DESIGN OF ZERO ENERGY BUILDING

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NATIONAL UNIVERSITY OF SCIENCES AND TECHNOLOGY

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It Is To Certify That The

Design and Analysis Work Titled

Design of Zero Energy Building

Submitted By

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Has been accepted towards the partial fulfillment

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For

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Contents

ABSTRACT

Energy crisis in Pakistan and economic slump along with increased global warming is an eye opener for everyone to look for the alternate energy resources and to decrease our dependency on electricity produced by fossil fuels. Although on international level, lots of research has been carried out on energy efficient construction yet concept of zero energy buildings is new in Pakistan. Our project depicts design of zero energy house (ZEH) to create awareness among the people about this concept. Our project deals with two major tasks. First, to discuss different techniques used in construction to reduce the heating and cooling loads of a building and also discuss the renewable resources available to fulfill energy demands of a building .Second, to by using simulation software, analyze the data, options available and explore the most effective and appropriate techniques to minimize cooling/heating loads of building."

CHAPTER –I

INTRODUCTION

1.1 BACKGROUND

Over past few decades our world has grown as a global village. Communities round the world have become integrated through more sophisticated and advanced network of communication and trade. More and more population is now oriented towards urban culture and so industrialization is growing at fast rate. This all leads to high energy demands all over the world and so increased use of natural resources like coal natural gas and water to produce enough energy to meet everyday demand of the world. And the irony is we are not only getting short of natural resources but also releasing high levels of CO_2 in atmosphere which eventually leads to global warming.

1.2 GLOBALWARMING

Global warming is the current rise in the average temperature of Earth's oceans and atmosphere and its projected continuation. It is occurring and was initiated by human .activities, especially those that increase concentrations of greenhouse gases in the atmosphere, such as deforestation and burning of fossil fuels. Scientists directly measured the global surface temperature increase during the 20th century at about 0.74°C (1.33T). Evidence of this seems to be that the polar ice caps and various glaciers are melting, which is also raising the height of the shorelines of the World's oceans.

1.3 GHG EMISSIONS

The primary greenhouse gases in the Earth's atmosphere are water vapor, carbon dioxide, methane, nitrous oxide, and ozone. Prior to the Industrial Revolution, carbon dioxide was at about 280 ppmv (parts per million by volume). Today's level is around 380 ppmv. World energy-related carbon dioxide emissions rise from 29.7 billion metric tons in 2007 to 33.8 metric tons in 2020 and 42.4 billion metric tons in 2035—an increase of 43 percent over the projection period. With strong economic growth and continued heavy reliance on fossil fuels expected for most non-OECD (Organization for Economic Co-operation and Development) economies under current policies, much of the projected increase in Co2 emissions occurs among the developing non-OECD nations.

1.4 EFFECT OF GREENHOUSE GASES:

The effect of global warming is quite visible in the form of increased natural hazards. For example

- World temperature is increasing. Most of the planet has, however, experienced an increased temperature of about 13°C per decade during the past 50 years.
- Increased dry weather (less rainfall) which is creating record-setting wildfires is one of the consequences of global warming
- Drought takes its toll on World food production. There world's worst drought from1999 through 2002,
- Warmer water in the oceans injects more energy into storms making

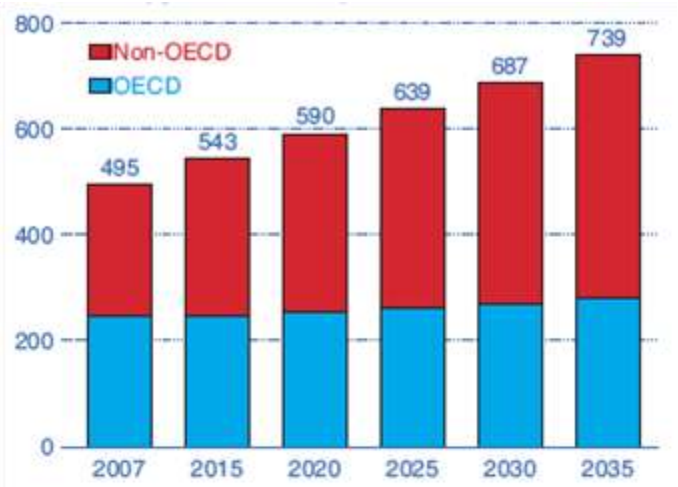
them stronger, and causing category 4 and 5 hurricanes during the last 35 years and increased ocean temperatures. Hurricane Katrina (2005) was one of the worst in our history.

- Severe flooding caused by extremely heavy rainfall.
- Scientists believe that higher levels of carbon dioxide lead to allergy weed growth, contributing to asthma.
- Certain species face extinction if global temperatures exceed 2.7 to 4.5 °F (such as polar bears who are now drowning)
- The oceans are becoming more acidic due to carbon dioxide emissions. A 3.6 °F increase could kill 97% of the World's coral reefs, which are an integral link in oceanic ecosystems.

The only way to reduce the hazardous effects of global warming is to reduce greenhouse effect Reducing world energy consumption will help a lot to reduce global warming. So today it’s becoming necessary to adopt sustainable living so to save the world and it its habitants.

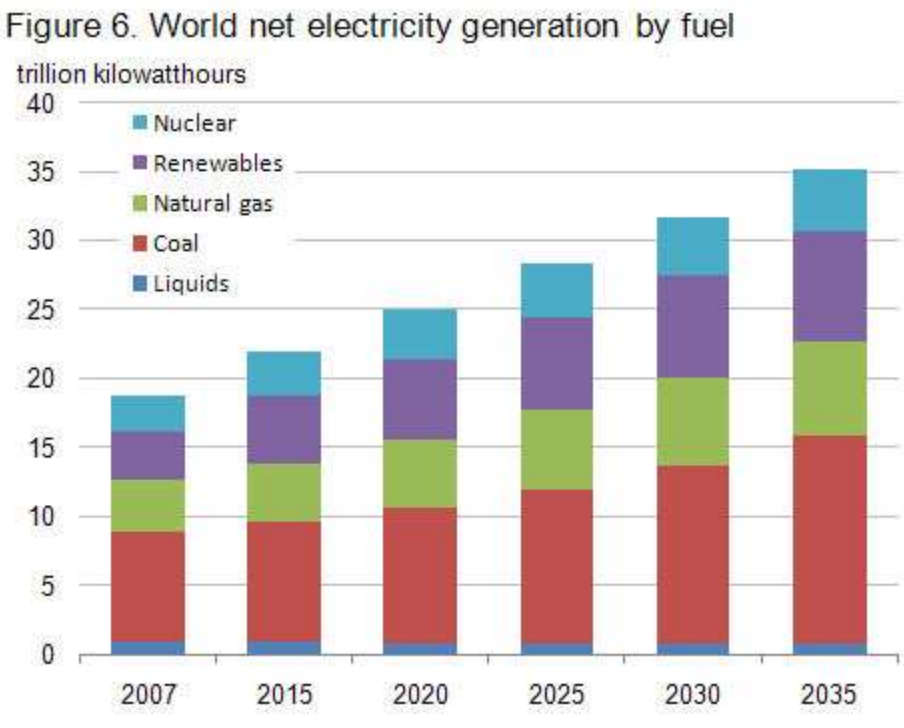
1.5 FOSSIL FUELS AS SOURCE OF ENERGY

Population and income growth are the two most powerful driving forces behind the demand for energy. Since 1900 world population has more than quadrupled, real income has grown by a factor of 25, and primary energy consumption by a factor of 22.5.World energy consumption is projected to increase by 71% from 2003 to 2030.World marketed energy consumption is shown as below



Graph - World Marketed Energy Consumption (quadrillion Btu)

Following graphs shows the world energy use by fuel type and energy consumption for electricity generation by fuel types.



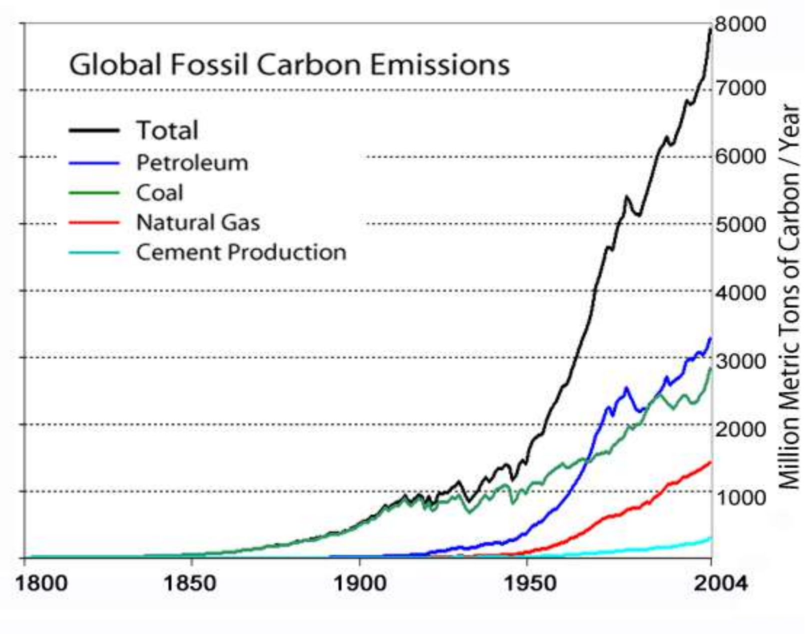
Graph - World Net Electricity Generation by Fuel

Fossil fuels are of great importance because they can be burned (oxidized to carbon and water), producing significant amounts of energy per unit weight. The use of coal as a fuel predates recorded history. Coal was used to run furnaces for the melting of ore. Fossil fuels are non-renewable resources because they take millions of years to form, and reserves are being depleted much faster than new ones are being made. The production and use of fossil fuels raise environmental concerns. A global movement toward the generation of renewable is therefore under way to help meet increased energy needs.

It was estimated by the Energy Information Administration that in 2007 primary sources of energy consisted of petroleum 36.0%, coal 27.4%, and natural gas 23.0%, amounting to a 16.4% share for fossil fuels in primary energy consumption in the world. The burning of fossil fuels produces around 21.3 billion tons (21.3 gigatons) of carbon dioxide (CO_2) per year, but it is estimated that natural processes can only absorb about half of that amount, so there is a net increase of 10.65 billion tons of atmospheric carbon dioxide per year (one ton of atmospheric carbon is equivalent to 44/12 or 3.7 tons of carbon dioxide).

1.5.1 **Oil** is expected to be the slowest-growing fuel over the next 20 years. Global liquids demand (oil, biofuels, and other liquids) nonetheless is likely to rise by 16.5 Mb/d, exceeding 102 Mb/d by 2030. Demand growth is highest in the developing world, but the United States is the world's largest consumer of petroleum.

1.5.2 **Natural gas** is a gas consisting primarily of methane, typically with 0-20% higher hydrocarbons. In 2009 the world use of gas was 131% compared to year 2000. 66% of the growth was outside EU, North America Latin America and Russia. Others include Middle East, Asia and Africa. The gas supply increased also in the previous regions: 8.6% in the EU and 16% in the North America 2000-2009



Graph - Global fossil carbon emission by fuel

1.5.3 **Coal** has been used since the industrial revolution. It is combustible sedimentary rock rich in hydrocarbons. Coal is primarily used as a solid fuel to produce electricity and heat through combustion. World coal consumption was about 6,743,786,000 short tons in 2006 and is expected to increase 48% to 9.98 billion short tons by 2030. At least 40% of the world's electricity comes from coal.

1.6 IMPACT OF BUILDINGS ON ENVIRONMENT:

Buildings have tremendous impact on environment in all life cycle stages, accounting for one-sixth of the world's freshwater withdrawals, one-quarter of its wood harvest, and two-fifths of its material and energy flows. This results to different problems and most significant influence on resource dissipation, biodiversity degradation (induced by extensive land exploitation) and human health. Structures also impact areas beyond their immediate location, affecting the watersheds, air quality, and transportation patterns of communities.

Globally, buildings use 30 to 40% of primary energy. Though this energy is typically generated from biomass in low income countries, it comes mostly from the burning of fossil fuels in middle and high income nations.

