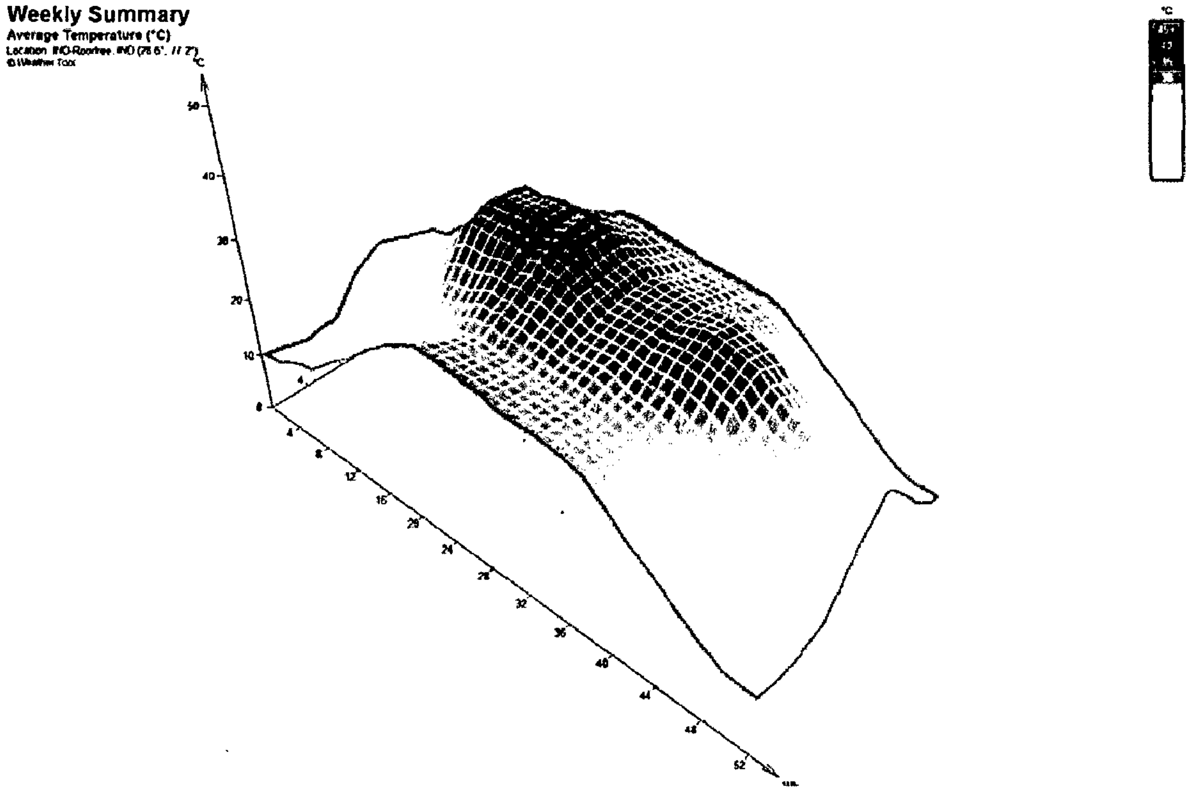


Figure 4.9- Average weekly temperature at Roorkee

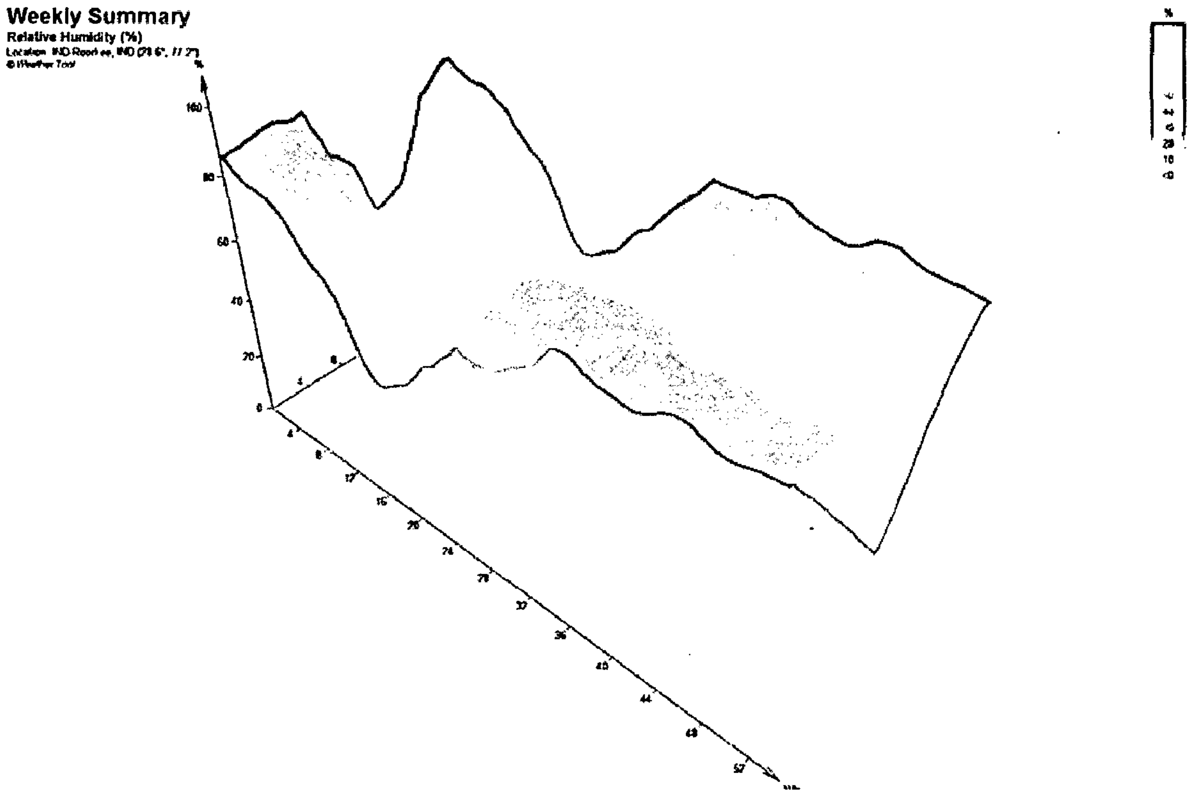


Figure 4.10- Average weekly RH at Roorkee

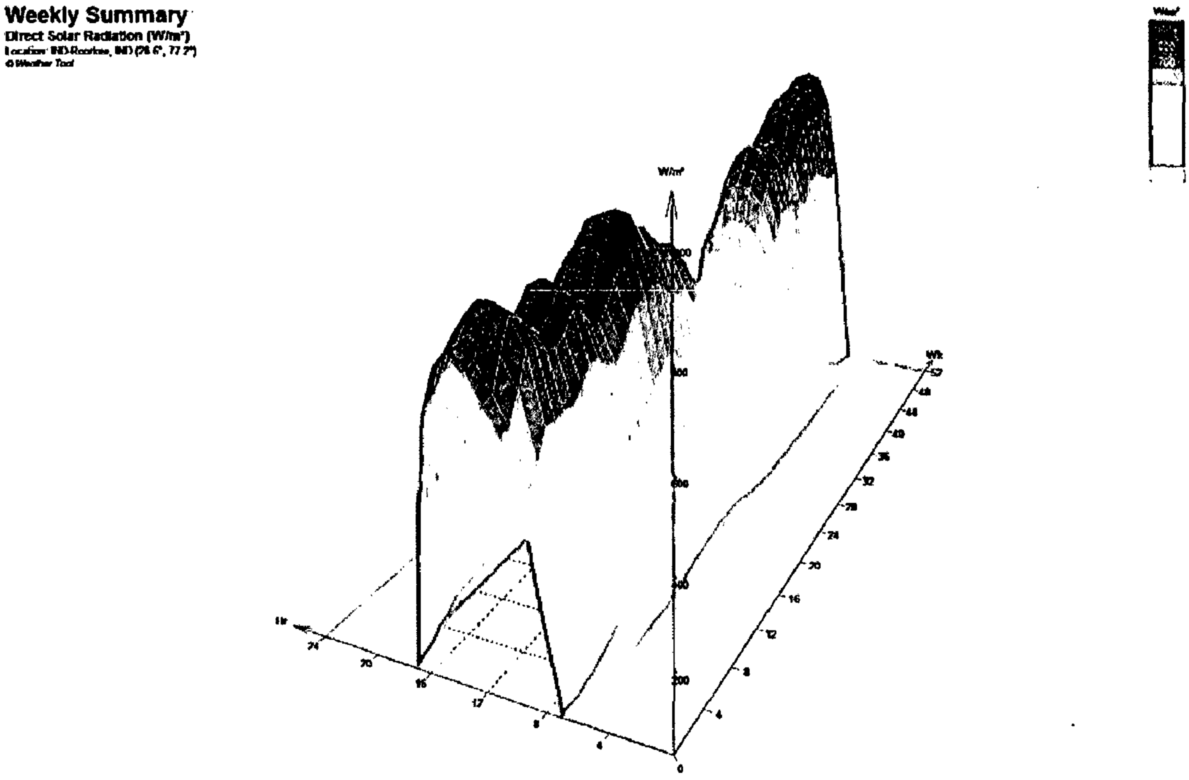


Figure 4.11- Weekly direct solar radiation at Roorkee

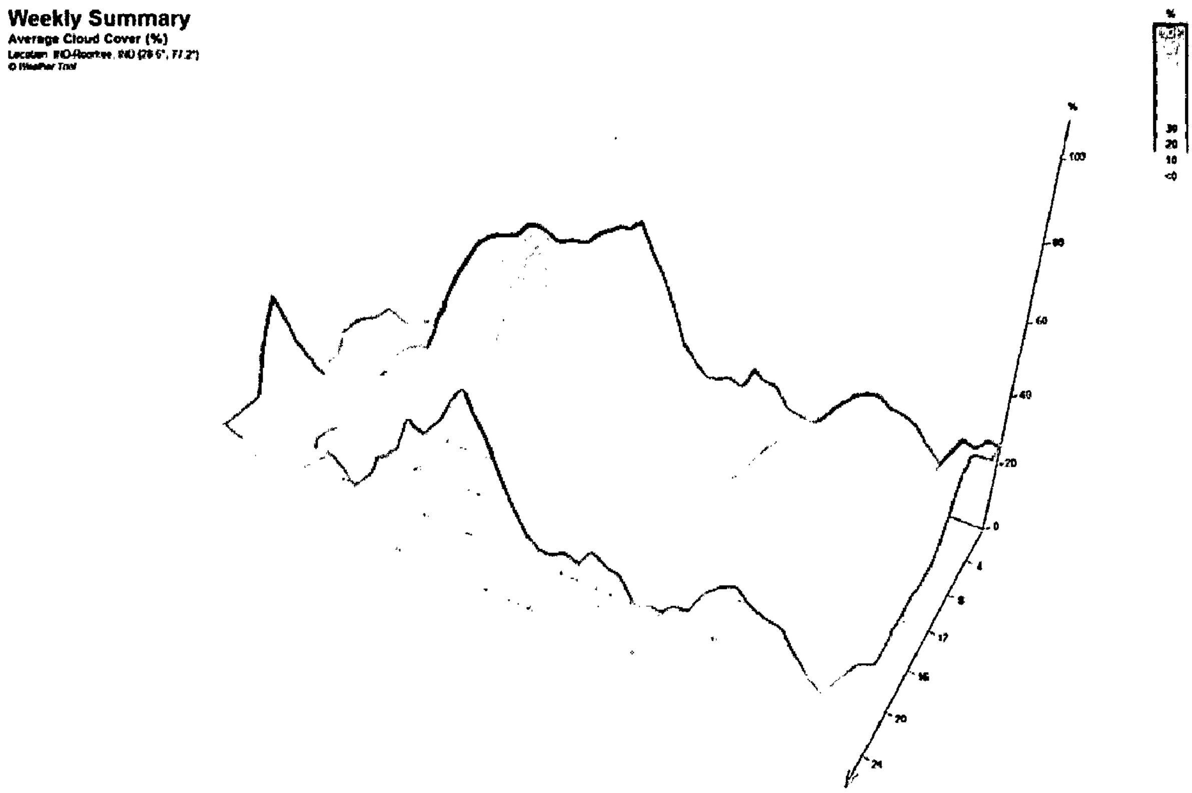


Figure 4.12- Weekly average cloud cover at Roorkee

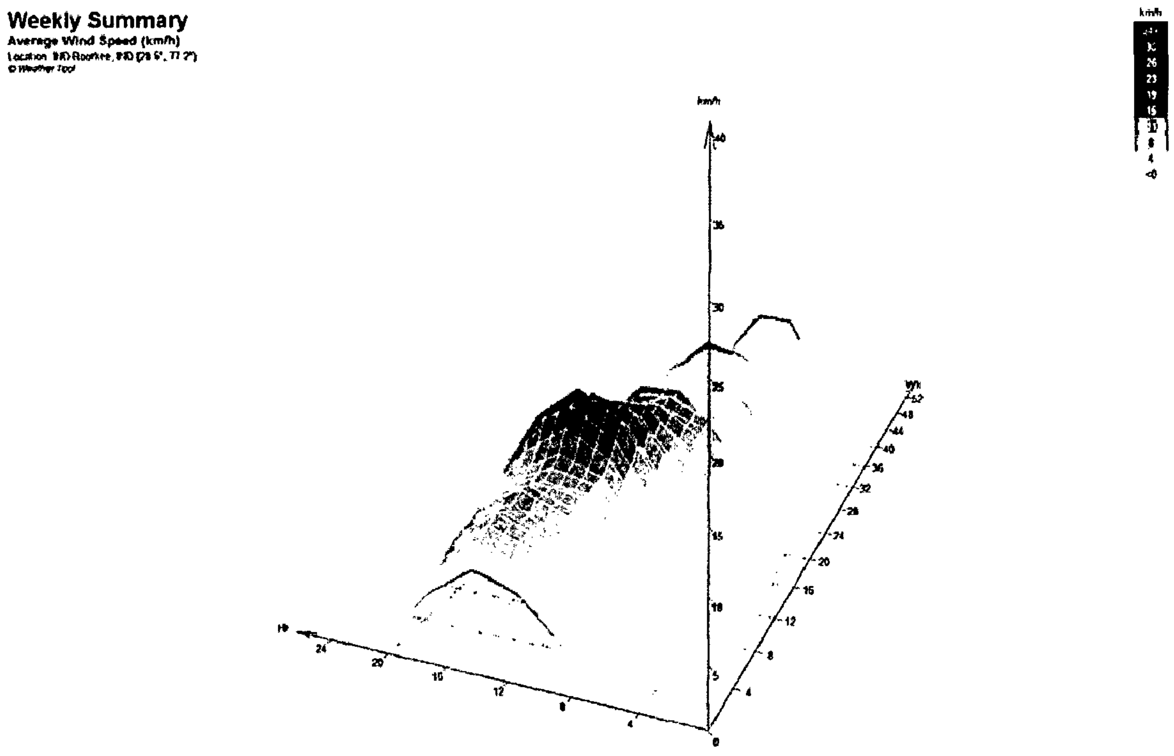


Figure 4.13- Weekly summary of average wind speed at Roorkee

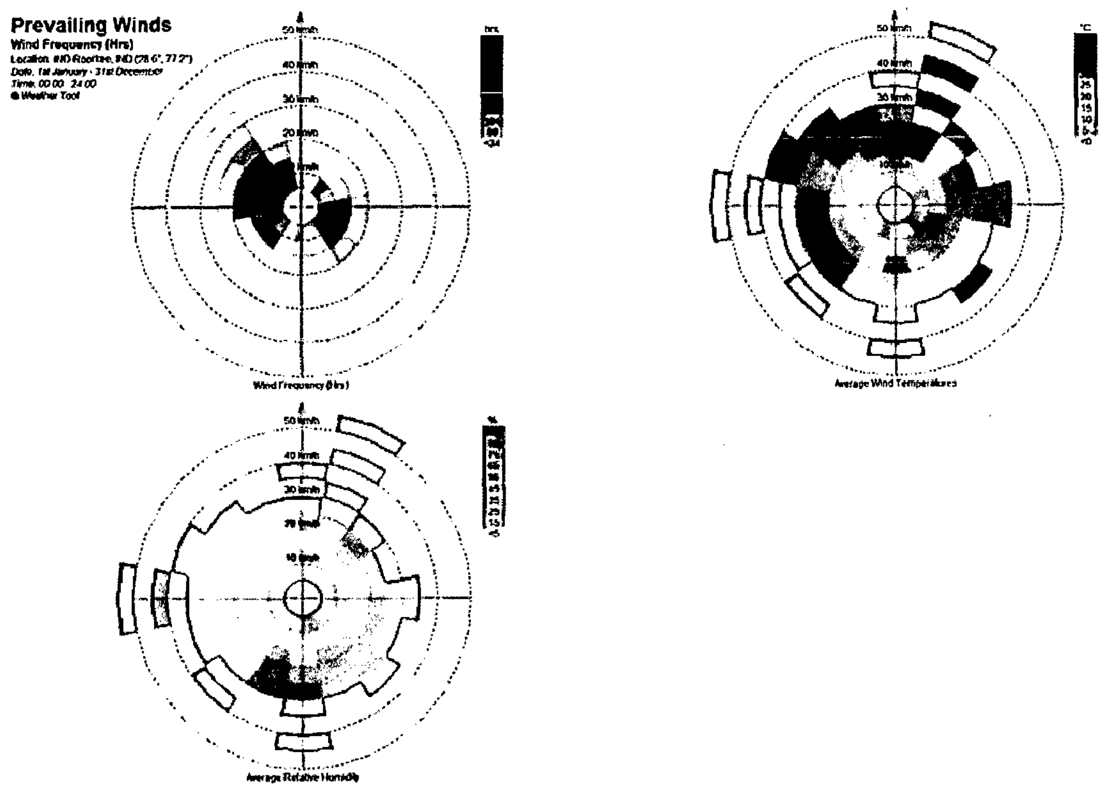


Figure 4.14- Wind rose diagram for Roorkee

4.3.2.2 Topography

It has an average elevation of 268 metres (879 feet). The site is almost flat and has a very gradual slope towards north. The drainage of the site has been taken care of by constructing storm water drain which is connected to the main sewer of the campus.

4.3.2.3 Orientation

The lecture hall complex building is rectangular in plan. Its longer axis is aligned to north south direction having the entry on the east side. First three floors consists of total 6 (six) lecture halls. Four of them are at the back (west side) and rest of the two in right (North) and left (South).

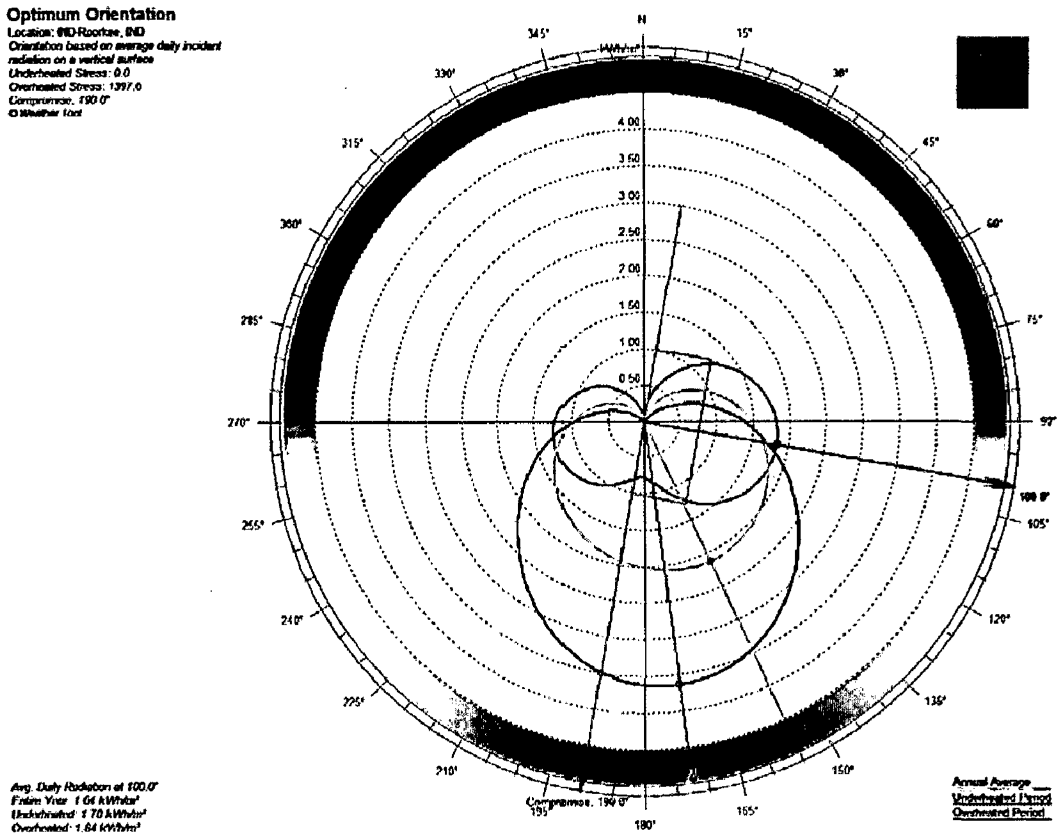


Figure 4.15- Optimum orientation

The arrowheads represent the orientation of the shorter axis of the building. The red o represents the worst case and the yellow one represents the most optimum direction. Th white box represents the current position of the building.

4.3.3 The Building Surrounding

The building can be seen from the main road of the campus approaching towards the main building. In the West, there is Ravindra Bhawan, in the East, the central library and the department of management studies (DOMS) is there. In the north there is a vacant plot of land.

- The building is situated almost at the centre of the site in the north-south direction.
- There are concrete roads surrounding the whole building.
- The parking space is also covered with concrete.
- There is a small lawn of grass at the north side which is properly maintained.
- There is no large tree in the site except at the side of the main entrance.

Figure 4.16- Parking space behind the building

4.3.4 The Building Envelope

Colour:- The building is painted in beige

4.3.4.1 Texture

The building is finished with textured rough cement and paint is applied on it. The rough external surface increases the surface area drastically and so increases the amount of absorbed heat.

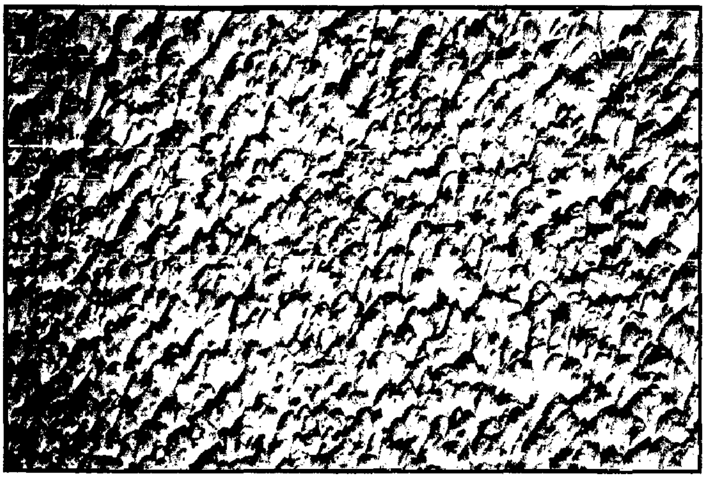


Figure 4.17- Wall texture

4.3.4.2 Wall Construction

All walls of the building are 230 mm thick brick wall. Cement mortar plaster is applied on the both sides of the wall. No insulation against the heat gain is present.

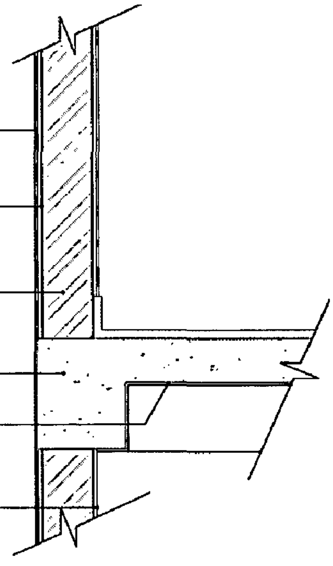


Figure 4.18- Wall section

4.3.4.3 Roof

The roof is flat with waterproofing treatment on the top of the roof slab. No insulation technique have been opted. The bare roof becomes very hot during the summer days.

4.3.4.4 Fenestration

4.3.4.4.1 Windows

All windows are aluminum framed single pane glass window. There are visible gaps between the window frame and window sash. In some cases, the window locking mechanism is not working. External windows are casement windows with operable sashes.

4.3.4.4.2 Doors

The main entrance door is of toughened glass. All other doors are single or double paneled flush doors depending upon the width of the opening. There are visible gaps between the door panel and door frame when the door is closed. Wide gaps are also present between the door panel and floor finish.

4.3.4.5 Shading devices

No permanent external shading device is present at the outer façade of the building. Inside the windows are covered with curtain which substantially reduces the heat gain but also restricts light to come in.

4.3.4.6 Atrium

The atrium of the building is always a good topic of debate as it has some advantages and disadvantages at the same time. It provides shade and protects from rain but it becomes very hot and humid compared to the outside temperature and humidity in summer.

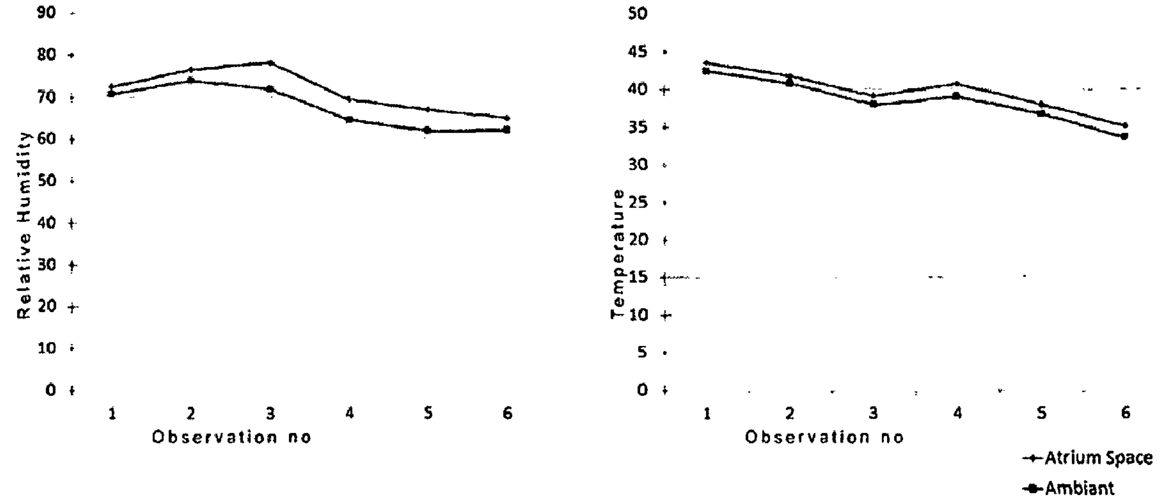


Figure 4.19- RH and temperature of atrium

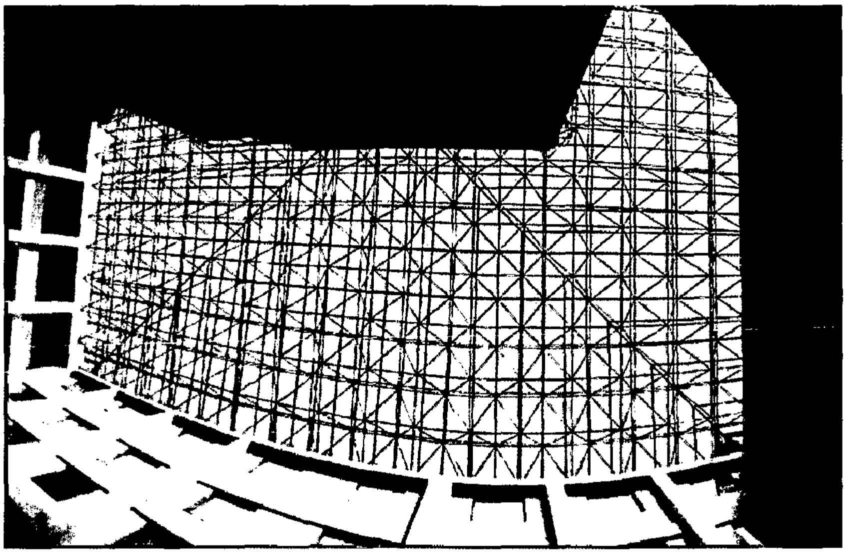


Figure 4.20- A fisheye view of the atrium of LHC

4.3.5 The Building Interior, Fixtures and equipment

4.3.5.1 Flooring

The floor is mostly finished with vitrified tiles. The floor finish inside the rooms is of stone.

4.3.5.2 Ceiling

Due to the need of large continuous space, coffer slab has been designed to support the span. Absence of suspended/ false ceiling greatly increases the volume of the room due to the dead air space above which increases the AC load.

4.3.5.3 HVAC

All lecture halls and Classrooms have 2 Ton Split AC systems manufactured by Voltas. There are two ACs in each large lecture hall, one per small lecture hall and one AC per one classroom. All rooms have fans.

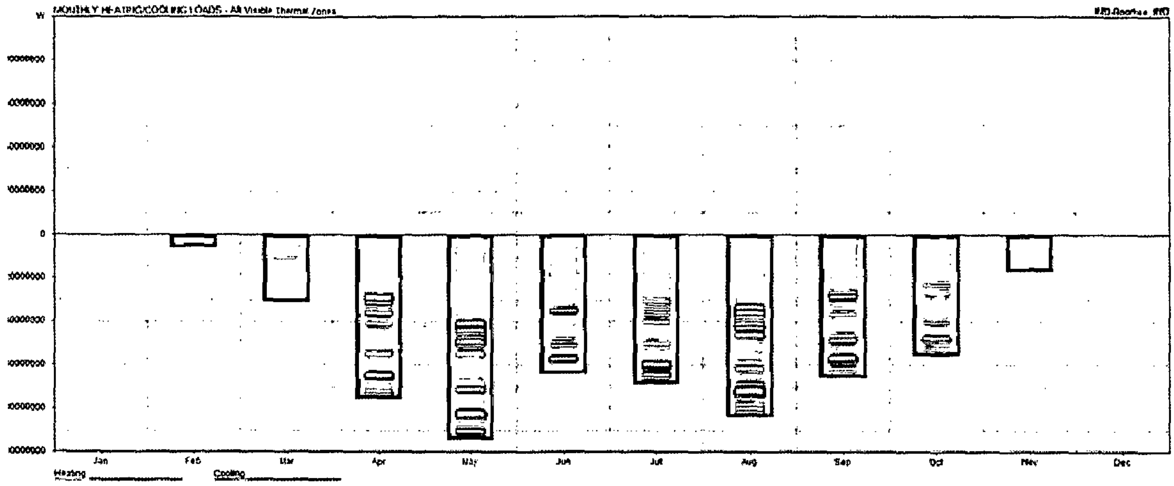


Figure 4.21- Monthly cooling load of the LHC

Table 4.1- Annual cooling load of LHC

Month	**Cooling Load (Watt Hour)**
January	14838
February	6094822
March	31417672
April	75528048
May	94557184
June	64296080
July	68614688
August	83804504
September	65888468
October	55757716
November	17137376
December	166051
Total	**563277447**

The actual total thermal load of the building which is calculated from the annual electricity consumed for air conditioning (3 star rated AC, EER 2.8) is 636804284 wh.

4.3.5.4 Lighting

The building performs very well if daylighting is considered. The atrium is well lit. Use of heavy curtains to cut down the heat brings the necessity of artificial lighting. All lighting fixtures have induction based choke coil fitted with dual T8 lamps manufactured by Philips.

Table 4.2- Daylighting levels in various halls of LHC.

Hall no	**Illumination level in lux**		
	Near window	centre	Corner
1	894	594	224
2	960	648	386
3	912	672	215
4	891	654	248
5	932	678	421
6	725	433	342

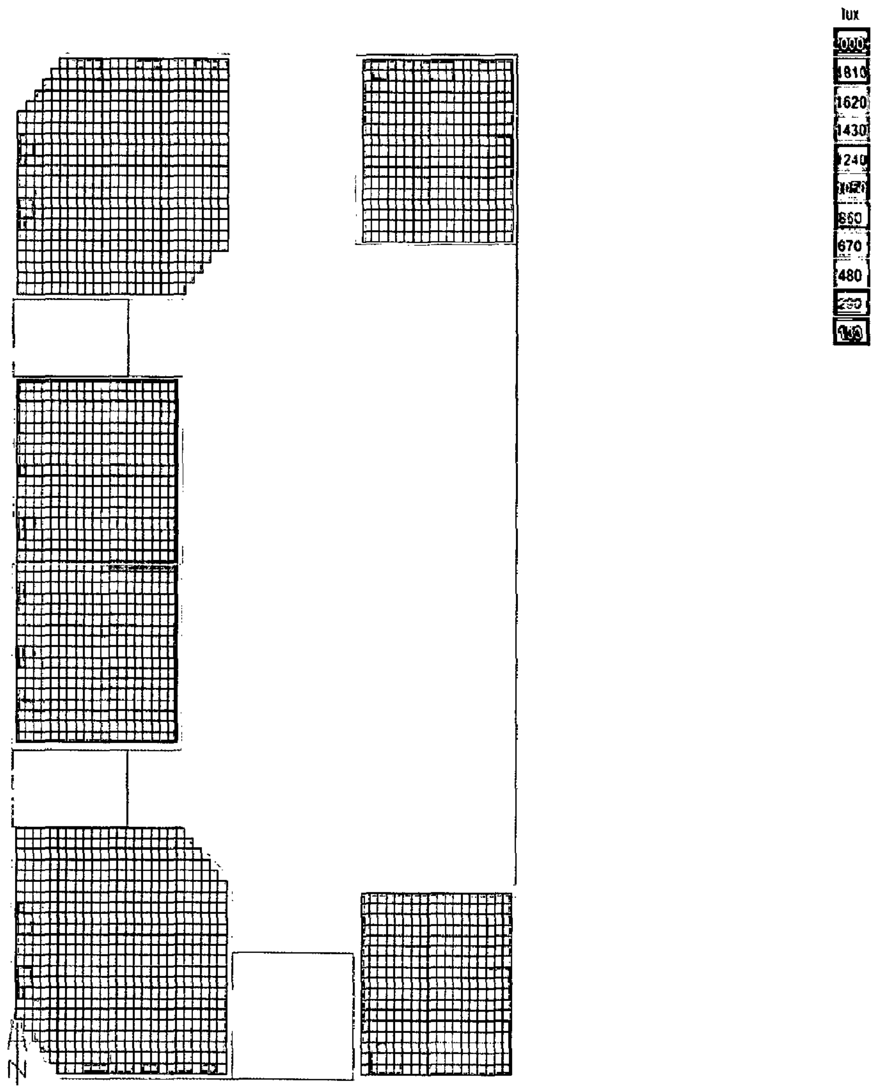


Figure 4.22- Daylighting simulation in ecotect

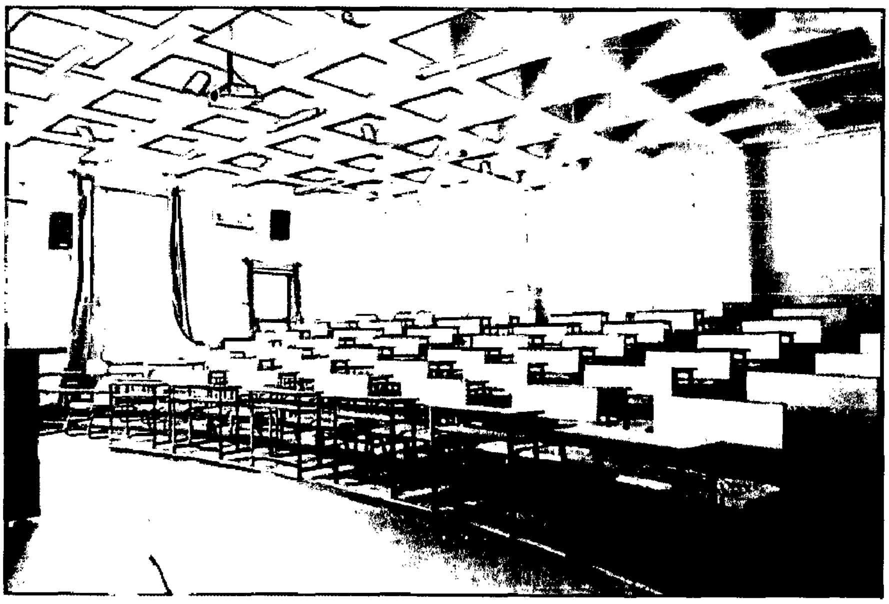


Figure 4.23- Natural daylighting in a lecture hall

4.3.6 Total Energy Consumption

As per the data supplied by the institute electrical engineering department, the building consumed 227430 units for Air conditioning and 116645 units for other purposes from 20th May 2011 to 16th April 2012. So two third of the electricity is consumed by HVAC.