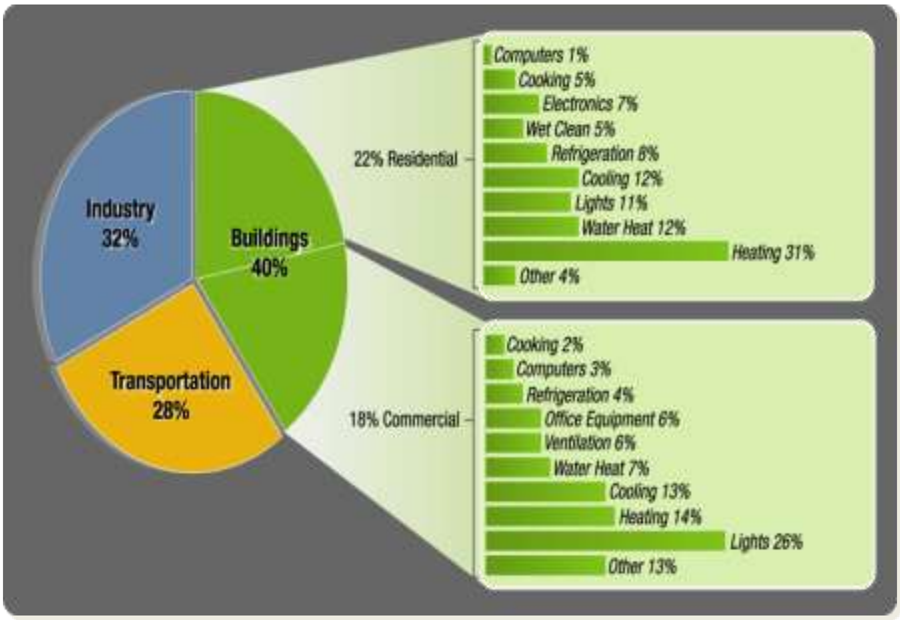


Fig- Consumption of Energy

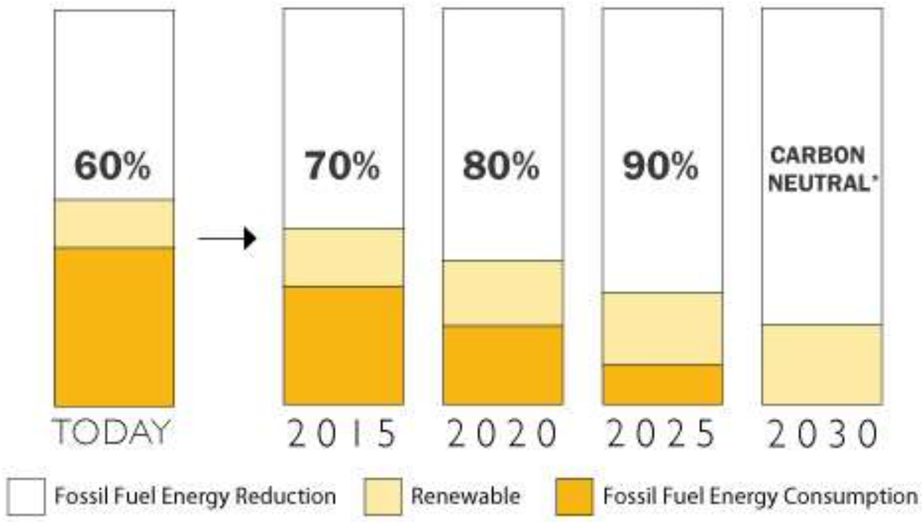
The building sector contributes up to 30% of global annual greenhouse gas emissions. Residential sector accounts for around 50%of the total energy consumed by buildings. Considerable amount of energy consumption can be reduced by reducing building energy demands. This can be done by using simple energy efficient techniques in building.

1.7 THE 2030 CHALLENGE:

Buildings are the major source of global demand for energy and materials that produce by-product greenhouse gases (GHG). Slowing the growth rate of GHG emissions and then reversing it is the key to addressing climate change and keeping global average temperature below 2°C above pre-industrial levels.

To accomplish this, Architecture 2030 issued 'The 2030 Challenge" asking the global architecture and building community to adopt the following targets:

- All new buildings, developments and major renovations shall be designed to meet a fossil fuel, GHG-emitting, energy consumption performance standard of 60% below the regional (or country) average for that building type.
- At a minimum, an equal amount of existing building area shall be renovated annually to meet a fossil fuel GHG-emitting, energy consumption performance standard of 60%of the regional (or country) average for that building type.
- The fossil fuel reduction standard for all new buildings and major renovations shall be increased to:
  - 70% in 2015
  - 80% in 2020
  - 90%in 2025
- Carbon-neutral in 2030 (using no fossil fuel GHG emitting energy to operate). These targets may be accomplished by implementing innovative sustainable design strategies, GENERATING on-site renewable power and/or purchasing (20% maximum) renewable energy.



The 2030 Challenge

1.8 STEPS TOWARDS SUSTAINABILITY:

To achieve objective we need to adopt sustainable architecture. Sustainable Architecture is all about being able to sustain what we have without damaging our planet. Sustainable architecture seeks to minimize the negative environmental impact of buildings by enhancing efficiency and moderation in the use of materials, energy, and development space. Most simply, the idea of sustainability, or ecological design, is to ensure that our actions and decisions today do not inhibit the opportunities of future generations.

Fig- Sustainable Building

1.9 SUSTAINABLE ARCHITECTURE AND ITS OBJECTIVES:

The main objectives of sustainable design are to avoid resource depletion of energy, water, and raw materials; prevent environmental degradation caused by facilities and infrastructure throughout their life cycle; and create built environments that are livable, comfortable, safe, and productive.

While the definition of sustainable building design is constantly changing, six fundamental principles persist.

- **Optimize Site/Existing Structure Potential:**
  Creating sustainable buildings starts with proper site selection, including consideration of the reuse or rehabilitation of existing buildings. The location, orientation, and landscaping of a building affect the local ecosystems, transportation methods, and energy use. Incorporate Smart growth principles in the project development process, whether it is a single building, campus or military base. Sitting for physical security is a critical issue in optimizing site design, including locations of access roads, parking, vehicle barriers, and perimeter lighting. Whether designing a new building or retrofitting an existing building, site design must integrate with sustainable design to achieve a successful project.

- **Optimize Energy Use:**
  With America's supply of fossil fuel dwindling, concerns for energy independence and security increasing, and the impacts of global climate change arising, it is essential to find ways to reduce load, increase efficiency, and utilize renewable energy resources in federal facilities.

- **Protect and Conserve Water:**

  In many parts of the country, fresh water is an increasingly scarce resource. A sustainable building should reduce, control and/or treat site runoff, use water efficiently, and reuse or recycle water for on-site use, when feasible.

- **Use Environmentally Preferable Products:**

  A sustainable building is constructed of materials that minimize life-cycle environmental impacts such as global warming, resource depletion, and human toxicity environmentally preferable materials have a reduced effect on human health and the environment and contribute to improved worker safety and health, reduced liabilities, reduced disposal costs, and achievement of environmental goals.

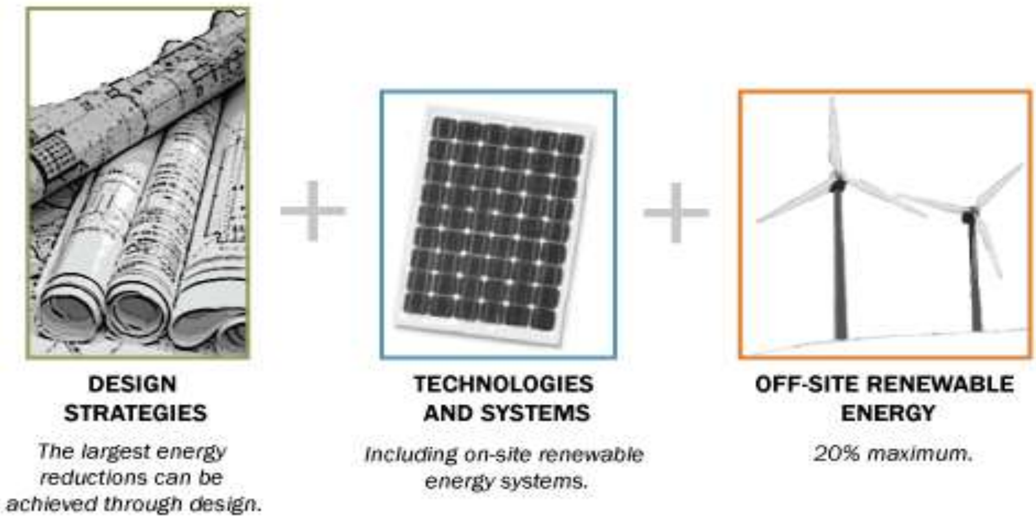
- **Enhance Indoor Environmental Quality (IEQ):**

  The indoor environmental quality (IEQ) of a building has a significant impact on occupant health, comfort, and productivity. Among other attributes, a sustainable building maximizes day lighting; has appropriate ventilation and moisture control; and avoids the use of materials with high-VOC (volatile organic compound) emissions. Additionally, consider ventilation and filtration to mitigate chemical, biological, and radiological attack.

- **Optimize Operational And Maintenance Practices:**

  Considering a building's operating and maintenance issues during the preliminary design of a facility will contribute to improved working environments, higher productivity, reduced energy and resource costs, and prevented system failures. Encourage building operators and maintenance personnel to participate in the design and development phases to ensure optimal operations and maintenance of the building. Designers can specify materials and systems that simplify and reduce maintenance requirements; require less water, energy, and toxic chemicals and, cleaners to maintain; and are cost-effective and reduce life-cycle costs. Additionally, design facilities to include meters in order to track the progress of sustainability initiatives, including reductions in energy and water use and waste generation, in the facility and on site

After making building environment friendly we need to find the sustainable source of energy to meet its energy needs. The renewable energy sources are then exploited to meet the rest of the energy demands of building.



Meeting the 2030 Challenge

1.10 ZERO ENERGY BUILDING

A zero-energy building, also known as a zero net energy (ZNE) building, is a popular term to describe a buildings use with zero net energy consumption and zero carbon emissions annually. Zero energy buildings can be used autonomously from the energy grid supply - energy can be harvested on-site usually in combination with energy producing technologies Like Solar and Wind while reducing the overall use of energy with extremely efficient HVAC and Lighting technologies. The zero-energy design principle is becoming more practical in adopting due to the increasing costs of traditional fossil fuels and their negative impact on the planet's climate and ecological balance.

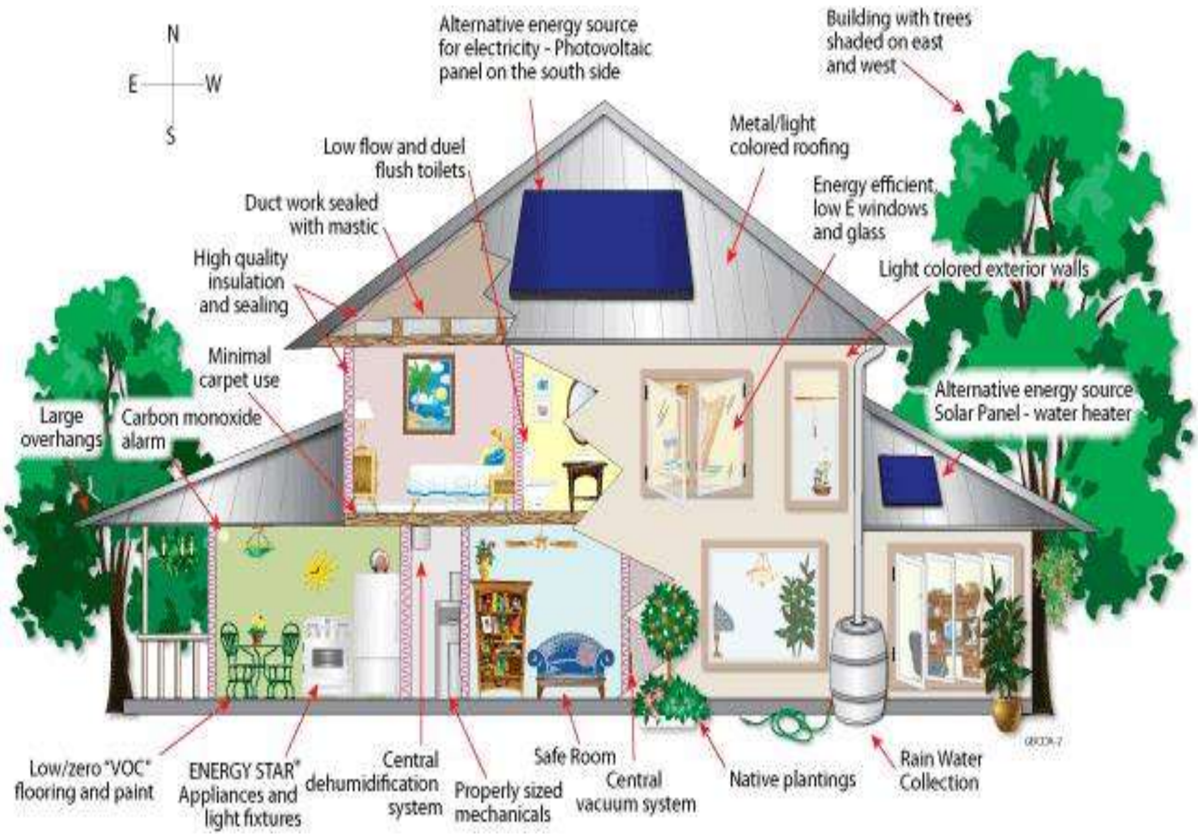


Fig. Zero Energy Building

The most cost-effective steps toward a reduction in a building's energy consumption usually occur during the design process. To achieve efficient energy use, zero energy design departs significantly from conventional construction practice. Successful zero energy building designers typically combine time tested passive solar or natural conditioning, principles that work with the on-site assets Sunlight and solar heat, prevailing breezes, and the cool of the earth below a building, can provide day lighting and stable indoor temperatures with minimum mechanical means. ZEBs are normally optimized to use passive solar heat gain and shading, combined with thermal mass to stabilize temperature variations throughout day, and in most climates is super insulated.