4.3.7 Monthly Fabric gain

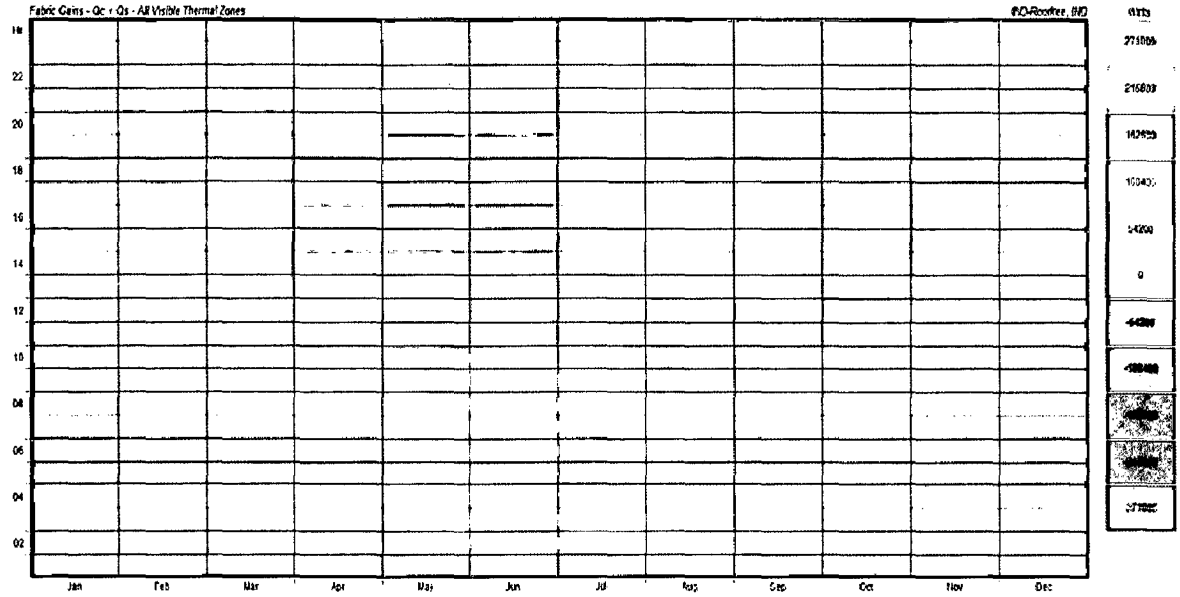


Figure 4.24- Monthly fabric gain

Table 4.3- Annual fabric gain table

ANNUAL LOADS TABLE												
Fabric Gains - Qc + Qs												
All Visible Thermal Zones - Monthly Averages												
HOUR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
	(Wh)	(Wh)	(Wh)	(Wh)	(Wh)	(Wh)	(Wh)	(Wh)	(Wh)	(Wh)	(Wh)	(Wh)
0	-6039	-575	3902	52942	107917	138260	101809	88957	76308	9961	0	-6664
1	-8452	-1097	2301	43281	96291	128397	96411	84182	71903	9357	0	-9496
2	-11950	-1905	790	32562	82082	117102	89602	79264	66961	9302	0	-14357
3	-15963	-2482	474	29096	74823	112772	85498	76359	61833	7827	0	-17620
4	-21048	-3102	253	24266	65077	106688	80127	72918	56189	6578	0	-22637
5	-26233	-4228	101	20200	55954	100988	75140	69557	50923	5305	-284	-28094
6	-23423	-3349	0	28379	71144	110825	82919	76816	53540	5367	-5	-24588
7	-22033	-2737	14	39702	87056	121201	90160	84634	57832	6414	0	-21815
8	-21316	-2313	760	55216	103893	132335	97693	92166	62898	10177	156	-19134
9	-7000	-495	6493	84499	140774	155914	115348	106400	81870	26582	1199	-6421
10	-2751	3665	26893	124663	180653	182725	137034	127554	111213	56293	9244	-1986
11	6373	15668	52178	160033	213765	202982	158310	146783	138045	87880	29415	9828
12	12987	20444	62834	177776	234890	218609	168219	158224	154138	105274	39791	15478
13	14083	24731	76050	194627	253506	233006	177043	169453	169367	123045	50400	17359
14	14914	30878	91055	210500	270015	245865	181481	176227	183359	141096	65581	21963
15	15631	30263	91648	210342	270646	252733	187077	180208	182198	136138	57299	17330
16	14288	30125	91010	209448	270182	255606	189557	178446	180653	131440	47996	14617
17	12849	28813	90471	207934	269535	258790	189616	175072	178553	125947	41056	15550
18	10964	19523	71571	186493	244734	244109	176146	161302	160646	97459	26798	13357
19	8419	14404	55482	163389	218695	229277	162156	146727	142429	69357	15559	7543
20	1814	7147	36630	135168	188571	210719	145109	129769	118014	42674	4307	0
21	-920	238	18600	104505	159259	184826	126713	111700	100453	26794	1033	-162
22	-2108	0	11667	85193	138491	164366	114131	100850	89825	16131	144	-1707
23	-5339	-565	5325	59968	113387	143024	102552	90157	78553	8591	0	-6603

4.3.8 Thermal Gains breakdown

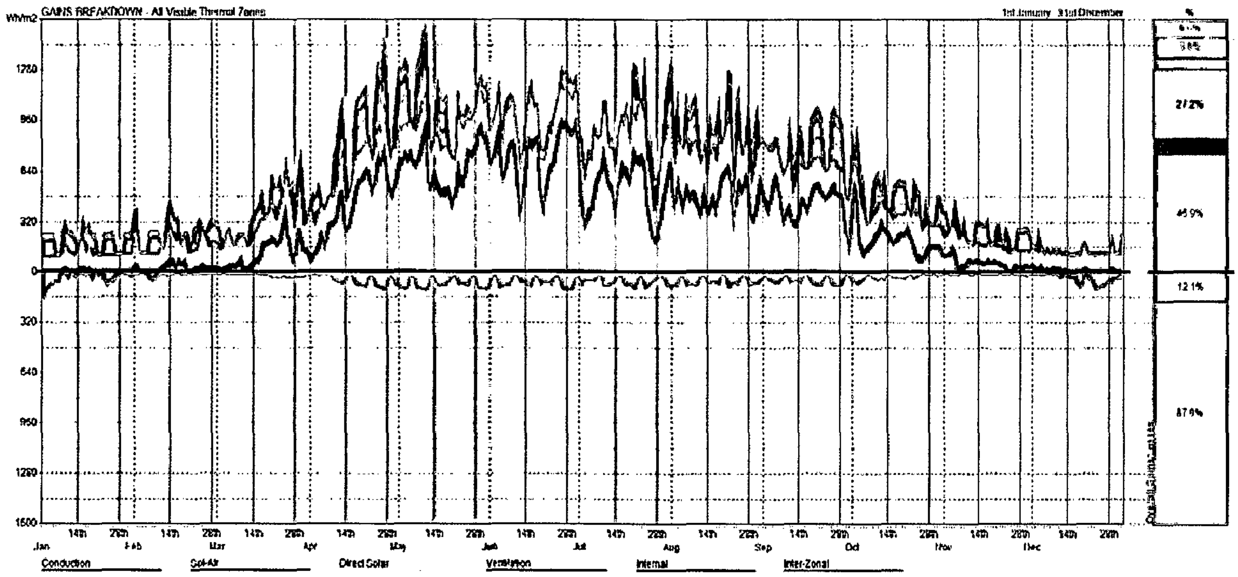


Figure 4.25- Passive Heat gain breakdown

Table 4.4- Annual thermal gains breakdown

GAINS BREAKDOWN - All Visible Thermal Zones		
FROM: 1st January to 31st December		
CATEGORY	**LOSSES**	**GAINS**
FABRIC	12.10%	46.90%
SOL-AIR	0.00%	4.10%
SOLAR	0.00%	27.20%
VENTILATION	0.00%	6.60%
INTERNAL	0.00%	8.60%
INTER-ZONAL	87.90%	6.60%

It is clear from the result of the simulation that the building maximum amount of heat from the conduction. Gains from direct solar radiation takes the second place. Gain from ventilation and inter zonal gains are not that much alarming. This analysis will actually help to determine the main action areas in the retrofit of the building.

4.3.9 Analysis

4.3.9.1 The building Surrounding

Due to the large hard concrete surface around the building, the surrounding air temperature of the building is substantially high compared to the average ambient temperature. The concrete covered surface becomes very hot and radiates heat which helps to increase the total fabric gain of the building.

The absence of any large tree in the west also helps in rise of the temperature and helps to increase the direct and indirect heat gain. It is observed that with an ambient air temperature of 28°C, the shaded areas of concrete parking shows a surface temperature of 31-32°C whereas the unshaded parking and road shoes a surface temperature of 47-49°C. The grass lawn at the north requires a lot of water to be maintained.

4.3.9.2 Building envelope

Considering the building envelope, the building is not energy efficient at all. Absence of any insulation facilitates the thermal exchange between the conditioned and non-conditioned space. Floor to floor height casement windows are inefficient because of heavy amount of solar gain through them. It is an established fact that the reduction of height of the window upto 1200 mm can reduce the heat gain without affecting the natural daylighting. Due to the heavy heat gain through the windows, even if the curtain is in place, the cooling load increases drastically and due to the use of curtain, artificial lighting is used which further increases the energy consumption.

Single pane clear glass windows do not have any mechanism (Such as low-e coating or tinted film) to cut down the heat waves which increases the problem of radiative heating.

Bad workmanship around the fenestration leaves ample space of escape of conditioned air which further pushes up the AC load. The conditioned space is not airtight at all.

Absence of shading device is a major drawback of the design as four of the six lecture halls in each floor gets direct west sun.

4.3.9.3 The building interior, Fixtures and equipment

Absence of suspended/ false ceiling greatly increases the volume of the room due to the dead air space above which increases the AC load.

According to the graphs of atrium temperature shown above, the temperature and humidity difference is visible. It forces to increase the rate of inter-zonal heat loss between the conditioned and non-conditioned zone (as δt increases). The small perpendicular opening at the top is not sufficient enough to enable the stack effect. Structural glazing upto three floors aid the greenhouse effect by acting as a heat trap.

The actual load of cooling is much higher than the simulation load. There are two main reasons behind it. When the software simulates the climatic conditions, it only takes into accounts the ambiant air temperature, but donot calculate the radiation from the large amount of hard cover around the building, which contributes greatly to the consumption of extra electrical load.

Another cause is the use of split ACs in the halls. These AC units always run in full capacity even when there is no demand of full capacity, a partial operation can be enough to cool the room.

Moreover, the AC units fail to provide the amount of cooling to the halls in the hottest day. As an example, The large lecture halls are fitted with two no. of two ton AC units which is not sufficient to serve the hall that needs to extract 20511 W at 12:00 on 26th April, which is basically 5.8 TR.

So the AC system installed , is inefficient in one respect and overdesigned on the otherhand.

The installed lighteing system installed is very much energy inefficient. Instead of using T12 lamps, T5 lamps can be used to cut down the energy use from 55 watts to 28 watts with better illumination level.

The fans are regular fans without any rating. If 5star rated fans are installed, the energy consumption can be cut down by half.

The toilet fixtures like urinals and taps are conventional one which uses a lot of water and increases the energy consumption of the building indirectly. Some measures like use of sensor taps can be a good way out.

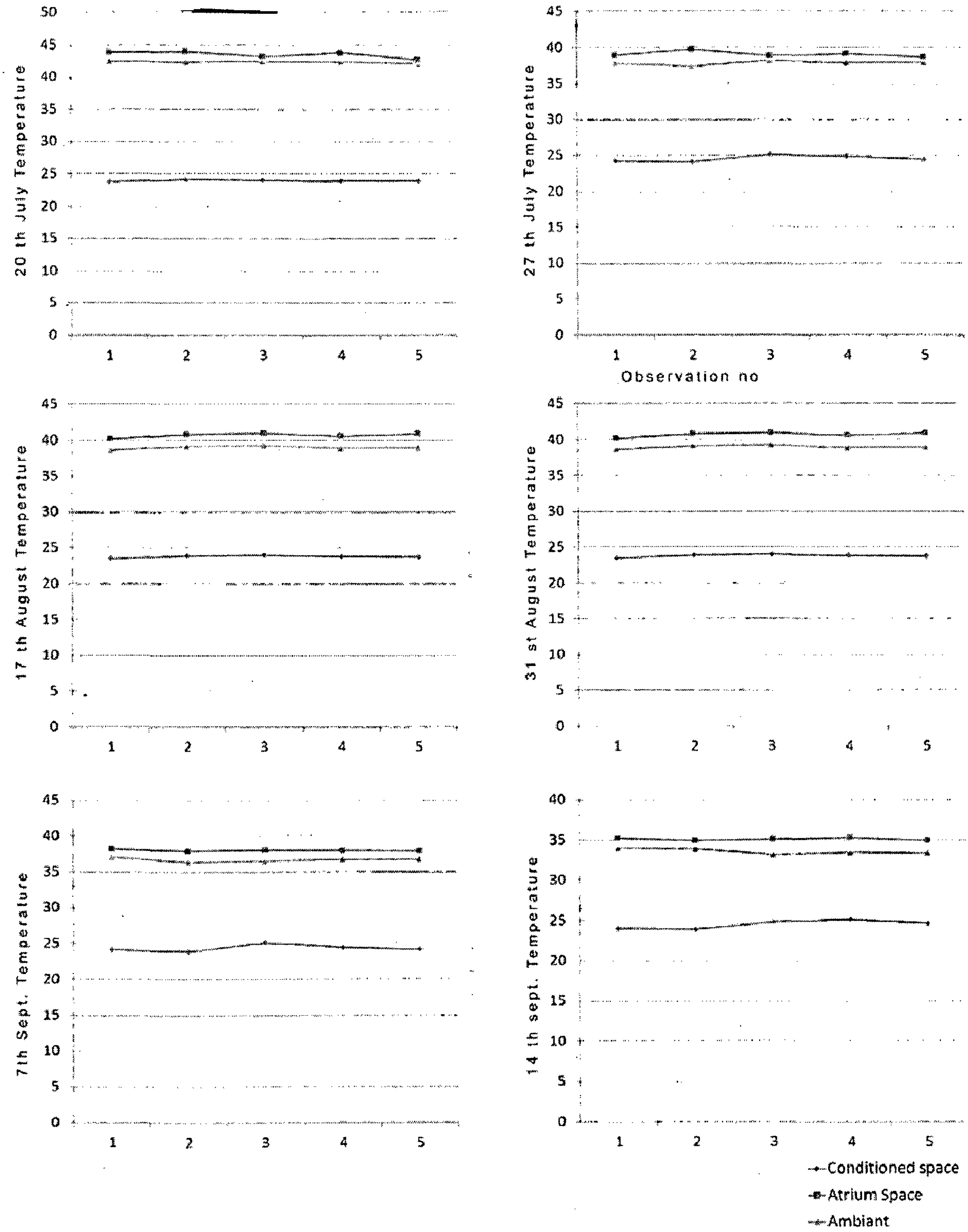


Figure 4.26- Temperature comparison of LHC

Table 4.5- Collected weather data from survey

S. No	Conditioned Space				Atrium Space				Ambiant		
	DBT	RH(%)	WV(m/s)		DBT	RH	WS		DBT	RH	WS
1											
20th July	23.8	63.5	nil		43.8	72.3	nil		42.5	70.4	0.8
	24.1	63.1	nil		43.9	72.6	nil		42.3	70.6	0.7
	24	63.4	nil		43.2	72.9	nil		42.5	71	0.2
	23.9	63	nil		43.8	72.1	nil		42.4	70.9	0.3
	23.9	62.9	nil		42.7	72	nil		42.1	70.4	0.1
Avg	23.94	63.18	nil		43.48	72.38	nil		42.36	70.66	0.42
2											
27th July	23.9	60.2	nil		42	76.5	nil		40.8	74.5	0.6
	23.8	60.1	nil		41.7	76.4	nil		41	73.6	0.2
	24.1	60.5	nil		41.9	76.8	nil		40.7	74.2	0
	24	60.7	nil		41.7	76.2	nil		40.6	73.6	0.2
	24.1	61	nil		41.6	76.5	nil		40.8	73.5	0.3
Avg	23.98	60.5	nil		41.78	76.48	nil		40.78	73.88	0.26
3	24.2	65.2	nil		39	77.7	nil		37.8	71.9	0.7
17th August	24.1	64.8	nil		39.8	78.2	nil		37.4	72	0.9
	25.1	63.4	nil		38.9	76.7	nil		38.2	71.7	1.4
	24.9	63.9	nil		39.1	78.4	nil		37.9	71.5	1.2
	24.5	63.2	nil		38.7	79.1	nil		38	71.8	1
Avg	24.56	64.1	nil		39.1	78.02	nil		37.86	71.78	1.04
4											
31 st August	23.5	63.9	nil		40.2	69.4	nil		38.6	64.2	0.9
	23.9	64	nil		40.8	68.9	nil		39.1	65.1	0.7
	24	63.8	nil		41	69.6	nil		39.3	64.6	0.2
	23.8	64.1	nil		40.6	69.5	nil		38.9	64.3	0.6
	23.7	63.9	nil		40.9	69.1	nil		39	64	0.2
Avg	23.78	63.94	nil		40.7	69.3	nil		38.98	64.44	0.52
5											
7th September	24.1	63.2	nil		38.2	66.9	nil		37.1	62	1.2
	23.9	63.4	nil		37.9	67.1	nil		36.4	61.8	1.1
	25.1	64.1	nil		38.1	67.2	nil		36.5	61.4	0.6
	24.5	63.9	nil		38	66.8	nil		36.8	61.8	0.2
	24.1	64.1	nil		37.9	66.9	nil		36.8	62.1	0.4
Avg	24.34	63.74	nil		38.02	66.98	nil		36.72	61.82	0.7
6											
14th September	24	63.8	nil		35.2	65.1	nil		34	61.8	0.2
	23.9	63.7	nil		34.9	64.7	nil		33.9	61.7	1
	24.8	64.1	nil		35.1	64.9	nil		33.2	62	0.5
	25.1	63.2	nil		35.3	65	nil		33.5	62.1	1.1
	24.6	63.4	nil		34.9	65.2	nil		33.4	62.3	0.7
Avg	24.48	63.64	nil		35.08	64.98	nil		33.6	61.98	0.7

This Chart represents the temperature, relative humidity, and wind speed in and around the lecture hall complex and the ambient temperature of the day. This clearly indicates that the temperature in the lecture hall complex is always higher than the ambient temperature of the day.

4.4 SUMMARY

It is very evident from the discussion above that there is ample scope of improvement of the energy efficiency of the lecture hall complex. Not only that, the user comfort should also be ensured in every weather condition. Apart from the energy efficiency, the performance of the building regarding fire safety, sustainability etc. are also very poor. Covering the entire ground surface with concrete and putting a few solar powered light masts cannot be a sustainable solution. In this age of modern technological advancement decade old fire extinguishing hose instead of automated sprinkler, manual operation of electrical equipment and HVAC system instead of BMS is really a compromisation with the comfort and safety of the users.

It is an agreed upon fact that there is ample scope of improvement in each and every sector of the building. But only energy consumption and energy efficiency related issues are addressed here. After finding out these energy related problems, the probable strategies which can reduce the energy consumption are discussed in the next chapter.

5 RETROFIT OPTIONS

Nowadays, the advancement of technology and research on new efficient building materials has opened a new horizon for retrofit of buildings. Their efficiency and convenient smart installation process is worth utilizing to reduce the energy consumption of existing buildings. But there is a plethora of materials available in the market and their applicability depends on the context of the project like climatic zone, cost and performance.

This chapter is not a mere collection of the plethora of available materials and their installation techniques, but only those materials which suits the project regarding the context are handpicked from various sources like advertisements of products, commercial brochure, literature, product booklets, e-catalogues, research papers on materials etc. The retrofitting strategies are mainly subdivided into three main intervention areas.

1. Building Surrounding,
2. Building Envelope,
3. Building interior, Equipment and fixtures.

5.1 THE BUILDING SURROUNDING

5.1.1 Reduction of Heat Island

Roads, parking, and similar surfaces absorb more sunlight, trap heat, and increase local temperatures. The lecture hall surrounding area has more roads, surrounding buildings, and parking lots and less green space. The high concentration of these heat-absorbing surfaces creates an isolated area where higher ambient temperature is prevailing. Studies have documented that this area has air and surface temperatures that are, on average, 1.8 – 5.4°C higher than temperatures in surrounding green areas.(EPA, 2010)

Strategies for mitigating local heat island impacts

1. Trees and vegetation
2. Cool Roof
3. Reduction of concrete roads
4. Light Pavement using permeable pavers.
5. Green Roof
6. Green Wall

5.1.1.1 Trees and vegetation

Trees and vegetation help reduce the impacts of heat islands by increasing the amount of shade and cooling the air by evapotranspiration (McPherson, 1994). Careful placement and choice of vegetation will maximize its cooling benefits. Shade provided by trees and other vegetation prevents sunlight from reaching heat-absorbing surfaces such as sidewalks and parking lots, cooling the area by 1.0- 9.0° F. Vines on or near building walls and ground cover and grass such as in a park or parking lot are other vegetation options that provide cooling benefits. Vegetation can also lower the cooling demand for a building by shading the walls from strong sunlight (EPA – RUHI, 2010).

Through the process of evapotranspiration, water stored in the leaves of plants and trees evaporates, dropping the temperature of the surrounding air (McPherson, 1994). Additional water is required for optimum cooling benefits from evapotranspiration, increasing maintenance costs. Because of the water and air quality concerns, new trees should be drought tolerant and low-VOC emitters. Low-VOC emitting trees ensure that an increase in vegetation does not increase ozone precursors.

For ultimate benefits, trees should be-

1. Low-pollen emitter
2. Low- VOC emitter
3. Drought tolerant
4. Planted southwest of building
5. No more than 5-15 m from building

5.1.1.2 Reduction of concrete surfaces

Reduction in the area of concrete road can be a very good alternative option to reduce local heat island effect. There is wide motorable concrete road around the building. Redesigning the circulation pattern can reduce the amount of hard cover around the building.

Replacement of the typical concrete parking space with grasscrete can effectively reduce the heat gain of the parking and therefore reduce the surface temperature successfully.

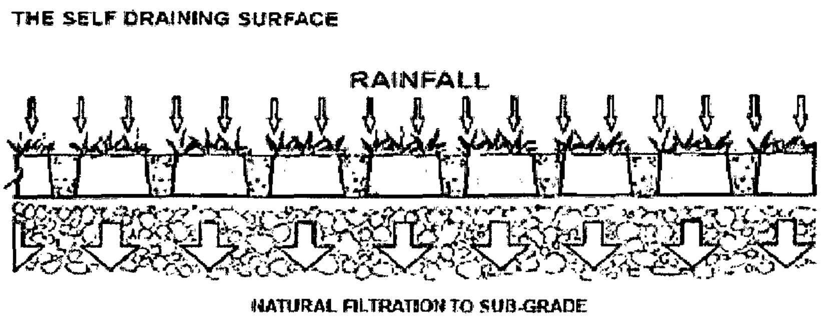


Figure 5.1- Permeable pavers

Grasscrete is similar in function to permeable pavers, except that grasscrete is constructed with interlocking concrete cells that can be filled with soil and planted. Grasscrete is also very heavy duty, and can be utilized for the construction of driveways. Another variation of this concept are grass cell pavers, which are similar to grasscrete, except the interlocking pieces are made out of plastic, which makes them a less expensive, (but less sturdy) application. Grass cells can support the weight of an average vehicle, but they have a shorter life span then grasscrete.

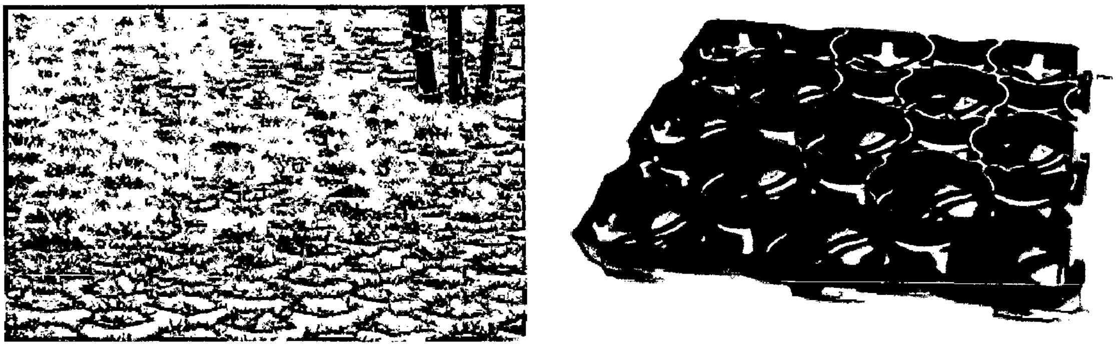


Figure 5.2- Grasscrete cover and PVC module

Costs & Savings

The cost of the placement of grasscrete instead of conventional concrete includes the removal of concrete surface and placement of modular grasscrete blocks. The cost of the laying process is 20- 30% less than conventional concrete as less amount of concrete is being used.

5.1.1.3 Light Pavement

The high reflectivity of light pavements helps lower surface temperatures and reduces heat absorption. Light pavements include high albedo surfaces such as permeable pavements that allow air, water, and water vapor to be absorbed into the pavement to help keep it cool. For every 10% increase in solar reflectance, the surface temperature of pavement can decrease by 1-2°C (EPA –RUHI, 2010).

Pavements are used on streets, parking lots, sidewalks, and in many other applications. Different locations require different paving types to fit the appropriate use, weather conditions, and type of traffic.

The main types of cool pavements include:

1. Reflective pavements- Used in low-traffic areas-
    a. Resin based pavements – clear tree resins to bind aggregate.
    b. Colored asphalt and concrete – pigments added to increase reflectance.

2. Permeable pavement- Voids in surface to allow water to drain to sublayer or ground.
    a. Porous asphalt.
    b. Rubberized asphalt – shredded rubber imbedded into asphalt.
    c. Brick or block pavers – clay or concrete with a variety of colors to increase reflectance; good for parking lots.

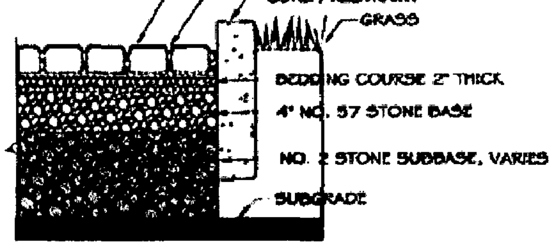


Figure 5.3- Permeable concrete pavers

3. Vegetated permeable pavements –

Permeable pavers are interlocking concrete blocks, set on a sub-grade of soil and sand that allow water to pass through to the water table below. When the pavers are set, a small gap between each paver allows water to flow through the surface to the ground below. Some pavers are made with notches in the corner to increase the overall permeability. Despite this permeability, these pavers are sturdy enough to be utilized for the construction of residential driveways and walkways.

Permeable pavers are a beautiful and highly functional alternative to concrete. In addition, permeable pavers are priced in the same range as concrete (and are less expensive than stone.) Since pavers are able to shift with the subsurface, they are not nearly as susceptible to cracking as concrete or other types of decorative flatwork.

4. White topping and Ultra-thin white topping – using a layer of concrete with fibers on top of roads for the lighter pavement color.

5. Microsurfacing – thin light-colored sealing layer for road maintenance.

Costs & Savings-

The costs of lighter, more porous pavements are 10 – 20% higher than traditional pavements. The frequency of repaving, recoating, and replacing pavements to maintain the high albedo of a light-colored pavement may become a detriment for high-traffic areas. The light surfaces easily become dirty and worn down, increasing the cost to clean and refinish to maintain the light surface. Microsurfacing is a good short-term solution to the replacement of dark pavements. Resurfacing can occur during normal maintenance for the street or highway.

Savings from permeable pavements include a decreased need for grading, treatment ponds, or other drainage features for water infrastructure (EPA's RUHI, 2010). Also, the energy savings usually outweigh the increased costs of light pavements. Based on a Los Angeles city study, a cooler pavement would generate a stream of savings of $0.06/m2 per year for the lifetime of the road—about 20 years (Rosenfeld et al, 1998). Light pavements and microsurfacing will help decrease the heat islands effect and improve air quality.

<u>*Where the measure has been put into practice-*</u>

University of California Merced's new parking lot has a light pavement lot in which cars park on gravel aggregate and the main driving section of the lot is asphalt. The gravel is more water permeable and a much lighter surface than asphalt, making it a cooler pavement.

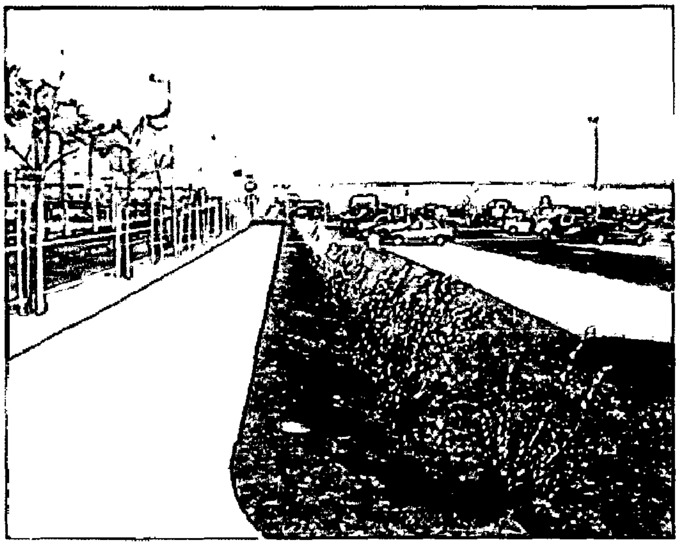


Figure 5.4- UCL parking lot

5.1.1.4 Cool roofs

Cool roofs reflect sunlight instead of absorbing it into the roof material. In the summer, a typical roof reaches temperatures of 65-70°C. Light colored or highly reflective tiles and roofing materials can stay within 6-10°C of the ambient temperature, instead of 20-30°C higher like most conventional roofs. These heat-deflecting roofing materials help cool the surrounding temperature and decrease the amount of energy used for cooling.

A variety of cool roof options are available, depending on whether the roof is flat or sloped. Cool roof coatings, ideal for retrofit projects, are composed of cement particles or polymers and have an albedo of 0.65 or higher. Albedo is defined as the potential a surface has to reflect ultraviolet rays, instead of absorbing them and increasing the heat of the surface. Single-layer membranes, used for cool roof new construction or extensive retrofit projects, are sheets of synthetic rubber or plastic polymer that are glued and fastened to the roof surface.

Benefits of a cool roof include:

1. Reduced ambient and inside temperature
2. Reduced energy usage
3. Improved human health and comfort
4. Reduce energy costs
5. Reduce greenhouse gases

5.1.1.5 Green roofs

A green roof is flat or slightly-sloped with a water seal, soil, and live plants in place of traditional roofing material. The roofing surface incorporates the soil, water, and plants to maximize the cooling potential without the risk of water leaks. Soil and plants cool by blocking sunlight from reaching the underlying roof membrane. The shading reduces the heat transferred into the building or back into the atmosphere, cooling the surrounding temperature and improving the building's energy efficiency.

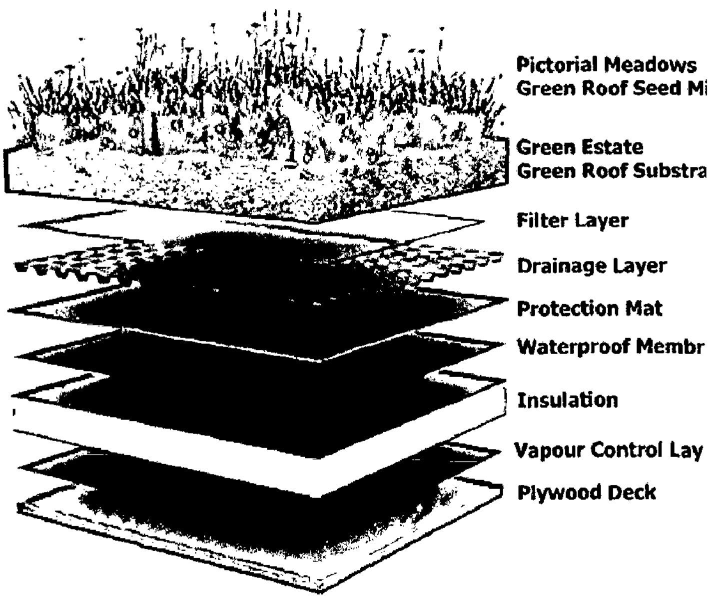


Figure 5.5- Green roof layers

There are two categories of green roofs: extensive and intensive. Extensive green roofs include succulent, hardy plants that need little maintenance or human intervention once planted. Plants suited for extreme climates are a good choice for extensive roofs as long as they are light-weight and drought tolerant. The extensive roofs are a more cost-effective retrofitting option for buildings because they require less structural support. Intensive green roofs include a variety of plants from trees, shrubs, and ground cover plants, creating a garden environment. The intensive roofs require more soil, an irrigation system, and more structural support to accommodate the larger plants. Some intensive roofs are made into a park or community garden, providing a green space for building residents.

Green Roofs help to

1. reduce pollution
2. Reduce energy costs
3. Reduce greenhouse gases
4. Reduced ambient temperature
5. Enhanced quality of life
6. Noise reduction
7. Aesthetic value

Costs & Savings

A green roof can reduce a building's total energy usage by 10% (EPA-RUHI, 2010). The initial cost of an extensive green roof is approximately $10 per square foot, and for an intensive green roof, $25 per square foot. Though this is more expensive than conventional roofs, the green roofs can last longer than conventional roofs. With that in mind, the annualized costs for a conventional re-roofing would be $0.51 - $1.74 per square foot, whereas an extensive green roof would be $1.03 – $1.66 per square foot. (EPA – RUHI) Over its lifetime, a green roof offers a total savings of about $200,000, primarily from reduced energy usage.

5.1.1.6 Green Wall

A 'Green Wall', also commonly referred to as a 'Vertical Garden', is a descriptive term that is used to refer to all forms of vegetated wall surfaces. Green wall technologies may be divided into two major categories: Green Facades and Living Walls, both of which are described below.

Figure 5.6- Mur Vegetal

Source: Patrick Blanc

Green Facades

Green facades are a type of green wall system in which climbing plants or cascading groundcovers are trained to cover specially designed supporting structures. Rooted at the base of these structures, in the ground, in intermediate planters or even on rooftops, the plants typically take 3-5 years before achieving full coverage. Green facades can be anchored to existing walls or built as freestanding structures, such as fences or columns.

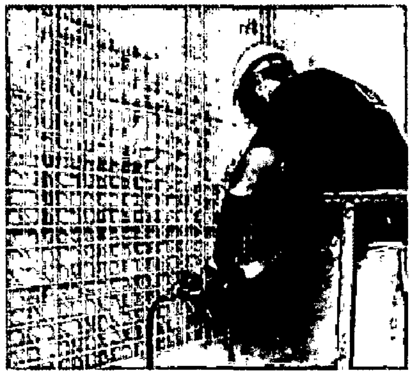
Self-clinging plants such as English Ivy have commonly been used to create green walls. Their sucker root structure enables them to attach directly to a wall, covering entire surfaces.

Modular Trellis Panel System

The building block of this modular system is a rigid, light weight, three-dimensional panel made from a powder coated galvanized and welded steel wire that supports plants with both a face grid and a panel depth. This system is designed to hold a green facade off the wall surface so that plant materials do not attach to the building, provides a "captive" growing environment for the plant with multiple supports for the tendrils, and helps to maintain the integrity of a building membrane. Panels can be stacked and joined to cover large areas, or formed to create shapes and curves, are made from recycled content steel and are recyclable. Because the panels are rigid, they can span between structures and can also be used for freestanding green walls.

Source: greenscreen®

Figure 5.8- A freestanding green wall being used for screening equipment.

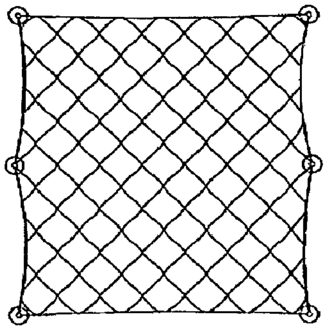


Source: greenscreen®

Figure 5.7- A wall mounted Modular Trellis Panel System

Cable and Wire-Rope Net Systems

The cable and wire-rope net systems use either cables and/or a wire-net. Cables are employed on green facades that are designed to support faster growing climbing plants with denser foliage. Wire-nets are often used to support slower growing plants that need the added support these systems provide at closer intervals. They are more flexible and provide a greater degree of design applications than cables. Both systems use high tensile steel cables, anchors and supplementary equipment. Various sizes and patterns can be accommodated as flexible vertical and horizontal wire-ropes are connected through cross clamps.



. Wire net systems are stretched, and may use a variety of connectors.
Source- www.greenroofs.org

Figure 5.9- A wire net system

close up showing cross clamp connector
Source- www.greenroofs.org

Figure 5.10- Cable system

Living Walls

Living wall systems are composed of prevegetated panels, vertical modules or planted blankets that are fixed vertically to a structural wall or frame. These panels can be made of plastic, expanded polystyrene, synthetic fabric, clay, metal, and concrete, and support a great diversity and density of plant species (e.g. a lush mixture of groundcovers, ferns, low shrubs, perennial flowers and edible plants). Due to the diversity and density of plant life, living walls typically require more intensive maintenance (e.g. a supply of nutrients to fertilize the plants) than green facades. There are various forms of living walls, with the main differences occurring between interior and exterior designs.

Modular Living Wall

A modular living wall system emerged in part from the use of modules for green roof applications, with a number of technological innovations. Modular systems consist of square or rectangular panels that hold growing media to support plant material. The composition of the growing medium may be tailored to the unique combination of plants selected, and to other design objectives.

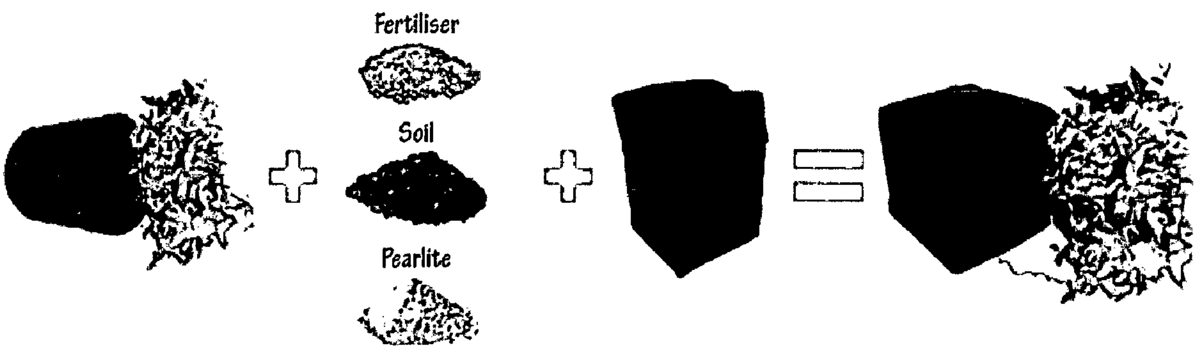
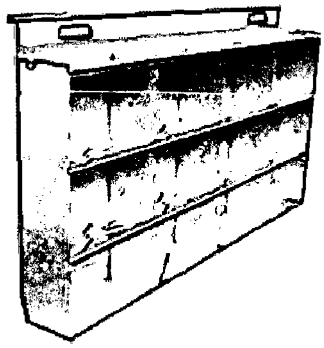


Figure 5.11- Modular Living Wall

Most of the nutrient requirements for the plants can be found in the growing media within the modules. Irrigation is provided with these systems at different levels along the wall, using gravity to move water through the growing media.

A pre-grown modular panel being prepared for installation.
Source: Green Living Technologies

Figure 5.12- Pre-grown modular panel



Before planting.
Source: Green Living Technologies

Figure 5.13- A standard modular un

Modular systems are often pre-grown, providing an 'instant' green effect upon completion of the installation. Notice of between 12 –18 months may be required to secure pre-grown modular systems.

Vegetated Mat Wall
The 'Mur Vegetal' is a unique form of green wall pioneered by Patrick Blanc. It is composed of two layers of synthetic fabric with pockets that physically support plants and growing media. The fabric walls are supported by a frame and backed by a waterproof membrane against the building wall because of its high moisture content. Nutrients are primarily distributed through an irrigation system that cycles water from the top of the system down.

Design Aspects

Wind flow

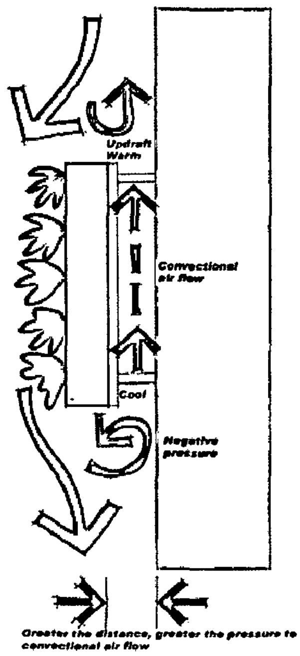


Figure 5.14- Facilitating Stack effect

Plant growth medium

Design Criteria

1. Growing medium minimum depth m150-250mm
2. Growing medium to be kept moist
3. Growing medium to be free draining

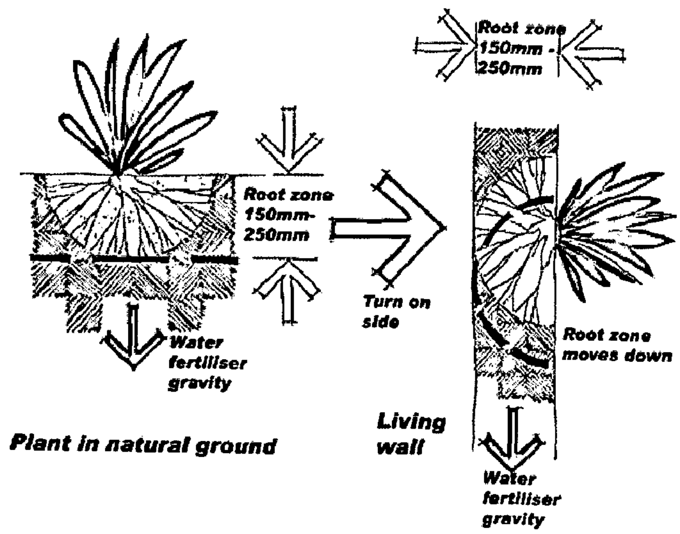


Figure 5.15- Shift of root zone due to gravity

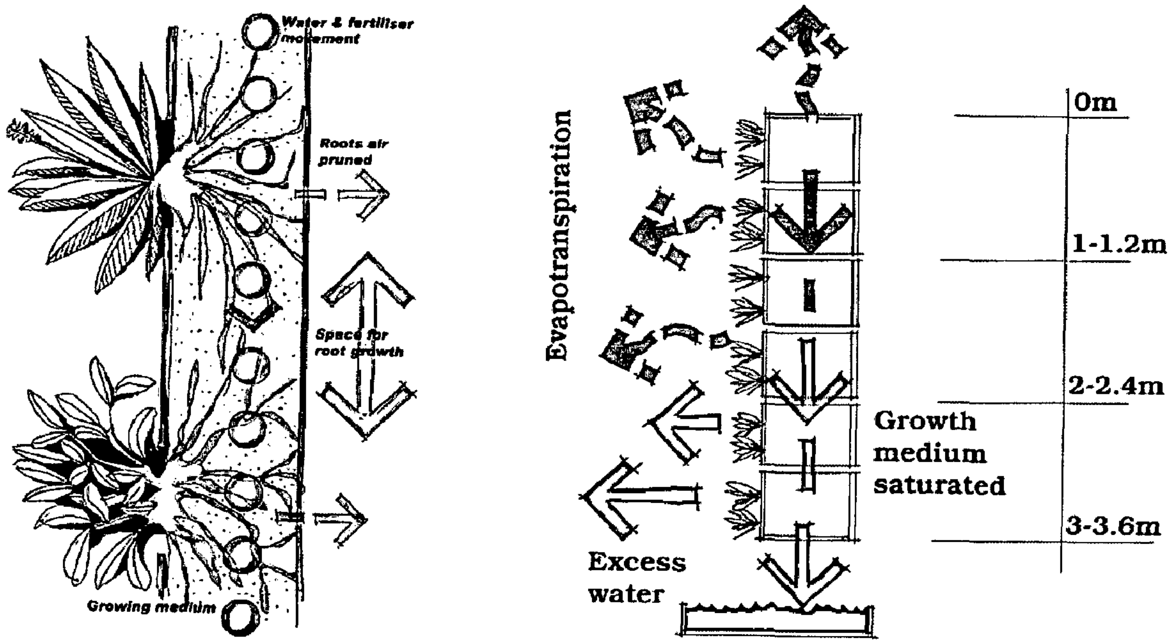
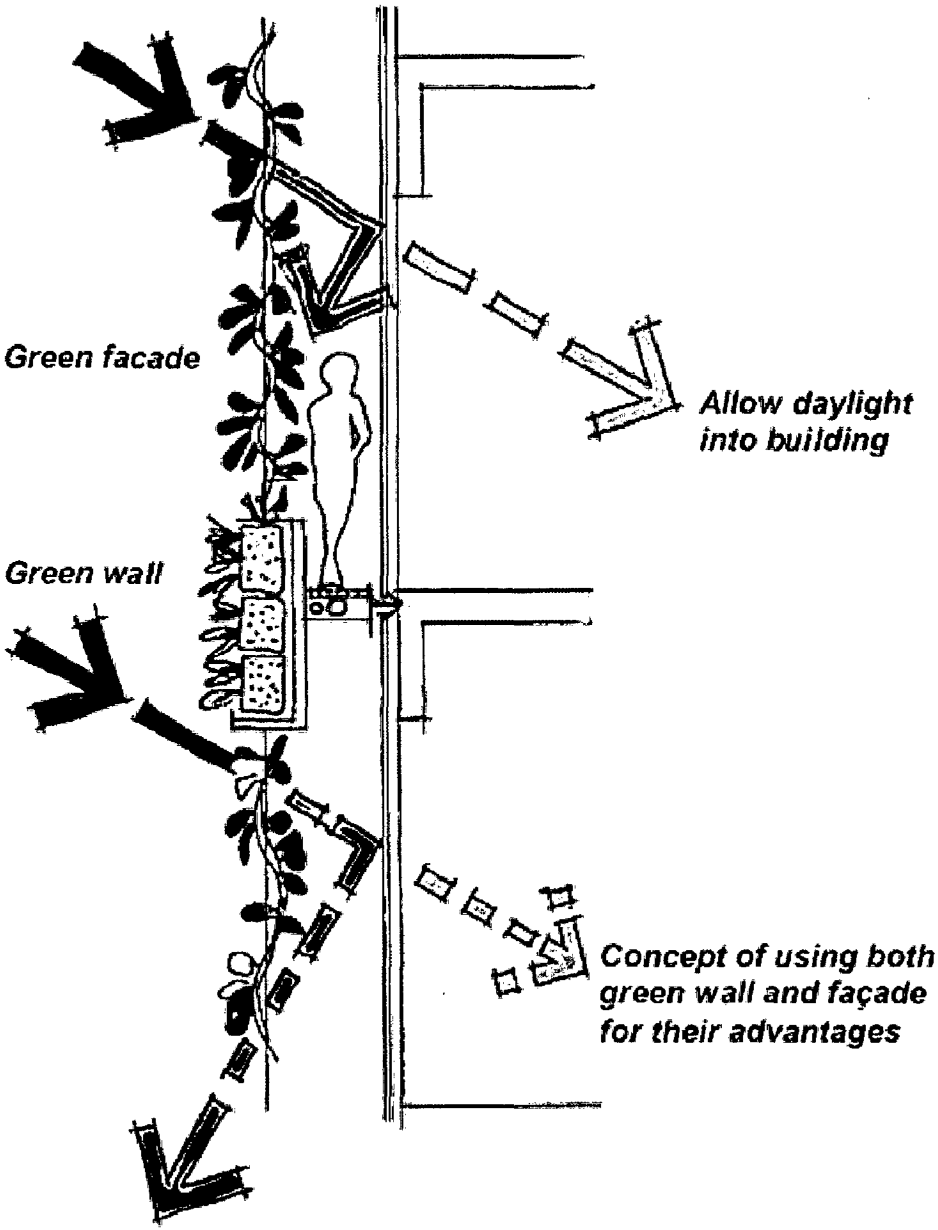


Figure 5.16- Water and fertilizer movement

t



Glazing issues

Light penetration
Reflectivity - heat
- various wavelengths

Figure 5.17- Hybrid system for better efficiency without restricting ligh

Existing concrete facade

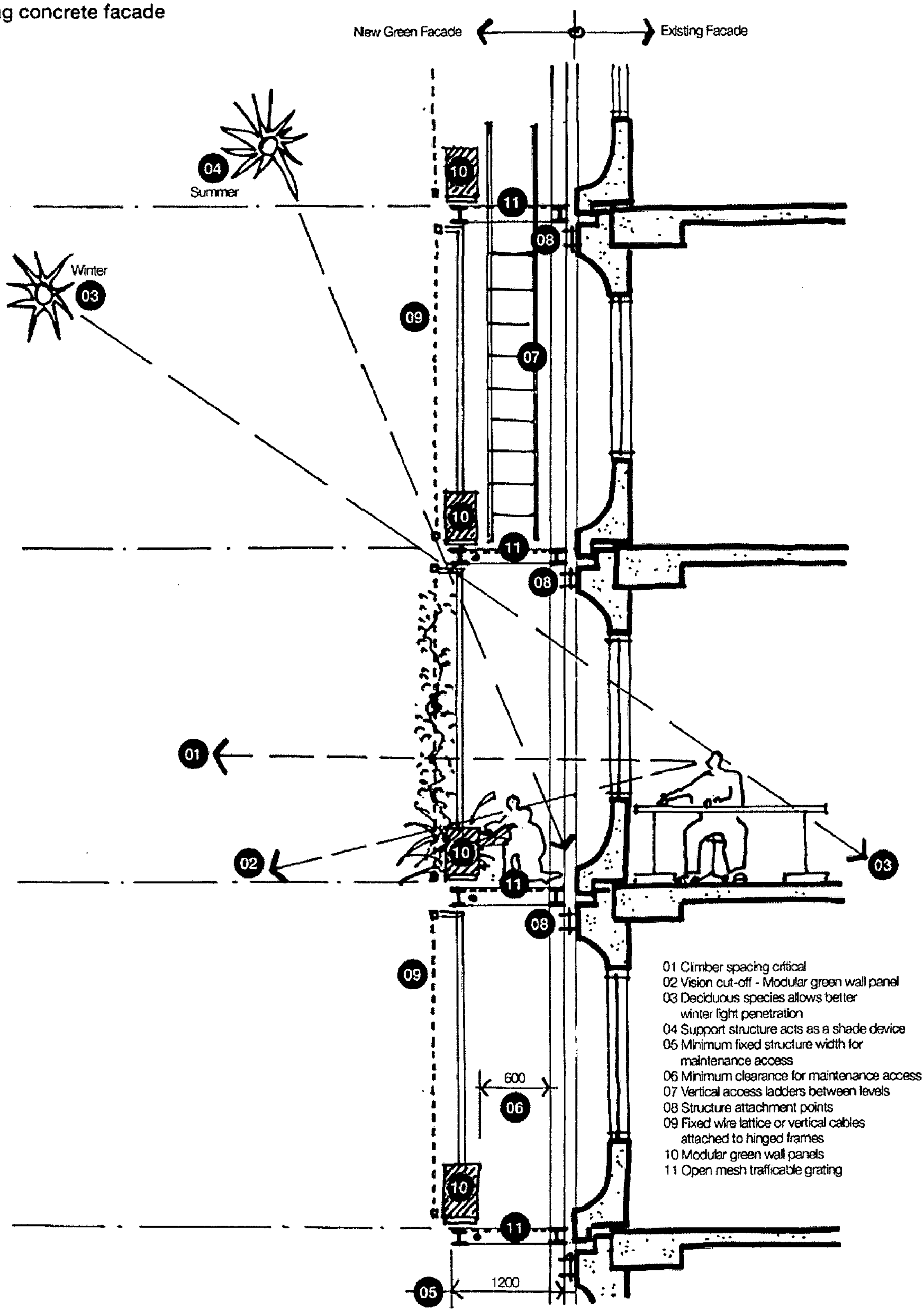


Figure 5.18- Integrating hybrid system with the existing building façade

Benefits

Thermal control-

All living walls will provide a certain level of shading onto the building façade but some types will have more intense shading than others. Green facades for instance generally are more transparent and therefore give less shading and insulation than green walls that are usually solid and allow no light through them. Shading the building façade will affect the heating and cooling loads on the air-conditioners and thus affect the running costs of the building.

Living walls with their planting and vegetation cover produce a process of evapotransportation consuming CO2 and producing water vapour. As the process of evapotranspiration actually cools the surrounding air therefore reducing the heat load onto the containing water vapour cools to the open sky quickly thus reducing the local air temperature.

Natural lighting-

There can be a conflict between the need for a living wall and the need for natural light. Similar to the shading effect, a green wall will block out the natural light into the building depending on the density of planting.

There are other techniques for having a green wall and natural light at the same time. For instance the CH2 building in Melbourne required both natural light and a living wall at right angles to the building to shade the building at an angle while allowing natural light to stream into the building.

- The other benefits include-
- Pollutants removal
- Dust control
- Noise reduction
- Connection to nature, etc.

Cost-

No two green walls are the same, so that each needs to have the associated costs and benefits calculated individually. Some of the most important variables that influence the capital and maintenance costs of green walls include the following:

1. Project size.
2. Design team costs.
3. System type.
4. Support structure requirements.
5. Building location.

6. Complexity of design, use of standard or custom components.
7. Site conditions and access.
8. Cost of installation labor.
9. Local availability of materials.
10. Project timeline.
11. Type of plants used.
12. Short and long term maintenance.

5.2 Building Skin

5.2.1 Fenestrations

5.2.1.1 Windows

Windows must be used to minimize the need for artificial lighting and to capture within the building a sizeable proportion of the sun's heat required to keep a comfortable temperature without overheating. The choice of glazing, shading, thermal mass and other factors can help achieve this. Modern windows are rated by national bodies and come with a declaratory label.

In the UK this is the British Fenestration Rating Council (BFRC). Choose windows with the highest possible rating on the label. 'C' is the minimum level for an eco-home (which the Energy Saving Trust says has a payback of five or six years). This label displays the following information:

1. the rating level: A, B, C, etc.;
2. the energy rating, e.g. –3kWh/(m2)/yr (= a loss of three kilowatt hours per square metre per year);
3. the U-value, e.g. 1.4W/(m2K);
4. the effective heat loss due to air penetration as L, e.g. 0.01W/ (m2K);
5. the solar heat gain G-value, e.g. 0.43

Solar gain

The heating effect of the sun in a building is called solar gain. It varies with the strength of the sun, its angle and the effectiveness of the glazing to transmit or reflect its energy. We want to maximize solar gain within the building in the winter (to reduce space heating demand) and to control it in summer (to minimize cooling requirements and solar glare). The composition and coating on each face of the glazing can be manipulated to optimize the greenhouse effect, while windows' size, position and shading can be used to optimize solar gain.

Using fenestrations to control solar gain

Variables that may be taken into account when choosing them include:

1. thickness;
2. number of panes;
3. coatings on the glass;
4. cavity size or fill;
5. nature of the spacer bar;
6. sealant used;
7. frame type;
8. frame materials;
9. fixing method.

Example of an energy label for a window from the BFRC

Note: The ratings are (in kWh/(m2)/yr):
A: 0
B: 0 to –10
C: –10 to –20
D: –20 to –30
E: –30 to –50
F: –50 to –70
G: –70 or worse
Source: www.bfrc.org

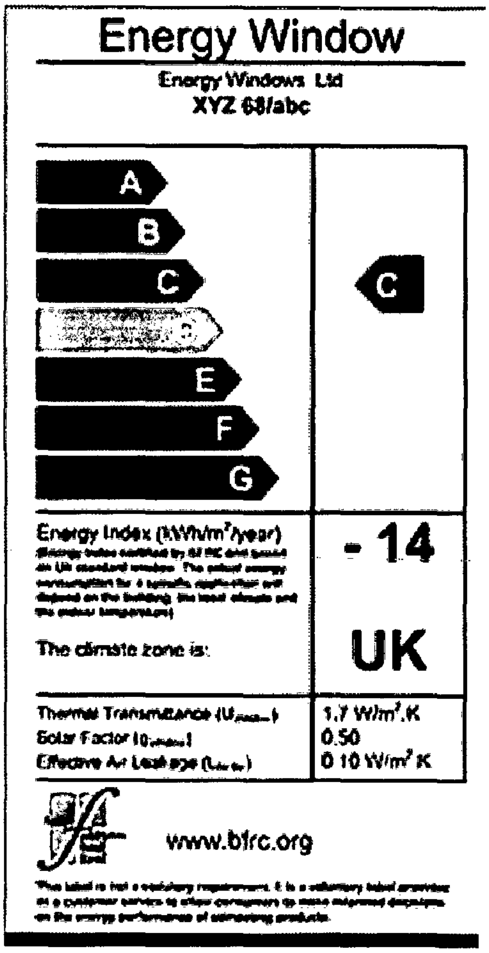


Figure 5.19- Example of window rating

5.2.1.1.1 Glazing

SHGC and VT-

The SHGC refers to total fenestration product system performance and is an accurate indication of solar gain under a wide range of conditions. SHGC is expressed as a dimensionless number from 0 to 1.0. A high SHGC value signifies high heat gain, while a low value means low heat gain.

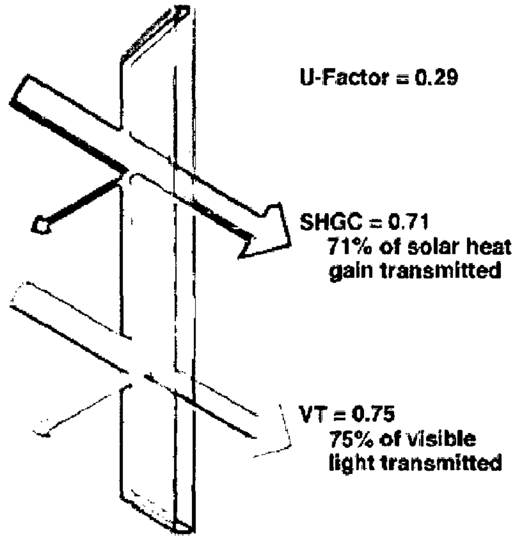


Figure 5.20- U-factor, SHGC, VT of a typical glass

Visible transmittance (VT)is the amount of light in the visible portion of the spectrum that passes through a glazing material. This property does not directly affect heating and cooling loads in a building, but it is an important factor in evaluating energy-efficient fenestration products. Transmittance is influenced by the glazing type, the number of layers, and any coatings that might be applied to the glazing.

Visible transmittance of glazing ranges from above 90 percent for water-white clear glass to less than 10 percent for highly reflective coatings on tinted glass. Visible transmittance is an important factor in providing daylight, views, and privacy, as well as in controlling glare and fading of interior furnishings. These are often contradictory effects: a high light transmittance is desired for view out at night, but this may create glare at times.

Table 5.1- shading coefficients for different type of glass and internal shadings

	Shading Coefficient, SC					
Type of glass	Thickness mm	No internal shading	Venetian blinds		Roller shades	
			Medium	Light	Dark	Light
Single glass Regular	3	1.00	0.64	0.55	0.59	0.25
Single glass Plate	6-12	0.95	0.64	0.55	0.59	0.25
Single glass Heat absorbing	6	0.70	0.57	0.53	0.40	0.30
Double glass Regular	3	0.90	0.57	0.51	0.60	0.25
Double glass Plate	6	0.83	0.57	0.51	0.60	0.25
Double glass Reflective	6	0.2-0.4	0.2-0.33	-	-	-

Glazing Materials-

Two basic materials are used for fenestration product glazing: glass, which is by far the most common, and plastics, which have many specialized applications.

Glass-

Traditionally, fenestration products have been made of clear glass. Most residential-grade clear glass today is produced with the float technique in which the glass is "floated" over a bed of molten tin. This provides extremely flat surfaces, uniform thicknesses, and few if any visual distortions. The glass has a slight greenish cast, due to iron impurities, but this is generally not noticeable except from the edge. An even higher-quality glass with reduced iron content eliminates the greenness and also provides a higher solar energy transmittance. This is commonly called "water-white glass." Obscure glasses still transmit most of the light but break up the view in order to provide privacy. This effect is generally achieved either with decorative embossed patterns or with a frosted surface that scatters the light rays.

By adding various chemicals to glass as it is made, glass can be produced in a wide variety of colors. Glass colors are typically given trade names, but the most frequently used colors can be generally described as clear, bronze, gray, and blue-green. After clear glass, the gray glasses are most commonly used in residential construction, as they have the least effect on the perceived color of the light. Tinted glass is discussed later in this chapter.

The mechanical properties of glass can be altered, as well as its basic composition and surface properties. Heat-strengthening and tempering make glass more resistant to breakage. Heat-strengthened glass is about twice as strong as standard glass. Tempered glass is produced by reheating and then quickly chilling the glass. It breaks into small fragments, rather than into long, possibly dangerous shards. Laminated glass is a sandwich of two outer layers of glass with a plastic inner layer that holds the glass pieces together in the event of breakage. Fully tempered and laminated glass is required by building codes in many door and fenestration product applications.

Plastics

Several plastic materials have been adapted for use as glazing materials. Their primary uses are fenestration products with special requirements and skylights.

The following list of plastic glazing materials covers the major types of plastic glazing materials and compares their general properties:

1. Clear acrylic is widely available and relatively inexpensive. It is available in various tints and colors. It has excellent visible light transmittance and longevity. However, it is softer than glass, which makes it vulnerable to scratching.
2. Frosted acrylic is like clear acrylic, except that it diffuses light and obscures the view. It comes in varying degrees of light transmittance. Most bubble skylights are made of frosted acrylic.

3. Clear polycarbonate is like acrylic sheet, but it is harder and tougher, offering greater resistance to scratching and breakage. It is more expensive than acrylic.

4. Fiber-reinforced plastic is a tough, translucent, flexible sheet material with good light-diffusing properties. Short lengths of fiberglass are embedded in a polymer matrix to form flat or ribbed sheets.

5. Stiff, insulating, translucent panels are created by bonding double layers to a metal frame and adding fiberglass insulation. It is also formed into corrugated sheets as a translucent roofing material. Surface erosion may shorten its useful life.

6. Extruded multicell sheet, usually made with acrylic or polycarbonate plastic, is a transparent or tinted plastic extruded into a double- or triple-wall sheet with divider webs for stiffness, insulating value, and light diffusion.

7. Polyester is a thin film used to carry specialized coatings and/or to divide the air space between two layers of glass into multiple air spaces. Highly transparent, it is protected from abuse and weathering by the two exterior glass layers. It can also be used in tinted or coated forms as film that is glued to the inner surface of existing fenestration products for retrofitting applications.

There are three fundamental approaches to improving the energy performance of glazing products:

1. Alter the glazing material itself by changing its chemical composition or physical characteristics. An example of this is tinted glazing. The glazing material can also be altered by creating a laminated glazing.

2. Apply a coating to the glazing material surface. Reflective coatings and films were developed to reduce heat gain and glare, and more recently, low-emittance and spectrally selective coatings have been developed to improve both heating and cooling season performance.

3. Assemble various layers of glazing and control the properties of the spaces between the layers. These strategies include the use of two or more panes or films, low-conductance gas fills between the layers, and thermally improved edge spacers.

Two or more of these approaches may be combined. Each of these improvements to the glazing is discussed below.

1. Tinted Glazing

Both plastic and glass materials are available in a large number of tints. The tints absorb a portion of the light and solar heat. Tinting changes the color of the fenestration product.

2. Reflective Coatings and Films

As the solar heat gain is lowered in single-pane tinted glazing, the visible light transmission drops even faster, and there are practical limits on how low the solar heat gain can be made using tints. If larger reductions are desired, a reflective coating can be used to lower the solar heat gain coefficient by increasing the surface reflectivity of the material.

3. Double Glazing

Double glazing reduce infiltration from winter winds by providing a seal around the entire operating sash and they improve the insulating value of the glazing as well.

The layers of glass are separated by and adhere to a spacer, and the sealant, which forms a gas and moisture barrier, is applied around the entire perimeter. Normally, the spacer contains a desiccant material to absorb any residual moisture that may remain in the air space after manufacture. Sealed insulating glass units are now a mature, well proven technology. Designs utilizing high-quality sealants and manufactured with good quality control should last for decades without seal failure.

4. Glass Coatings and Tints in Double Glazing

Both solar reflective coatings and tints on double-glazed fenestration products are effective in reducing summer heat gain; however, only certain coatings contribute to reducing winter heat loss, and tints do not affect the heat loss rates at all. It is possible to provide reflective coatings on any one of the four surfaces, although they are usually located on the outermost surface or on the surfaces facing the air space. Coating location can also depend on the type of coating. Some vacuum-deposited reflective coatings must be placed in a sealed air space because they would not survive exposure to outdoor elements, finger prints, or cleaning agents. Pyrolytic coatings that are created with a high-temperature process as the glass is formed are extremely hard and durable and can be placed anywhere. Each location produces a different visual and heat transfer effect.

5. Multiple Panes or Films

By adding a second pane, the insulating value of the fenestration product glass alone is doubled (the U-factor is reduced by half). As expected, adding a third or fourth pane of glass further increases the insulating value of the fenestration product, but with diminishing effect. Triple- and quadruple-glazed fenestration products became commercially available in the 1980s as a response to the desire for more energy-efficient products. There is a trade-off with this approach, however. As each additional layer of glass adds to the insulating value of the assembly, it also reduces the visible light transmission and the solar heat gain coefficient, thereby reducing the fenestration product's value for providing solar gains or daylighting. In addition, other complications are encountered. Additional panes of glass increase the weight of the unit, which makes mounting and handling more difficult and transportation more expensive.

6. Heat Reflecting Low Emissivity Glass

Low emissivity (low-E) or thermally insulating glass has a transparent metallic coating on one side. This coating reduces the amount of heat lost through a window by reflecting the heat generated inside the house (long wave infra-red radiation) back into the room. There are two types of low-E glass depending on the manufacturing process used –'soft coat' and 'hard coat' low-E glass.

Heat-reflecting windows are usually sealed, double-glazed units—ones with two panes of glass separated by a noble (unreactive) gas such as argon that improves insulation (stops heat from escaping in air drafts). The inner surface of one of the panes of glass is coated with a very thin layer of metal or metallic oxide. The coating can be applied in two ways. One way is a process called sputtering, where a thin film is fired onto the surface of the glass to make what's called soft-coated glass. The other process involves heating glass to high temperatures in a chemical vapor, so the coating material condenses onto its surface. That makes what's called pyrolitic or hard-coated glass. The coating in soft-coated glass is relatively delicate (gradually eroded by moisture and air and easier to rub off), so it's used only on the inside face of sealed double-glazed units. Hard-coated glass is slightly less effective at reflecting heat though much more robust, so it can be used in single-pane windows (though that also makes it less effective as heat insulation, since the air gap in double-glazed units plays a major part in retaining heat).

Table 5.2- thermal and optical properties of commercially available glazing units.

House of Color	Shade	Brand / Product	Light Transmission	Solar Factor	U-Value
Neutrals	Clear Cosmos	ET 125 / Evo	24	0.22	1.94
	Iris	SKN 144 / Envision	40	0.23	1.6
Blues	Blue Breeze	ST 736 / Cool-Lite	22	0.25	2.8
	Misty Blue	KT 755 / Nano	33	0.25	1.8
	Twilight Blue	KT 740 / Nano	24	0.2	1.8
	Lumosa	SKN 744 / Envision	26	0.18	1.6
	Quasar	SKN 754 / Envision	32	0.2	1.5
	SKN	SKN 765 / Envision	39	0.23	1.6
Blue Greens	Turquoise	ST 436 / Cool-lite	27	0.25 0%	2.76
Greens	Olive	KT 455 / Nano	39	0.25	1.86
	Tropica Green	KT 440 / Nano	30	0.21	1.8
	Futura	SKN 444 / Envision	33	0.2	1.6
	Nebula	SKN 454 / Envision	41	0.22	1.5
	SKN	SKN 465 / Envision	49	0.25	1.6

Table stating the thermal and optical properties of commercially available glazing units.
Source- Saint Gobain India

Frames

Wooden Frames

Wood-framed products perform well. The thicker the wood frame, the more insulation it provides. Wood-framed fenestration products typically exhibit low heat loss rates. Metal cladding, metal hardware, or the metal reinforcing often used at corner joints can degrade the thermal performance of wood frames. If the metal extends through the fenestration product from the cold side to the warm side of the frame, it creates a thermal short circuit.

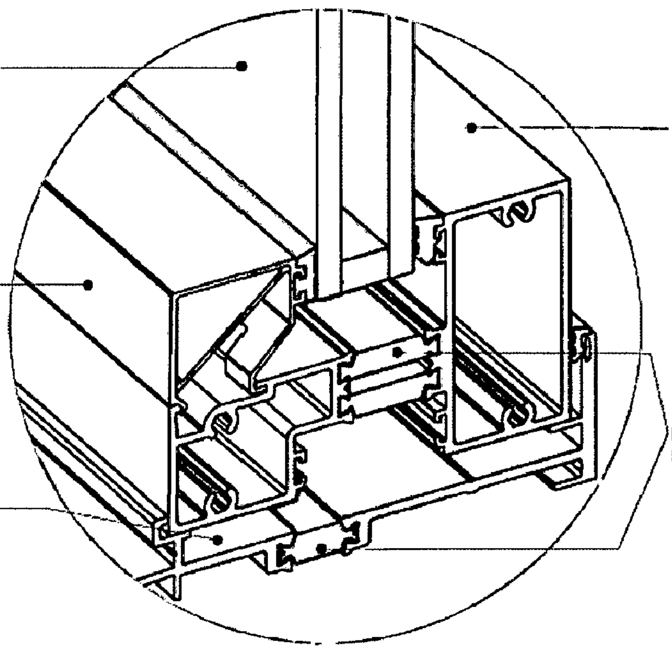
Aluminum Frames

As a fenestration product frame material it has its high thermal conductance. It readily conducts heat, greatly raising the overall U-factor of a fenestration unit.

The most common solution to the heat conduction problem of aluminum frames is to provide a "thermal break" by splitting the frame components into interior and exterior pieces and use a less conductive material to join them.

Vinyl Frames

Plastics are relative newcomers as fenestration product frame materials in North America. Vinyl, also known as polyvinyl chloride (PVC), is a versatile material with good insulating value. The thermal performance of vinyl frames is roughly comparable to wood. Large hollow chambers within the frame can allow unwanted heat transfer through convection currents. Creating smaller cells within the frame reduces this convection exchange, as does adding an insulating material.



Source-Thermalheart.com.au

Figure 5.21- Typical thermally broken aluminium window frame

5.2.1.2 Doors

Some doors may need to be replaced. Replacement doors and windows should have insulated cores, in other words, insulation between the two outer surfaces, to prevent cold-bridging. One can get doors with U-values as low as 0.6W/m2K, commonly using an insulating core of polyurethane sandwiched between an outer skin, preferably of hardwood timber.

5.2.2 Airtightness

The core aim of energy efficient retrofit is to reduce the demand for energy for heating and cooling while improving the comfort of occupants. The first step to achieving this is to reduce unwanted draughts or air infiltration and leakage. Uncontrolled airflow in and out isn't what is needed. Instead, buildings must breathe in a controlled way that permits the occupiers to regulate air quality – humidity, cleanliness, temperature and so forth. This will ensure huge savings over the building's lifetime.

The aim of airtightness is to 'build tight, ventilate right'. This means that there are no breaks or gaps in the envelope of the building fabric, to maintain a controllable interior temperature at low operating cost regardless of the conditions outside – a climate-controlled home can keep out hot air during hot spells, as well as banish cold air streams in wintry weather.

Airtightness is measured in air changes per hour (ACH) – the number of times the home's air is replaced by outside air in an hour. Tightly constructed buildings may reach an ACH of 0.6 to 0.5 or less.