ZEBs harvest available energy to meet their electricity and heating or cooling needs. In the design of individual houses, various micro generation technologies may be used to provide heat and electricity to the building, using solar cells or wind turbines for electricity, and bio fuels or solar collectors linked to seasonal thermal stores for space heating. To cope with fluctuations in demand, zero energy buildings are frequently connected to the electricity grid export electricity to the grid when there is a surplus, and drawing electricity when not enough electricity is being produced.

1.11 **ZERO ENERGY HOUSE:**

Energy efficiency and solar energy technologies can result in zero net energy consumption from non-renewable sources. A Zero Energy Home (ZEH) combines state-of-the-art, energy-efficient construction and appliances with commercially available renewable energy systems such as solar water heating and solar electricity. This combination can result in net zero energy - consumption from the utility provider. Zero Energy Homes are connected to the utility grid but can be designed and constructed to produce as much energy as they consume annually.

1.11.1 Energy Homes Have A Number Of Advantages Like:

- **Improved Comfort**—an energy-efficient building envelope reduces temperature fluctuations.
- **Reliability**—a ZEH can be designed to continue functioning even during blackouts.
- **Security**—a home that produces energy protects its owner from fluctuations in energy prices.
- **Environmental Sustainability-----** a ZEH saves energy and reduces pollution.

Fig- Zero Energy House

1.12 SIGNIFICANCE OF PROJECT

Our project "Design of Zero Energy House" is of great significance especially in Pakistan. Undoubtedly, in the new millennium, the importance of energy sector for the development of our country is undeniable. Rapidly increasing knowledge along with speedy technological inventions has resulted in the provision of abundance of facilities. In Pakistan the major energy source is gas which is 32% of the total supplied. The other energy supply sources along with their percentage shares are as under oil (24 %), hydro (3 %), coal (6 %) and nuclear (1%). Electricity is the most important sources of energy in Pakistan. It has become a necessity in the present life, having a wide range of uses in residential as well as in commercial sector.

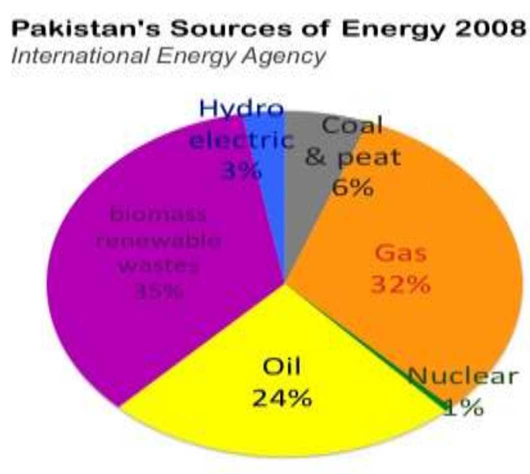


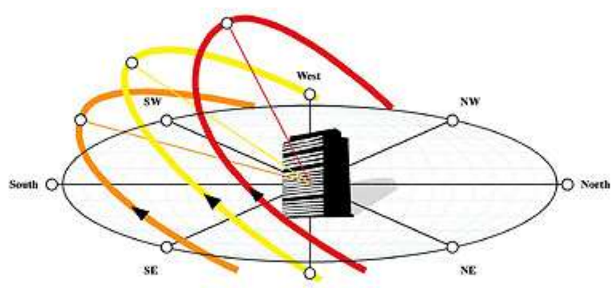
Fig- Energy Supply Sources

Since last five years, Pakistan is facing the worst energy crisis of her history, the increase in the oil prices at the world level is severely affecting the common people and on the other hand, the shortage of electricity is creating havoc in the country. It is the need of time to introduce energy efficient, sustainable and zero energy in our country by reducing the energy demands by building sector will have significant effect on energy demands. This is why we chose this subject as our research project.

TECHNIQUES TO REDUCE THE USE OF ENERGY

2.13 SITE PLANNING

Solar geometry is the determining factor of heat gain, shading and the daylight penetration. Temperature, precipitation, wind and sunshine have a direct effect on buildings. Following factors need to be efficiently controlled:



Solar geometry

a. **ORIENTATION:**

Orientation strongly relates a building to the natural environment-the sun, wind, weather patterns, topography, landscape, and views. Decisions made in site planning and building orientation will have impacts on the energy performance of the building over its entire life cycle.

Energy Conservation strategies relating to building orientation are:

(1) Orient a rectangular building with the long axis running east and west rather than north and south to promote solar heating gains in the winter and reduce solar gains in the summer.

(2) Maximizing north and south facade exposure for daylight harvesting to reduce lighting electrical loads.

(3) Using southern exposure for solar heat gain to reduce heating loads in the heating season.

(4) Using shading strategies to reduce cooling loads caused by solar gain on south facades.

(5) Turning long facades toward the direction of prevailing breezes to enhance the cooling effect of natural ventilation.

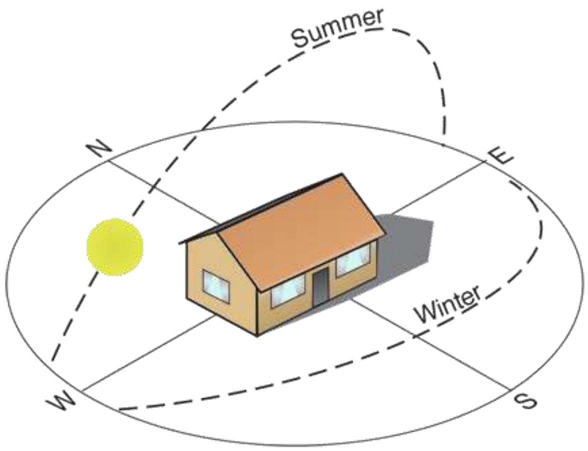
(6) Turning long facades in the direction parallel to slopes to take advantage of cool updrafts to enhance natural ventilation.

(7) Shielding windows and openings from the direction of harsh winter winds and storms to reduce heating loads.

(8) Orienting the most populated building spaces toward north and south exposures to maximize delighting and natural ventilation benefit.

(9) Determining building occupant usage patterns for public, commercial, institutional, or residential buildings, and how occupants will be affected by the building orientation, by time of day, on different exposures.

(10) Locate an attached garage on the west, north, or northwest corner of a house to provide protection from hot afternoon sun in the summer and cold westerly winds in the winter.



Ideal House Orientation

b. LANDSCAPING

Landscapes are integral to building's performance. Decisions about the envelope need to be coordinated with existing and new landscaping schemes on year round basis. An effective landscape plan can reduce the overall energy loads on a building. Trees properly placed around buildings can reduce air-conditioning needs by 30% and can save 20-50% in energy used for heating.

(1) **Ground Surfaces:**

Ground cover also affects heat gain. Minimize the use of masonry materials, such as concrete patches, on the south side of the house. They can reflect heat into the house. Lawn, shrubs, and other low-growing vegetation help prevent overheating in summer, while allowing sunlight to strike the south elevation. Grass can also help cool the air around a building by as much as 10F.The temperature on a hard surface such as concrete pathways can be more than 5 degree centigrade greater than on soft surfaces such as organic paving or vegetative areas.

(2) **Paving:**

Reduce paved areas to lessen heat build-up. Consider selection of paving color with a high reflectance to minimize heat gain. Glare factors should also be considered. Use of pervious paved surfaces is recommended for green building design. Pervious surfaces are ground covers that allow rainwater to infiltrate and flow through to subsurface layers. Paving of pervious surface materials are of particular interest to green building design as a means of preventing urban storm water runoff and reducing the flow of pollutants off site. Pervious surfaces can be used at a variety of scales (from patios to parking lots) and vary in composition and construction.

Paving

The effectiveness of this strategy depends upon the type of pervious surface selected and its intended use (i.e. parking, roadway, walkway, etc.). Pervious surfaces are amenable to use in most climates. Pervious surfaces options include the following:

(a) Porous or open graded asphalt pavement is appropriate for roads and parking lots.

(b) Porous block pavement system can be used for high load conditions (as well as low-traffic applications such as sidewalks and driveways).

(c) Porous Portland cement concrete is appropriate for many paving applications, including parking lots and streets.

(3) **Shading by trees:**

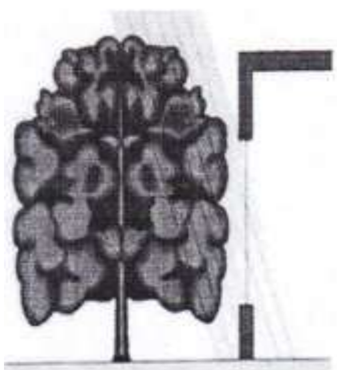
Use of vegetation provides valuable shading and cools the surrounding air by evaporation. The process is transpiration and it draws tremendous amount of heat out of the air around a building.

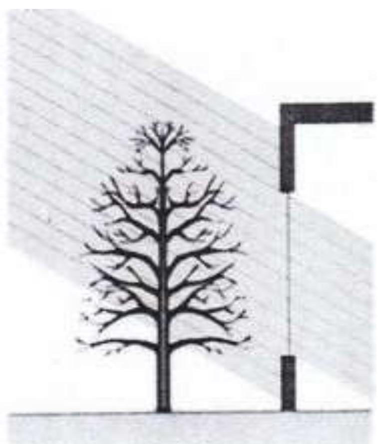
Deciduous trees are effective as they Nock the sun in the summer when it is not desired and allow sun penetration during the winter. On the south side of a building, planting high-crowned deciduous trees—which grow tall with few low-lying branches—is most effective. These trees can provide shade to roofs and south-facing walls in lower buildings when fully leafed in the summer. Thev also permit access to ground-level breezes, and when they lose their leaves in the fall, sunlight is able to stream into south facing widows for passive solar gain.

Shading By Trees

Solar Transmission can be as low as 20% for a mature tree in the summer

Solar Transmission can be as high as 70% for a mature tree in the winter





Vegetation Shading

Vines on more transparent “fence like” elements are effective as they too bear leaves so shade in the summer, and keep their leaves until later in the fall when sun is again desired. Vines are often used as well on south facing elevations on trellises to achieve seasonal variation in the opaqueness of the overhangs.

Evergreens such as pines and spruces can also support a shading strategy. However, they retain their needles year round, evergreens planted along the south side of building can block wintertime solar gain. Along the north, west, and east sides of a building they can support the shading strategy but may also block breezes that can help passively cool a building.

c. **BUILDING FORM**:

The shape of a building determines how much area is exposed to the outdoors through exterior walls and ceilings. To save energy, we have to keep this exposed area to a minimum. The most economical house to build and heat is one with a simple square or rectangular floor plan. Exposed surface area increases and so do construction and energy costs when a house has a complex shape. The surface area to volume (S/V) ratio is important factor determining heat loss and gain. Greater the surface area more will be the heat gain/loss through it. So small S/V ratios imply minimum heat gain and minimum heat loss. In hot dry climates S/V ratio should be as low as possible as this would minimize heat gain. In cold dry climates also S/V ratios should be as low as possible to minimize heat losses. In warm humid climates the prime concern is creating airy spaces. This might not necessarily minimize the S/V ratio. Further, the materials of construction should be such that they do not store heat.

14. **BUILDING ENVELOPE:**

A building envelope is the separation between the interior and the exterior environments of a building. It serves as the outer shell to protect the indoor environment as well as to facilitate its climate control.

A building envelope includes all the components that make up the shell or skin of the building. These components separate the exterior of the building from the interior. Physical components of the envelope include the foundation, roof, walls, doors and windows. The dimensions, performance and compatibility of materials, fabrication process and details, their connections and interactions are the main factors that determine the effectiveness and durability of the building enclosure system. Decisions about the construction details play an important role in design of building envelope. Building materials conduct heat at different rates. The building envelope can affect both the lighting and heating and cooling needs of the building.

ROLE OF ENVELOP ON ENERGY PERFORMANCE:

Building envelope is of great importance since it functions as an environmental filter. It forms a skin around the building and control the influence of the outdoor environment. Basic function of the envelope or enclosure of a building is to protect the covered or otherwise conditioned interior spaces from the surrounding environment. Common measures of the effectiveness of a building envelope include physical protection from weather and climate (comfort), indoor air quality (hygiene and public health), durability and energy efficiency. Proper orientation and fenestration of the building can both amplify or lessen the heating and cooling loads, daylight penetration and ventilation. In addition to improved energy consumption, provision of window improves the workers' productivity, by instilling the feeling of openness within the interior spaces, leaving the positive psychological impact on the occupants.

CLIMATIC CONSIDERATIONS

To determine appropriate envelope materials and building designs the following considerations should be taken into account, depending on the climate type.

- **Hot/Dry Climates:**

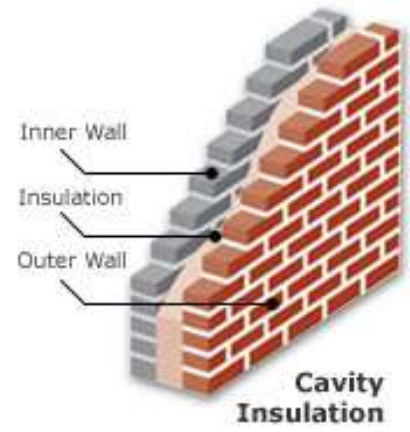
  In hot/dry climates materials with high thermal mass should be used. Buildings in hot/dry climates with significant diurnal temperature swings have traditionally employed thick walls constructed from envelope materials with high mass, such as adobe and masonry. Openings on the north and west facades are limited and large southern openings are detailed to exclude direct sun in the summer and admit it in winter.

  A well-insulated building material with high thermal mass and adequate thickness, lessen and delay the impact of temperature variations from the outside wall on the wall's interior. The material's high thermal capacity allows heat to penetrate slowly

15. **WALLS**

CAVITY WALLS:

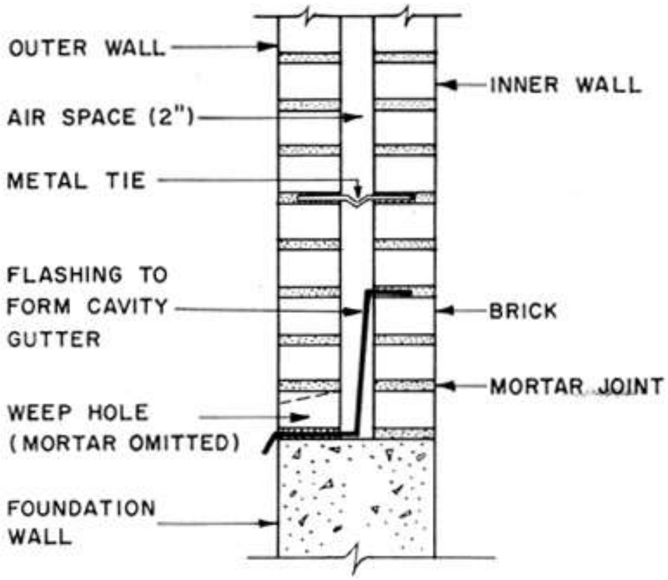
Cavity walls consist of two skins separated by a hollow space (cavity).The skins are commonly masonry such as brick or concrete block. Masonry is an absorbent material, and therefore will slowly draw rainwater or even humidity into the wall. The cavity serves as a way to drain this water to suck out through weep holes at the base of the wall system or above windows. A cavity wall with masonry as both inner and outer skins is more commonly referred to as a double way masonry wall.



Typical Cavity Wall

Different masonry materials can be used on either side of the cavity. The cavity is initially empty but can be filled with insulation by various methods. The two leaves are connected by wall tires to spread lateral loads. Cavity walls are more time consuming and therefore slightly more expensive to build than walls with the two skins bonded together, but they provided better sound and heat insulation and resistance to rain penetration. Main benefit of cavity wall construction is that it provides the ability to more adequately insulate the building. Cavity wall insulation is a cost effective way to reduce the amount of heat(as much as 35%) lost from convection off walls. A continuous layer of rigid insulation is easily fitted between the cavity and the inner skin of the wall. The insulation does not fill the cavity but rather slip in behind it. The cavity itself also helps in insulating the building by acting as a thermal break between the two skins of the wall.

Cavity walls are often used as a first step to reduce the energy costs, due to its low payback time and smaller initial installation costs.



Section of Cavity Wall

INCREASED THICKNESS TECHNIQUE:

As the earth possesses vast heat storing capacity, it takes a long time for it to cool down after sunset, as well as longer time for the temperature to increase after the sun rise. As a result of this phenomenon, higher temperatures are available in the afternoons than mornings although the amount of solar radiation at both times is similar.

Therefore, the design of the buildings should be based on a similar concept, in that buildings should be design to achieve a steady state thermal condition without variations due to changes in external climate conditions. This procedure involves the integration of thick walls which store heat during the day, preventing the seepage of heat into the interior of the building. During the night, when there is no sunshine, heat stored by thick walls will be dissipated into the building. In order to achieve thermal comfort by occupants in a building, it is necessary for them to lose amount of heat which are proportional to the amount generated by physical activities.

VEGETATION ON WALLS:

Vegetation on walls can assist cooling buildings in summers and insulating them in winter. In the summer, solar gain on the facade of the building is reduced by shading and as many species of climbing plants raise their leaves in response to the high angle of the sun, the effect of ventilation blind is created; cool air is drawn inwards and upwards, and warm air is vented at the top.

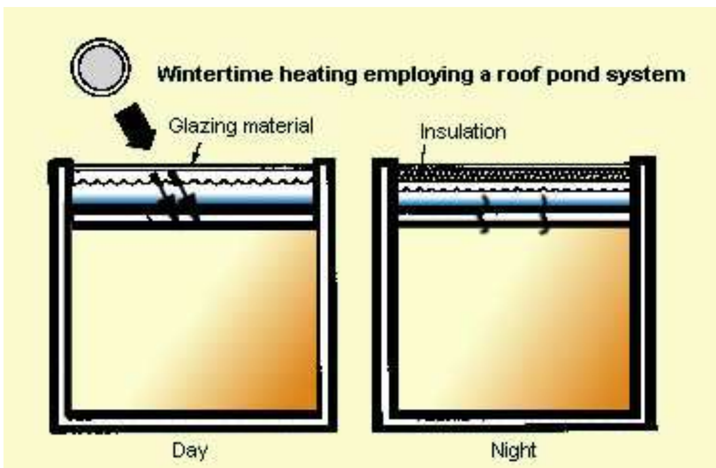
Mosee Du QuaiBranly, Paris

Evaporation and transpiration provide an additional cooling force In winter, evergreen species offer a degree of insulation by trapping a layer of air against the facade and reducing conventional heat loss. Energy savings are less significant on well-insulated buildings, such as those with brick cavity walls.

16. **ROOFS:**

POND ROOF:

A Roof pond system usually consists of six to twelve inches of water contained on a flat roof. Water can also be stored in large plastic or fiberglass containers covered by glazing and the space below is warmed by radiant heat from the warm water above. In the daytime when the sun is shining the water in the "pond" heats up. At night insulation is moved over the "pond" and the heated water radiates to the space below heating the room.



Roof Pond System

GREEN ROOF

Is a roof of a building that is completely covered with vegetation.

GREEN ROOF COMPONENTS

The components of green roofs, from the bottom to top, include:

- Waterproofing membrane
- Roof barrier to protect the membrane (made of gravel, impervious concrete, pvc, copper)
- Insulation (if the building is heated or cooled)
- Water Retention Layer
- Drainage Layer
- Filter (Polyester fiber mats, polypropylene mats or non- biodegradable fabrics)
- Soil
- Vegetation

TYPES OF GREEN ROOFS

These are categorized in two types:

a. **Extensive Green Roofs**

Green roof have a shallow (< 6" depth) growing media and are light weight structures (approximately 10-35 lbs/sq ft) when wet that cover large space of roof top requiring minimal maintenance.

b. **Intensive Green Roof**

Intensive green roof or a rooftop gardens' use deeper growing media (>6') and include small trees and shrubs, creating park like settings that are more inconvisible. They tend to be more expensive and heavier weight on the roof approx. 50-300 (lbs/sq.ft). When wet must be considered in design. Intensive green roofs are more common in tropical climate than extensive green roofs climates than extensive green roofs.

ELEMENTS OF GREEN ROOF

These types of green roof offer a variety of benefits including

a. Improved air quality as the plants observes and convert carbon dioxide to oxygen
b. Long Life span
c. Excellent insulation
d. Cooled surrounding environment
e. Potentially increase the area of habitat for while such as birds and insects.
f. Roof Garden
g. Roof garden is any garden on the roof of a building. Besides the decorative benefit, roof planning may provide food, temperature control. Hydrological benefits, architectural enhancement, habitants or corridors for wildlife and recreational opportunities.
h. Roof top gardens providing resistance to thermal radiation, rooftop gardens are also beneficial in reducing rain run-off. A roof garden can delay runoff, reduce the rate of runoff.

DIFFERENCE BETWEEN A GREEN ROOF AND A ROOF GARDEN

A given roof requires a complicated, multi-layer structure to support it. The hole is covered with soil were plants grow. On the other hand, vegetation is planned in pots to form a roof garden, which is basically used for its aesthetic living.

The growing medium; little , stressful conditions for plants;	Deep soil; irrigation system; more favorable conditions for plants; high plant diversity; often accessible.
Advantages: • Light weight, roof generally does not require reinforcement. • Suitable for large areas • Suitable for roofs with 0-30* (slope) • Low maintenance and long life • Often no need for irrigation and specialized drainage systems • Less technical expertise needed • Often suitable for retrofit projects • Relatively inexpensive • Looks more natural • Easier for planning authority to demand as a condition of planning approvals	**Advantages:** • Greater diversity of plants and habitats. • Good insulation properties • Can simulate a wildlife garden on the ground • Can be made very attractive visually • Often accessible, with more diverse utilization of the roof, i.e., for recreation, growing food, as open space • More energy efficiency and storm water retention capability • Longer membrane life

Disadvantages:	**Disadvantages**:
• Less Energy efficiency and storm water retention benefits • More limited choice of plants • Usually no access for recreation or other uses • Unattractive to some, especially in winter	• Greater weight loading on roof. • Need for irrigation and drainage systems requiring energy, water, materials. • Higher capital & maintenance costs • More complex systems and expertise

17. **ROOF TREATMENT**

a. **Tile Insulation**

(1) Clean the surface and remove all loose particles and pebbles from the roof.

(2) Mix the ingredients of cement sand mortar (1:4) in the required proportion. Sand should be free from mud and other impurities.

(3) Lay the tiles in 1 inch thick cement sand mortar. Start lying from the edges. Use trowel to spread and set the mortar in required thickness.

(4) Fix and level the tiles. Do not strike tiles hard with the hammer as this may cause damage. Use rubber hammer if possible, if not strike gently.

(5) Carefully handle the tiles to avoid marks of cement sand mortar on surface of tiles.

(6) Use white cement slurry to fill the joints. Cure the surface for at least three days. Surface should be kept clean for better performance.