Airtightness is also described in terms of building envelope permeability – in cubic metres of air leakage per square metre of external area of the building per hour – m3/m2 h at 50 Pascals. It is defined in BS EN 13829. Minimum targets apply as follows:

Table 5.3- Air changes per hour standards

Target	m3/m2h
Part L of the UK Building Regulations	10[a]
Energy Saving Trust Best Practice	5[b]
Code for Sustainable Homes (CSH) level 3–5	3[c]
Higher CSH levels (they go up to 6)	1
Passivhaus	0.6
NBC	5 to 8[d]

Notes:

a. *Source: Amendments to SAP 2005 (version 9.81) April 2008.*

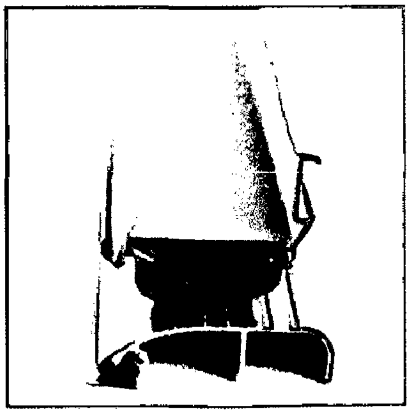
b. *Upper limit under Part L Source: 'Proposed Building Regulations Part L1a 2010': NHER Summary of the Consultation, National Energy Services Ltd, June 2009; Source: EST CE83.GPG155 'Energy-efficient refurbishment of existing housing' (Nov 2007 edition).*

c. *The Code itself stipulates no figures for airtightness or permeability. Instead it discusses the building fabric in terms of heat loss parameters. But the Energy Saving Trust has produced helpful documents to show strategies for achieving the targets, which take for granted a target of 3m3/h m2 at 50 Pascals. Sources: 'Energy efficiency and the Code for Sustainable Homes Level 3 EST CE290' (June 2008 edition); 'Energy efficiency and the Code for Sustainable Homes Level 4 EST CE291' (May 2008 edition); 'Energy efficiency and the Code for Sustainable Homes – Levels 5 and 6 EST CE292' (May 2008 edition).*

d. *SP 7, National Building Code, India, 2007.*

5.2.2.1 Doorframes and doors

Badly fitting doors are major sources of draughts. Draughtstripping is inexpensive, simple to install and can greatly improve comfort as well as reducing fuel bills. Exterior doors should be fixed first, then (unless you're installing whole house ventilation) the interior doors, to stop air travelling from unheated (or uncooled) areas of the building to others. Typical payback for doors and windows is three to four years.



Source: © Energy Saving Trust

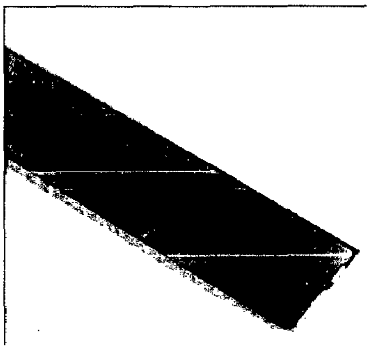
Figure 5.22- Compression seal

Various types of seals are available depending on the door and the side to be sealed:

Compression seals: for external doors-

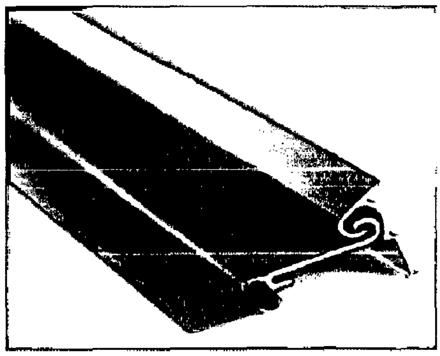
Draughtstrips with a range of 6mm and a compression allowance of 3mm will allow for a seasonal variation in gap size of up to 3mm. The seal is maintained if the gap expands and when it shrinks the door will still close. Synthetic rubbers (including EPDM and silicone seals), sheathed foam or nylon brush, all perform well, with rigid PVC-U or aluminium carriers nailed or screwed to the frame of the door. Don't over-paint them.

Low-friction or wiper seals-
suitable for most doors and window types. Commonly made of nylon brush pile, they are self-adhesive and available in a variety of heights for different gaps; especially good on sliding windows and doors. Rubber blade types are good for wooden doors and casement windows and sliding applications.



Source: © Energy Saving Trust

Figure 5.23- Brush strip



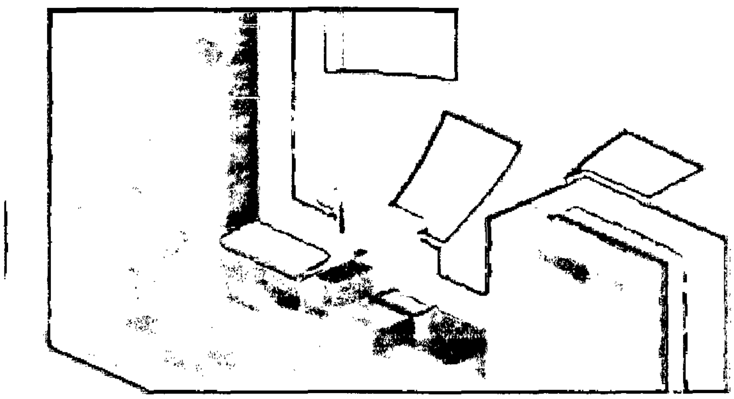
Source: © Energy Saving Trust

Figure 5.24- Wiper seal

Gun-applied sealants and fillers-
larger gaps, including those at the heads of windows, can be filled using silicone or polyurethane sealants. These expand, set and harden to fill the gap permanently. Do not apply to dusty or wet surfaces and check that the filler has fully filled the gap and bonded.

5.2.2.2 Window frames and openings

A typical building gains 10 per cent of its heat through the windows. Many of the same seals used for doors can be used for most casement windows and can be fitted to the frame. Repairing any damage and ensuring the casements, sashes and top-lights close firmly.is a very good solution Replacement is essential for any ineffective closing mechanisms with tightfitting ones.



Source: © Energy Saving Trust

Figure 5.25- Air paths around a typical window

Application of draughtproofing to gaps around window opening casements, sashes and top-lights.is important Outside, a sealant is used to fill the gaps around frames to prevent air leakage from the reveals. Inside, a bead of mastic is applied to any gaps between the wall reveals/ window boards and units. Fitting draughtstrips can be difficult because of varying gap sizes around the edges of the frame. Strips are meant for specific gap ranges, for example, 3–5mm or 1–2mm. Choose the right one for your gap size. Tiny gaps along the length of a door or window may be tackled by enlarging the gap so it can take a strip, or one can be fitted outside the gap (face fixed).

Face-fixed seals have two parts: a seal which moves against the door or window to close the gap and a carrier fixed to the frame which holds it firmly in place. These are adapted to the variable gaps of warped frames and doors by adjusting the position of the carrier. For historic buildings, specialist companies cut grooves into the frames to hide the draughtstrips. Hidden brushes or seals can be fitted to the bottom sections of wooden doors which retract automatically upon opening.

Sash windows present a particular problem. The gaps around the average one can equate to an aperture measuring up to $25cm^2$. Various brush or plastic/rubber beads are available. Some can be push-slotted in without damaging the timber, also preventing rattle and improving sound insulation. Compression seals are also good. A compression of 3mm is usually fine.

Secondary glazing is an improvement on draughtstripping, if the windows cannot be replaced. These are removable glazed frames constructed to fit snugly in the window recess to prevent draughts and be easy to remove for window cleaning, painting or opening. They can also really help in cutting noise from outside.

Figure 5.26- Secondary glazing on a sash window

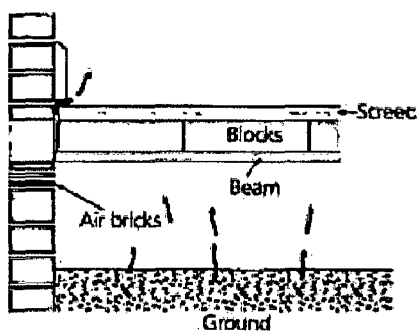
Poorly fitting window frames can also be a source of draughts. Check particularly underneath the window sill, where it penetrates the wall. Gunned-in compatible sealant is ideal for small joints, but first clean joints and prime surfaces to ensure a good bond. For larger openings use a pre-compressed flexible expanding foam strip. Ensure that where present the airtight membrane meets and overlaps the seal to maintain the airtight layer overall.

5.2.2.3 Gaps: Between walls, floors, ceilings, and skirtings

Suspended ceilings will almost certainly have gaps at the junctions with walls (inside and out), cornices and around service entry points (water pipes behind baths, sinks and WCs). Air can slip to and from the unheated floor void. Often it's because blocks were left out somewhere or large holes cut through them to let pipes pass through. First, around all the edges of rooms should be sealed. With solid ground floors, junctions between the ground floor slab and the external walls are usually hidden by the skirting board; air can leak through the small gap underneath. In the absence of a damp-proof membrane, gaps and cracks in the ground floor can allow air and ground gases (e.g. radon and landfill gas) to be drawn into the building.

5.2.2.4 Construction joints between materials

Gaps between slats in timber construction, around the ends of floor joists or joist hangers and between solid insulation and rafters, struts or floorboards are all your enemy – sources of draughts which can ruin your best attempts to be airtight. Apply the same logic here as described above under window and door frames: ensure the joints between boards are sealed. If there are many large gaps consider fitting an airtightness membrane.



Air leakage around perimeter of beam-and-block floors

Figure 5.27- air leakage around beams

5.2.3 Insulation

Insulation materials come in many different forms, shapes and sizes. It is very difficult to choose between them. When we are modeling our retrofitting plans, we need technical information about their performance and characteristics.

Thermal conductivity (k)

Thermal conductivity, k (also known as psi), tells us how well a material conducts heat. It is:

k = Q/t times 1/A times x/T

or the quantity of heat, Q, transmitted over time t through a thickness x, in a direction perpendicular to a surface of area A, due to a temperature difference T. The units used are either SI: W/mK or in the US: Btu/(h/ft/°F). To convert, use the formula 1.730735Btu/(h/ft/°F) = 1W/mK.

R-value

The R-value is a measure of how well a material resists heat travelling through it. It is the ratio of the temperature difference across an insulator and the heat flow per unit area through it. The bigger the number the better the insulator. It is the depth or thickness of a material divided by its thermal conductance, in other words, R = d/k.

Doubling the thickness of an insulating layer doubles its thermal resistance. R-values are often used when there are multiple materials through which heat can travel. The R-values of adjacent materials can be added together to calculate the overall value; e.g., R-value (brick) + R-value (insulation) + R-value (plasterboard) = R value (total).

U-value

R-value is the reciprocal of U-value (and vice versa of course). A lower U-value is better than a higher one, indicating greater insulation value. It is commonly used in Europe and is the overall heat transfer coefficient, describing the rate of heat transfer through a building element over a given area, under standardized conditions. The usual standard is at a temperature gradient of 24°C, at 50 per cent humidity with no wind.

Thermal properties of some building materials.

Table below lists the thermal properties of some building materials: their density, thermal conductivity (k) and specific heat capacity (a measure of how much heat energy is required to increase its temperature by a specific amount).

Table 5.4- thermal properties of some building materials

Material	Density specific (kg/m³)	Thermal (k) conductivity (W/mK)	Heat capa (J/kgK)
WALLS			
Brickwork (outer leaf)	1700	0.84	800
Brickwork (inner leaf)	1700	0.62	800
Cast concrete (dense)	2100	1.40	840
Cast concrete (lightweight)	1200	0.38	1000
Concrete block (heavyweight)	2300	1.63	1000
Concrete block (mediumweight)	1400	0.51	1000
Concrete block (lightweight)	600	0.19	1000
Fibreboard	300	0.06	1000
Plasterboard	950	0.16	840
Stone (artificial)	1750	1.3	1000
Stone (limestone)	2180	1.5	910
Tile hanging	1900	0.84	800
SURFACE FINISHES			
External rendering	1300	0.50	1000
Plaster (dense)	1300	0.05	1000
Plaster (lightweight)	600	0.16	1000
ROOFS			
Aerated concrete slab	500	0.16	840
Asphalt	1700	0.50	1000
Felt/bitumen layers	1700	0.50	1000
Screed	1200	0.41	840
Stone chippings	1800	0.96	1000
Tile	1900	0.84	800
Wood wool slab	500	0.10	1000
FLOORS			
Cast concrete	2000	1.13	1000
Metal tray	7800	50.00	480
Screed	1200	0.41	840
Timber flooring	650	0.14	1200
Wood blocks	650	0.14	1200
INSULATION			
Expanded polystyrene slab	25	0.035	1400
Glass fibre quilt	12	0.040	840
Glass fibre slab	25	0.035	1000
Mineral fibre slab	30	0.035	1000

Source: Bath University Civil Engineering Department, www.bath.ac.uk/mech-eng/sert/embodied

5.2.3.1 External wall insulation

External wall insulation involves applying an insulating layer and a decorative weatherproof finish to the outside wall of a building. The aim is to reach U-values of below 0.30W/m2K (half of this for Passivhaus standard). The external cladding or render is generally the major cost, so you want to maximize the amount of insulation to maximize the benefits.

Benefits-

1. allows the wall's thermal mass to moderate the internal temperature, reducing the need for heating and cooling;
2. unlike cavity wall insulation (limited by cavity size) can achieve almost any thermal performance – used on 'zero carbon' buildings;
3. can be installed without inconvenience to occupants and reduction in room sizes so can often be easier and quicker especially if a whole block or terrace is treated at once;
4. interstitial and internal condensation (damp, mould) can be banished;
5. any gaps and cracks in the wall are covered in one go;
6. weather protection;
7. a wide variety of decorative finishes;
8. solves thermal bridging problems for example where there is an exposed concrete frame;
9. protects the structure from external/internal temperature differentials;
10. the dew point, where vapour from inside the building is likely to condense, is further towards the outside and away from critical structural or load-bearing wall elements.

Systems available

Three generic types of external insulation are available:

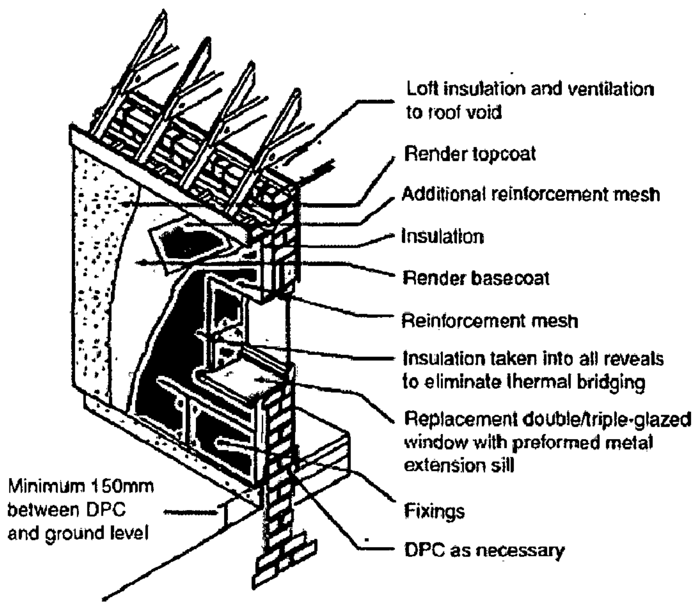
1. wet render systems;
2. dry cladding systems;
3. bespoke systems.

The first two are most commonly used in external wall insulation.The third one is very limited field application (only in cold climates).

Wet render systems-

These eliminate the need for extensive re-pointing, saving money. In general they are cheaper than dry cladding. What distinguishes a high-performance from a low-performance system is the quality and thickness of the render. They consist of:

1. insulant;
2. adhesive mortar and/or mechanical fixings;
3. profiles and edgings used on corners, at damp-proof course (DPC) level, window
4. reveals, verges and copings;
5. a base-coat render, incorporating a glass fibre, plastic or metal mesh;
6. a top-coat render, with or without a finish.

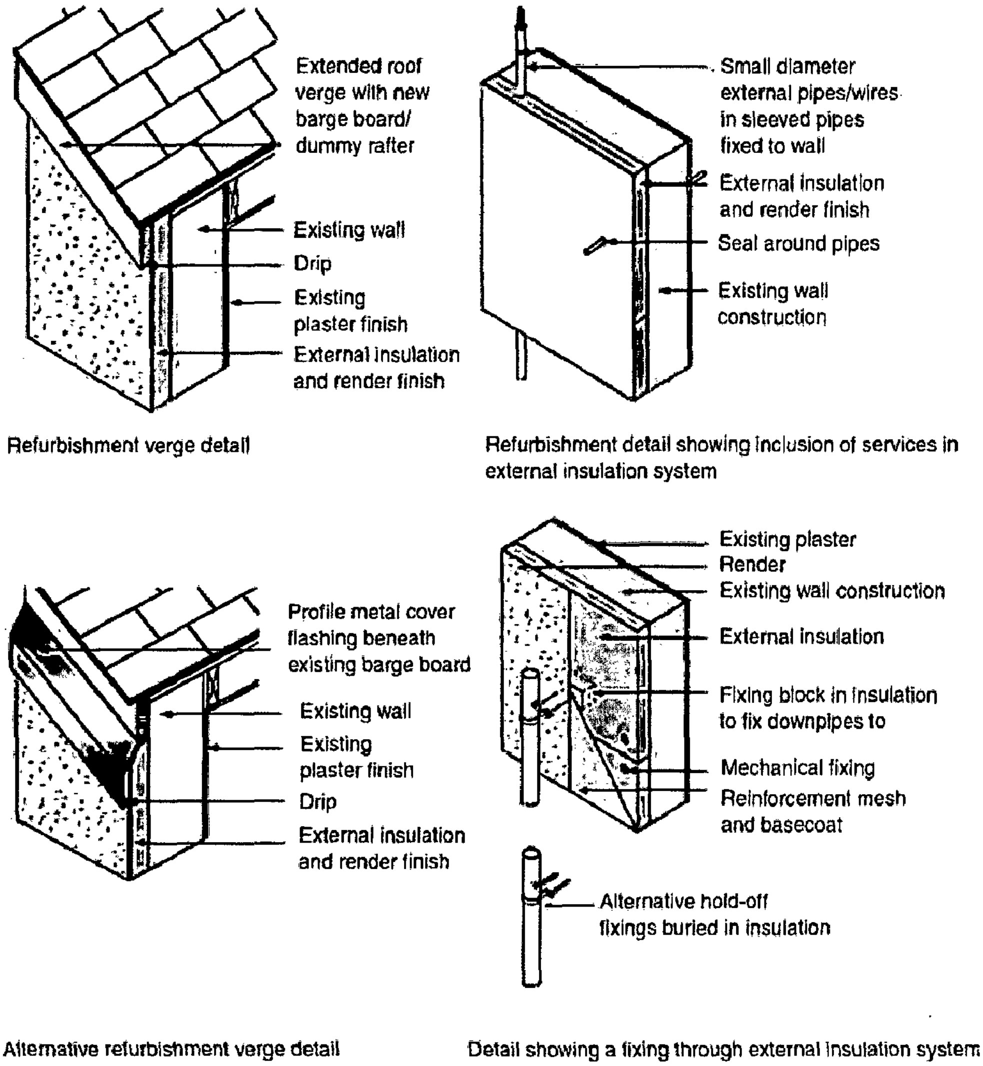


Typical wet render system applied to an existing solid masonry wall

Source: © EST

Figure 5.28- Typical wet render system

Traditional render and polymer-modified cementitious render can be used in low-rise and high-rise applications. Polymer helps make the render more workable on site and, in larger quantities, gives weather protection and flexibility. However its quality is variable – it can weather out, especially on EPS, making maintenance a headache. The reduced weight may be advantageous in high-rise. These coatings do not need movement joints unless the building has them.



Source: EST (2006)

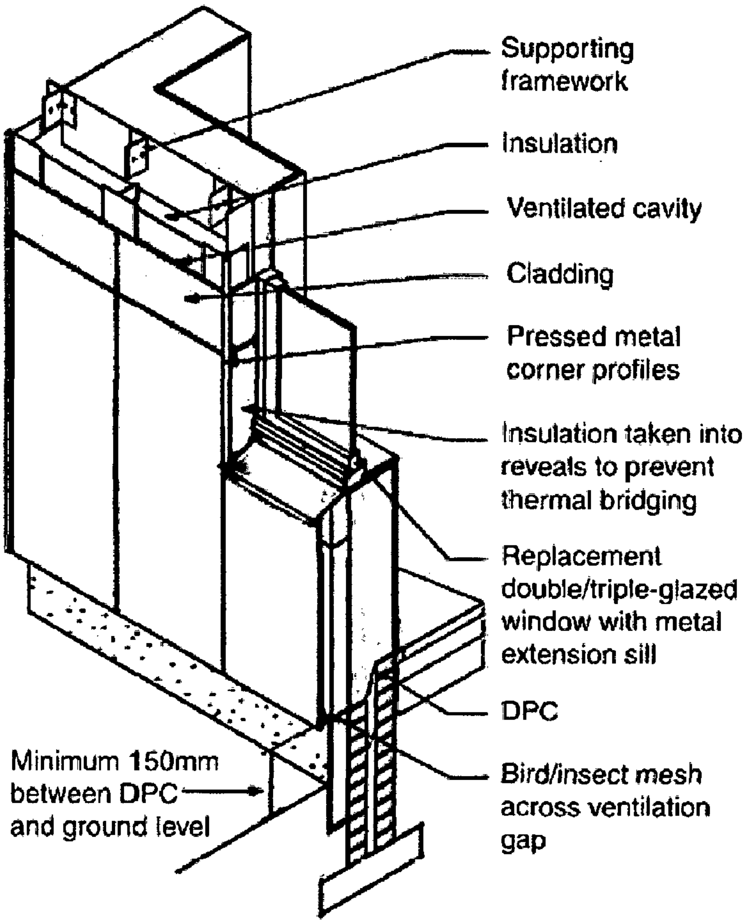
Figure 5.29- External insulation details

Dry cladding systems

Useful where fixings have to be restricted to particular areas. Seldom used on low-rise as cost can be prohibitive. Access can be gained for periodic checks and maintenance, often necessary on high-rise buildings. Use a variety of supporting frameworks fixed to the substrate or building structure. The cladding is fixed to the framework using standard technologies. They consist of:

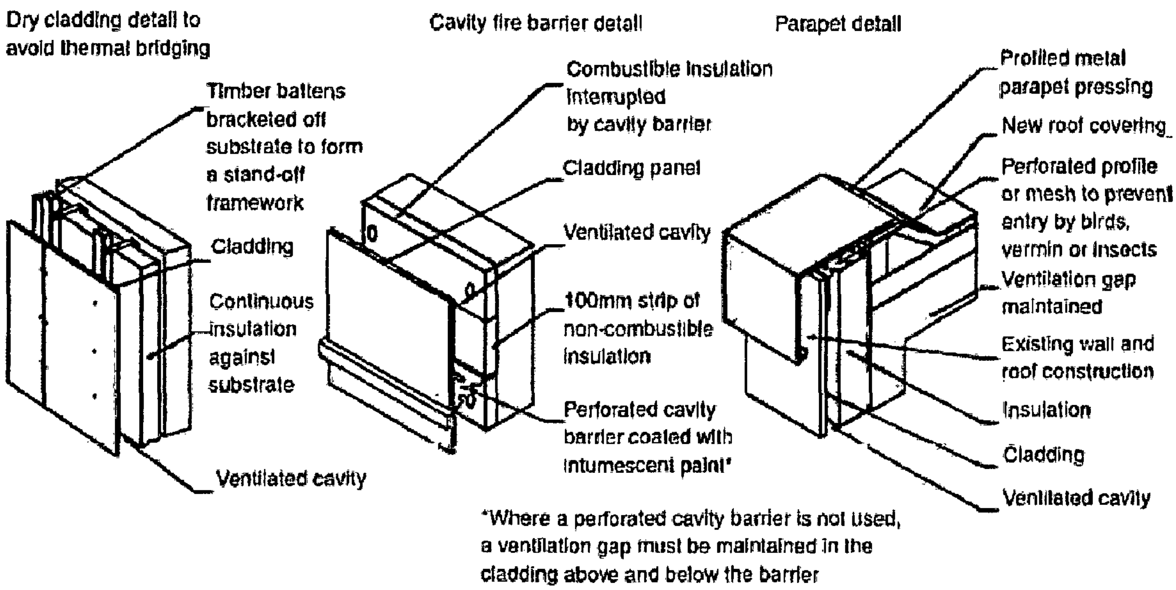
1. the insulant, fixed to the substrate in a similar way to wet systems;
2. a supporting framework or cladding fixing system;
3. a ventilated cavity;
4. cladding material and fixings.

The insulant may be independently fixed to the substrate with a mechanical or adhesive fixing, or partially retained by the framework. Supporting frameworks are made of treated timber, steel or aluminium. An adjustable framework enables a true plane to be constructed over an uneven substrate. With a stand-off framework or crossbattening, a continuous layer of insulation can be applied, minimising thermal bridging. Quilt material (rolls) can also reduce this risk by forming a tight fit around the framework. Insulation boards may be mineral fibre, expanded polystyrene, polyisocyanurate or phenolic. One brand is manufactured from recycled marine and industrial waste and used specifically on 'park homes' – mobile homes/bungalow-chalets. These systems can span over substrate areas where fixings cannot be anchored. The size and frequency of framework members, as well as the strength of fixing to the substrate, must be designed to withstand wind-loadings in accordance with manufacturers' recommendations. Most systems incorporate a ventilation cavity between the cladding and the insulation to ensure that any penetrating moisture is carried away. Materials must not be flammable.



Source: © EST

Figure 5.30- Typical dry cladding system



Source: © EST

Figure 5.31- Details for dry cladding systems

Common cladding materials include:

1. resin-impregnated laminates;
2. highly compressed mineral wool;
3. fibre-reinforced calcium silicate aluminium panels;
4. clay tiles;
5. recycled glass granulate suitable for seamless thin coat render.

A rainscreen cladding will have open joints, while a fully sealed system will have sealed joints. A wide range of colours and textures are available. Pressed profiles, trims and cover/edge retention strips can be added to enhance the decorative effect.

Bespoke systems

Designed for individual projects and tend to have simple detailing, allowing a non-specialist to construct them. A typical design may consist of a rainscreen fastened onto a substrate such as single blockwork with timber framing.

The photograph on the right illustrates the use of unseasoned oak weatherboard as an external cladding and blockwork providing internal thermal mass. Timber studwork and a sheathing material create a 250mm cavity filled with loose cellulose insulation.

Bespoke system using unseasoned oak cladding.
Source: © Clive Boursnell

Figure 5.32- Bespoke system

5.2.3.2 Internal insulation

External insulation is usually the best solution but it can be more expensive and, for example with listed buildings in conservation areas, may not be possible. Internal insulation is therefore the way to go and is also used when the dwelling is being renovated piecemeal fashion.

A U-value of at least 0.30W/m2K is the aim. A major disadvantage, besides the loss of internal space, is the need to move electrical sockets and light switches and problems in a home with character features such as coving, panelling and picture rails. The condition of the wall must be assessed and repaired first. Then consider where any fixtures such as kitchen units, radiators and wash basins may be located afterwards and fit timber fixing battens within the insulation layer. However, the battens form thermal bridges and should be minimized.

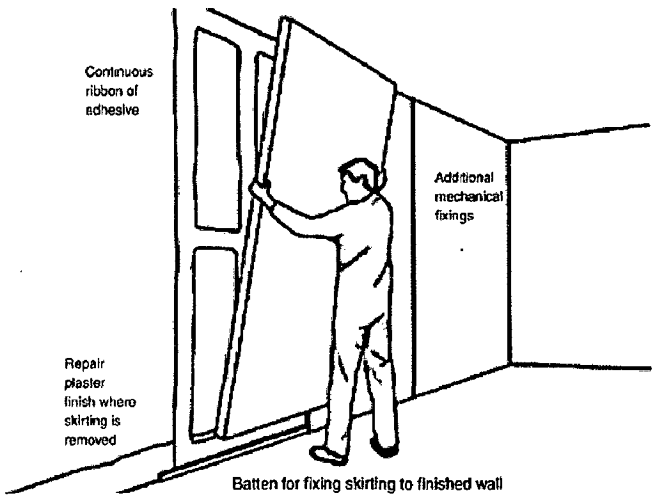
Avoid covering cables in insulation – especially high load ones – it can cause them to overheat and create a fire hazard; if in doubt, consult an electrician, as with all work associated with electrical systems. PVCsheathing on electrical cables may degrade in contact with polystyrene – use cover strips or place in ducts. Cables less than 50mm from the surface of the plasterboard should be enclosed in metal conduits.

This will, however, create a 'step' in level of the surface of the wall/floor/ceiling which will need to be designed for. Where the outside wall receives driving rain you'll need a small space (2–3cm) behind the dry lining to break any moisture transmission path and reduce damp risk.

Two techniques are available:

5.2.3.2.1 Insulated plasterboard:

Thermal boards glued directly on to the internal walls. Can be a plasterboard sheet laminated to an insulation board, or the board may be separate. Some have a built-in vapour control layer to stop moist internal air condensing on the cold brick behind the insulation. The thicker the board, the lower the U-value (higher R-values). There must be absolutely no gaps between the boards. If the brickwork is uneven (perhaps after the removal of existing plaster), render the wall first to provide an even surface. Apply thick continuous ridges of plaster adhesive round the edges of the wall and around all openings (such as sockets and plumbing) to preserve airtightness by plugging potential leaks. Leave a small cavity between the internal wall surface and the insulation. Some even recommend spreading adhesive over the entire surface area to eliminate the possibility of any air movement.



Directly applied internal insulation using insulated plasterboard.
Source: © EST

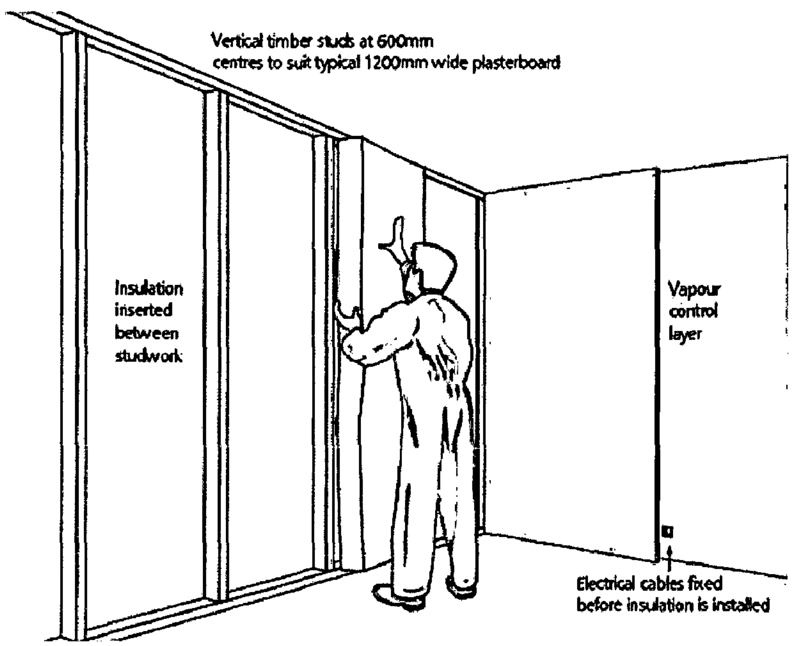
Figure 5.33- Internal insulation with plasterboard

5.2.3.2.2 Studs:

should be employed on a wall that has previously suffered from damp. This lets you create a cavity between the internal wall surface and the insulation. Studwork is also good where the wall is bowed or uneven and space is not at a premium. Three types of systems are available:

1. steel systems with thermally broken sections will give improved performance but higher embodied energy;
2. insulating studs made of extruded polystyrene laminated to oriented strand board (OSB), like timber studs but with an improved U-value;
3. traditional timber – treat with preservative, including exposed end grain.

A damp-proof membrane should be placed between the studs and wall. Studs are fixed to the walls at intervals relative to the thickness of the material that's going to fill the gaps between them: boards, batts or even wet-blown cellulose. The insulation is then inserted – absolutely no gaps – and plasterboard fixed to the studs. Next, an 'intelligent' vapour control layer (VCL) is continuously fitted, by lapping and bonding the membranes together, sealing them back to the floor, internal walls and windows. In some situations, for example in rented accommodation or where hanging wall units are needed, a more robust structure featuring studs at 400mm centres may be more suitable. It should be remembered that more studwork will reduce thermal performance.



Installing internal insulation with studwork
Source: © EST

Figure 5.34- internal insulation with stud

5.2.3.3 Ceiling insulation

Suspended, false or dropped ceiling insulation is a very important measure to reduce the thermal gain and contact of cool inside air with the hot roof. False ceiling reduces the active air volume of rooms and reduces the AC load at the same time. It conceals the electrical wire ducts, AC ducts and sprinkler supply line to increase the aesthetics of the room. The degree of insulation by the false ceiling mainly depends on the thickness of the main insulating material. The suspended ceiling is a good option to reduce the AC load even when no insulating material is used.

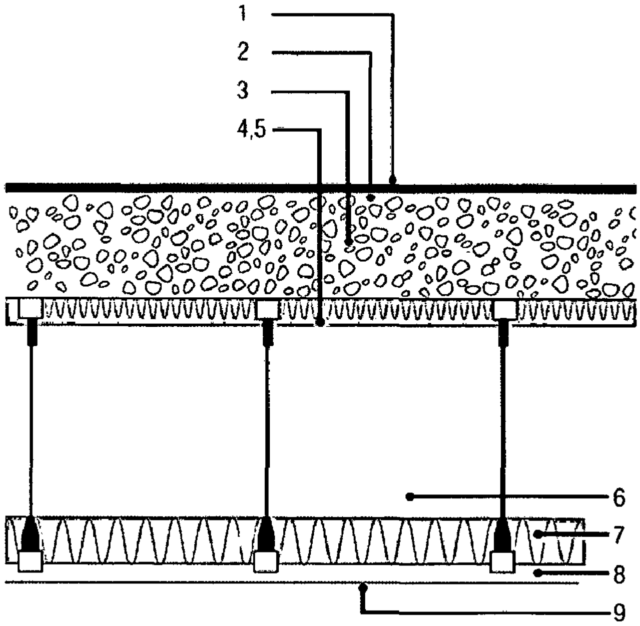


Figure 5.35- Ceiling insulation details

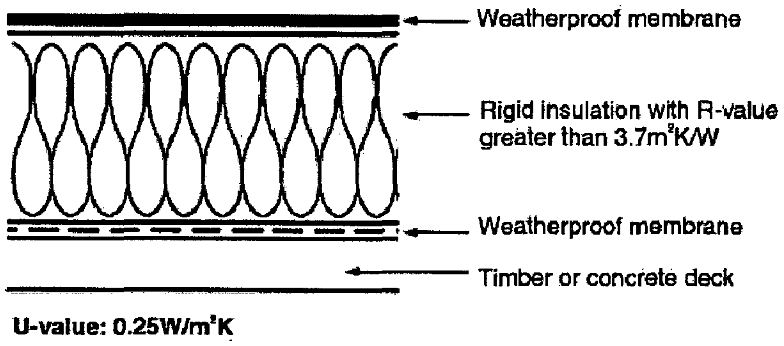
Table 5.5- R values of various ceiling systems

R-VALUES FOR SYSTEMS		FOIL FACED R1.3 BLANKET WITH R2.5 CEILING BATT		FOIL FACED R1.3 BLANKETBOARD		30mm ANTIGLARE REFLECTIVE EPS BOARD	
No:	Element Description:	WINTER	SUMMER	WINTER	SUMMER	WINTER	SUMMER
1	Outdoor Air Film	0.04	0.04	0.04	0.04	0.04	0.04
2	Roof Water Proofing Membrane	0.061	0.061	0.061	0.061	0.061	0.061
3	Concrete Slab	0.104	0.104	0.104	0.104	0.104	0.104
4 & 5	Reflective Insulation Material R-value	1.384	1.204	1.173	1.214	0.763	0.706
6	Reflective Air Space	0.587	1.878	0.562	1.809	0.059	1.786
7	Ceiling Insulation	2.61	2.437	NA	NA	NA	NA
8	10mm Plasterboard	0.059	0.059	0.059	0.059	0.059	0.059
9	Indoor Air-Film (Non-Reflective Surface)	0.11	0.16	0.11	0.16	0.11	0.16
	Total R-Value	**5**	**5.9**	**2.3**	**3.4**	**1.7**	**2.9**
	Total R-Value of roof and ceiling materials	0.54	0.58	0.54	0.58	0.54	0.58
	Added R-Value of insulation	**4.4**	**5.4**	**1.8**	**2.9**	**1.1**	**2.3**

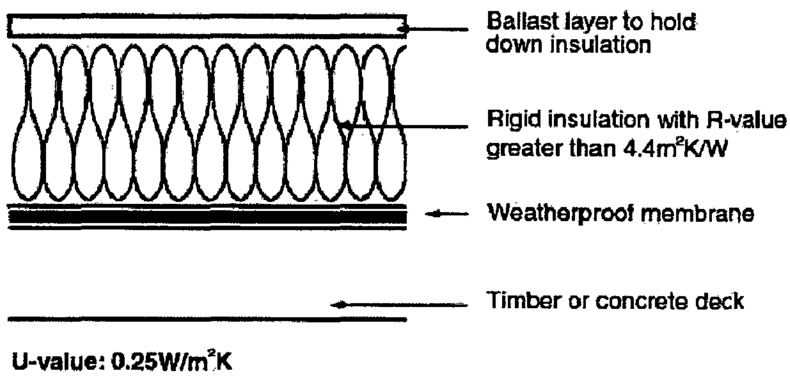
1. Calculations and assumptions in accordance with AS/NZS 4859.1:2002. Amendment 1. 2006 on the path of the insulation, as required by BCA Vol 1. Part J and Vol 2. Section 3.12.
2. Temperatures and parameters are based on Australian climate assumptions. Air temperature difference 12oC (36oC less 24oC) for summer conditions and 6oC difference (18oC less 12oC) for winter.
3. Thermal resistance of air films and attic spaces based on values obtained from Section K5 and K6 of AS/NZS 4859.1:2006.
4. Building material elements based on 2000 AIRAH Handbook and attic thermal value based on AS/NZS 4859.1 App K6 table K2.
5. Where reflective insulation is installed, a simple addition of R-values is not possible. Care must be taken to ensure the performance of reflective air spaces is not "double-counted".
6. The emittance of the reflective surfaces are dependent on tested values and the conditions of the installation, as specified by AS/NZS 4859.1. Amendment 1. 2006.