PERFORMANCE

House with No Improvement

Time	06:00	09:00	12:00	15:00	18:00	21:00	24:00
Temperature OUTSIDE	29.1	34.3	39.7	41.0	39.2	34.1	32.0
Temperature INSIDE	32.6	33.3	34.9	36.2	37.6	37.1	36.7

House with Tile Insulation (MAT)

Time	06:00	09:00	12:00	15:00	18:00	21:00	24:00
Temperature OUTSIDE	29.1	34.3	39.7	41.0	39.2	34.1	32.0
Temperature INSIDE	31.7	31.9	32.8	33.0	33.2	33.7	33.4

b. **Gypsum Board With Aluminium**

PERFORMANCE

House with No Improvement							
Time	06:00	09:00	12:00	15:00	18:00	21:00	24:00
Temperature OUTSIDE	29.1	34.3	39.7	41.0	39.2	34.1	32.0
Temperature INSIDE	32.6	33.3	34.9	36.2	37.6	37.1	36.7

House with False ceiling Insulation (Gypsum Board with aluminum foil)							
Time	06:00	09:00	12:00	15:00	18:00	21:00	24:00
Temperature OUTSIDE	29.1	34.3	39.7	41.0	39.2	34.1	32.0
Temperature INSIDE	33.6	34.0	34.7	34.9	35.1	35.0	34.5

c. **Aerosol Paint**

PERFORMANCE

House with No Improvement							
Time	06:00	09:00	12:00	15:00	18:00	21:00	24:00
Temperature OUTSIDE	29.1	34.3	39.7	41.0	39.2	34.1	32.0
Temperature INSIDE	32.6	33.3	34.9	36.2	37.6	37.1	36.7

House with Paint Insulation (Aerosol Paint)							
Time	06:00	09:00	12:00	15:00	18:00	21:00	24:00
Temperature OUTSIDE	29.1	34.3	39.7	41.0	39.2	34.1	32.0
Temperature INSIDE	30.3	30.3	32.5	34.2	34.9	35.0	33.4

d. **Enamel Paint**

PERFORMANCE

House with No Improvement							
Time	06:00	09:00	12:00	15:00	18:00	21:00	24:00
Temperature OUTSIDE	29.1	34.3	39.7	41.0	39.2	34.1	32.0
Temperature INSIDE	32.6	33.3	34.9	36.2	37.6	37.1	36.7

House with Paint Insulation (Enamel Paint)							
Time	06:00	09:00	12:00	15:00	18:00	21:00	24:00
Temperature OUTSIDE	29.1	34.3	39.7	41.0	39.2	34.1	32.0
Temperature INSIDE	30.0	30.1	32.0	33.1	33.6	33.8	32.9

e. **Slake Lime**

PERFORMANCE

House with No Improvement							
Time	06:00	09:00	12:00	15:00	18:00	21:00	24:00
Temperature OUTSIDE	29.1	34.3	39.7	41.0	39.2	34.1	32.0
Temperature INSIDE	32.6	33.3	34.9	36.2	37.6	37.1	36.7

House with Paint Insulation (Slaked lime)							
Time	06:00	09:00	12:00	15:00	18:00	21:00	24:00
Temperature OUTSIDE	29.1	34.3	39.7	41.0	39.2	34.1	32.0
Temperature INSIDE	31.0	31.1	32.0	33.1	33.6	32.9	32.6

f. **Weather Shield Paint**

PERFORMANCE

House with No Improvement							
Time	06:00	09:00	12:00	15:00	18:00	21:00	24:00
Temperature OUTSIDE	29.1	34.3	39.7	41.0	39.2	34.1	32.0
Temperature INSIDE	32.6	33.3	34.9	36.2	37.6	37.1	36.7

House with PAINT Insulation (Weather Shield Paint)							
Time	06:00	09:00	12:00	15:00	18:00	21:00	24:00
Temperature OUTSIDE	29.1	34.3	39.7	41.0	39.2	34.1	32.0
Temperature INSIDE	30.8	31.0	33.4	33.7	33.9	33.9	32.6

g. **Flat Brick tile**

PERFORMANCE

House with No Improvement							
Time	06:00	09:00	12:00	15:00	18:00	21:00	24:00
Temperature OUTSIDE	29.1	34.3	39.7	41.0	39.2	34.1	32.0
Temperature INSIDE	32.6	33.3	34.9	36.2	37.6	37.1	36.7

House with Tile Insulation (Flat Brick Tile)							
Time	06:00	09:00	12:00	15:00	18:00	21:00	24:00
Temperature OUTSIDE	29.1	34.3	39.7	41.0	39.2	34.1	32.0
Temperature INSIDE	31.9	32.5	32.7	33.1	33.7	33.8	33.9

18. WINDOWS

New window technologies have increased energy benefits and comfort, and have provided more practical options for consumers. As illustrated below, three major types of energy flow occur through windows:

a. Non-solar heat losses and gains in the form of conduction, convection, and radiation

b. Solar heat gains in the form of radiation

c. Airflow, both intentional (ventilation) and unintentional (infiltration

- **U Values**

  The U value of a double glazing window is the measure of its ability to transfer heat - so double glazing windows with the lowest U value are the most efficient insulators against heat loss from a room.

- **Solar Heat Gain**

  The Solar Heat Gain Coefficient (SHGC), which measures a thermal insulation glass' ability to transmit solar energy into a room, is measured in value from 0 to 1. The SHGC is commonly referred to as the g-value, or solar factor. The higher the g value, the greater a thermal insulation window's ability to transmit solar heat and thus increase its energy efficiency.

- **Visible Transmittance**

  Visible transmittance (VT) measures how much light comes in through a product. It is an optical property that indicates the amount of visible light transmitted. VT is expressed as a number between 0 and 1. The higher the number, the more light is transmitted.

- **Low –e- Glass**

A low-e- coating is a microscopically thin, virtually invisible, metal or metallic oxide coating deposited on a glazing surface. The coating may be applied to one or more of the glazing surfaces facing an air space in a multiple-pane window or to a thin plastic film inserted between panes. The coating limits radiated heat flow between panes by reflecting heat back into the home during cold weather and back to the outdoors during warm weather. This effect increases the insulating value of the window. Most window manufacturers now offer windows and skylights with low-E coatings. The spaces between window panes can be filled with gases that insulate better than air. Argon, krypton, sulphur hexafluoride, and carbon dioxide are among the gases used for this purpose. Gas fills add only a few dollars to the prices of most windows and skylights. They are most effective when used in conjunction with low-E coatings. For these reasons, some manufacturers have made gas fills standard their low-e- windows and skylights.

- **GLAZING**

Glazing types which reduce the impression of daylight significantly darken both the interior, and the view, whilst the view from the outside towards the building makes the facade look black. It is only when comparisons are made between the view through a clear glass window and one with a modifying glass that reduces the daylight, that the results create disappointment. It is true to say that it is human nature to appreciate the natural environment, with all its variations of color, light and shade.

There are basically three main types of glazing as follows

- Clear glazing
- Tinted glass

- **Clear glazing**

  This can be single sheet, double or triple glazed or alternatively a 'thick' glass, but the more sheets or the greater the thickness of glass the more the daylight will be diminished, although the impression of the color of the exterior will still be perceived as natural. Clear glass whilst allowing a high transmission of daylight, will at the same time and on certain building facades allow a high transmission of solar radiation.

  Single-glazed windows are impractical in heating-dominated climates. Double glazed windows use two sheets of glass with a gap between them which creates an insulating barrier, whilst triple glazed windows have three sheets of glass. Both options can deliver a high level of energy efficiency.

Glass Type	U Value W/m/C	SHGC	VT	Payback Period (yrs)
Single Clear Glazing	5.8	0.81	0.87	-
Low-e- Single Glazing	3.7	0.70	0.82	7.8
Double Clear Glazing	2.7	0.70	0.78	4.7
Low-e- Double Glazing	1.9	0.66	0.73	6.1

- **Tinted Glass**

Tinted glass is that which is coated with microscopically thin layers of metallic oxides which reflects the heat away and out of the building. These coatings are applied to the inside layer of glass generally in association with other panes in a sealed double glazed unit as a protection, since on their own they would be vulnerable to damage.

These coated glasses can be designed to have high daylight transmission, due to the very thin layer of reflective materials; so that they almost give the appearance of clear glass, and do not suffer from the objections raised by tinted glasses which reduce the daylight significantly.

19. **SHADING:**

Other than building shape, orientation and location of openings, shading is a fundamental strategy for comfortable building design and energy saving.

OBJECTIVE:

a. Control intense direct sunlight to ensure a comfortable workspace

b. This is critical for occupant visual and thermal comfort and for minimizing mechanical cooling loads.

TYPES OF SHADING DEVICES

a. External Devices

b. Internal Device

c. In the Window Plane

a. **<u>EXTERNAL SHADING DEVICES</u>**

In order to control sun penetration to the interior of buildings it is important to provide exterior shading as a part of the architectural envelope design. Such shading devices can be attached to the building or can be achieved by the articulation and disposition of the building floors to create overhangs.

Basic types of exterior shading devices can be identified as:

(1) **HORIZONTAL DEVICES:**

Horizontal shading devices are suited to southern exposures. Roof overhangs can also easily be used to shade southern exposures on low rise buildings. This is perhaps the most economical and potentially aesthetically pleasing solution for residential applications.

(a) ***Straight overhangs*** are most effective on southern exposure.

(b) ***Louvers parallel*** *to* wall allows hot air to escape. And are most effective on southern exposure.

(c) ***Horizontal louvers*** hung from solid overhangs cuts out the lower rays of the sun. Effective on south, east and west exposures.

(d) ***Vertical strip*** parallel to wall cuts out the lower rays of the sun. Effective on south, east and west exposures.

(e) **Awnings** are fully adjustable for seasonal conditions and most effective on southern exposure.

(f) ***Rotating horizontal louvers*** are adjustable for daily and seasonal conditions. Effective on south, east and west exposures.

(2) **VERTICAL DEVICES:**

Where sun is hitting the facade from a south-easterly or south-westerly direction, vertical devices can effectively block the sun.

(1) **Vertical fins** are most effective on the near east, near-west and north exposures.

(2) **Slanted vertical fins** are most effective on east and west exposures. Slant toward north and separation from wall minimizes heat transmission.

(3) **Rotating vertical fins** are the most flexible and adjustable for daily and seasonal conditions. Most effective on east and west exposures

18. **INSULATION MATERIALS:**

Heat flow through building components can be modified by the choice of materials. The main heat transfer process for solid, opaque building elements is by conduction. Thermal insulation, which provides a restriction to heat flow, is used to reduce the magnitude of heat flow in a 'resistive manner'.

Since air provides good resistance to heat flow, many insulation products are based upon materials that have numerous layers or pockets of air trapped within them Such materials are thus low density and lightweight, and, in most cases, not capable of giving structural strength. Generally, the higher the density, greater the heat flow. Since structural components are often, of necessity, rather high in density, they are unable to provide the same level of resistive insulation.

Warmth is a valuable commodity and it will seek every possible means to escape from a building. Walls, roofs, floors, chimneys, windows are all escape routes. It may be necessary to provide additional layers of insulation around them to prevent such elements acting as weak links or 'cold bridges' in the thermal design.

When specifying insulation materials it is important avoid those which are harmful to the environment such as materials involving chlorofluorocarbons (CFCs) in the production process and to select materials with zero ozone depletion potential (ZODP).

19. **CLASSIFICATION OF INSULATION MATERIALS:**

Insulation materials fall into three main categories:

a. **Inorganic/mineral:** These include products based on silicon and calcium (glass and rock) and are usually evident in fibre boards e.g. glass fibre and 'Rockwool

b. **Synthetic organic:** Materials derived from organic feedstock based on polymers.

c. **Natural organic** - vegetation-based materials like hemp and lamb's wool which must be treated to avoid rot or vermin infestation.

a. INORGANIC MINERAL – BASED INSULANTS

Inorganic/mineral-based insulants come in two forms,

(1) Fibre

(2) Cellular structure.

(1) FIBRE

(a) **Rockwool**

Rock wool is produced by melting a base substance at high temperature and spinning it into fibres with a binder added to provide rigidity. It is vapour and air permeable due to its structure. Moisture can build up in the insulant reducing its insulating value. It may degrade over time. Lambda value 0.033-

0.040 W/mK

(b) **Glass wool**

As for rock wool

20. DAYLIGHTING

Daylighting is the controlled admission of natural light into a space though windows to reduce or eliminate electric lighting. By providing a direct link to the dynamic and perpetually evolving patterns of outdoor illumination; day lighting helps create a visually stimulating and productive environment for building occupants, while reducing as much as one-third of total building energy costs.

DAYLIGHT FACTOR

The daylight factor (DF) is a very common and easy to use measure for the subjective daylight quality in a room. It describes the ratio of outside illuminance over inside illuminance, expressed in per cent. The higher the DF, the more natural light is available in the room. It is expressed as such:

$$DF = 100 * E_{in} / E_{ext}$$

Ein = inside illuminance at a fixed point

E_{ext} = outside horizontal illuminance under an overcast (CIE sky) or uniform sky.

There are three possible paths along which light can reach a point inside a room through glazed windows. They are:

- Light from the patch of sky visible at the point considered, expressed as the sky component (SC)
- Light reflected from opposing exterior surfaces and then reached the point, expressed as the externally reflected component (ERC).
- Light entering through the window but reaching the point only after reflection from internal surfaces, expressed as the internally reflected component (IRC). Hence, the daylight factor can be expressed as the sum of three component

$$DF = SC + ERC + IRC$$

- Daylight factors can then be used to determine the displaced artificial illuminance with in zone, thus reducing the demand on the artificial lighting system and associated energy requirements.

BENEFITS OF DAY LIGHTING:

Day lighting has the potential to significantly improve life-cycle cost, increase user productivity, reduce emissions, and reduces operating costs:

- **Improved Life-Cycle Cost**: At an estimated incremental first cost increase of from $0.50 to $0.75 per square foot of occupied space for dimmable ballasts, fixtures and controls, day lighting has been shown to save from $0.05 to $0.20 per square foot annually[in 1997 $1.