5.2.3.4 Roof insulation

A U-value of 0.25W/m2K or better should be aimed for retrofitting. The insulation should be located between the roof deck and the weatherproof membrane, but above the weatherproof membrane in an inverted construction. The latter type of construction is less reliable as poor installation can lead to condensation on the underside of the waterproof membrane, which may lead to rot internally. It is most economic to add insulation when replacing the existing roof covering. Careful detailing at the edge and parapet areas of flat roofs is vital for reliability and durability. The correct specification and installation methods for these can be found in BRE (2002) and Great Britain Department for Transport, Local Government and the Regions et al (2001).



Normal construction Source: © EST



Inverted construction Source: © EST

Figure 5.36- Roof insulation methodes

5.2.3.5 Cool roof and green roof

Cool roofs are the roofs that can deliver high solar reflectance (the ability to reflect the visible, infrared and ultraviolet wavelengths of the sun, reducing heat transfer to the building) and high thermal emittance (the ability to radiate absorbed, or non-reflected solar energy) The benefits associated with cool roofs include reduced cooling energy load, reduced air pollution and greenhouse gas emission, and improved human health and comfort. Cool roofs may extend the roof service life and help mitigating the urban heat island effect.

Types of cool roofs

Cool roofs for commercial and industrial buildings fall into one of three categories: roofs made from inherently cool roofing materials, roofs made of materials that have been coated with a solar reflective coating, or green planted roofs.

5.2.3.5.1 Inherently cool roofs

White vinyl roofs, which are inherently reflective, achieve some of the highest reflectance and emittance measurements of which roofing materials are capable A roof made of thermoplastic white vinyl, for example, can reflect 80 percent or more of the sun's rays and emit at least 70% of the solar radiation that the building absorbs. An asphalt roof only reflects between 6 and 26% of solar radiation, resulting in greater heat transfer to the building interior and greater demand for air conditioning.

5.2.3.5.2 Coated roofs

An existing (or new) roof can be made reflective by applying a solar reflective coating to its surface. The reflectivity and emissivity ratings for reflective roof products can be found.

Table 5.6- properties of some roof coatings

Manufacturer	Colour	Product type	Solar reflactance	Thermal emittence
Akzo Nobel Paints (Puerto Rico) Inc.	Off-White	Field-Applied Coating	0.85	0.89
Malarkey Roofing Products	Off-White	Field-Applied Coating	0.9	0.87
Bayer Materials Science, LLC	Off-White	Field-Applied Coating	0.77	0.86
U-LIM Mastic Industry Co., Ltd	Off-White	Field-Applied Coating	0.81	0.89

5.2.3.5.3 Green roofs

Green roofs provide a thermal mass layer which helps reducing the flow of heat into a building. The solar reflectance of green roofs varies depending on the plant types (generally 0.3-0.5). Because of the lower solar reflectance, green roofs reflect less sunlight and absorb more solar heat than white roofs. The absorbed heat in the green roofs is trapped by the greenhouse effect and then cooled by evapotranspiration.

Cooling capacity of cool roof-

In a 2001 federal study in Texas (31° N), the Lawrence Berkeley National Laboratory (LBNL) measured and calculated the reduction in peak energy demand associated with a cool roof's surface reflectance. LBNL found that, compared to the original black rubber roofing membrane on the Texas retail building studied, a retrofitted vinyl membrane delivered an average decrease of 24 °C in surface temperature, an 11% decrease in aggregate air conditioning energy consumption, and a corresponding 14% drop in peak hour demand. The average daily summertime temperature of the black roof surface was 75 °C, but once retrofitted with a white reflective surface; it measured

52 °C. Without considering any tax benefits or other utility charges, annual energy expenditures were reduced by $7,200 or $0.07/square feet.

Instruments measured weather conditions on the roof, temperatures inside the building and throughout the roof layers, and air conditioning and total building power consumption. Measurements were taken with the original black rubber roofing membrane and then after replacement with a white vinyl roof with the same insulation and HVAC systems in place.(Konopacki and Akbari, 2001)

Table 5.7- thickness and U values of roof insulating materials

Insulation Material	Typical thermal conductivity (W/mK)	Insulation thickness (mm)					
		60	80	100	120	140	160
		U-values achieved					
Polyisocyanurate and polyurethane	0.023	0.32	0.26	0.21	0.18	0.16	0.14
Expanded polysytrene and mineral wool (slab)	0.038	0.45	0.36	0.3	0.26	0.23	0.2
Cellular glass	0.042	0.51	0.42	0.35	0.3	0.27	0.24

Source: EST (2009)

5.2.3.6 Qualities for choosing proper insulating materials-

1. Ease of installation
2. Longevity and durability;
3. Fire resistance
4. Cost
    a. Transport cost
    b. Installation cost
5. Thermal performance;
6. Embodied energy
7. Carbon storage
8. Environmental issues.

5.2.3.7 Available Insulating materials

5.2.3.7.1 Organic sources

Wood fibre batts

K-value: 0.038–0.043W/mK. Hygroscopic up to 20 per cent. Cut to shape using sharp blade – easy and safe to install, no irritating fibres. Good dimensional stability. Fire-resistant and uses no glue (formed under high pressure). Recyclable, renewable, biodegradable in landfill, non-hazardous. Use FSC (Forest Stewardship Council) approved sources or recycled cellulose. Good for most walls, ceilings, roofs, timber joisted floors. Embodied energy: 20MJ/kg or 2800MJ/m3 at 140kg/m3.

Sheep's wool batts and rolls

K-value: 0.038–0.043W/mK (CIBSE, 2006). A recyclable, renewable resource with a low embodied energy (more if imported). Safe to install. Can absorb some moisture whilst remaining efficient, but when very wet assumes the U-value of water – high. Naturally resistant to decay and fungus, borate-treated to enhance pest and fire resistance but excessive wetness can leach out the borax. Expensive. Will eventually biodegrade in landfill.

Source: © Dave Baines

Figure 5.37- Sheep's wool batts in situ

Cotton-based batts and rolls

K-value: 0.038–0.043W/mK. Recyclable, recycled and renewable, a natural, non-hazardous fibre that's safe to install. Cotton mill scraps or recycled cotton is mixed with a bulking fibre such as hemp and a thermoplastic binder like polyester. The low-melt polyester gives structural integrity to make it self-supporting in stud wall applications, therefore it contains fossil-carbon-based elements.

Comes as slabs or rolls. Good acoustic insulation and hydrophobic properties, it is biodegradable. Borate additives for pest, fungal and fire control pose none of the health concerns associated with some synthetic pesticides. Well-suited for breathable construction; good sound insulation; stable, durable and rot-proof.

Cotton and hemp batt internal wall insulation

Source: © Russell Smith

Figure 5.38- Cotton and hemp batt

Cellulose (loose, batt or board)

K-value: 0.038–0.040W/mK. Recyclable, renewable, made from finely shredded newspaper, safe to install. Loose-fill is blown in dry, e.g. in lofts, or wet on non-horizontal spaces. In batt form it is comfortable to work with and is readily cut to fit. The board form includes recycled jute sacking and is supplied in various thicknesses with tongue and groove edges. Boards may be used for external walls, reveal coverings, over rafter insulation and as internal non-waterresistant insulating fibreboard for use in floor, roof and wall constructions. Easy to cut with a sharp knife. Treated with an additive to resist insects and fire (borax is preferable to aluminium sulphates) and sometimes a binder to reduce settling. Hygroscopic, so can absorb moisture and gently give it off again.. Biodegradable in landfill, low embodied energy: 0.94 to 3.3MJ/kg.

Semi-rigid cellulose slabs made of wood chippings – over 90% recycled – and polyolefin fibres
Source: © Homatherm GmbH

Spraying in cellulose loft insulation
Source: © Excel Industries

Figure 5.39- Cellulose insulation

Flax batts, slabs and rolls

K-value: approximately 0.042W/mK. Made from a plant whose fibres are bound together with potato starch and treated with borax to make them fire and insect resistant. Recyclable, renewable, a natural, non-hazardous fibre, safe to install. Some products may use plastic binding agents. Biodegradable in landfill. Prolonged exposure to water will cause decay. Embodied energy: 39.5MJ/kg or 1185MJ/m3 at 30kg/m3.

Hemp batts

K-value: 0.043W/mK. Recyclable, renewable, natural, nonhazardous. Like wool and cotton batts, contains 15 per cent polyester fibre to retain lift and stability and borax. Biodegradable in landfill. Relatively expensive; embodied energy unknown/ variable. Prolonged exposure to water will cause decay.

Coconut fibre board

K-value: 0.045W/mK. Made from the outer husk of coconuts with borax and minimal processing. Made into batts or used in screed or timber floor and ceiling constructions. Sustainable/renewable, with variable embodied energy; reclaimable/recyclable/biodegradable, stable, durable, non-toxic, naturally resistant to rot, bacteria and mildew; well suited to a breathable construction.

Cork board

K-value: 0.042–0.050W/mK. Renewable resource from largely sustainably managed cork forests (harvesting the outer bark of cork oak), may contain recycled cork.

Commonly used as underlay under hardwood and ceramic floors. Cork is granulated, expanded and glued together under high pressures and temperatures. Hygroscopic. Naturally resistant to rot, fire and termites. Retains its shape over time; its compression-resistance makes it ideal for flat roofing. Recyclable and bio-degradable. Embodied energy: 4MJ/kg or 640MJ/m3 at 160kg/m3.

Wood fibre board

K-value: 0.080W/mK. The rigid insulation has a higher (worse) U-value than the batt form. Works due to sealed air cells within the fabric. Fire-resistant and uses no glue (formed under high pressure). Recyclable, renewable, biodegradable in landfill, non-hazardous. Some products are made from recycled cellulose. Good for wall and pitched roof construction. Embodied energy: 20MJ/kg or 2800MJ/m3 at 140kg/m3.

Source: © Gavin Killip

Figure 5.40- Interlocking wood fibre board

5.2.3.7.2 Insulation from naturally occurring minerals

Aerogel

K-value: 0.013W/mK. Aerogel has given rise to highly expensive new products such as flexible sheets and laminates, a type of glass and composite materials including plasterboard and sandwiched within PVC panels. Uneconomic but useful where width is limited as performance is so good. Made by extracting water from silica gel, replacing it in nano-sized pores with a gas such as carbon dioxide to comprise 99 per cent of volume. Very high compressive strength, high strength-to-weight ratio. Do not drill holes through to screw on wall, but fix on to battens. A type of insulating glass – 'Airglass', k-value: 0.021W/mK – looks like a normal windowpane, but is much lighter. Good electrical and sound insulating properties, stable and rigid, durable and rot-proof, impermeable to water-vapour, non-combustible, reclaimable. However, highly processed, non-renewable, high embodied energy and non-bio-degradable.

Fibreglass mineral wool batts and rolls

K-value: 0.033–0.040W/mK. Made from molten glass, sometimes with 20 to 30 per cent recycled content. The most common residential insulant. Usually applied as batts, pressed between studs. Can be unfaced, paper-faced with a thin layer of asphalt (vapour retarding), or foil-faced (vapour barriers; the vapour barrier must face the proper direction). Long-lasting and rot-resistant. Moisture ingress and compression will reduce performance. Most mineral wools include a formaldehyde-based binder – exceptions are beginning to appear. Non-renewable, durable and rot-proof, non-flammable, except for the facing, non-biodegradable, reclaimable, not recyclable. Manufacturing can emit chlorides, fluorides, particulates, VOCs (volatile organic compounds) and solvents. Risks of cancer and breathing problems from exposure to glass fibres – use protective clothing when installing. Formaldehyde may off-gas from backing/resin. High embodied energy: 28MJ/kg at 30kg/m3 or 840MJ/m3 at 30kg/m3.

Foamed glass slab

K-value: 0.042W/mK. Contains tiny sealed cells formed by reacting finely-ground oxidized glass (up to 60 per cent recycled) with carbon at high temperature. No additional foaming agents, CFCs, HCFCs, organic binders or other potentially harmful substances. Photochemical oxidants, SO2 and NO2 released in manufacture. High, durable compressive strength, non-permeable, high thermal mass, inherently resistant to fire and air movement. Needs bitumen or synthetic adhesives to install. Re-usable. High embodied energy: 27MJ/kg or 3240MJ/m3 at 120kg/m3.

Perlite

K-value: 0.045–0.05W/mK. Naturally occurring volcanic glass that greatly expands and becomes porous when heated sufficiently. Loose-fill, granular, light weight. Poured into place, to fill concrete block cores, or mixed with cement to create a lighter, less heat-conductive concrete. Also made into boards of expanded perlite, cellulose binders and waterproofing agents. Top surface is treated to retain bitumen for tight bond with a membrane. Must be installed in sealed spaces. Reclaimable, safe to install, non-flammable, moisture resistant. Non-renewable, mined. High embodied energy.

Exfoliated vermiculite

K-value: 0.063W/mK. Clay-based, otherwise like perlite with many of same properties, advantages and disadvantages.

Expanded clay aggregate

K-value: 0.09–0.1W/mK. Small, fired pellets like vermiculite; a structural, lightweight granular aggregate. Many of the same features.

5.2.3.7.3 Fossil carbon

All manufactured at high temperatures, derived from fossil fuels. Extremely high embodied energy. Vulnerable to sunlight and high temperatures. Flammable. Emit more toxic fumes when burnt, non-biodegradable in landfill, must be recycled at end of life. Reclaimable, hydrophobic. Long-lasting, resistant to moisture, air movement, rot and compression.

The expanding agent used in foam insulation can be a halocarbon, pentane, water, or CO2 depending on the type of insulation and its use. Halocarbons harm the ozone layer and cause global warming. Pentane is a greenhouse gas but has a much lower global warming potential (GWP) of 7 (CO2 has 1). The least damaging options for blowing agents for each type of insulant are:

1. polyisocyanurate and polyethylene terephthalate (PET) foam: pentane, cyclopentane;

2. polyurethane (PU): pentane, CO_2, CO_2/H_2O (for spray foams); various isomers of pentane;

3. Extruded polystyrene (XPS): pentane, CO_2; cyclopentane/ isopentane blends (Ashford et al, 2005).

Phenolic foam board

K-value: 0.020–0.25W/mK. Closed cell phenolic foam is designed for roofing, cavity board, external wall board, plaster board dry linings systems, floor insulation and as sarking board. Manufactured by sandwiching phenolic resin (petrochemical-derived), a catalyst and blowing agent within facings, one of which is usually reflective, passing it through ovens.

Expanded polystyrene board and beads (EPS)

K-value: 0.032–0.040W/mK (beads are towards the high end of the scale). Thermoplastic, melts if heated (for moulding or extrusion), produced from 90–95 per cent polystyrene and 5–10 per cent gas – pentane or carbon dioxide. Expanded into foam using heat. Polystyrene beads are used primarily in masonry cavities. Can be recovered for re-use or recycled into new sheeting. Boards not recommended for older, breathable constructions, but their rigidity, lightweight, acoustic insulation, longevity and other properties listed above make them very popular. Embodied energy: 88.6MJ/kg or 1772MJ/m3 at 20kg/m3.

Extruded polystyrene board (XPS)

K-value: 0.028–0.036W/mK. Uniform closed-cell structure, smooth continuous skin. Some products use recycled polystyrene. Very high compressive strength.

Polyurethane/polyisocyanurate board and foam

K-value: 0.02–0.033W/mK. Foam or rigid board. Foam is sprayed in at high temperatures; within seconds it will expand by over 30 times giving a seamless rigid covering. Stable, durable, ideal for plugging gaps or leaks. Any thickness can be achieved. High in compressive strength. Hydrophobic. The use of gastight foils such as aluminium can reduce the degradation. Embodied energy: 72.1MJ/kg or 2307MJ/m3 at 32kg/m3.

5.2.3.8 Examples

Case study 1

An estate in Peel Avenue, Wirral, Merseyside, UK, of Wimpey-built 'no-fines' houses: 1940s–1950s mass-produced concrete social housing so-called because of the type of concrete used – concrete with no fine aggregates – has been modernized both internally and externally using external wall insulation. The PermaRock mineral fibre insulation system was installed, with scratch render on the upper floors and dry dash finishes. A predicted U-value of 0.35W/m2K was achieved with 70mm of mineral wool. New windows, doors and canopies were added. A much higher level of energy saving could have been achieved with higher U-values specified on the doors, windows and thicker insulation. Designer: Permarock Products Ltd. Installer: E.J. Horrocks Ltd.

Source: © PermaRock, an INCA member

Figure 5.41- Peel Avenue, Wirral, Merseyside, UK

Case study 2

Canterbury House, Borehamwood, Hertfordshire, an 18-storey no-fines tower block overclad with Permarock's acrylic through-coloured render in three contrasting colours to provide identity on the elevations, with brick slips at ground floor level. The insulation thickness specified by the Ridgehill Housing Association – 75mm mineral fibre and 20mm phenolic – achieves a predicted U-value of 0.35W/m2K. System designer: PermaRock Products Ltd. Installer: Repex Ltd.

Source: © PermaRock, an INCA member

Figure 5.42- Canterbury House, Borehamwood, Herts, UK

5.3 BUILDING INTERIOR, FIXTURES AND EQUIPMENT

5.3.1 Electricity Efficiency and Supply

It is evident that if we insulate well and protect from draughts, we need far less energy for heating and cooling. Some Retrofit and new builds attempt to proclaim themselves as environmentally sound by bolting on a renewable energy feature like a wind turbine or photovoltaic panels to a fairly conventional structure. This is simply a waste of resources.

The gadgets used in buildings have been getting more energy efficient over the last 20 years. However, still the same amount of electricity.is being used. They have got cheaper, but the price of electricity has not, yet habits like leaving the light on are hard to break.

5.3.1.1 Voltage optimization

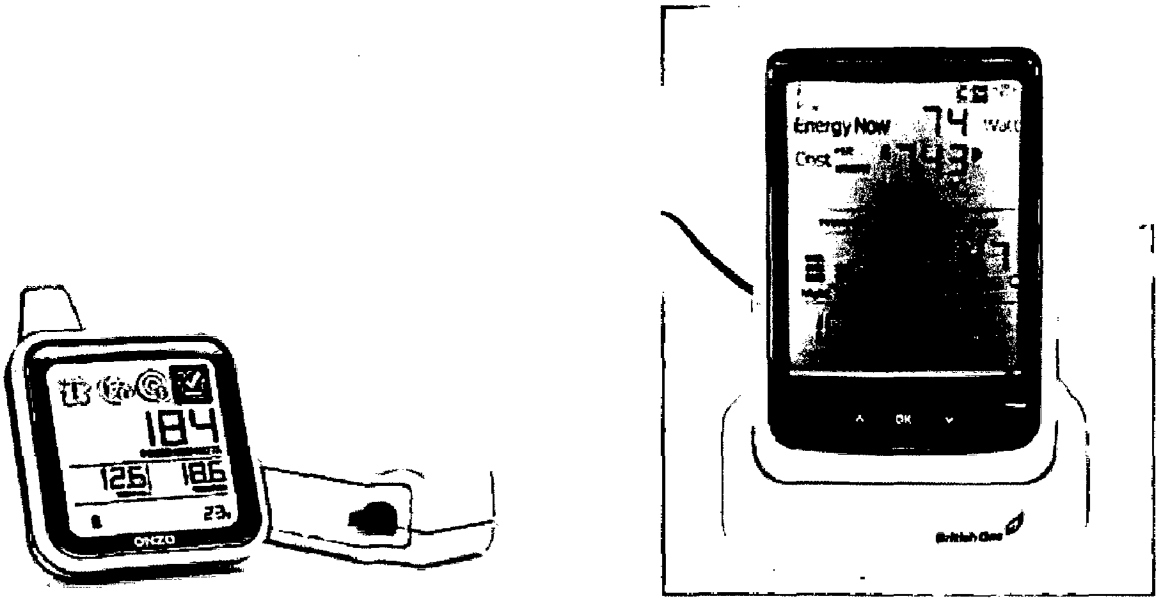
In some countries large businesses have been benefiting from voltage optimization for years, saving huge sums of money. Now the technology is available for homes. A small box connected to the consumer unit (fuse box) where the power supply enters the property adjusts the incoming voltage to a constant 220V, regardless of the incoming voltage.

The actual savings vary from country to country because the delivered voltage varies. Most electrical equipment manufactured for Europe and the UK is rated at 220V and may operate satisfactorily at voltages down to 200V. By efficiently bringing supply voltages to the lower end of the statutory voltage range, less electricity is used which can generate average carbon and cash savings of around 13 per cent – and equipment is protected from power surges too. It works particularly well with motors – e.g. pumps– and lighting.

5.3.1.2 Advanced metering

Further efficiencies using smart meters can be gained by wirelessly connecting electric appliances to them, allowing the appliances to be remote-controlled. This will enable the energy service management to switch on and off appliances which are not time sensitive according to the level of demand elsewhere on the local grid.

This is called advanced metering. Already widespread in Italy and Sweden, it is being introduced elsewhere in Europe. Customers receive favourable tariffs in return for surrendering control of their appliances (although they'll hardly notice any effect on performance). In a major retrofitting programme of a block, a housing authority may be able to negotiate the roll-out of advanced metering with the energy service company as part of a bulk energy procurement deal.



Two electricity monitors, by Onzo (left, with the sensor part that clips on to a cable by the meter) and by British Gas, which gives more detailed information

Figure 5.43- Electricity monitors

5.3.1.3 Exorcising phantom loads

Standby electricity use is that which is trickling away even when electric products are switched off or not in use. These ghostly energy vampires could be little LED lights, internal or external transformers and chargers, or features such as remote control, memory, clock display and instant-on features.

A survey in 75 houses in Halifax, Canada (Fung et al, 2003), found that the annual average standby energy consumption per household was a staggering 427kWh, equivalent to a constant load of 49W.

An international effort is ongoing to get all standbys reduced to one watt. Meanwhile, aside from persuading everyone to laboriously turn each one off every night, some techno-fixes are available, all of which plug into electric sockets between the appliance and the socket:

1. Standby busters: enable easy switching off of whatever is plugged into them via a remote control.
2. Timer switches: can be programmed, with manual override, to turn appliances on and off automatically when no one is around to use them.
3. IntelliPanels and IntelliPlugs: automatically power up and down peripheral equipment like printers when the desktop computer is switched on and off.

5.3.2 Lighting

Traditionally, lighting can account for up to 30 per cent of electricity use in a building. It is possible to cut that figure by 90 per cent by using the tricks of daylighting, together with modern lighting solutions. These mean that all kinds of exciting effects can be created very cheaply.

Old-fashioned tungsten-filament incandescent lights bulbs are being phased out in many places. Compact fluorescent lamps (CFLs) are the main energy-saving alternatives to these, being eight times more efficient and lasting up to 12 times longer, meaning that you can save more than 10 times the cost of the bulb over its lifetime compared to the cost of using incandescent, while using one-eighth of the carbon emissions. There are many new kinds of CFLs coming on to the market and LEDs (light-emitting diodes) are adding to the interior design possibilities. Organic LEDs (OLEDs) are on the horizon.

Lights sold in Europe have to carry EU energy labels. These show the energy efficiency category, how many lumens they emit and their average expected life in hours.

Some lamps contain hazardous substances like mercury. You can now obtain lamps all of whose components are compliant with legislation like the Restriction on the Use of Certain Hazardous Substances in Electrical and Electronic Equipment Regulations 2008 (the 'RoHS Regulations'), which bans new equipment containing more than agreed levels of lead, cadmium, mercury, hexavalent chromium, polybrominated biphenyl (PBB) and polybrominated diphenyl ether (PBDE) flame retardants. It is also possible to recycle all lights at special recycling centres – important because of the hazardous components they contain.

5.3.2.1 Types of bulbs and fittings

5.3.2.1.1 CFLs

Compact fluorescents, or CFLs, used to have a bad reputation of being slow to start up, producing a cold light and not working with dimmers. No longer: the latest range includes daylight, cool white and warm comfort light – very similar to standard incandescents – in many styles to match the variety of modern fittings, including downlights, spotlights, dimmable wall lights, mirrors and much more.

Many lights require 'ballasts' and most dimmable ballasts require additional wiring, but some are available which require no additional wiring for changing a centre pendant. For multiple lights a three core and earth cable is required to carry a permanent live and a switch live for control.

5.3.2.1.2 LEDs

The light-emitting diode is a semiconductor which converts electricity into light. They use a tiny amount of electricity and last for over 25,000 hours, compared to CFLs' 10,000 hours and incandescents' 1000. But the light is directed and groupings of LEDs are required to get the equivalent amounts of lux to CFLs. They can be ideal for reading and task lighting, strip lighting and furniture etc, outdoor and landscape lighting, stair and low-level lighting, and backlighting.

The technology is developing fast: white LEDs are now available, prices are reducing and light levels increasing. LED ribbons and projections produce astounding mood effects and a huge variety of stylish fittings for every taste and location (except larger area lighting) is available.

5.3.2.1.3 Halogens

A halogen is a type of incandescent lamp with a tungsten filament. This means it gives off a lot of heat, which is wasted energy, but is more efficient than oldfashioned incandescents, using 30–50 per cent less energy while lasting perhaps two to three times longer. Because of their smaller size, halogens achieved popularity with directed and mood lighting. Nowadays, the same effect can be achieved with LEDs and CFLs much more efficiently and they should be replaced with these when they wear out.

5.3.2.2 Intelligent lighting systems

Every now and then people forget to turn the lights off. They can then be on for a few hours and this adds up. There are a couple of ways to deal with this:

1. Occupancy sensors, also known as microwave, radar or Doppler sensors, can be used with all lights. These work by sending out high-frequency sound waves and listening for the bounce back. When it is returned at a different frequency it knows there is a moving object around. It then sends a signal to the dimmable ballast to raise the light levels. When no movement is detected after a certain period of time, the light will return to its original level. This type is preferable to infrared motion sensors, which are vulnerable to dust and blocking objects, can be confused by radiators and fires and have a shorter lifespan.

2. Adjustable light level sensors make lighting even more intelligent. They can automatically turn a light on and off in response to changing amounts of daylight.

3. Timers: there's always the tried and tested method used in apartment block and hotel stairways throughout the world: a switch with a timer built into it.

5.3.3 HVAC Systems

Systems for air conditioning need to control temperature and humidity within predetermined limits throughout the year. Various types of refrigerating systems are available to accomplish the tasks of cooling and dehumidifying, which are an essential feature of air conditioning. Systems for air conditioning may be grouped as all-air type, air and water type, all water type or unitary type.

5.3.3.1 All-air system

This type of air conditioning system provides complete sensible and latent cooling, preheating and humidification in the air supplied by the system. Most plants operate on the recirculation principle, where a percentage of the air is extracted and the remainder mixed with incoming fresh air. Low velocity systems may be used. High velocity systems although require smaller ducts, are high on fan energy, require careful acoustic treatment and higher standards of duct construction.

5.3.3.1.1 Constant volume system

Accurate temperature control is possible, according to the system adopted. Low velocity system variations include dehumidification with return air bypass, and multi-zone (hot declclcold deck mixing). High velocity system may be single or dual duct type.

5.3.3.1.2 Variable volume system

Most Indian air conditioning systems operate at partial load for most of the year and the variable air volume (VAV) system is able to reduce energy consumption by reducing the supply air volume to the space under low load conditions. Thp VAV system can be applied to interior or perimeter zones, with common or separate fans, with common or separate air temperature control. The greatest energy saying associated with VAV occurs at the perimeter ztmes, where variation in solar and outside temperature allow tbe supply air quantity to be reduced. Good temperature control is possible but care should be taken at partial load to ensure adequate fresh air supply and satisfactory control of air distribution and space humidity.

5.3.3.2 Air and water system

Control of conditions within the space is achieved by initial control of the supply air from a central plant but with main and final control at a terminal unit within. the conditioned space. The supply air provides the necessary ventilation air and the small part of the total conditioning. The major part of room load is balanced by water through a coil in the terminal unit, which can be either a fan coil unit or an induction unit.

5.3.3.3 All water system

In the simplest layout, the fan coil units maybe located against an outside wall with a direct, fresh air connection. A superior arrangement utilizes a ducted, conditioned, fresh air supply combined with mechanical extract ventilation.

Control of unit output maybe achieved by fan speed and water flow/temperature control. Electric power is required at each terminal unit.

Provision of variable volume water flow system for chilled water circulation is recommended for varying load conditions. This may be incorporated with the help of constant volume primary chilled water circuit and variable flow secondary chilled water circuit having pumps with variable speed drives and pressure sensor to control the speed. This system allows better control on energy consumption under partial load conditions due to diversity or seasonal load variations.

5.3.3.4 Unitary systems

Such systems are usually those incorporating one or more units or packaged air conditioners having a direct expansion vapour compression refrigeration system. Similar units using chilled water from a central plant would be designated fan coil systems. Most units are only suitable for comfort applications but specially designed units are also available for process and industrial applications.

5.3.3.5 Vapour Compression Water Chiller

These normally contain the complete refrigerating system, comprising the compressor, condenser, expansion device and evaporator together with the automatic control panel. The unit can be set down on to a solid foundation on resilient mountings. Pipe connection require flexible couplings; these should be considered in conjunction with the design of the pump mountings and the pipe supports. Capacity control is normally arranged to maintain an approximately constant temperature of the chilled water leaving the evaporator. This may be adequate for one or two packages, but a more elaborate central control system may be necessary for a large number. The design of the refrigeration control system should be integrated, or be compatible, with the control system for the heat transfer medium circulated to the air cooler.

The classification of the water chilling packages is by the type of compressor.

5.3.3.5.1 Centrifugal compressors

These compressors have an impeller that imparts to the refrigerant vapour a high kinetic energy, which is then transformed into pressure energy. For water chilling applications, compressors with one or two stage of compression are used. Two stage units often incorporate an interstate economizer for improving efficiency.

5.3.3.5.2 Screw compressors

Two types of screw compressors are available, that is, single and twin screw, and both are positive displacement machines. Compression of the refrigerant vapour is achieved by the progressive reduction of the volume contained within the helical flutes of the cylindrical rotor(s) as they rotate.

5.3.3.5.3 Reciprocating compressors

These are available in a wide range of sizes and designs. They are almost invariably used in packages up to 120 TR cooling capacity.

5.3.3.6 Turbocor compressor

The compressor is one of the largest energy consumers within the HVAC system and at the heart of chiller operation. It's for this reason that Turbocor chillers are such an important step forward for energy efficiency. In its target capacity range, there is no other compressor currently on the market that produces better efficiency in operation.

However, it is the seamless integration of the Turbocor compressor within the Turbo Power chiller which also featuring new heat exchange and control technology, which is providing outstandingly reliable operating efficiencies.

Advantages of the Turbocor chillers include:

a. An EER in excess of 8 at part load conditions and up to 4 at full load, representing an efficiency increase of more than 100% and up to 10% respectively on conventional chillers.

b. Magnetic compressor bearings which have friction losses typically 500 times less than traditional oiled bearings, reducing starting current to just 2A

c. An oil free compressor avoids the need for an oil management system and the inherent costs of maintenance.

d. Micro channel condenser coils (air cooled series) increase performance by up to 45%, providing further energy savings by reducing the capacity or number of fans required.

e. Condenser fans feature low noise sickle blades arranged to reverse on the compressor off cycle, to blow out accumulated dust on condenser surfaces to maintain efficient heat exchange.

f. Flooded type evaporator specially designed for R134A and more efficient than a direct expansion shell and tube evaporator

g. Electronic expansion valves achieve precise control of refrigerant mass flow and as the pressure drop across this valve is significantly less than a mechanical one, the system can operate at lower condensing pressures and further reductions in compressor power input are achieved.

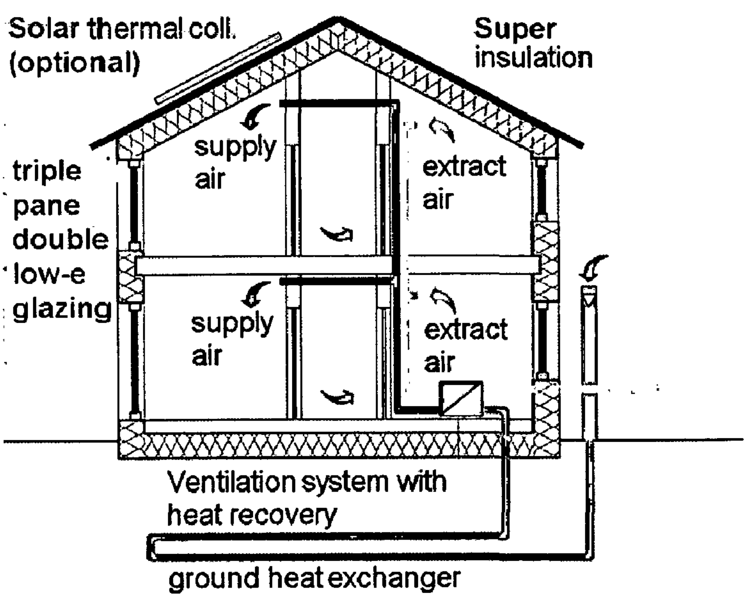
h. Microprocessor control provides management of each compressor and condenser fan speed control to give smooth control of variations in load and ambient temperatures down to 5°C.

i. Eurovent guaranteed performance. The performance of this range is further verified by testing carried out in the Rhoss Laboratory, itself Eurovent certificated.

*Source-http://www.cooling4industry.co.uk/turbocor-compressor-chillers

5.3.4 Earth air tunnel

An Earth Air Tunnel is an underground heat exchanger that can capture heat from and/or dissipate heat to the ground. They use the Earth's near constant subterranean temperature to warm or cool air or other fluids for residential, agricultural or industrial uses. If building air is blown through the heat exchanger for heat recovery ventilation, they are called earth tubes (also known as earth cooling tubes or earth warming tubes) in Europe or earth-air heat exchangers (EAHE or EAHX) in North America. These systems are known by several other names,



Source- www.wikipedia.org

Figure 5.44- Schematic diagram of earth air tunnel.

including: air-to-soil heat exchanger, earth channels, earth canals, earth-air tunnel systems, ground tube heat exchanger, hypocausts, subsoil heat exchangers, underground air pipes, and others.

Earth tubes are often a viable and economical alternative or supplement to conventional central heating or air conditioning systems since there are no compressors, chemicals or burners and only blowers are required to move the air. These are used for either partial or full cooling and/or heating of facility ventilation air.

The system uses either an open- or closed-loop configuration. In an open-loop system, outdoor air is drawn into the tubes and delivered directly to the inside of the building. This system provides ventilation while hopefully cooling the building's interior. In a closed-loop system interior air circulates through the earth cooling tubes. An alternative is to direct the cooled air from either type of system into a mechanical air conditioning system to reduce the air conditioner's cooling load.

5.4 ENERGY GENERATION

Only reduction of energy consumption by the equipment and fixtures is not only the way to reduce the total energy demand of the building but generation of energy from renewable sources also helps to reduce the overall energy demand from the grid. Two most popular options has been discussed here.

5.4.1 Wind turbines

A wind turbine is a device that converts kinetic energy from the wind into mechanical energy;.a process known as wind power. If the mechanical energy is used to produce electricity, the device may be called a wind generator or wind charger.

The generation of power from a wind turbine depends upon the speed and duration of wind flow, type of the turbine and place of installation. Modern vertical axis wind turbines can be installed at individual building level. The most important feature of these type of turbines is that it can utilize both horizontal and vertical flow of air.

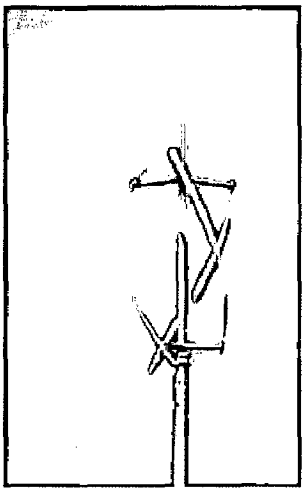


Figure 5.45- Wind turbine

5.4.2 Photovoltaic panels

A solar panel (also solar module, photovoltaic module or photovoltaic panel) is a packaged, connected assembly of photovoltaic cells. The solar panel can be used as a component of a larger photovoltaic system to generate and supply electricity in commercial and residential applications. Each panel is rated by its DC output power under standard test conditions, and typically ranges from 100 to

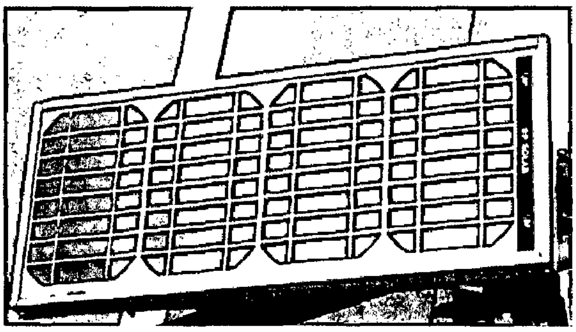


Figure 5.46- solar PV panels

450 watts.

Because a single solar panel can produce only a limited amount of power, most installations contain multiple panels. A photovoltaic system typically includes an array of solar panels, an inverter, and sometimes a battery and or solar tracker and interconnection wiring.

Currently the best achieved sunlight conversion rate (solar panel efficiency) is around 21% in commercial products, typically lower than the efficiencies of their cells in isolation. The energy density of a solar panel is the efficiency described in terms of peak power output per unit of surface area, commonly expressed in units of watts per square foot (W/ft2). The most efficient mass-produced solar panels have energy density values of greater than 13 W/ft2 (140 W/m2).

5.5 SUMMARY

In this chapter the probable strategies for retrofit has been discussed. In the next chapter, some of the strategies will be implemented on the base model to analyze the retrofit potential of the Lecture Hall Complex.

6 ANALYSIS OF RETROFIT ALTERNATIVES

6.1 PROCESS DEVELOPMENT

Retrofitting any existing building depends upon smart decisions. A streamlined sequential process facilitates these apt decisions for successful implementation. The procedure of successful retrofit has been elaborated in the following paragraphs.

Analysis of the base case presents limitations in the building's energy performance. At the same time, their analysis also presents opportunities for improvement From the pool of suitable materials and techniques discussed in the previous chapter it is really a phenomenal task to choose the best one. In some cases, the best one costs so much that it is out of reach of the client. Sometimes, that can affect the aesthetics of the building or cannot be used for very high payback period.

It entirely depends upon the stakeholders i.e. the financer, the architect, the energy consultant, the owner and the use to choose among the materials and technologies together to achieve the goal of energy efficient retrofit depending upon the framework.

Here, in this chapter, some strategies will be adopted to implement on the model and the performance improvement will be discussed individually for each one.

In each and every retrofit project, initial cost and payback period is the most important question. Though the operational cost reduction is a vital issue, some other issues like resource conservation, user comfort often get unnoticed. Actually energy efficient retrofit is a small part of a bigger goal which is sustainability. Some solutions can be the best if only energy efficiency is considered but may not be much suitable if we consider the holistic sustainability. As an example, use of mechanical louvers can be much more effective to restrict direct sunrays than green wall or trees, but the latter option has some more non-measurable benefits like carbon storage, nil embodied energy and pleasing aesthetics.

From the case study of Empire State Building retrofit, it is learnt that the grouping of various retrofit options has been done to find out the particular one which suits the demand of the client, financer's budget, environmental benefits and substantial savings. These groups of strategies are termed as "Packages". Here also some similar sort of packaging approach has been adopted. But here is not only one package but three different level of packages keeping in mind the variable need and financial condition of various levels of clients.

Each package is subdivided into three main action areas as discussed in the base case

6.1.1 Intervention level I-

The building surrounding- impacts the ambient temperature, local heat island effect and provides shading.

6.1.2 Intervention level II-

The building skin which deals with fenestration, insulation, drought proofing etc.

6.1.3 Intervention level III-

The building interior, fixtures and equipment which takes care of the internal environment, lighting, HVAC etc.

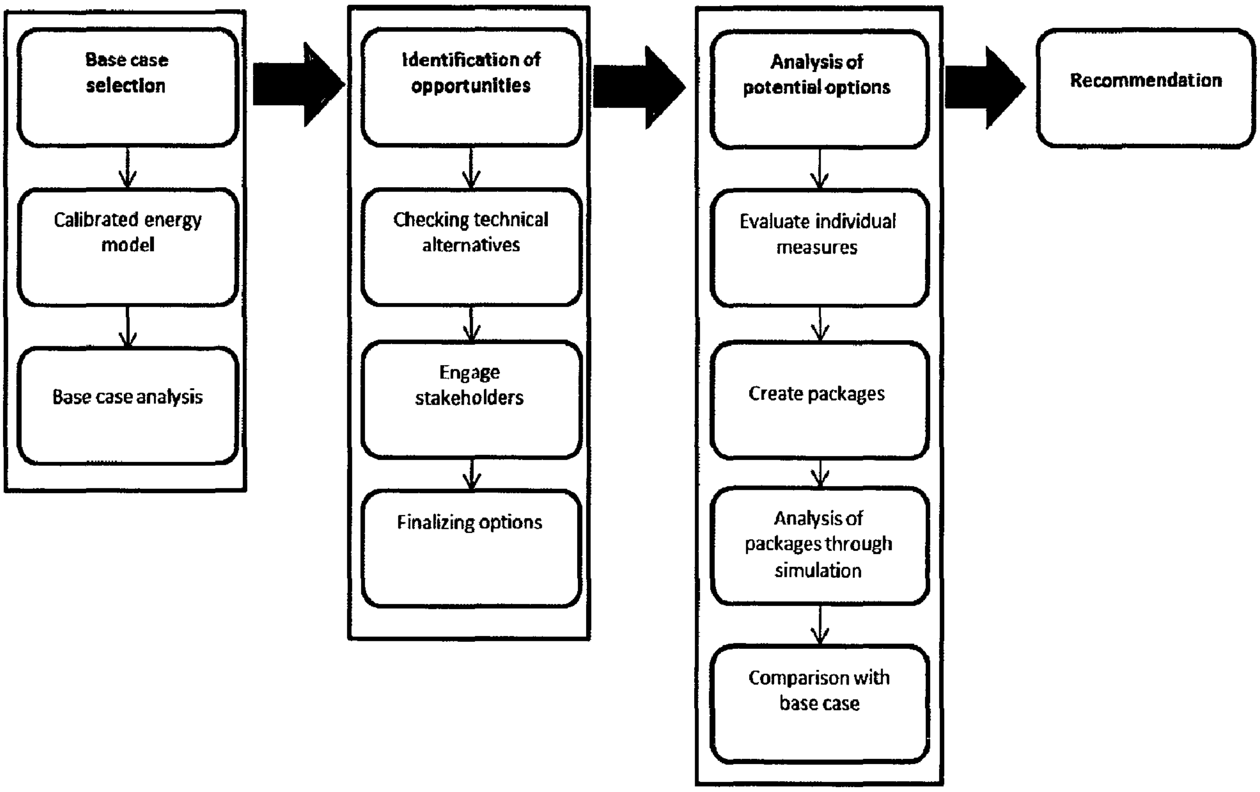


Figure 6.1- Chart showing the process development

First package consists of most inexpensive yet effective strategies which can reduce the energy consumption to a substantial amount. This package is named as package A.

Table 6.1- Details of package A

	Interventions		
	I	II	III
Package A	Reflective paint	Draughtproof windows	Energy eff. Lighting
	deciduous trees	Internal Insulation	VRF AC
		Removal of top of atrium	
		Low E film on window pane	

The next package is another step towards the energy efficiency combining some more strategies with package A and termed as package B. Package B can be addressed as the optimum solution for the energy efficiency maintaining a balance between cost and energy efficiency.

Table 6.2- Details of package B

	Interventions		
	I	II	III
Package B	Reflective paint	Draughtproof windows	Energy eff. Lighting
	Tiremark	Draughtproof Doors	Energy eff. Ventilation
	deciduous trees	Internal Insulation	Turbocor Chiller AC
		External Insulation	Direct Digital Control
		Removal of top of atrium	
		Low E window glazing	
		Increase window sill ht.	
		Reflective paint	
		Cool roof	

The next step is the ultimate level of energy efficient retrofit. This package combines all the effective solution to reduce the energy demand with package B. This package is addressed as package C

Table 6.3- Details of package C

	Interventions		
	I	II	III
Package C	Reflective paint	Draughtproof windows	Energy eff. Lighting
	Tiremark	Draughtproof Doors	Energy eff. Ventilation
	Grasscrete	Draughtproof Ducting	Water Management
	deciduous trees	Draughtproof ceiling	Earth air tunnel
	Green wall	Internal Insulation	Direct Digital Control
		External Insulation	
		Thermal brakes	
		Mechanical louvers	
		Double glazed Low E window	
		Increase window sill ht.	
		Reflective paint	
		Removal of textured finish	
		Cool roof	

It should also be taken into account that with the rapid progress of technology and new inventions every day, nothing is ultimate. And here only those strategies are taken into account which pays back the investment during their lifecycle in spite of their high initial cost.

Before the application of the strategies, the problems which are identified in the previous chapter will be addressed and feasible solutions will be picked to be incorporated in the packages according to their potentials.

6.2 DEVELOPMENT OF SCENARIOS

To analyze the efficiency and applicability of packages four scenarios have been developed. Each scenario will tell about the monthly heat gain, Total electricity load and estimated savings.

Scenario 1- stands for the existing situation of the building i.e. the base case.

Scenario 2- Application of package A over the base case.

Scenario 3- Application of package B over the base case.

Scenario 4- Application of package C over the base case.

Table 6.4- Scenarios, Intervention areas and Packaging

Scenario		Interventions		
		I	II	III
1	**Base case**	NA	NA	NA
2	**Base case + Package A**	Reflective paint	Draught proof windows	Energy eff. Lighting
		deciduous trees		
			Internal Insulation	VRF AC
			Removal of top of atrium	
			Low E film	
3	**Base case + Package B**	Reflective paint	Draught proof windows	Energy eff. Lighting
		Tire mark	Draught proof Doors	Energy eff. Ventilation
		deciduous trees		
			Internal Insulation	Turbocor Chiller AC
			External Insulation	Direct Digital Control
			Removal of top of atrium	
			Low E window pane	
			Increase window sill ht.	
			Reflective paint	
			Cool roof	
4	**Base case + Package C**	Reflective paint	Draught proof windows	Energy eff. Lighting
		Tire mark	Draught proof Doors	Energy eff. Ventilation
		Grasscrete	Draught proof Ducting	Water Management
		deciduous trees	Draught proof ceiling	
		Green wall		Earth air tunnel
			Internal Insulation	Direct Digital Control
			External Insulation	Demand control Ventilation
			Thermal brakes	
			Mechanical louvers over atrium	
			Double glazed Low E window	
			Increase window sill ht.	
			Reflective paint	
			Removal of textured finish	
			Cool roof	

6.3 BASIS OF SELECTION OF STRATEGIES

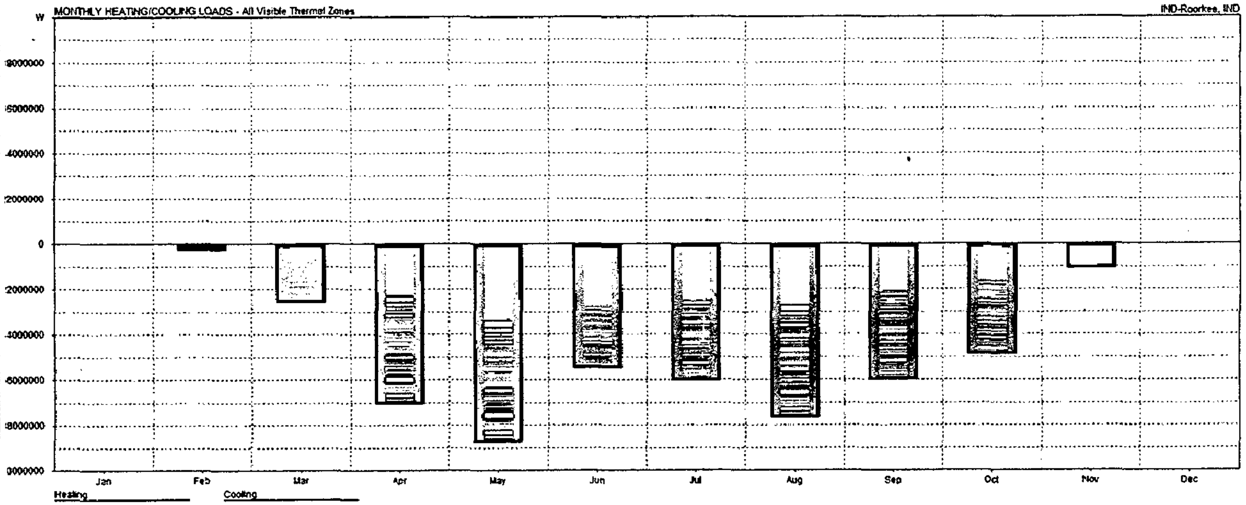
In real context, among numerous alternative strategies, a few are chosen according to the need and feasibility of implementation. The dialogue and discussion among various stakeholders like architect, owner, contractors etc. helps to decide which strategies will be applied. As the stakeholders are absent, the strategies are selected regarding the cost, ease of implementation, environmental impact of the strategies during the fabrication and implementation process etc.

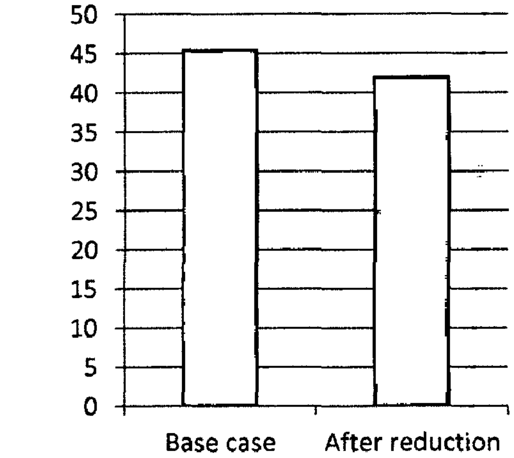
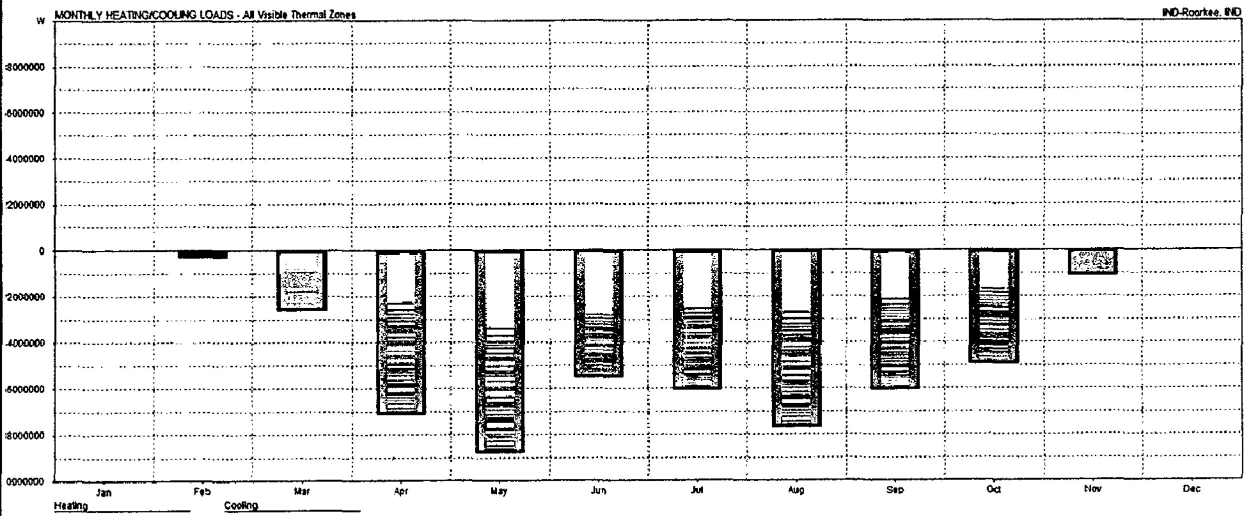
6.4 ANALYSIS

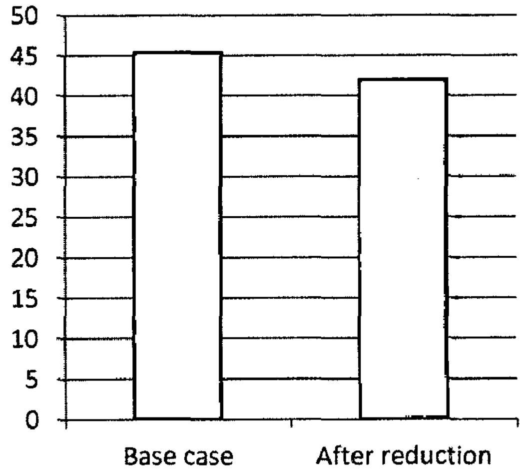
The analysis of the potential of retrofit strategies to reduce the energy consumption has been done two different ways. The first one (part 3.3.1) tells about the potential of the strategies in individual. Next they are analyzed with the combination of other strategies which are basically the packages (part 3.3.2). When the packages are applied on the base case they are termed as scenarios which has been discussed earlier (part 3.2). During this analysis it should be remembered that the impact of the individual strategies varies widely when applied with other strategies. They are not the arithmetic sum of the impact of the individual strategies that belongs to that package.

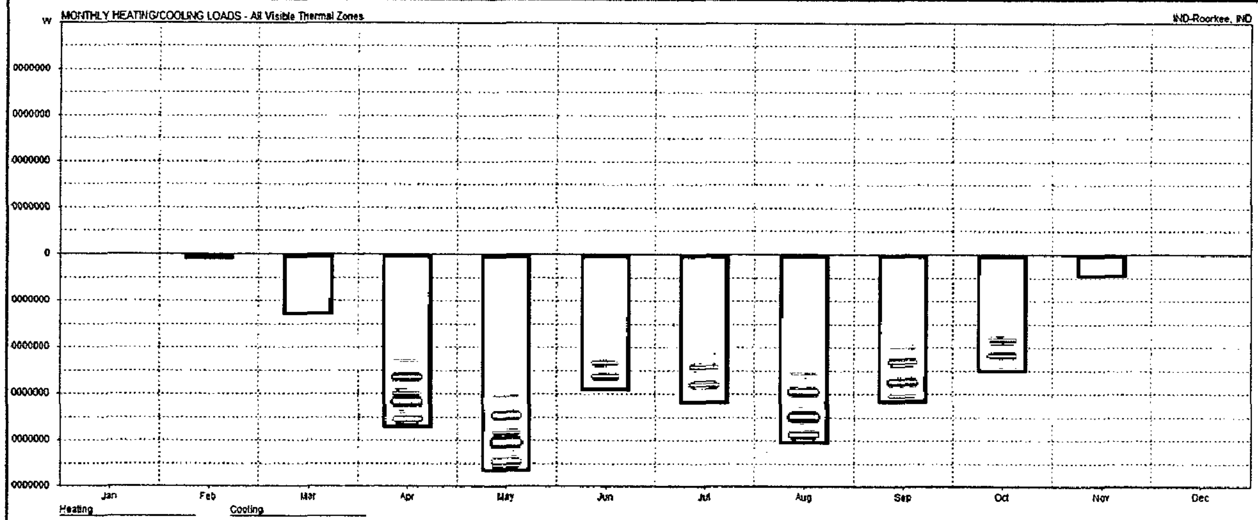
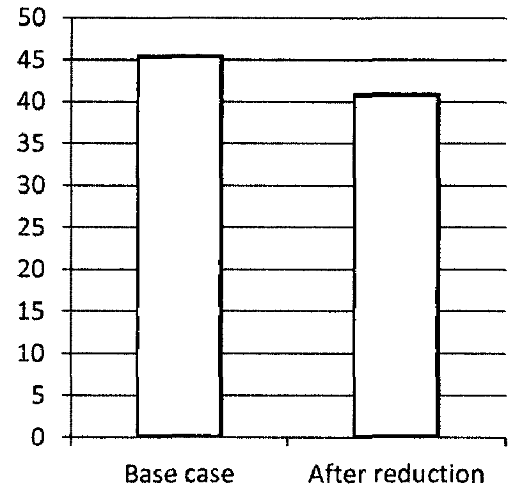
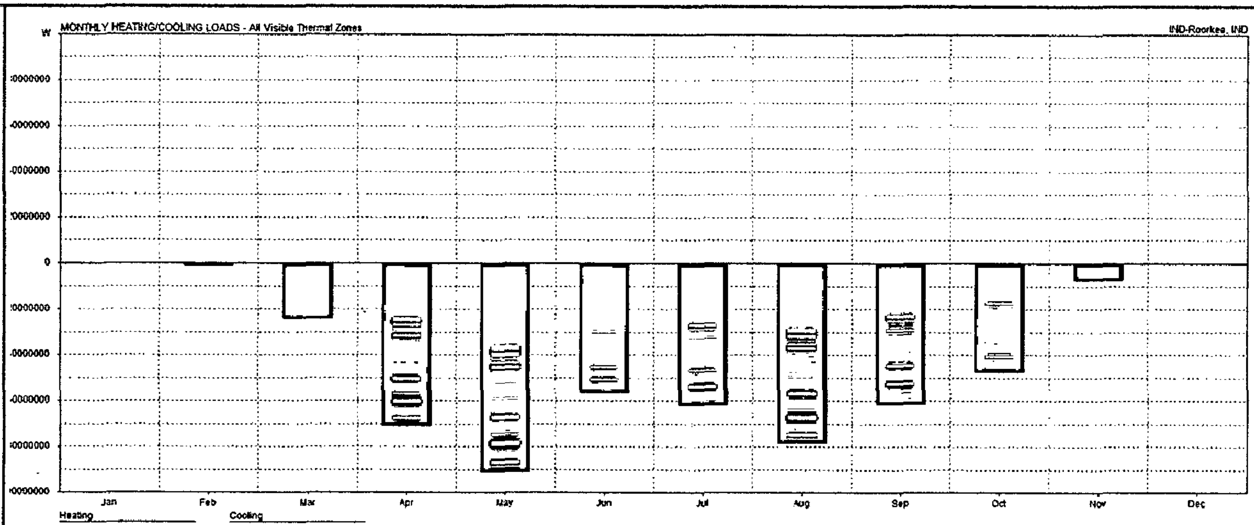
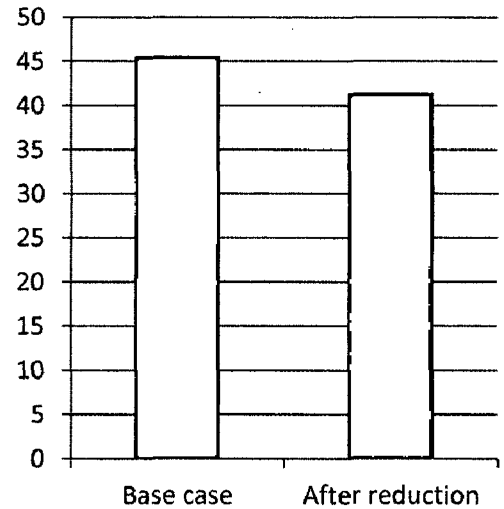
6.4.1 Analysis of Individual Strategies

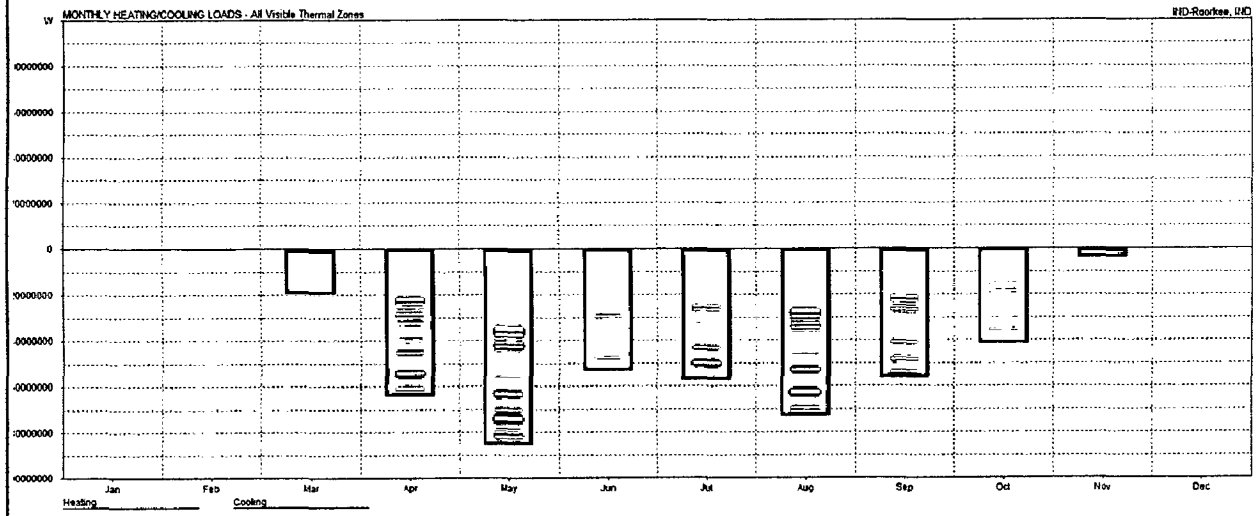
The analysis of performance has been shown in a tabular format mentioning the percentage of change in energy consumption for the application of the strategy. Only the strategies which affect the total heat gain are discussed in the table. Other strategies like the efficient lighting, HVAC systems, which reduces the energy load due to their different working principle than their conventional counterparts, are only discussed and comparative graphs are shown showing the reduction in the annual cumulative energy consumption compared with the base case.

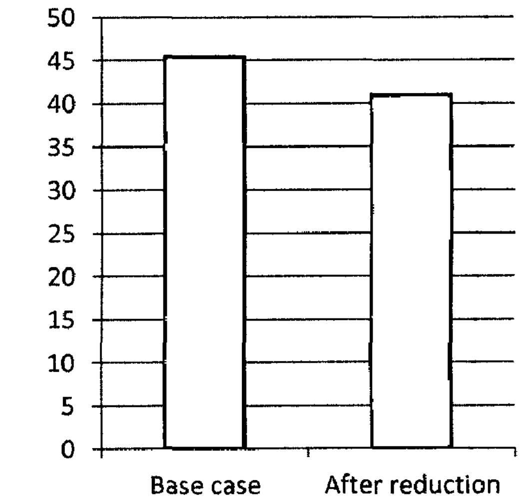
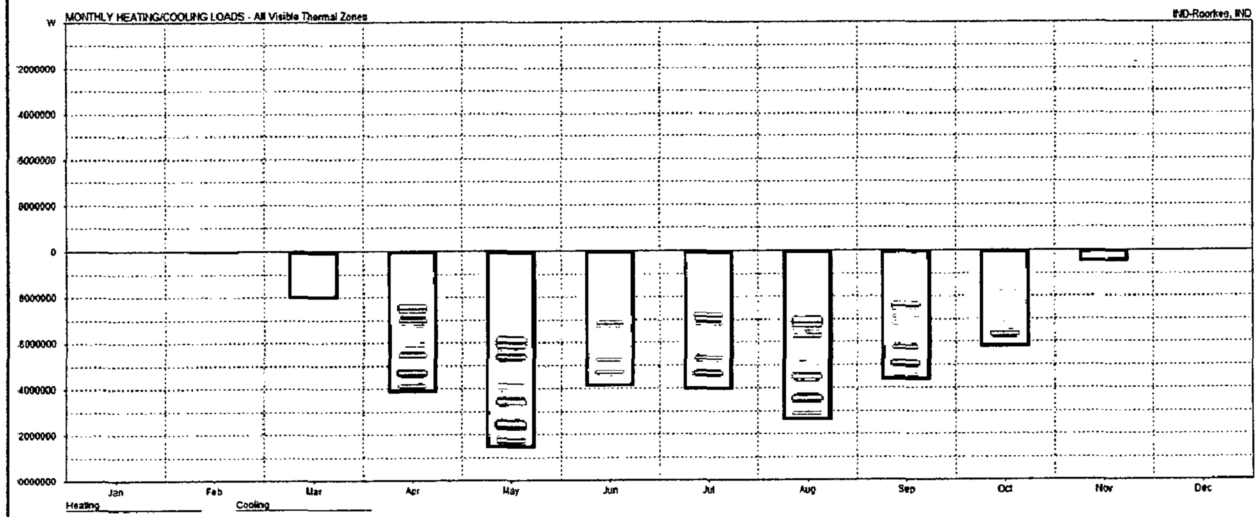
<table>
<tr><th></th><th></th><th colspan="2">PARAMETERS</th></tr>
<tr><th>lo.</th><th>Strategies</th><th>Monthly cooling loads</th><th>Annual cooling. load comperison (in 10K KWh)</th></tr>
<tr><td>1</td><td>Reflective paint on concrete surface</td><td>

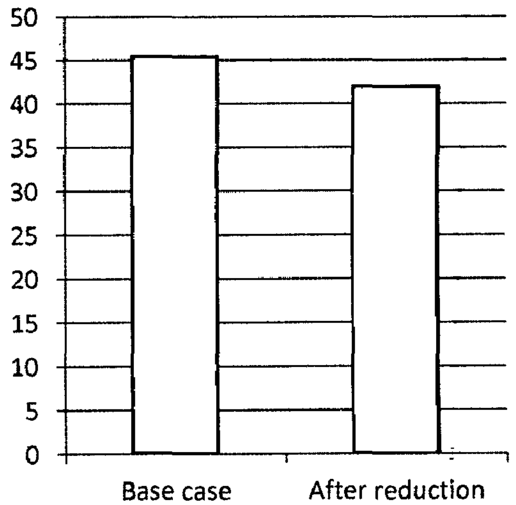
Reduction 1.54%</td><td>
</td></tr>
<tr><td>2</td><td>Tiremark</td><td>

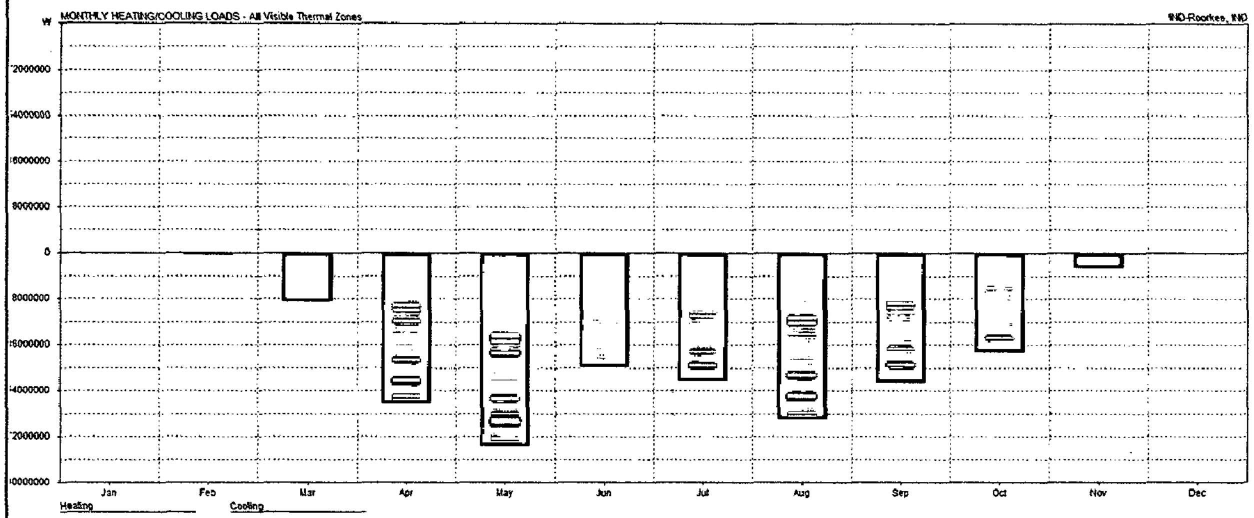
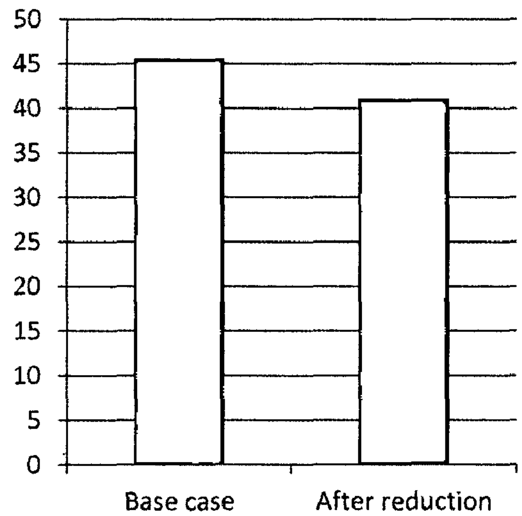
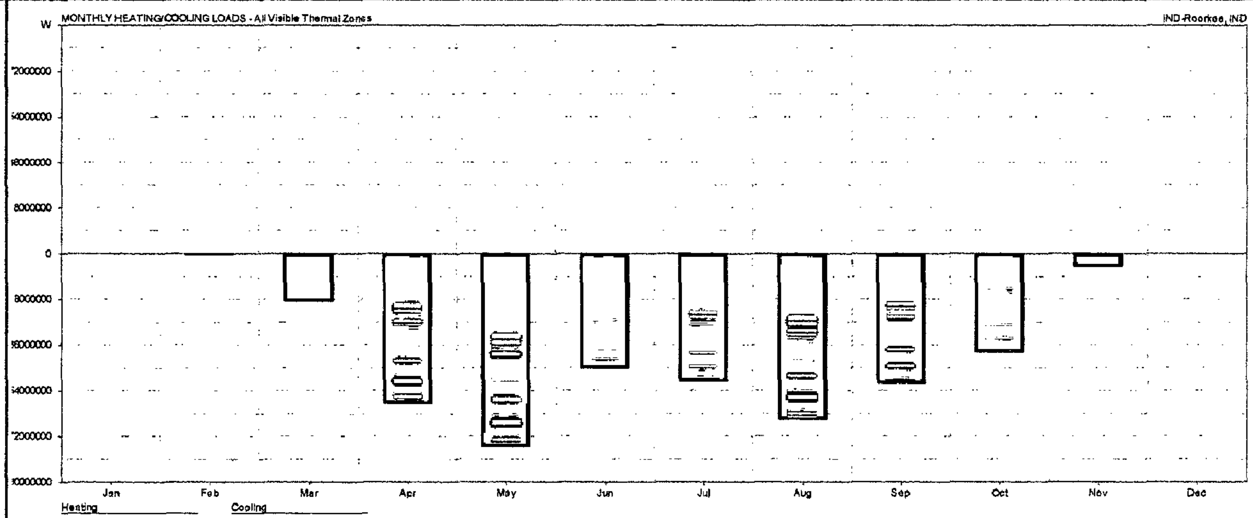
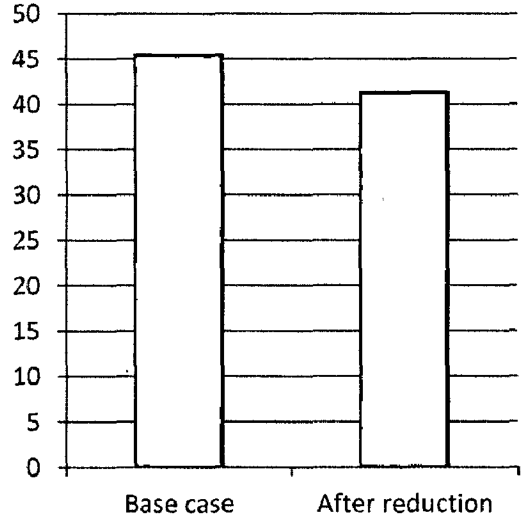
Reduction 2.68%</td><td>
</td></tr>
</table>