- **Increased User Productivity**: Daylight enlivens spaces and has been shown to increase user satisfaction and visual comfort leading to improved performance.
- **Reduced Emissions**: By reducing the need for electric consumption for lighting and cooling, the use of daylight reduces greenhouse gases and slows fossil fuel depletion.
- **Reduced Operating Costs**: Electric lighting accounts for 35 to 50 percent of the total electrical energy consumption in commercial buildings. By generating waste heat, lighting also adds to the loads imposed on a building's mechanical cooling equipment. The energy savings from reduced electric lighting through the use of day lighting strategies can directly reduce building cooling energy usage an additional 10 to 20 percent. Consequently, for many institutional and commercial buildings, total energy costs can be reduced by as much as one third through the optimal integration of day lighting strategies.

As with all energy-efficient design strategies, there are some costs associated with the use of day lighting. Designers must be sure to avoid glare and overheating when placing windows. More windows do not automatically result in more day lighting. That is, natural light has to be controlled and distributed properly throughout the workspace. Also, for cost savings to be realized, controls have to be in proper functioning order. Poor installation, commissioning, or Operations and Maintenance (O&M) practices can all lead to sub-optimum performance.

21. **NATURAL VENTILATION:**

Almost all historic buildings were ventilated naturally although many of these have been compromised by the addition of partition walls and mechanical systems. With an increased awareness of the cost and environmental impacts of energy use, natural ventilation has become an increasingly attractive method for reducing energy use and cost and for providing acceptable indoor environmental quality and maintaining a healthy, comfortable, and productive indoor climate rather than the more prevailing approach of using mechanical ventilation.

Natural ventilation is the process of supplying and removing air through an indoor space by natural means.

22. **TYPES OF NATURAL VENTILATION**

There are two types of natural ventilation occurring in buildings:

a. Cross/wind driven ventilation
b. Stack ventilation

a. Cross ventilation:

Cross ventilation relies on wind to force cool exterior air into the building through an inlet (window, door, etc.) and to force warm interior air out of the building through an outlet (window, door, etc)

Cross ventilation depends on two continues changing factors

(1) Wind availability

(2) Wind directions

In cross ventilation the wind creates a high pressure zone where it impacts the building and a low pressure zone on the leeward side, drawing air through the building. Pressure is highest near the centre of the windward wall diminishing to the edges as the wind finds other ways to move around the building so air intakes are preferable near the centre or the high pressure zones.

Using cross ventilation will have a strong influence on building aesthetics and site planning. To maximize the effectiveness of openings, narrow buildings with open plans and well placed openings work best (particularly if the longest faces of the building are perpendicular to the typical wind direction). Furthermore, single-loaded corridors (rooms only on one side of a corridor) will provide better airflow than double-loaded ones as it makes it easier to provide openings on opposite walls. Building elements like fins, wing walls, parapets and balconies may be designed to enhance wind speeds and should be an integral part of cross-ventilation design though caution needs to be taken that they do not cause turbulence and block air flow.

b. Stack ventilation:

Stack ventilation is a passive cooling strategy that takes advantage of temperature stratification. It relies on two basic principles:

(1) As air warms, it becomes less dense and rises

(2) Ambient (hopefully cooler) air replaces the air that has risen.

This system of natural convection creates its own air current, where warmer air is evacuated at a high point, and cooler outdoor air is brought in at a lower level. Stack ventilation will only work for thermal comfort conditioning when outside air temperature is cooler than the desired inside temperature. In order to function effectively (ie., generate a substantial air flow), the difference between ambient indoor and outdoor air temperatures needs to be at least 3°F f 1.7T1. A greater temperature difference can provide more effective air circulation and cooling. Because it creates its own air current, stack ventilation is only minimally affected by building orientation. Air won't flow properly, however, if an outlet faces the windward direction.

To work well, a stack needs to generate a large temperature difference between exhaust air and incoming air. This can be done in several ways, including increasing stack height. A typical stack will provide effective ventilation for areas within the lower half of the total height. This implies that stacks be double the height of the building if they are to serve all floors of a building, or that they only serve a portion of the total floor area. Another way to increase the temperature difference between entering and exiting air is to use solar energy to heat the air. Exterior finishes and landscaping (plants, misting, and ground covers) can lower the incoming air temperature. Inlet (and outlet) sizing are critical to system performance. Inlet location, quantity, and size can affect build security, building facade appearance, and the quality of the incoming air.

23. **SOLAR HOT WATER SYSTEM:**

COMPONENTS OF SOLAR HEATING SYSTEMS:

A solar heating system is composed of three essential parts;

a. Collector
b. Storage system
c. Distribution and terminal system

a. **SOLAR COLLECTORS:**

The function of the collector is to receive and capture as much of the radiant energy from the sun as is practical. There are three types of collectors;

(1) Flat plate

(2) Concentrating

(3) Evacuated tube

(1) **Flat plate:**

The flat plate collector has a receiving surface that is flat in shape. The collector is stationary and therefore receives the maximum radiation only when it faces the sun directly. Flat-plate collectors heat the circulating fluid to a temperature considerably less than that of the boiling point of water and are best suited to applications where the demand temperature is 30-70°C (86-158°F) and/or for applications that require heat during the winter months.

(2) **Concentrating:**

Concentrating or focusing collectors have a concave surface that concentrates the rays received. The result is a collector that can produce a much higher temperature than the flat plate collector. Concentrating collectors are often designed to move and track the sun, thus they always receive maximum radiation.

(3) **Evacuated tube:**

Evacuated tube collectors have multiple evacuated borosilicate glass tubes which heat up solar absorbers and, ultimately, solar working fluid (water or an antifreeze mix—typically propylene glycol) in order to heat domestic hot water, or for hydronic space heating. The vacuum within the evacuated tubes reduce convection and conduction heat losses, allowing them to reach considerably higher temperatures than most flat-plate collectors.

b. **STORAGE AND DISTRIBUTION SYSTEMS**

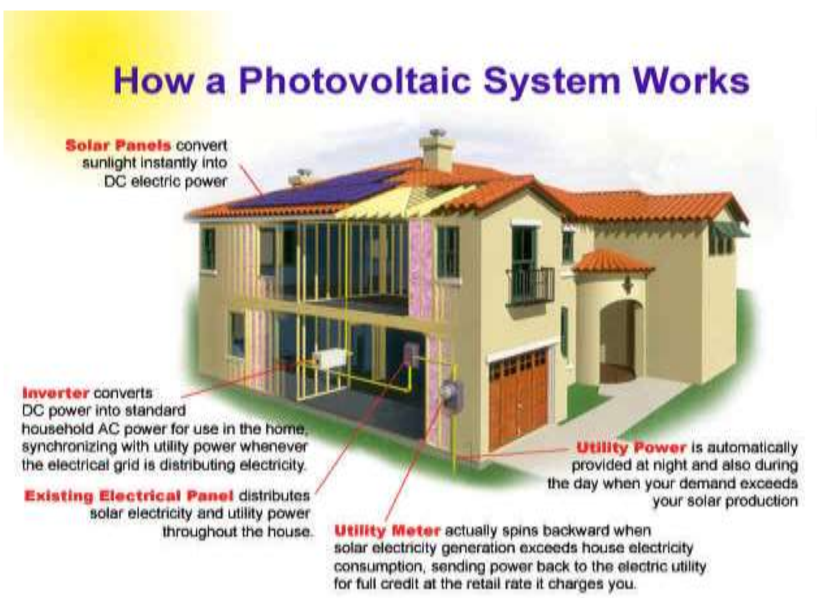
The collector does not collect heat at night or on overcast days. Therefore, it is common to store any excess heat collected when operating to be used when the sun is not shining.

RENEWABLE SOURCES OF ENERGY TO TARGET ZERO ENERGY

26. PHOTOVOLTAIC CELLS:

The sun provides an almost limitless resource that could provide more than enough energy to power the entire globe. But that energy has to be harnessed, this is where photovoltaic (PV) technology comes in.

Photovoltaic is the direct conversion of light into electricity at the atomic level. Some materials exhibit a property known as the photoelectric effect that causes them absorbs photons of light and release electrons. When these free electrons are captured, an electric current is produced that can be used as electricity.



27. **PHOTOVOLTAIC SYSTEM**

TYPES OF PV PANELS:

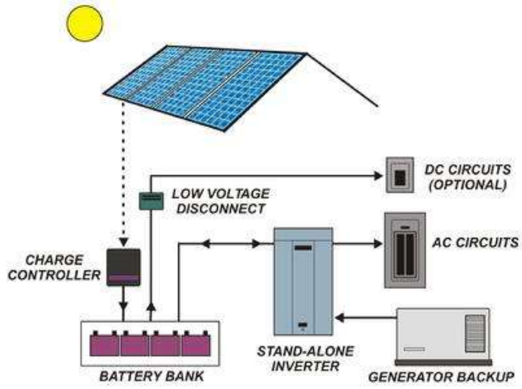
Type	Approximate Cell Efficiency %	Approximate Module Efficiency %
Mono-crystalline Silicon	13-17	12-15
Polycrystalline Silicon	12-15	11-14
Thin Film silicon (Using Amorphous Silicon)	5	4.5-4.9

28. **PHOTOVOLTAIC SYSTEMS**:

There are two different types of PV system

- Standalone systems
- Grid connected systems
- **Stand Alone Systems:**

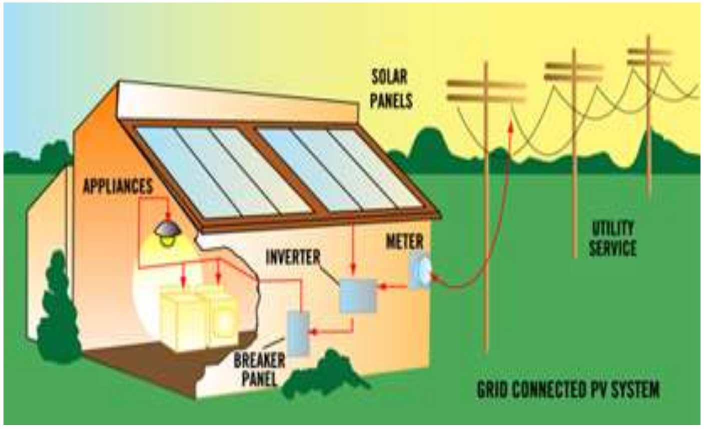
  As its name suggests this type of PV system is a separate electricity supply system. It supplies electricity to a single system and is connected only to that system. This means that it is not linked to the mains electricity supply. Usually a stand alone system includes one or more batteries, used to store the electricity.



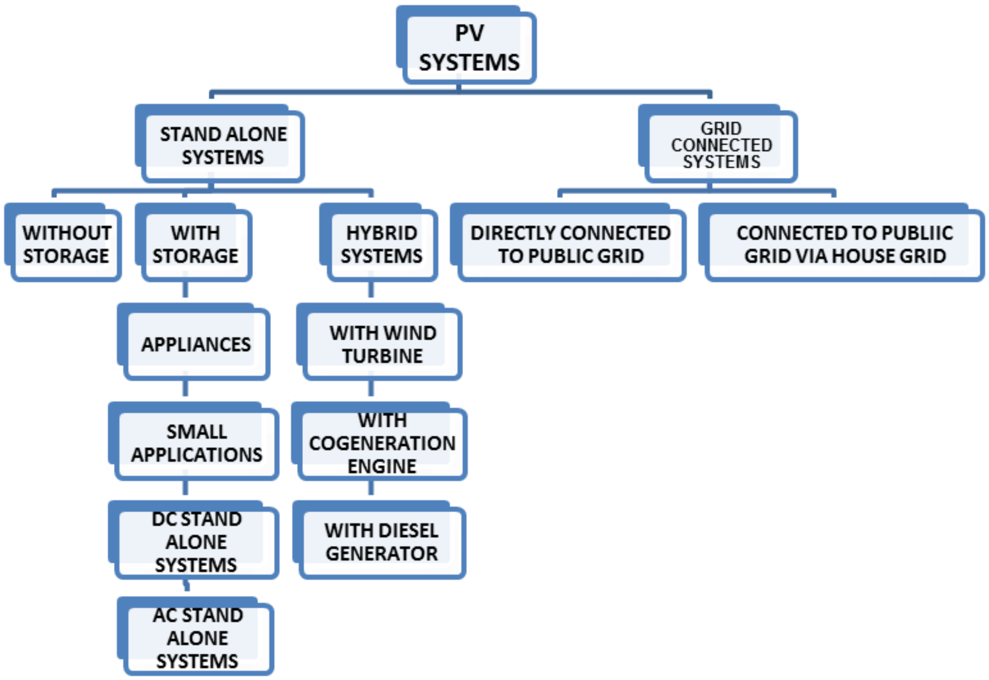
Stand Alone Systems

- **Grid Connected Systems:**

  The national grid is the network of cables by which electricity is transported from power stations to your home, your school and other places. A grid connected PV system is linked to this grid or electrical network. This means that it can deliver the electricity it produces into the electricity network and therefore no battery or other storage is needed.



Grid Connected Systems



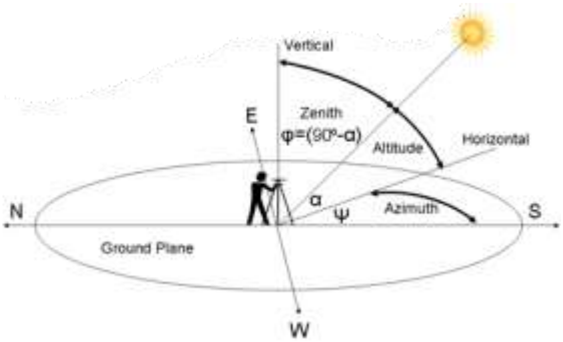
29. FACTORS AFFECTING THE OUTPUT:

The output from building-integrated PV installations is the output of the PV array less the losses in the rest of the system. The output from the array will depend on:

- The daily variation due to the rotation of the earth and the seasonal one
- Location, i.e. the solar radiation available at the site
- Tilt
- Azimuth, i.e. orientation with respect to due south
- Shadowing
- Temperature

Azimuth:

Azimuth is the horizontal angle measured in degrees clockwise from a northern or southern point. In the northern hemisphere, PV Panels should always be installed pointing towards true south, but they are very effective facing east or west as well (or anywhere in between).



Shadowing and Temperature:

Shadowing will depend on the geography of the site, neighboring buildings and self-shading by the architectural forms, the effects of shadowing can be mitigated somewhat through system design. Building-integrated modules can reach 20-40°C above ambient in conditions of high radiation. For each 1°C increase in cell temperature above 25°C the power output decreases by about 0.4-0.5%.

30. SIZING THE PV SYSTEM:

- **Calculate the Electrical Load**

Examine the uses of energy in a home in three categories (thermal or heat energy, electrical energy, and refrigeration), conservation opportunities can then be isolated in each category that can affect overall electrical consumption. The following is the work sheet to use in calculating the size of a residential PV system.

APPLIANCE	QUANTITY	HOURS OF USE	WEIGHTAGE	TOTAL DAILY WATT HOURS USED

Wattage is usually listed on the appliance. If not, multiply the voltage times the amperage to obtain wattage.

- **Determine Peak Sun Hours**

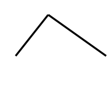
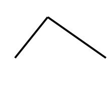
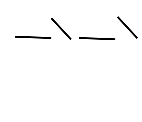
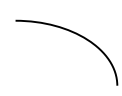
At the meteorological station closest to your site, look up the average sunlight hours for each month of the year at your site location. Determine the Minimum Monthly Sunlight Hours at your location for the months that you expect to be using the PV system.

31. **INTEGRATING PVs IN BUILDINGS**:

Continuing with the effect of introducing PVs into the brief, the next step might be to consider the design options. There are three basic ways of integrating PVs in buildings:

- Roof-based systems.
- Facade systems.
- Sunshades and sunscreens

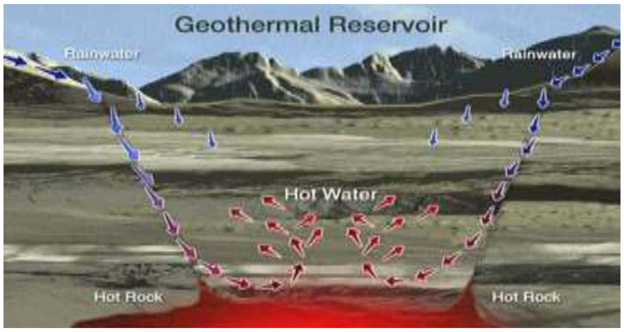
- **ROOF SYSTEMS**

Position Of PV's	**System**	**Characteristics**	**Shape**
Inclined Roof	PV Roof Panels	Combined With Structural System	
Inclined Roof	PV Roof Tiles	Likely To Find Easy Acceptance	
SawTooth North Light Roofs	PV Panels	Allow Daylighting	
Curved Roof	Opaque flexible substrate or rigid modules arranged on a curve	Extends design possibilities	

Atrium	PV roof panels	Variations include part glazing, part-opaque PVs and semi- transparent PVs	

32. GEOTHERMAL ENERGY

Geothermal energy is heat from within the Geothermal energy is generated in the earth's core, almost 4,000 miles beneath the earth's surface. The double-layered core is made up of very hot magma (melted rock) -surrounding a solid iron center. Very high temperatures are continuously produced inside the earth by the slow decay of radioactive particles. This process is natural in all rocks.



GEOTHERMAL PROCESS

33. **DIRECT USE OF GEOTHERMAL HEAT**

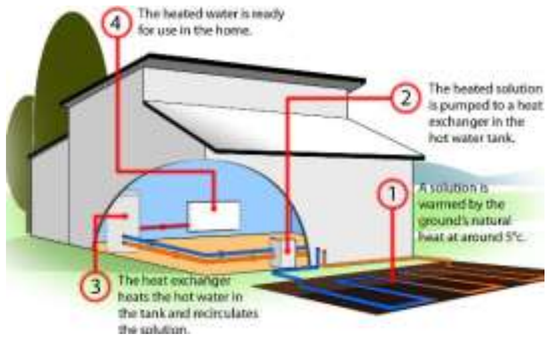
Geothermal springs can also be used directly for heating purposes. Hot spring water is used to heat green houses, to dry out fish and de-ice roads, for improving oil recovery, and to heat fish farms and spas. In Iceland, virtually every building in the country is heated with hot spring water. In fact, Iceland gets more than 50% of its energy from geothermal sources.

34. **GROUND-SOURCE HEAT PUMPS**

A much more conventional way to trap geothermal energy is by using geothermal heat pumps to provide heat and cooling to buildings. They take advantage of the constant year-round temperature of about 50°F that is just a few feet below the ground's surface. Either air or antifreeze liquid is pumped through pipes that are buried underground, and re-circulated into the building. In the summer, the liquid moves heat from the building into the ground. In the winter, it does the opposite, providing pre-warmed air and water to the heating system of the building.

In the simplest use of ground-source heating and cooling, a tube runs from the outside air, under the ground, and into a house's ventilation system. More complicated, but more effective systems use compressors and pumps—as in electric air conditioning systems—to maximize the heat transfer.

Heat pumps are much less expensive to operate, and since buildings are widely spread out, installing underground loops is not an issue. Underground loops can be easily installed during construction of new buildings as well, resulting in savings for the life of the building.



GROUND-SOURCE HEATING SYSTEM

35. WIND ENERGY AND WIND POWER

Wind turbines convert the kinetic energy in the wind into mechanical power. This mechanical power can be used for specific tasks (such as grinding grain or pumping water) or a generator can convert this mechanical power into electricity to power homes, businesses, schools, and the like.

MECHANISM

Generating electricity from wind is relatively simple. All effective wind turbines have often 3 blades that are aerodynamically architecture to easily create a rotating movement as air blows. When the wind blows, the blades create a lift, similar to the wings of airplanes and the blades begin to rotate. When the blades rotate, a low-speed shaft is spanned 30 to 60 times in a minute. This low-speed shaft is connected with a gearbox or a high-speed shaft that accelerates the rotation to 1000 to 1800 rotation in a minute. The high-speed shaft drives the generator and produces electricity. The generator is then connected to an electric power grid.

36. WIND TURBINE TYPES

- Horizontal axis
- Vertical axis

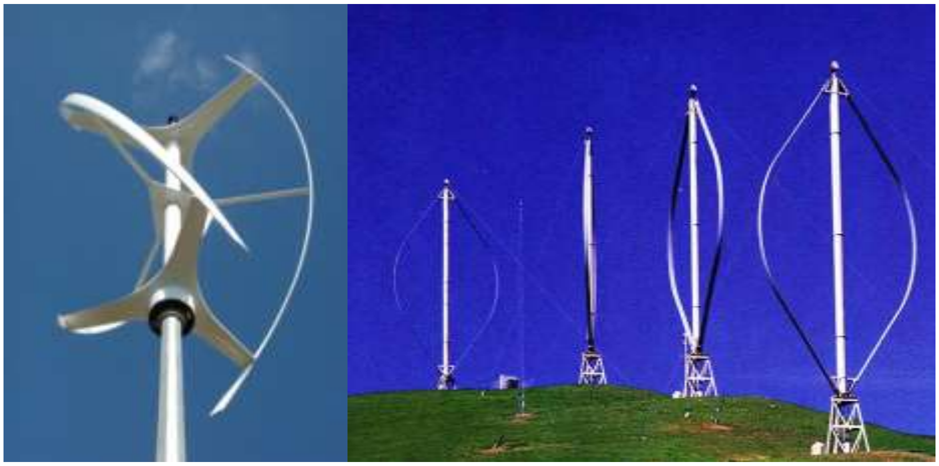
- **Horizontal axis**

  Horizontal-axis wind turbines (HAWT) have the main rotor shaft and electrical generator at the top of a tower, and must be pointed into the wind. Small turbines are pointed by a simple wind vane, while large turbines generally use a wind sensor coupled with a servo motor.

Wind Turbine

- **Vertical axis**

  These generally have a lower power output than the horizontal axis machines. There are two basic designs: Savonius and Darrieus. Savonius machines are S-shaped in plan view, and Darrieus systems are basket shaped. They generally need slightly higher wind speeds to work well and they need more power from the wind to get moving.



Wind Turbines

37. **TURBINE COMPONENTS:**

Horizontal turbine components include:

- Blade or Rotor, which converts the energy in the wind to rotational shaft energy
- A Drive Train, usually including a gearbox and a generator
- A Tower that supports the rotor and drive train
- Other equipment, including controls, electrical cables, ground support equipment, and interconnection equipment.

38. **BUILDING MOUNTED WIND TURBINES**

They have special mountings to minimize potential vibration issues. Systems are available from half a dozen suppliers in the range of 400 W to 1.5kW. No long-term performance data is yet available, but most experts confidently predict that the maximum likely output from building-mounted systems will be in the region of 300-800 kWh a year on most windy sites. This is because turbulence around buildings effectively reduces local wind speed by at least 25 per cent, and at these lower wind speeds the power output of the larger machines will not be much greater than that from the smaller ones. At this level of output the cost per unit of electricity generated over the lifetime of the turbines is comparable to PV generation.

39. BIOMASS AND WASTE UTILIZATION:

Biomass is the sum total of all the Earth's living matter within the biosphere. It is continually regenerated by the sun through the process of photosynthesis. The energy reaching the planet is equivalent to about seven times its primary energy consumption. If biomass is converted to a fuel when it is at its peak as a store of chemical energy the process is carbon neutral.

This means that the carbon emitted when it is burnt is equal to the carbon absorbed during growth. It is not a complete zero sums since there is a carbon component in the energy used in accumulating, processing and transporting the biomass.

40. SYSTEMS FOR THE CONVERSION OF BIOMASS To ENERGY:

There are three main systems for converting biomass to energy:

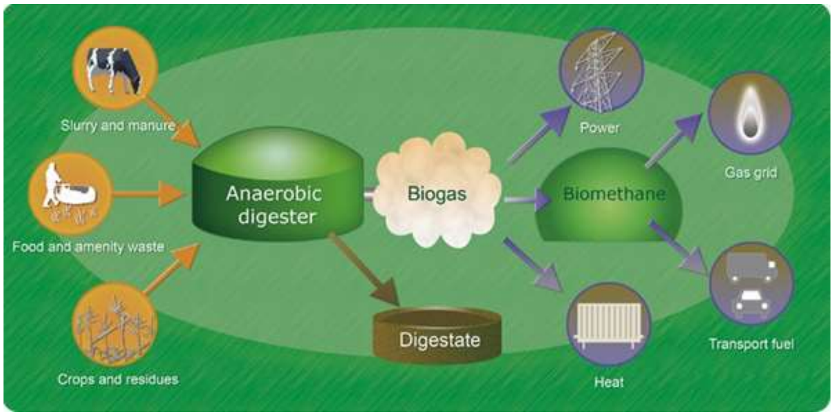
- Direct combustion
- Anaerobic digestion from organic waste producing biogas
- LUG fills gas conversion.

- **Direct Combustion**

Direct combustion represents the greatest use of biomass for fuel worldwide. The direct burning of municipal waste is becoming increasingly popular. However, the presence of heavy metals in such waste poses a danger from toxic emissions including dioxins.

- **Anaerobic Digestion from Waste**

Anaerobic digestion (AD) is becoming increasingly important as a means of disposing of waste. In this process, wet waste comprising dung or sewage is transformed into slurry with about 95% water content. This mixture is fed to a sealed digester where the temperature can be controlled. Digesters range in size from a domestic scale holding 200 gallons to up to 1000m^3 for industrial-size installations. The digestion process involves the breaking down by bacteria of organic material into sugars and then into various acids. These decompose to produce the final gas. Biogas can be used to provide heat and electricity.