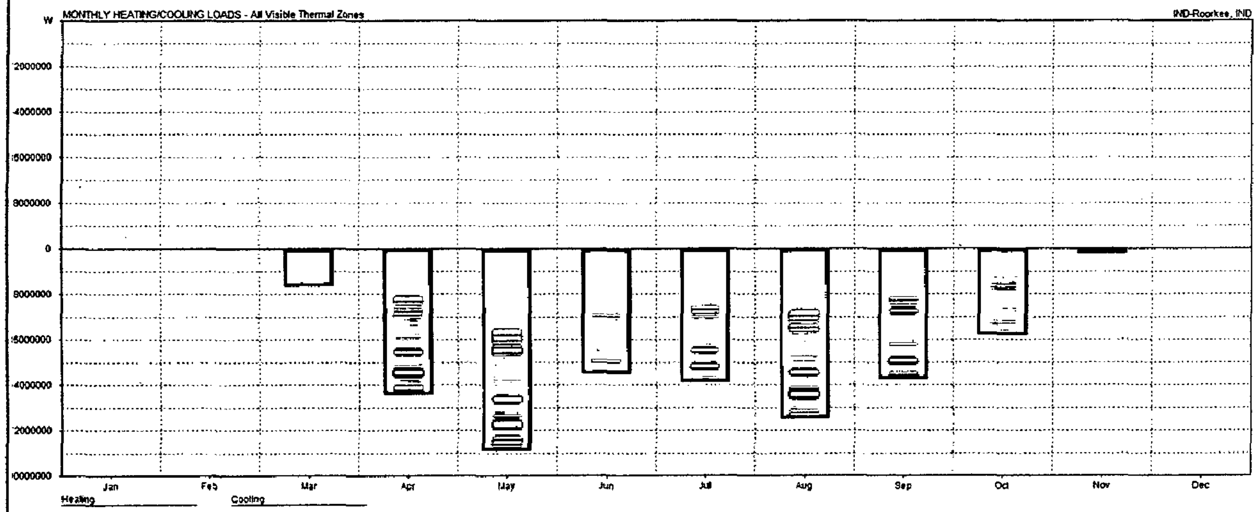
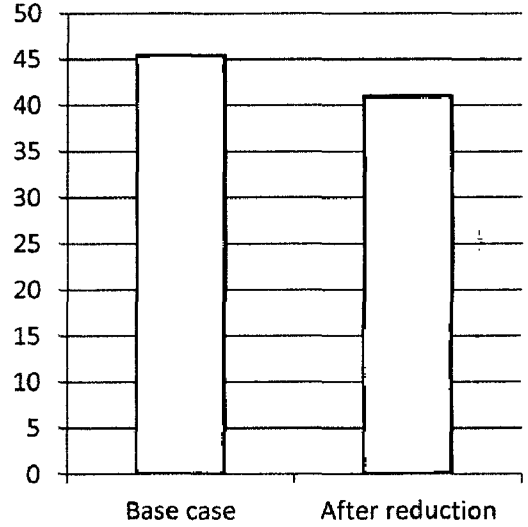
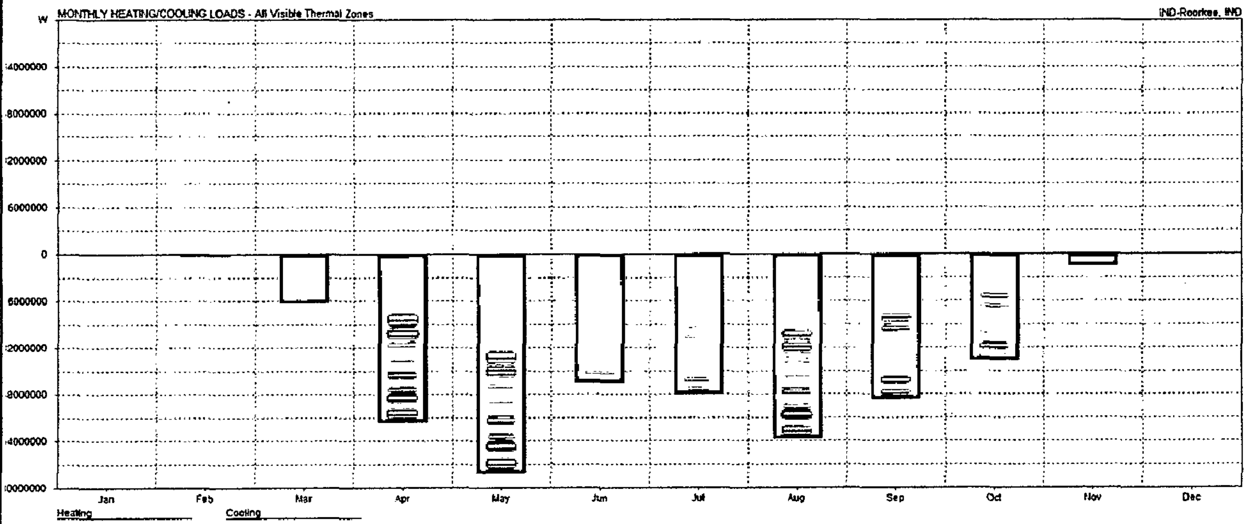
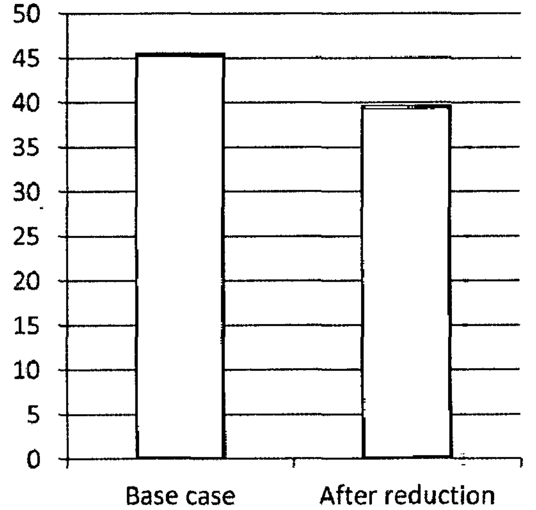
No.	Strategies	PARAMETERS: Monthly cooling loads	PARAMETERS: Annual cooling, load comperison (in 10K KWh)
3	Grasscrete in parking	 Reduction 5.91 %	
4	Deciduous trees	 Reduction 10.23%	

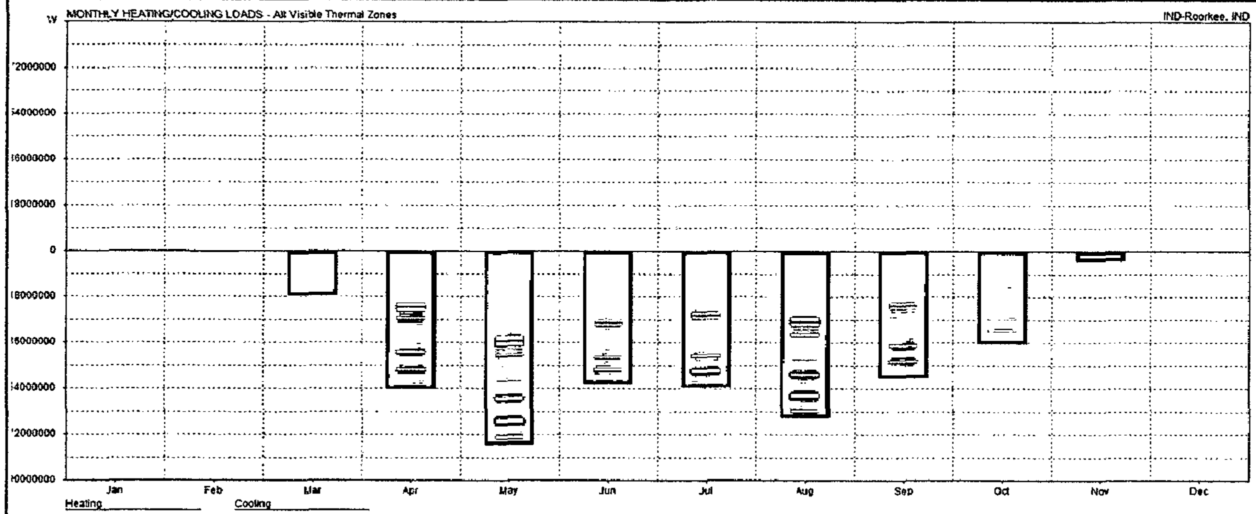
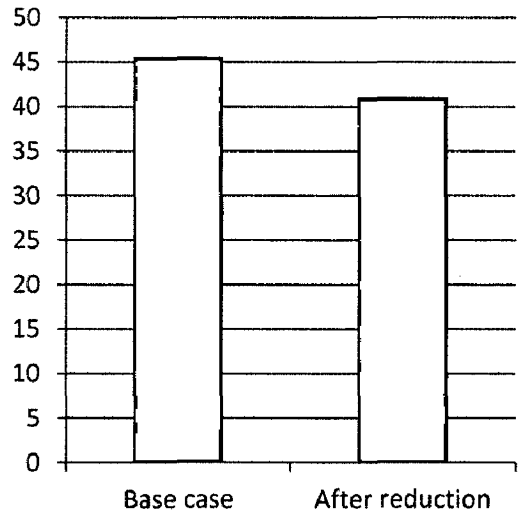
<table>
<tr><th rowspan="2">lo.</th><th rowspan="2">Strategies</th><th colspan="2">PARAMETERS</th></tr>
<tr><th>Monthly cooling loads</th><th>Annual cooling. load comperison (in 10K KWh)</th></tr>
<tr><td>5</td><td>Green Wall</td><td>

Reduction 18.48%</td><td>
</td></tr>
<tr><td>6</td><td>Draughtproofing</td><td>

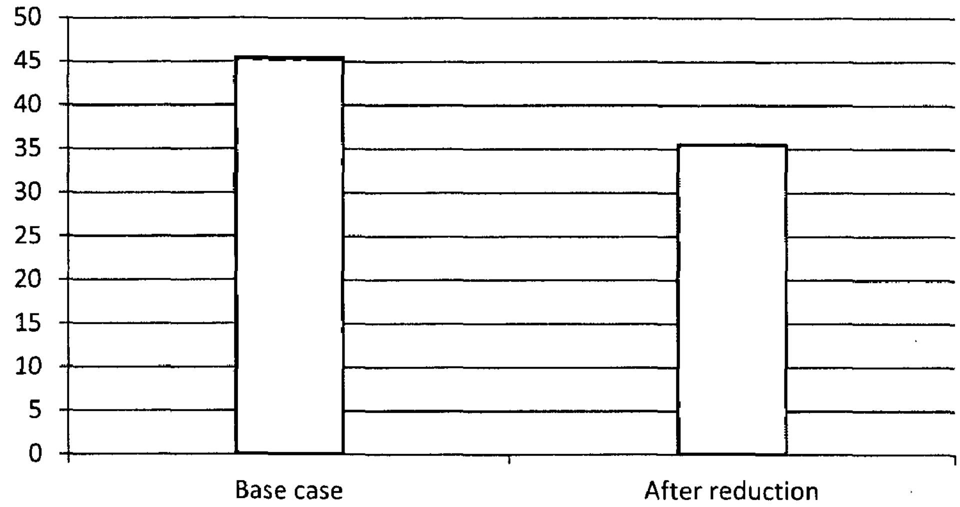
Reduction 7.45%</td><td>
</td></tr>
</table>

No.	Strategies	PARAMETERS	
		Monthly cooling loads	Annual cooling, load comperison (in 10K KWh)
7	Internal Insulation	 Reduction 9.87%	
8	External Insulation	 Reduction 9.05%	

		PARAMETERS	
No.	Strategies	Monthly cooling loads	Annual cooling. load comperison (in 10K KWh)
9	Cool roof	 Reduction 9.7%	
10	Low E glazing	 Reduction 12.98%	

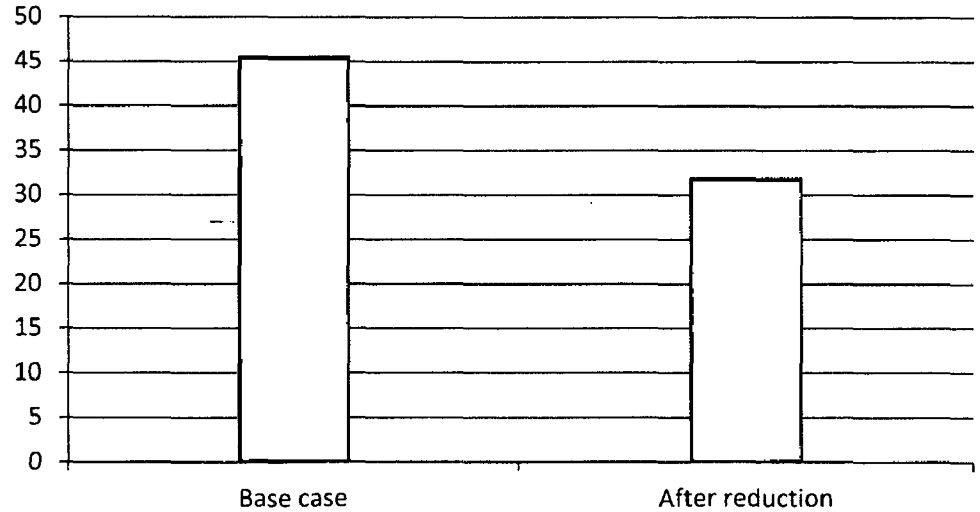
No.	Strategies	PARAMETERS	
		Monthly cooling loads	Annual cooling. load comperison (in 10K KWh)
11	Window height reduction	 Reduction 9.93%	

Change in electricity consumption for replacement of Split AC with VAV AC.



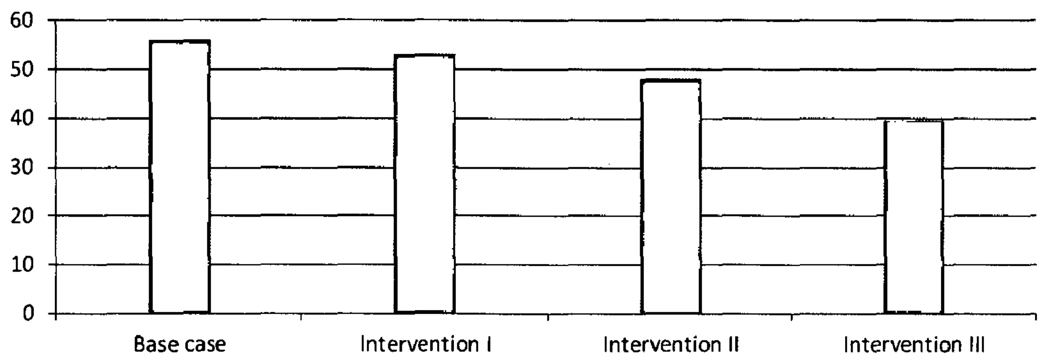
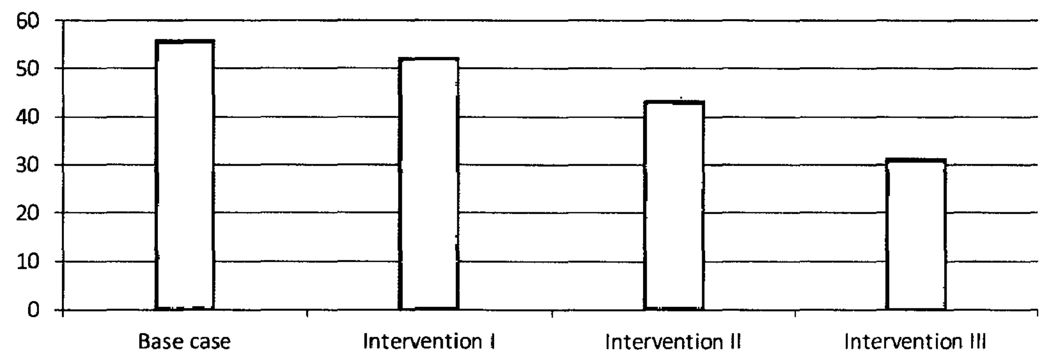
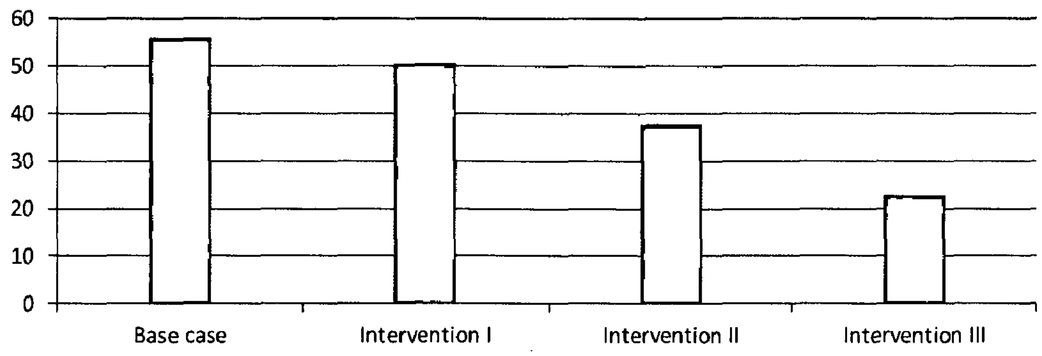
Consumption in base case- 559266112 Wh (Cooling load)
Consumption in retrofitted Case-438464631 Wh (Cooling load)
Reduction-21.6%

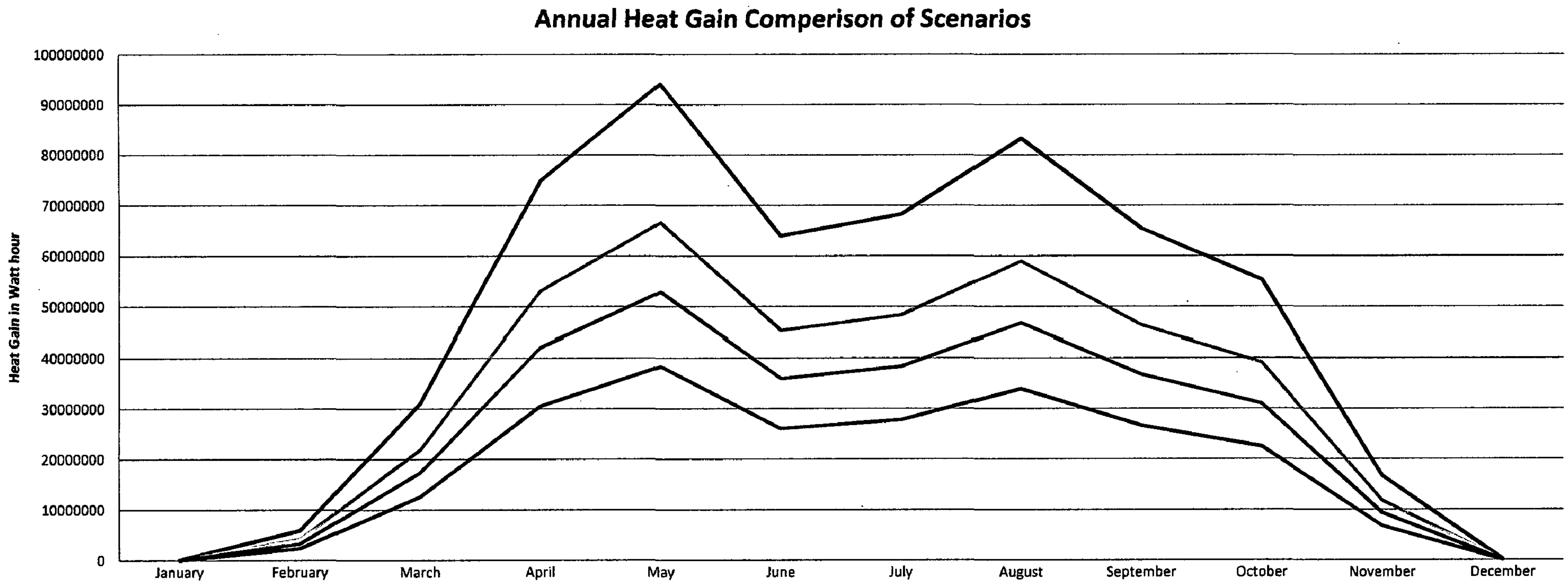
Change in electricity consumption for replacement of Split AC with Turbocor AC.



Consumption in base case-559266112 Wh (Cooling load)
Consumption in retrofitted Case-390927012 Wh (Cooling load)
Reduction-30.10%

6.4.2 Analysis of Scenarios

Scenario	Energy consumption comparison			
1	Base case			
2				
	Base case	Intervention I	Intervention II	Intervention III
	559266112 Wh	531526512 Wh	480074746 Wh	396061665 Wh
		Reduction 4.86%	Reduction 9.68%	Reduction 17.49%
	Total Reduction- 29.182%			
3				
	Base case	Intervention I	Intervention II	Intervention III
	559266112 Wh	524423833 Wh	434327818 Wh	314149311 Wh
		Reduction 6.23%	Reduction 17.18%	Reduction 27.27%
	Total Reduction- 43.824%			
3				
	Base case	Intervention I	Intervention II	Intervention III
	559266112 Wh	531526512 Wh	480074746 Wh	396061665 Wh
		Reduction 9.76%	Reduction 25.19%	Reduction 39.62%
	Total Reduction- 59.257%			



	January	February	March	April	May	June	July	August	September	October	November	December
Scenario 1	148382	5915752	31023110	74944944	94106424	64008084	68232584	83319640	65474976	55249432	16676677	166051
Scenario 2	105081	4189424	21969981	53074595	66644393	45329317	48321028	59005396	46368142	39126605	11810108	117594
Scenario 3	83349	3322979	17426212	42097857	52861188	35954436	38327410	46802067	36778414	31034551	9367575	93274
Scenario 4	60455	2410255	12639746	30534819	38341780	26078814	27800002	33946921	26676469	22510276	6794579	67654

6.5 CALCULATION OF PAYBACK PERIOD

If energy efficient retrofitting is considered only for the economic benefit purpose, then the payback period is one of the most important factors for a successful retrofit. But in real life scenario, it is very hard to predict the exact payback period due to a number of reasons.

1. The cost of implementation of strategies can vary from place to place regarding the availability of the material in that area, transportation cost, labour charge, contractor profit, etc.
2. Same material of different quality and durability is available in the market. A particular material of a particular brand can be much more costly than its counterparts for better product quality and durability.
3. In some cases, the reduction of operational and maintenance cost is reduced due to efficient fixtures and management systems which may not be visible form the savings due to reduced energy use.
4. The duration of the retrofitting project sometimes halts the usual use of the building and causes some inconveniences to the users that can not be measured in terms of money.
5. Because of intelligent control systems installed, the building responds according to the need of the user and thus the user comfort is increased many folds which is beyond economic profit and loss.
6. Retrofitting often improves the prestige and glamour of the owner and can become an icon itself. It has more social impact than the financial benefit. At the same time the resale cost of the building increases dramatically due to its glorified new image.
7. Apart from all these, one of the most important aims of energy efficient retrofit is basically to reduce the impact of the building on the environment which can never be measured in terms of money.

As it is very hard to predict and calculate considering the real life constraints and uncertainty factors, the specialized experts of corresponding fields do the calculation of payback. But here for the research purpose, a simple case will be discussed to represent how the payback period is calculated. During the simplified calculation process, risk factors are not taken care of. The loss during the time taken for the retrofit, interest of the invested capital, inflation, depreciation factors for older equipment, previous maintenance cost and the income from the resale of the removed fixtures are ignored.

The calculation is based on the strategies implemented on scenario 2, which is basically the application of package A over the base case.

6.5.1 Implementation of reflective paint

Laying cost- Rs. 15 per sq.m

Savings per annum- Rs. 4 per sq.m per annum (EPA- RUHI 2010)

Expected lifetime- 10-12 years

Payback-(4 X 10) / 15 = 2.66 Years

6.5.2 Plantation of deciduous trees

Annual cost of plantation and maintenance of a tree is Rs 500 approx. per annum. The lecture hall complex needs almost 20- 25 trees. The savings generated from the full grown trees is almost Rs 60000 per year. But it takes 6-10 years to mature, so that(6 to 10 years) can be the tentative payback period.

6.5.3 Droughtproofing the windows

Cost of sealant is Rs 40 to 50 per metre run. The building needs almost 800 metres of sealant which costs around thirty thousand rupees. But the savings generated from it is almost 50 thousand rupees per year which means that it pays back within one year.

6.5.4 Internal insulation

The internal insulation of the conditioned spaces of the building can cost almost three to four lacks but it can generate a savings of almost 60 thousand rupees per year which means it pays back within 5-6 years.

6.5.5 Installation of Low e film on window

Cost- Rs 40 per sq.m and it is paid back by 2-3 years which has been derived by simulation in virtual environment.

6.5.6 Equipment and fixtures

Changing of lighting fixtures and fans do have the scope to reduce the energy usage by half. For this particular case of Lecture Hall Complex, individual energy usage data for light and fan is not available. So it will not be very wise to predict the payback time.

6.5.7 Installation of VAV AC units

According to the leading AC suppliers like Blue Star, Daikin etc. The installation of VAV AC units pays back within 3-4 years in Indian climate. The actual calculation is much complex and it is out of scope of this dissertation.

from the explanation given above it is evident that proper implementation of retrofit measures can pay the initial investment back approximately by 5-6 years.

The calculation showed above is a very simplified one excluding the uncertainty factors though these factors play a vital role in fluctuation of the payback period.

It is an agreed upon fact that in spite of the availability of outstanding technological advancement, the best way is to compare the prospective building with an already retrofitted building which is comparable in terms of the use of the building, orientation, and latitude.

It is observed from various projects in the USA, Australia and even in India that the payback period generally varies between three to five years and in some particular individual cases, it can even be as low as one to one and half year.

Table 6.5- Core financial measures regarding the payback

Measure	Explanation	Pros	Cons
Comparison to another building on a usage per square foot basis	Examining the results for a building that has similar properties	Quick way of determining whether to look at a retrofit – but comparison must be made to a retrofitted building	No building is exactly the same – footprint and orientation of the building can have an impact. Better to look at a pool of buildings
Simple payback	The time it takes to return back to the organization the funds invested through the savings generated	Easy to apply and a good risk indicator – how long will my capital be at risk? For projects beyond 4–6 years, results more uncertain	Ignores continuing cash flows beyond the payback period and the "time value of money" (what it is costs to use capital for these purposes). Biased against investments for which the highest returns actually occur in the 8-10 year time frame. Short-term focus can therefore rule out better decisions. More of a "take out" rather than "invest in" approach to running the business and biased against the very measures that are important to long-term success.
Financial payback	The time it takes to return the funds invested plus the financing costs through the savings generated	Reflects more of the cost of capital in the investment equation	Cons very similar to simple payback

Measure	Explanation	Pros	Cons
Internal rate of return (IRR)	The interest rate that brings the value of the investment back to zero – the output of the calculations is the interest rate that achieves this result. If the organization has to achieve or exceed a hurdle rate (say an *IRR of 6%)* and the result of the calculations shows a rate of return greater than that value, the project has positive cash flows and a positive return	Good measure that has practical application and clearly reflects the time value of money	Needs to be combined with NPV
Net Present Value (NPV)	The value of an organization will increase by the amount equal to the present value today of future cash flows. Therefore, if the increase in NPV is positive, the increase in the value of the organization (or business) has increased by the same amount.	Clearly focuses on the time value of money and confirms (or denies) the net positive value of the investment	Some work involved: Needs to be combined with IRR and payback to provide an overall picture of the project – calculating the cost of capital can become an intellectual exercise!
Increase in building value using Net Operating Income (NOI)	An investment in capital equipment that improves NOI improves the value of the building. That value improvement will depend on the "CAP" rate (see note below). Divide the NOI by the cap rate to see the increase in value.	Concentrates decision on long term and short term value of building 100,000/6% = $588,000 (17 years to pay for itself)	Cost of appraisal – methods vary somewhat – cap rates vary

Life Cycle Costing	Comprehensive measure that encompasses the expected cost and expected repair and replacement costs over an extended period of time	Comprehensive approach takes into account most reliable measures.	Usually needs a specialist and significant research is required on product longevity. Many assumptions are used with regards to escalation of prices
Cost of waiting for incentives – lower rates	Demonstrates the benefit of moving forward with the decision to retrofit		

(1) The "Cap Rate"

An investment in equipment that improves energy efficiency and increases the building's cash flow will both pay back the original investment and increase the value of the building.

Once the investment is paid back the additional cash flow may continue on for many years, to the benefit of the owner. For example, consider a $500,000 investment yielding a $100,000 improvement in cash flow. The investment will be repaid in five years with improved cash flow potentially continuing for many years after that.

The amount of value improvement depends on the capitalization rate ("CAP rate"). The value of a commercial building is based on the expected earnings expressed as a percentage return. For example if a building yields a net income of $70,000 and the market expects a return of 7%, the value of the building is $1 million ($1 million x 7% = $70,000). The expected return is called the CAP rate.

To determine the increase in the value of the building, we divide the increase in cash flow by the CAP rate. For the example above, that is $100,000 in additional cash flow divided by 7% for an improvement in building value of $1.4 million. The net benefit for the building owner, therefore, is $900,000 ($1.4 million - $500,000 invested in upgrades) or, put another way, an investment return of 180%.

These numbers are real and achievable. Therefore it obviously makes good business sense to reduce the waste of non-renewable energy usage.

**Source-www.towerwise.ca/greening_moving*

6.6 Discussion

After the application of retrofit strategies on the base case, it is evident that there is a huge scope of improvement of the energy efficiency of the Lecture Hall Complex at IIT Roorkee. Though all the packages are made according to their cost, due to some limitations their exact payback period has not been calculated. If the intervention areas are looked at minutely, it can be observed that only intervention area I and II i.e. building surrounding and building skin have a direct impact on the toatal thermal gain of the building. The third intervention area which is building interior, equipment and fixtures, only works to take the gained heat out of the building and user comfort.

6.6.1 The Building Surrounding

The first and one of the most important issues to reduce the thermal gain is to improve the building surrounding so that the building gets least solar radiation in summer and maximum in winter. As none of the buildings inside the campus has heating facilities except the Central Library building, the provision and calculation for heating has been ignored. As four lecture halls among six at each floor have openings on the west, it gains direct solar radiation after 12 o' clock throughout the year.

Plantation of tall deciduous trees along the west façade, is an effective yet cheap solution to restrict sunrays in summer and allow in winter. Restricting the direct sunrays is only a part solution of the problem as trees can not restrict the radiative heat from the huge hard surface around the building. The reduction of hard paved surface by permeable pavers and transforming the parking space concrete with more sustainable grasscrete reduces the heat gain from radiation by almost 10%.reflective paints on the surface also reduaces the particular problem efficiently.

6.6.2 The Building Envelope

Due to the wrong orientation, the building skin transmits a huge amounts of heat through which actually increases the cooling load and decreases the efficiency of the HVAC system indirectly. Due to high U value of brick masonry wall and absence of any insulating material on inner or outer surface the building performs badly. The installation of insulation material on the wall reduces the energy load by almost 18%. Not only that, by decreasing the heat gain it actually reduces the peak cooling demand and the cumulative cooling load on the HVAC system.

Making the doors and windows droughtproof eliminates the chance of escape of cooled air through the gaps, which results I the decrease of cooling load.

The casement windows are retrofitted with a sill height of 800 mm which donot affect the lighting level of the halls as the workplane is almost at the same height. But this reduces the heat gain by 10%.

The west facing windows are really a menace considering the thermal gain of the building. So applying the low e glazing solution for the windows work very effectively. A wide array of solutions depending on the budget of the project is available like the low e film, single pane low e or argon filled double glazed low e coated windowpanes. But the replacement of the windowpane with the last is the most effective solution which reduces the heat gain by almost 13%.

Enveloped by huge amount of uncoated tinted structural glazing and acrylic top with very small side openings under it, the atrium becomes a hot chamber in scorching summer days. A large cut out at the top fitted with vertical wind turbines, solves the problem easily and generate power at the same time by the air movement for stack effect. Another option is the installation of mechanical louvers with rain sensor, which can protect the atrium in the rainy seasons.

Insulating the roof with cool roof technique reduces the heat gain further by almost 10% and provides additional benefit to reduce the heat island effect. Though green roof has a number advantages regarding the aesthetics, biodiversity etc. it has not been suggested because of the extra amount of load the roof has to carry.

6.6.3 The Building Interior, Equipment and Fixtures

Restricting the heat gain to a substantial amount, the focus has been given on the building interior to reduce the cooling loads. As the floor to floor height of the building for the first three floors is 5.2 metre, there is a vast dead air space at the upper portion of the lecture halls. This actually increases the load on HVAC system. This problem has been taken care of by introducing a suspended ceiling which actively reduce the dead air space with the added benefit of insulation. It also hides the ducts and houses sensors for HVAC and fire.

Installing an efficient HVAC system does not reduce the heat gain of the building but it can pump out the gained heat more efficiently that the installed split AC using much less electricity. The split AC systems always run in their full capacity even when it is not needful. But the VAV (Variable air volume) AC or the turbocor AC or the earth air tunnel with a variable flow drive (VFD) motor, can modify their output according to the need of the situation without overcooling the room. The savings of VAV and turbocor AC are 21% and 30% respectively. The savings by the earth air tunnel has not been calculate due to resource limitation but it is widely acclaimed that in spite of theit high initial cost, they are more economic than any existing HVAC system.

The lighting fixtures in the rooms are twin T12 florescent lamps with choke which consumes 55 watts approximately. Replacing them with modern 28-watt T5 lamps reduces the load by half with better efficacy. The added benefit is the elimination of heat from the choke coils.

Replacing the conventional 60 watt fans with energy efficient 30watt 5 star rated fans reduces the energy consumption by half without affecting their performance.

Water usage may not be directly related to the energy consumption but reducing the water usage indirectly reduces the energy consumption by saving the power used by the pump to lift water to the rooftop reservoir. So replacement of normal urinals with the waterless variant and regular taps with the sensor type not only saves the energy but also saves fresh water for better sustainability.

Use of rooftop PV panels and installation of omnidirectional mini wind turbines generate electricity, which further reduces the use of grid energy and thus reducing the whole electricity load of the building.

6.7 SUMMARY

Some of the strategies discussed in the previous chapter are picked to be implemented on the model and simulated to analyze how much potential they really posses to increase the energy efficiency of the building. After the analysis it is clear that retrofitting of this building can be a very good option to reduce the operational cost as well as reducing the carbon footprint of the building.

The literature review, case studies and the analysis of retrofit options of the lecture hall complex gives an opportunity to make some recommendations for retrofitting the institutional building in India which are discussed in the following chapter.

7 CONCLUSION AND RECOMMENDATIONS

7.1 CONCLUSION

Considering the present day scenario in energy sector in the whole world, it can be easily assumed that the near future is going to face an acute energy crisis. It can also be assumed that the institutional buildings like the lecture hall complex have a life expectancy of more than 50 years. However, such a power hungry building can not perform in the future due to its exponentially increasing operational cost. The building may be functionally and structurally sound, but its high energy cost can force it to be abandoned or demolished to build a new energy efficient one. Energy efficient retrofitting can give a new life to the building reducing the energy consumption and a better indoor environment to the users.

According to the simulation results, the retrofit strategies have the potential to reduce the energy consumption of the Lecture Hall Complex upto 60% using todays commercially available technologies and strategies. There is no doubt that the buildings, which are not built as energy efficient or green can be retrofitted to reduce the energy demand by implementing very simple yet effective measures.

It is observed from the analysis that the two third of electricity has been used to cool the building only. So to reduce the energy load, the heat gain by the building is lowered. Passive strategies like restricting solar radiation in summer and improvement of the building skin largely reduces the heat gain. Efficient HVAC system does the rest. Implementing these strategies not only reduces the energy demand and rips economic benefit; they also help to reduce the greenhouse gas emission and rate of global temperature rise.

Being a world class technological institute, the IITs can opt for energy efficient retrofit strategies for its buildings to set an example of the technological excellence in front of the whole country to give a thrust on the retrofitting programme which not only saves energy but also saves our earth.

7.2 RECOMMENDATIONS

- The main key of any successful retrofit programme is nothing but a streamlined sequential chain of processes which starts from the selection of the building on which retrofitting will be done.

- The selected building should be in a condition to serve a long span of time in future to maximize the benefits and properly utilize the investment on it.

- Coordination between the people involved i.e. the owner, the architect, the energy consultant, the contractor and the financer, is a must for a successful retrofit project.

- Repeated discussions and dialogues between the stakeholders help to avoid complication regarding finance, project implementation, contextuality etc. and arriving at an optimum solution.

- After taking the decision of retrofitting, the first objective should be to find out the areas of improvement of the energy performance of the building by studying the building physically and and using the simulation tools like Ecotect, VisDOE, E-Quest etc.

- The further step should be to explore the available feasible solutions for the areas of improvement. This includes literature survey, market survey and study of successful retrofits done earlier.

- The next step is one of the most important steps which determines the success of any energy efficient retrofit. It is basically to decide which strategies to be chosen from the large number of available solutions. The conversation between the stakeholders are the most important to decide which solutions suits the best for the particular project. The selection criteria can be the options with most efficiency, least payback period, least primary investment, least environmental impact etc.

- After the selection of individual strategies, the grouping or packaging of the strategies should be done to analyze their cumulative potential regarding the particular building using the simulation tools. The prospective packages should be selected and given to the stakeholders to choose the one that meets their requirement the best.

- Another important thing is to choose the intervention areas where the packages are being applied. Selecting the right intervention area and applying proper package on it can give the most effective result.

- Improvement of the building surrounding by plantation along the heat gaining surfaces, i.e. the south and the west, reducing the hard cover with permeable pavers and grasscrete in parking can effectively reduce the heat gain and so it should be implemented in first place wherever possible.

- As the building skin transmits heat from outside to inside, proper measures like droughtproofing, insulating the exposed and internal surfaces, replacing the conventional clear glass window with argon filled double glazed low-e window is recommended.

- Installation of energy star rated fixtures and equipment like fans, lights are recommended to reduce the energy load of the building.

- Efficient lighting, HVAC systems, Demend Control Ventilation (DCV) and Direct Digital Control (DDC) to the HVAC system make the building interior respond according to the need of the user and eliminates scope of unwanted artificial lighting and supply of cool air which reduces the energy demand.

- Installation of solar PV panels and wind turbines are recommended for supply of renewable non polluting energy to the building. This also reduces the use of grid power.

- The last but not the least is the recommendation for proper maintainance of the systems installed. As these hi-tech equipment like DCV and DDC control panels are highly susceptible to mishandling some trained efficient personnel should be in charge to make sure that they can work upto their full capacity.

7.3 SCOPE OF FURTHER STUDY

1. Implementation of the recommendations suggested here on some other buildings and analyze the results to provide a proper guideline for retrofitting of institutional buildings in India.

2. Comparative cost analysis and calculation of payback period by surveying the industry and cost of the implementation from market survey.

3. Retrofitting for total sustainability considering the other aspects like water management, solid waste management etc.

4. Research on the possibility of net zero energy retrofitting.

5. Research on the scope of change in policy to facilitate retrofitting.

REFERENCES

1. Ashford, P., Wu, J., Jeffs, M., Kocchi, S., Vodianitskaia, P., Lee, S., et al (2005) 'Foams', Chapter 7 in 'IPCC/TEAP Special report on safeguarding the ozone layer and the global climate system: Issues related to hydrofluorocarbons and perfluorocarbons', Cambridge University Press, Cambridge

2. Bazilian, M.D., F. Leenders, B.G.C. van Der Ree, and D. Prasad, 2001: Photovoltaic cogeneration in the built environment. *Solar Energy*, 71, pp. 57-69.

3. Bill Prindle, *Energy Efficiency in the U.S. Economy: Current and Potential Investment*, (Houston, Texas, USAEE/IAEE North American Conference), 8, online, *http://www.usaee.org/USAEE2007/submissions/presentations/Bill%20Prindle.pdf.*

4. BRE (2002) 'Thermal insulation: Avoiding risks', BRE Report BR262, BRE, Stirling, C., BRE Publications, Bath

5. CIBSE (Chartered Institute of Building Services Engineers) (2006) Guide A: Environmental Design, CIBSE, London

6. Doug Foy , Joel Rogers, *Efficiency Cities: A Preliminary Assessment of Potential in Boston, Cleveland, Minneapolis, Philadelphia, Pittsburgh, St. Paul, San Francisco and Seattle*, (Living Cities report, December 1, 2008) 1.

7. European Commission, 2005: Green paper on energy efficiency. Doing more with less.

8. Energy Saving Trust (2006) 'CE184 – Practical refurbishment of solid-walled houses', EST, London

9. Energy Saving Trust (2007) 'CE83 GPG155 – Energy efficient refurbishment of existing dwellings', EST, London

10. EPA's Reducing Urban Heat Island Compendium of Strategies http://www.epa.gov/heatisland/resources/pdf/BasicsCompendium.pdf

11. Fischer, J.C., J.R. Sand, B. Elkin, and K. Mescher, 2002: Active desiccant, total energy recovery hybrid system optimizes humidity control, IAQ, and energy efficiency in an existing dormitory facility. *ASHRAE Transactions*, 108 (Part 2), pp. 537-545.

12. Garg, V. and N.K. Bansal, 2000: Smart occupancy sensors to reduce energy consumption. *Energy and Buildings*, 32, pp. 81-87.

13. Gutschner, M. and Task-7 Members, 2001: Potential for building integrated photovoltaics. International Energy Agency, Photovoltaic Power Systems Programme, Task 7, Paris, Summary available from <www.iea-pvps.org>, accessed on July 3, 2011.

14. Hastings, S.R., 1994: Passive solar commercial and institutional buildings: a sourcebook of examples and design insights. John Wiley, Chichester, 454 pp.

15. Hastings, S.R., 2004: Breaking the 'heating barrier'. Learning from the first houses without conventional heating. *Energy and Buildings*, 36, pp. 373-380.

16. Her Majesty's Stationery Office (2006) 'The building regulations 2000: Approved document C: Site preparation and resistance to contaminants and moisture', HMSO, London

17. Hestnes, A.G., R. Hastings, and B. Saxhof (eds.), 2003: Solar energy houses: strategies, technologies, examples, Second Edition. James & James, London, 202 pp.

18. Humm, O., 2000: Ecology and economy when retrofitting apartment buildings. *IEA Heat Pump Centre Newsletter*, 15(4), pp. 17-18.

19. Hyvarinen, J., 1991: Cost benefit assessment methods for BEMS. International Energy Agency Annex 16, Building and Energy Management Systems: User Guidance. AIVC, Coventry, U.K.

20. IEA, 2003b: Trends in photovoltaic applications: survey report of selected iea countries between 1992 and 2002. International Energy Agency, Photovoltaic Power Systems Programme, Task 1, Paris, <www.ieapvps. org>,

21. IEA, 2006b: *Light's Labour's Lost.* Policies for energy-efficient lighting. IEA, Paris.

22. IEA, 2006e: *World Energy Outlook 2006.* IEA, Paris.

23. *International Journal of Energy Technology and Policy*, 2(1-2), pp. 153-178.

24. IPCC/TEAP, 2005: *Safeguarding the ozone layer and the global climate system: Issues related to hydrofluorocarbons and perfluorocarbons.* Special Report, Cambridge University Press, Cambridge, 478 pp.

25. Jakob, M. and R. Madlener, 2004: Riding down the experience curve for energy efficient building envelopes: the Swiss case for 1970-2020.

26. Jason Walsh and Sarah White, *Greener Pathways: Jobs and Workforce Development in the Clean Energy Economy* 2008 (Madison, WI: Center on Wisconsin Strategy,), 15, online, http://www.cows.org/pdf/rp-greenerpathways.pdf.

27. Jennifer Cleary and Allison Kopicki, *Preparing the Workforce for a "Green Jobs" Economy*, (Rutgers, New Jersey: John J. Heldrich Center for Workforce Development, February 2009), 5, online, *http://www.heldrich.rutgers.edu/uploadedFiles/Publications/Heldrich%20Center_Green%20Jobs%20Brief.pdf.*

28. Gorgolewski, M. Optimizing renovation strategies for energy conservation in housing, Building and Environment 30 (1995) 583–589.

29. Konopacki, S and Akbari 2001, 'Measured Energy Savings and Demand Reduction from a Reflective Roof Membrane on a Large Retail Store in Austin',

Energy Analysis Department, Environmental Energy Technologies Division, Lawrence Berkeley National Laboratory, pp.2-3.

30. Krapmeier, H. and E. Drössler (eds.), 2001: CEPHEUS: Living comfort without heating. Springer-Verlag, Vienna, 139 pp.

31. Levermore, G.J., 1985: Monitoring and targeting; motivation and training. In *Energy Management Experience Conference,* A.F.C. Sherratt (ed.), CICC, Cambridge, UK, pp. 21-30.

32. McKinsey & Company, *Pathways to a Low-Carbon Economy: Version 2 of the Global Greenhouse Gas Abatement Cost Curve*, 2009 (McKinsey and Company, December), *http://www.mckinsey.com/clientservice/ccsi/pathways_low_carbon_economy.asp.*

33. McPherson, E.G. 1994. Cooling urban heat islands with sustainable landscapes. In: Rutherford, H.P., R.A. Rowntree and P.C. Muick (eds.). The ecological city: preserving and restoring urban biodiversity. Amherst: University of Massachusetts Press, pp151-171

34. Mirasgedis, S., Y. Sarafidis, E. Georgopoulou, V. Kotroni, K. Lagouvardos, and D.P. Lalas, 2006: Modeling Framework for estimating the impacts of climate change on electricity demand at regional level: case of Greece, energy conversion and management.

35. Laitner, S., S. Bernow, and J. DeCicco, 1998: Employment and other macroeconomic benefits of an innovation-led climate strategy for the United States. *Energy Policy*, 26(5), pp. 425-432.

36. Parker, P., I.H. Rowlands, and D. Scott, 2000: Assessing the potential to reduce greenhouse gas emissions in Waterloo region houses: Is the Kyoto target possible? *Environments*, 28(3), pp. 29-56.

37. Payne, A., R. Duke, and R.H. Williams., 2001: Accelerating residential PV expansion: supply analysis for competitive electricity markets. *Energy Policy*, 29, pp. 787-800.

38. Peuser, F.A., K.H. Remmers, and M. Schnauss, 2002: Solar thermal systems: Successful planning and construction. James & James & Solarprazis, Berlin, 364 pp.

39. Price, L., S. De la Rue du Can, S. Sinton, E. Worrell, N. Zhou, J. Sathaye, and M. Levine, 2006: Sectoral trends in global energy use and greenhouse gas emissions. Lawrence Berkeley National Laboratory, Berkeley, CA.

40. Robert Pollin, Heidi Garrett-Peltier, James Heintz, and Helen Scharber, *Green Recovery: A Program to Create Good Jobs and Start Building a Low-Carbon Economy*, 2008 (Washington, D.C.: Center for American Progress and PERI,), 19, online, http://www.peri.umass.edu/green_recovery/.

41. Rosenfeld Y, I.M. Shohet, Decision support model for semi-automated selection of renovation alternatives, Automation in Construction 8 (1999) 503–510.

42. Rosenfeld, A.H., J.J. Romm, H. Akbari, and M. Pomerantz. 1998. Cool Communities; Strategies for Heat Island Mitigation and Smog Reduction, Energy and Buildings, pp. 51-62

43. Roth, K.W., F. Goldstein, and J. Kleinman, 2002: Energy consumption by office and telecommunications equipment in commercial buildings. Volume 1: Energy Consumption Baseline, Arthur D. Little Inc., Cambridge (MA), 201 pp. <http://www.eere.energy.gov/buildings/ info/documents/pdfs/office_telecom-vol1_final.pdf>,

44. Shonder, J.A., M.A. Martin, H.A. McLain, and P.J. Hughes, 2000: Comparative analysis of life-cycle costs of geothermal heat pumps and three conventional HVAC systems. *ASHRAE Transactions*, 106(Part 2), pp. 51-560.

45. Socolow, R.H., 1978: Saving energy in the home: Princeton's experiments at Twin Rivers. Ballinger Press, Cambridge, MA.

46. Taylor, P.B., E.H. Mathews, M. Kleingeld, and G.W. Taljaard, 2000: The effect of ceiling insulation on indoor comfort. Building and Environment, 35, pp. 339-346.

47. Ueno, T., F. Sano, O. Saeki, and K. Tsuji, 2006: Effectiveness of an energy consumption information system on energy savings in residential houses based on monitored data. *Applied Energy*, 83, pp. 166-183.

48. Van Uffelen, Chris, 2011, Façade Greenery, contemporary landscaping, Braun Publishing AG

49. Weiss, W., I. Bergmann, and G. Faninger, 2005: Solar heating worldwide, markets and contribution to the energy supply 2003. IEA Solar Heating and Cooling Programme, Graz, Austria.

50. **Zavadskas**, E.K. A. Kaklauskas, S. Raslanas, Renovation of multi-storey apartment buildings from the aspect of real estate market value, in: Proceedings of Sixth International Conference on Energy for Buildings, Vilnius, (2004), pp. 375–385.

51. **Zavadskas**, E.K. A. Kaklauskas, S. Raslanas, Evaluation of investments into housing renovation, International Journal of Strategic Property Management 8 (3) (2004) 177–190

EPILOGUE

Green building retrofits are truly global in developed nations. Retrofit case studies from the U.S., Canada, the European Union, Asia and Australia. shows that Green certification protocols for existing buildings are going global. BREEAM and LEED are used worldwide, and green certification systems are popping up everywhere from the Middle East to South Africa, to Mexico. to Asia Pacific. A common international language on sustainable properties and protocols is being forged.

Energy efficient and sustainable retrofits can be remarkably cost-effective. A number of the case studies achieved payback in a year or less, and an early sample of U.S. LEED-certified retrofits showed average paybacks of approximately 17 months, with an average cost per square foot of just $.21.

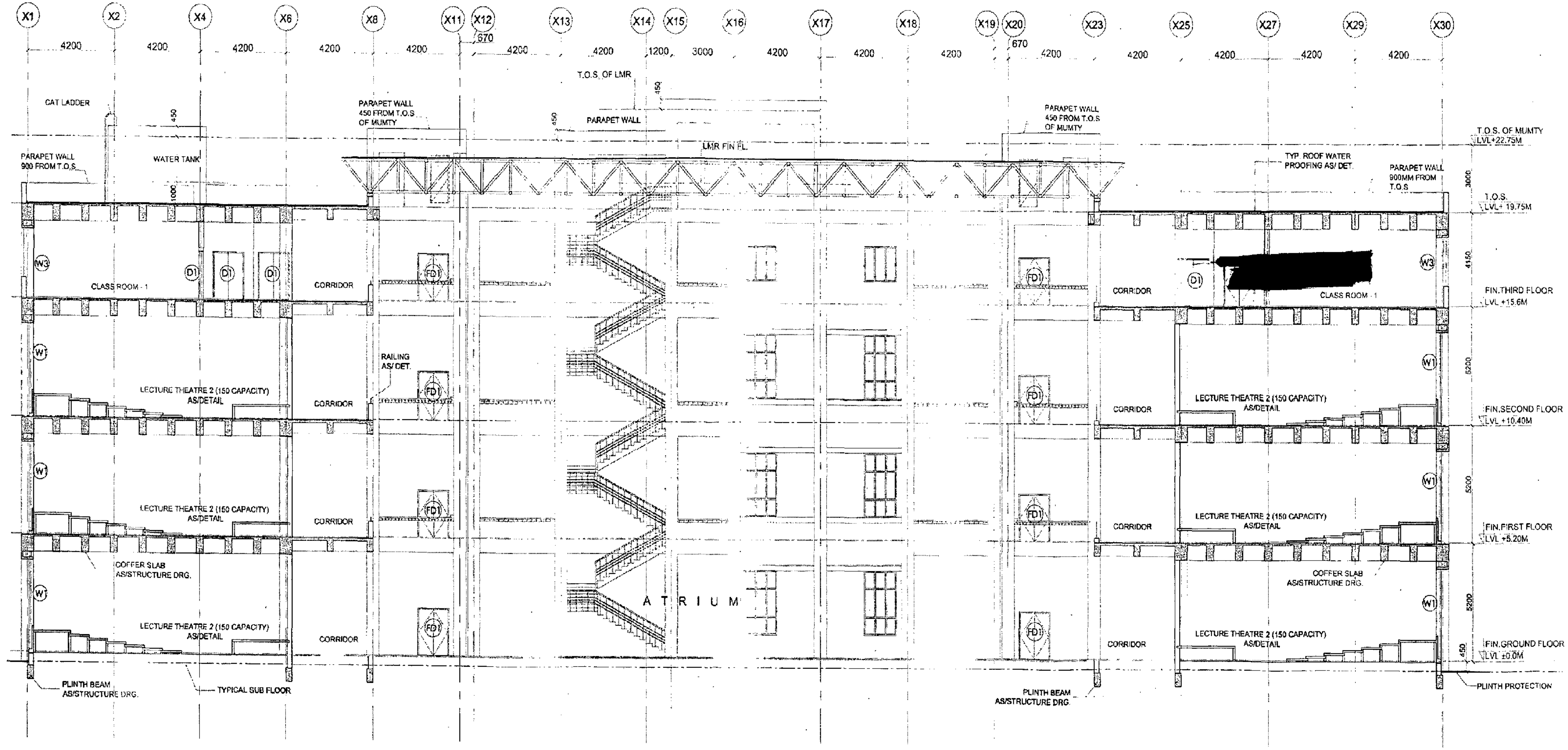
Many of the retrofit approaches with the best paybacks are the simplest. A few of the readily implemented, low-cost ways to reduce building energy use include such approaches as operational changes, lighting retrofits, and replacing constant speed drives with variable speed drives on major mechanical equipment. These types of changes are not technologically advanced, but they are extremely cost-effective. The key point: energy-efficiency can be simple (although it does require careful attention to planning and maintenance).

There are also some fascinating technological advances being introduced to the building energy-efficiency market. Among them: smart meters and smart grid systems, which use wireless technology to monitor and optimize energy use in real time; heat management paints that shield exteriors from heat absorption; and the use of nanotechnology to produce next-generation insulating materials.

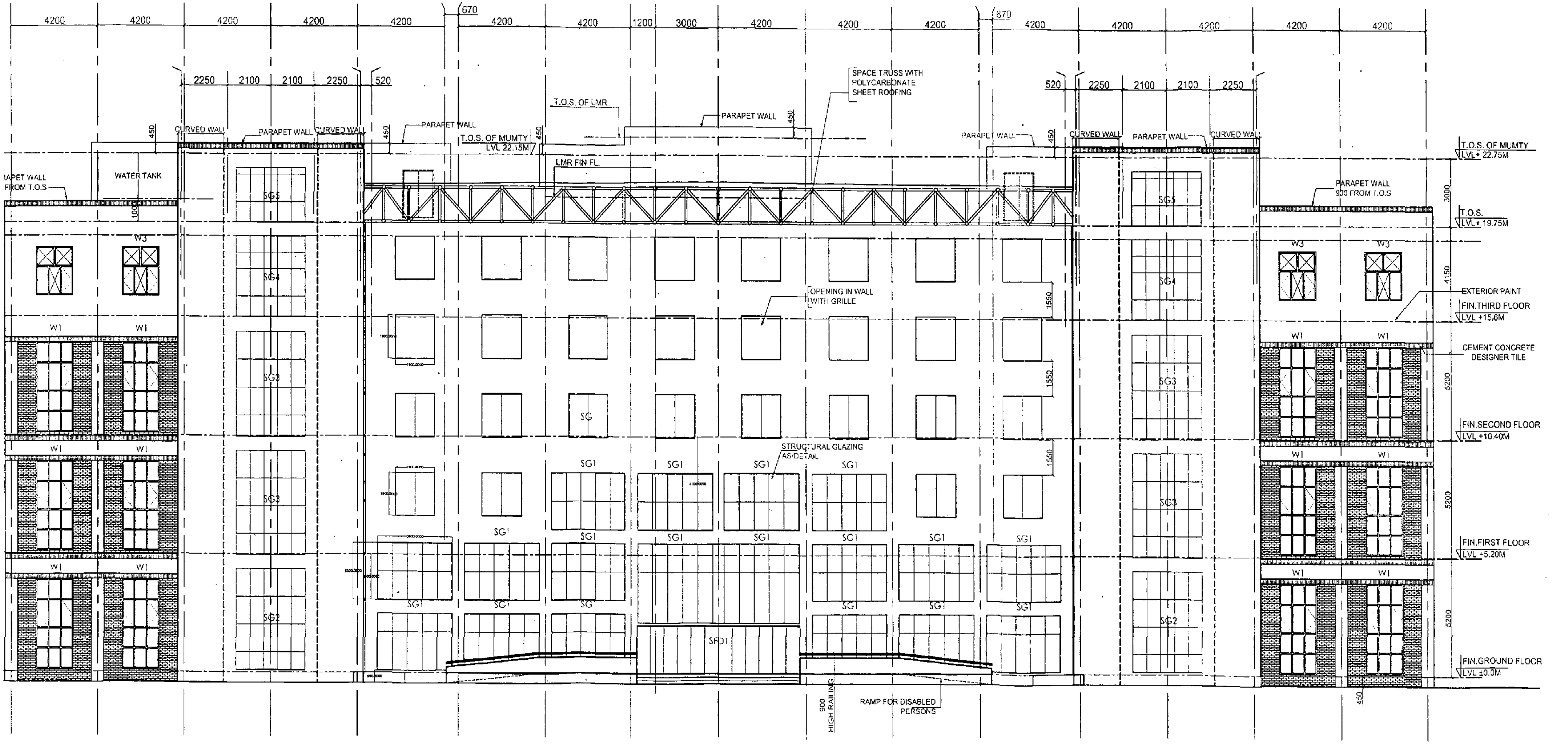
One of the most intriguing trends is the extensive use of passive heating and cooling to minimize reliance on mechanical systems. Passive heating and cooling approaches include the use of natural ventilation, and the use of vents or chimneys to regulate interior temperatures. Historic structures are often particularly well-suited to the use of passive heating and cooling.

Next on the horizon- Net-zero energy building retrofit. Structures that consume no more energy than they produce on an annual basis.are called as net zero energy buildings The first net-zero retrofits are being completed.in San Jose The Integrated Design Associates (IDeAs) headquarters.

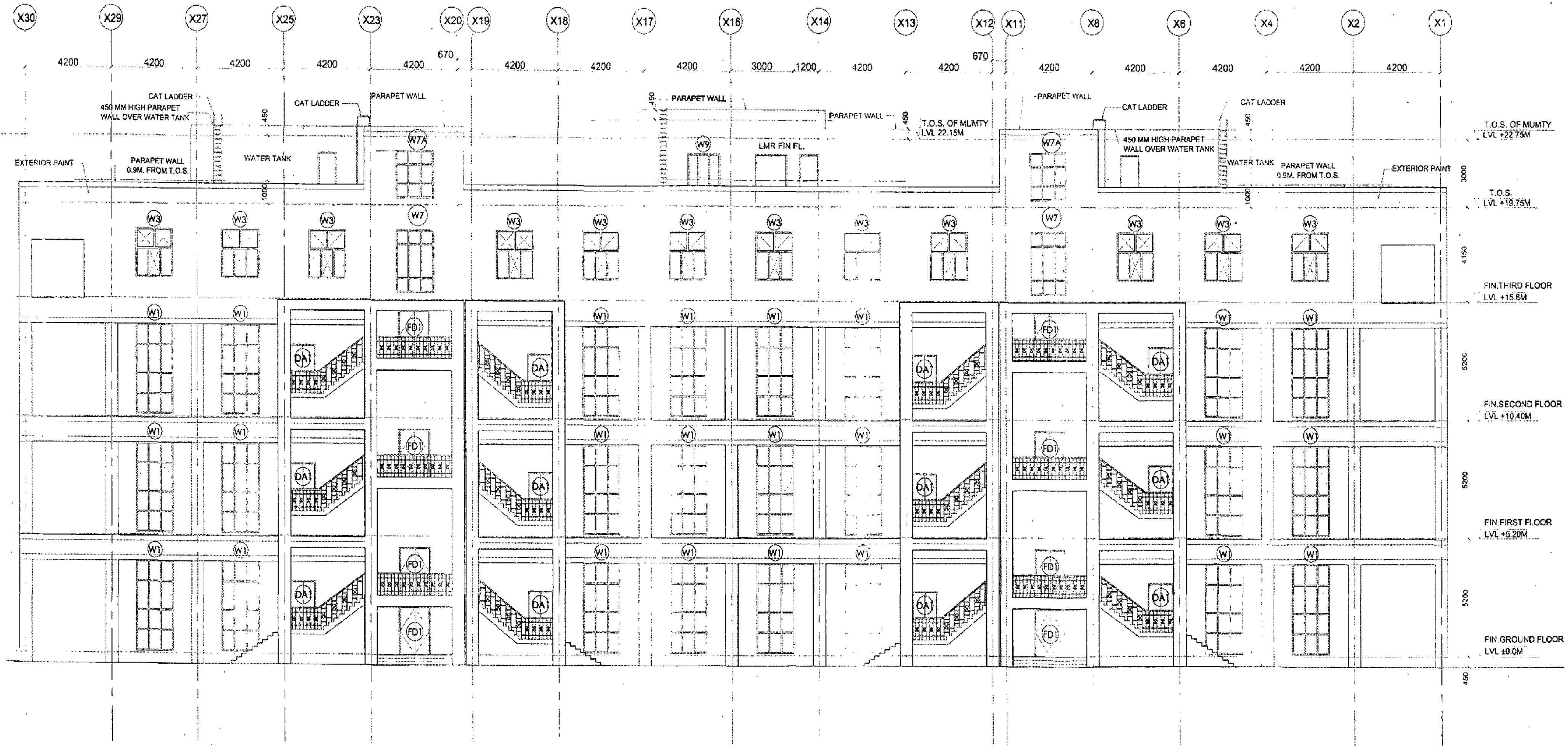
ANNEXURES



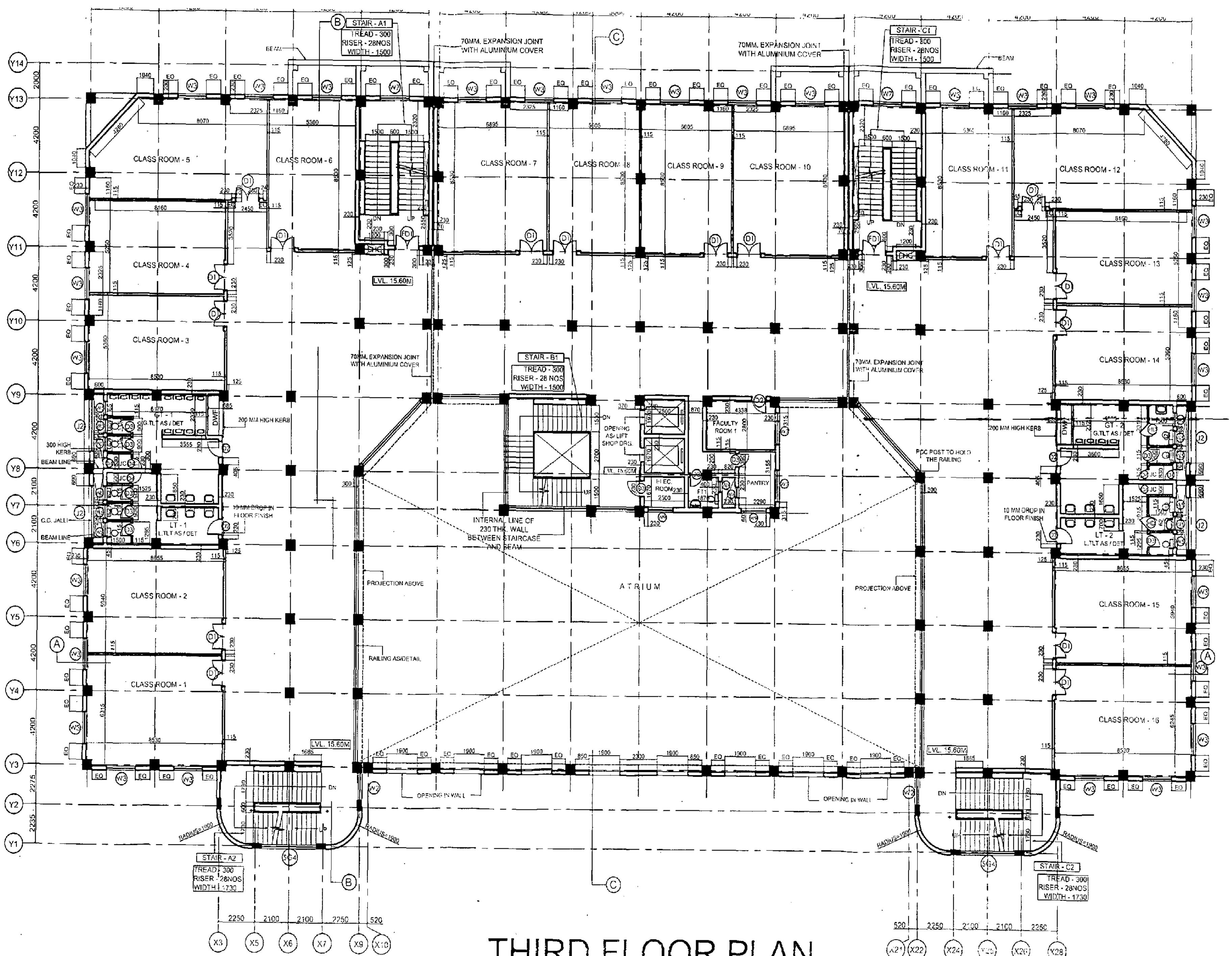
Section Through AA



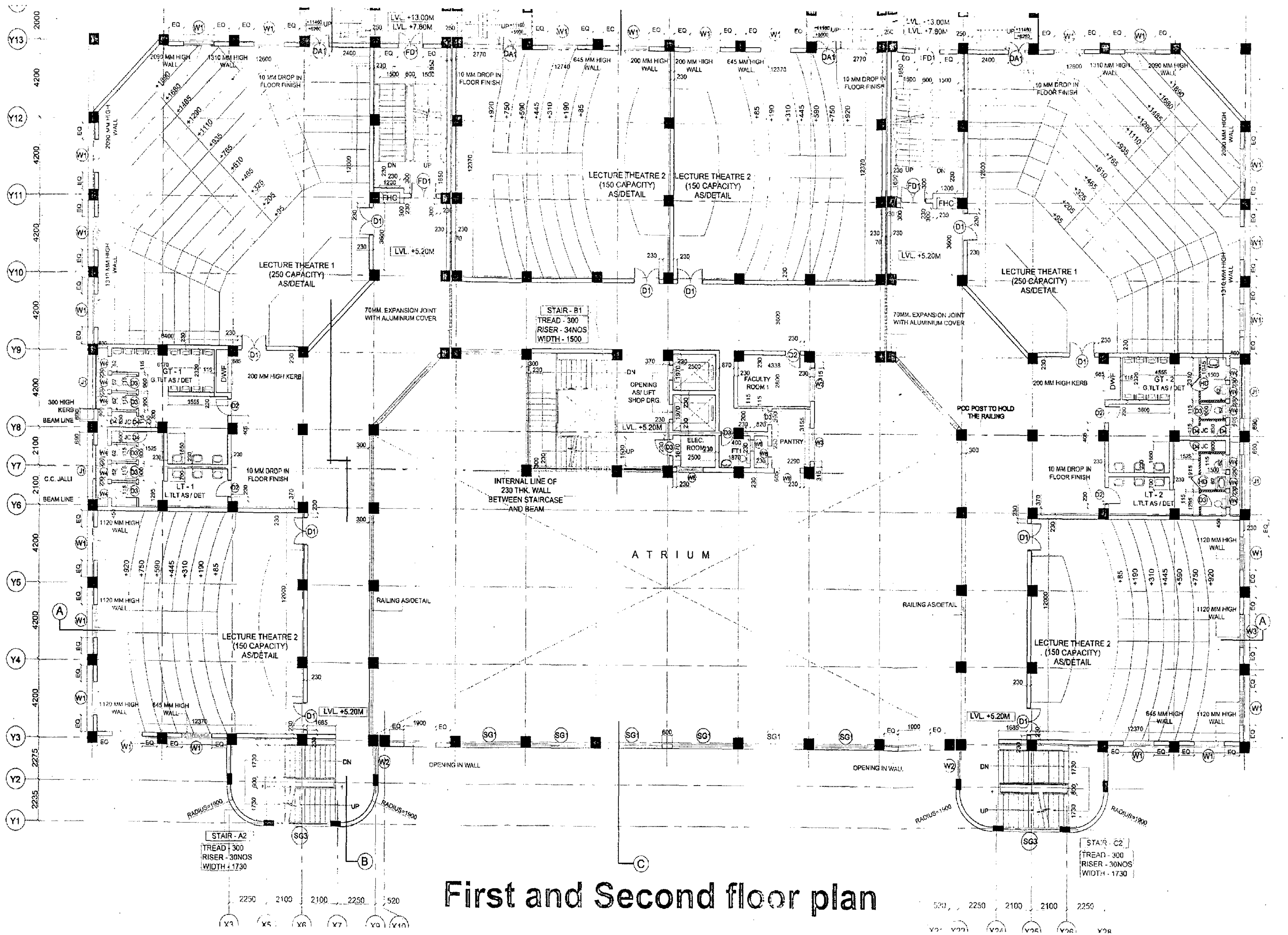
EAST SIDE ELEVATION



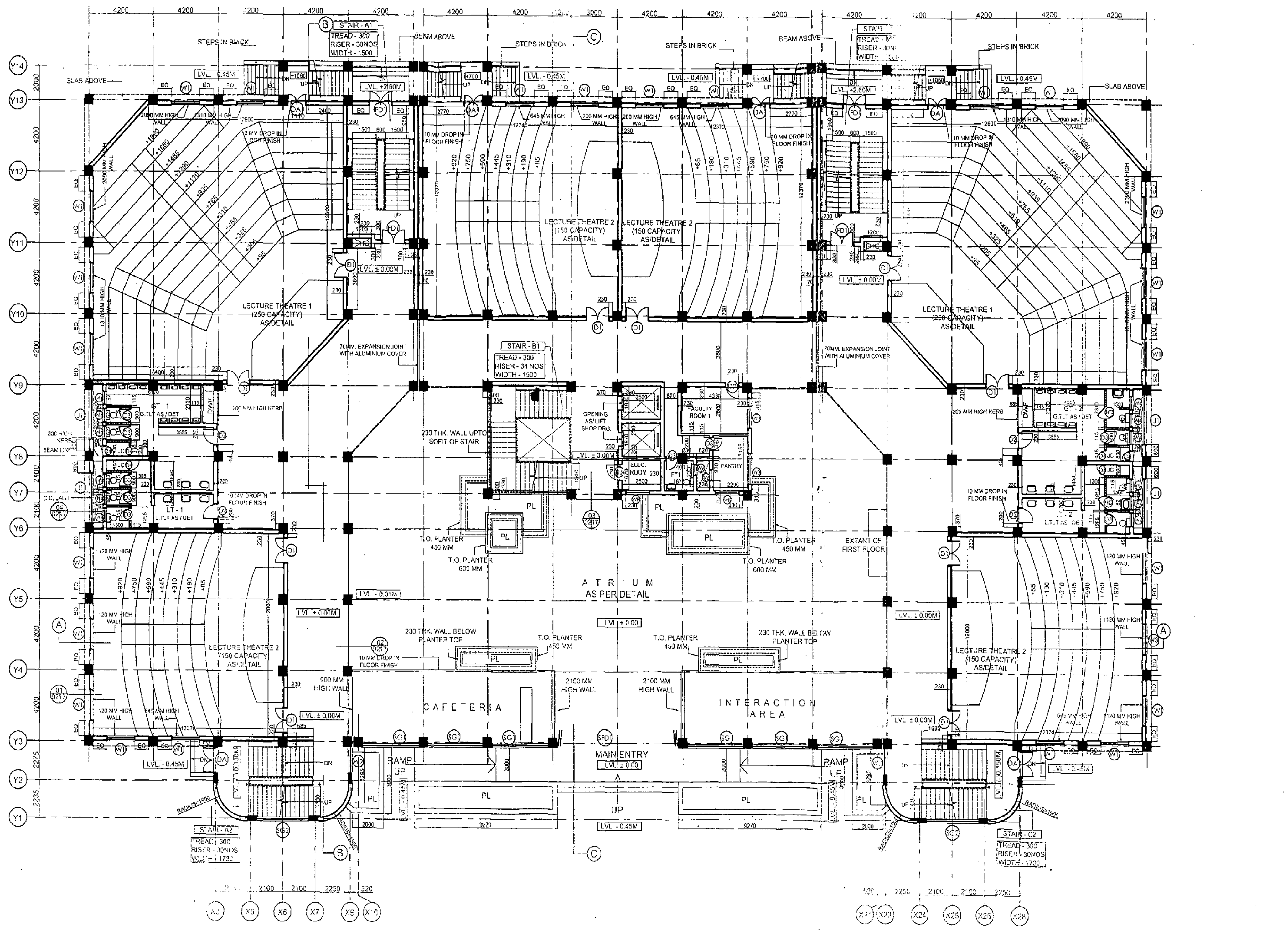
West Side Elevation



THIRD FLOOR PLAN



First and Second floor plan


STAIR - A1
TREAD - 300
RISER - 30NOS
WIDTH - 1500
STEPS IN BRICK
BEAM ABOVE
SLAB ABOVE
LECTURE THEATRE 1
(250 CAPACITY)
AS/DETAIL
LECTURE THEATRE 2
(150 CAPACITY)
AS/DETAIL
STAIR - B1
TREAD - 300
RISER - 34 NOS
WIDTH - 1500
70MM. EXPANSION JOINT WITH ALUMINIUM COVER
230 THK. WALL UPTO SOFIT OF STAIR
OPENING AS/LIFT SHOP DRG.
FACULTY ROOM 1
PANTRY
ELEC. ROOM
GT - 1
LT - 1
GT - 2
LT - 2
T.O. PLANTER 450 MM
T.O. PLANTER 600 MM
EXTANT OF FIRST FLOOR
ATRIUM
AS PER DETAIL
230 THK. WALL BELOW PLANTER TOP
10 MM DROP IN FLOOR FINISH
900 MM HIGH WALL
2100 MM HIGH WALL
CAFETERIA
INTERACTION AREA
MAIN ENTRY
RAMP UP
UP
LVL. ± 0.00M
LVL. - 0.45M
STAIR - A2
TREAD - 300
RISER - 30NOS
STAIR - C2
TREAD - 300
RISER - 30NOS
WIDTH - 1730