Anaerobic Digestion from Waste

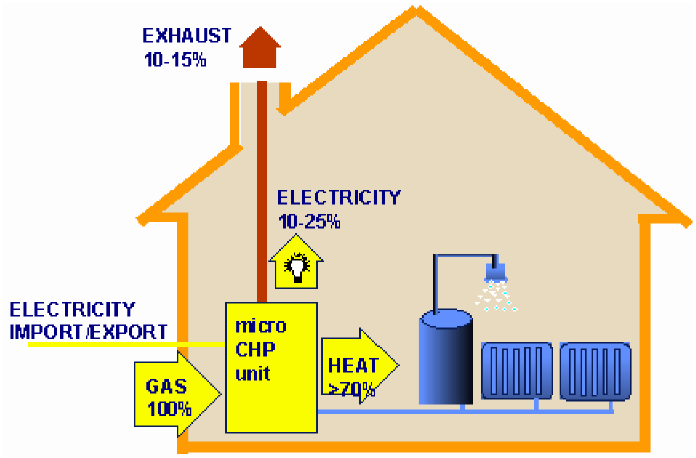
Biogas can be processed to serve the piped network. To use natural gas pipelines it has to be processed as follows:

- Large scale removal of CO_2 to 3-6%
- Removal of fine particles and other trace components
- Drying
- Desulphurization
- Odorization
- Liquid Fuel

41. COMBINED HEAT AND POWER(CHP)

Once available only to large commercial buildings, Combined Heat and Power generation (CHP) systems are now being produced on a scale that is safe, practical, and affordable to homeowners.

A CHP system uses fuel such as natural gas to produce heat and electricity simultaneously. The electricity can be used for any household device such as lights and appliance. Simultaneously, the heat produce can be used for water heating and / or space heating. About 10% of the fuel used is lost as exhaust, much like high efficiency furnace.



CHP Process

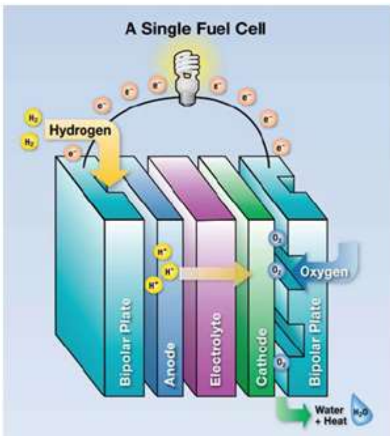
CHP systems are extremely efficient, offering combined heat and power generating efficiency of about 90%, compared to about 30 to 40% for electricity from a central power station.

The primary challenge for getting the highest efficiency and best economic return on CHP is to fully utilize all of the thermal energy produced when generating electricity. As the technology develops, various operating regimes will be tested to optimize the energy available based on variables such as the loads in the home, the climate and the season.

42. HYDROGEN FUEL CELLS

Hydrogen-powered fuel cells are not only pollution free, but also can have two to three times the efficiency of traditional combustion technologies. Fuel cells directly convert the chemical energy in hydrogen to electricity, with pure water and potentially useful heat as the only by-products.

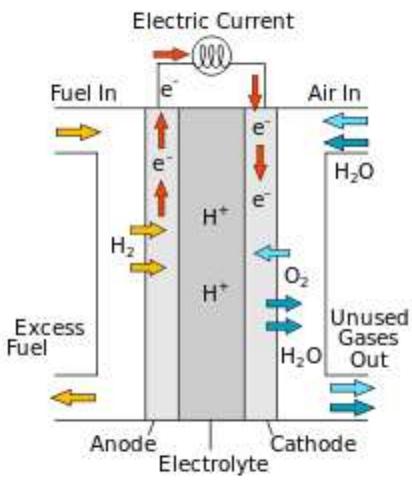
A single fuel cell consists of an electrolyte sandwiched between two electrodes, an anode and a cathode. Bipolar plates on either side of the cell help distribute gases and serve as current collectors. Hydrogen gas flows through channels to the anode, where a catalyst causes the hydrogen molecules to separate into protons and electrons. The membrane allows only the protons to pass through it. While the protons are conducted through the membrane to the other side of the cell, the stream of negatively-charged electrons follows an external circuit to the cathode. This flow of electrons is electricity that can be used to do work, such as power a motor.



Single Fuel Cell

On the other side of the cell, oxygen gas, typically drawn from the outside air, flows through channels to the (from cathode. When the electrons return from doing work, they react with oxygen and the hydrogen protons (which have moved through the membrane) at the cathode to form water. This union is an exothermic reaction, generating heat that can be used outside the fuel cell.

Anode Cathode



Hydrogen Fuel Cell

43. CONCLUSION

Chapter 2 is the foundation of our thesis. It includes all the research data which we compiled before we could initiate our design process. The first part which relates to the passive techniques very important and relevant to all types of buildings in all sorts of climate.

A few ZEBs fail to fully exploit more affordable conservation technology and all use onsite active renewable energy technologies like photovoltaic to offset the building's primary energy consumption. If applied correctly the Passive techniques could reduce about 30-40% of the annual energy demands. Few techniques like nano-vent, bionic breathing and ventilated facades are latest technologies and are not feasible in residential construction especially in our area.

Next part is about the active techniques. Here we have discussed all the cooling, heating, ventilation and lighting methods. Again the cooling techniques like phase change, desiccant dehumidification, ammonia absorption, ground coupling etc. are very high tech and not feasible in our project.

In the last part we have referred to the methods of producing on site, pollution free generation of electricity and their viability in different climates and geographical limitations.

44. INTRODUCTION

The world faces two major challenges: climate change and the growing energy demand .Pakistan's oil reserves won't be able to fulfill its increasing energy demands in the future. Pakistan needs to reposition itself as a nation conducive to rapid adoption of alternative energy sources.

We as a group thus decided to take up this project as we see better opportunities regarding this field in the future . The sky is the limit for a country that is desperate to reduce its dependence on imported oil.Our main emphasis was to adopt simple energy conservation techniques in house construction thus to reduce the cooling and heating load of building and to adopt the renewable energy resources to decrease dependency on grid energy.

45. THE CHALLENGE

The aim of our project was to design a net zero energy house in DHA Phase-II in the city of Islamabad. In extreme climatic condition where summer temperatures reach about 40°C, the design was to incorporate methods to minimize cooling loads along with the techniques to produce renewable source of electricity. The key goals were to control solar gain through appropriate selection of building envelope materials. Strategies like thermal insulation, double glazing of windows and roof insulation were adopted to buffer the interior of the building from the fluctuating temperature outside.

46. PROJECT CONSTRAINTS:

The model house was to be designed as a conventional house. It was not possible to locate water bodies around the building. The construction was to be done in locally available materials.Because of the geographical location the use of hydro power and biomass was not possible. Wind turbines were out of question as the wind speed is more or less non-existent throughout the year. Geothermal heat pump technology is not available at present in the area so the idea of a hybrid zero energy house was dismissed and we were left only with the option of photovoltaic to produce on site pollution free electricity.

Energy-efficient Building Design

There is a three-tier approach explaining the way to design energy-efficient building, which is one aspect of Zero Emission Buildings.

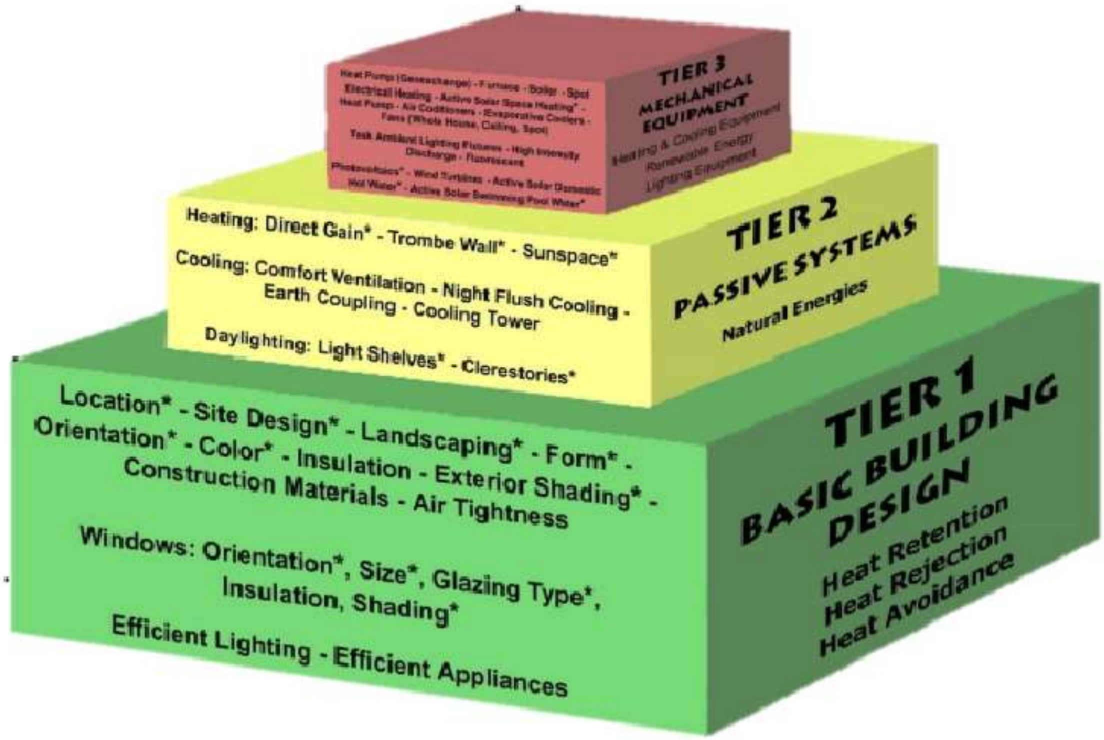


Figure : The three-tier approach to the sustainability design of heating, cooling and lighting

In order to optimum the energy consumption of the buildings, it is important to know the right steps to design energy-efficient buildings. As Figure illustrates, the first tier is the architectural design of the building, which can itself to minimize heat loss in the winter, to minimize heat gain in the summer, and to use light efficiently. Poor decisions at this point can easily double or triple the size of the mechanical equipment and energy eventually needed. On the other hand, making the right design choices in tier one can reduce the energy consumption of buildings as much as 60 percent. In our project, the main research question is from this tier, which is about the impact of “Form” on the energy consumption of buildings. The second tier involves the use of natural energies through such methods as passive heating, cooling and daylighting systems. The proper decisions at this point can reduce the energy consumption another 20 percent. Thus, the strategies in tiers one and two, which are both purely architectural, can reduce the energy consumption of buildings up to 80 percent. Tier 3 consists of designing the mechanical equipment to be as efficient as possible. That effort could reduce energy consumption by another 8 percent. Thus, only 12 percent as much energy is needed as in a conventional building. That small amount of energy can be derived from renewable sources both on and off site (Lechner, 2009)

PROJECT DETAILS:

Building Type	Residential
Building Area	250m^2
Building Address	Plot no. 286, Street no. 10,Sector C.DHA Phase II Islamabad.
No. of occupants	4

47. **SITE LOCATION**

The site is located in DHA phase 2 which is considered as one of the exclusive residential areas in Islamabad, DHA is known for its wider streets, cleaner air, and is a lot quieter and less chaotic than central areas.

48. **BUILDING PLAN:**

Points considered during the Design

- **BUILDING FORM:**

  Plan of our house is simple and rectangular which is the most economical shape to build and cool. Exposed surface area increases and so do construction and energy costs when a house has a complex shape.

- **INTERNAL ROOM ZONING:**

  The garage, laundry, bathrooms, kitchens and store are placed on west side as these rooms are used least.. Living areas are located on the east with large sized windows to allow early morning light in the room.

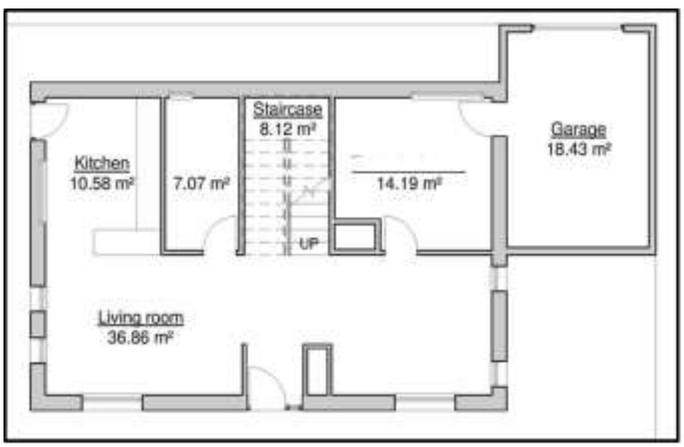


Fig: Ground Floor

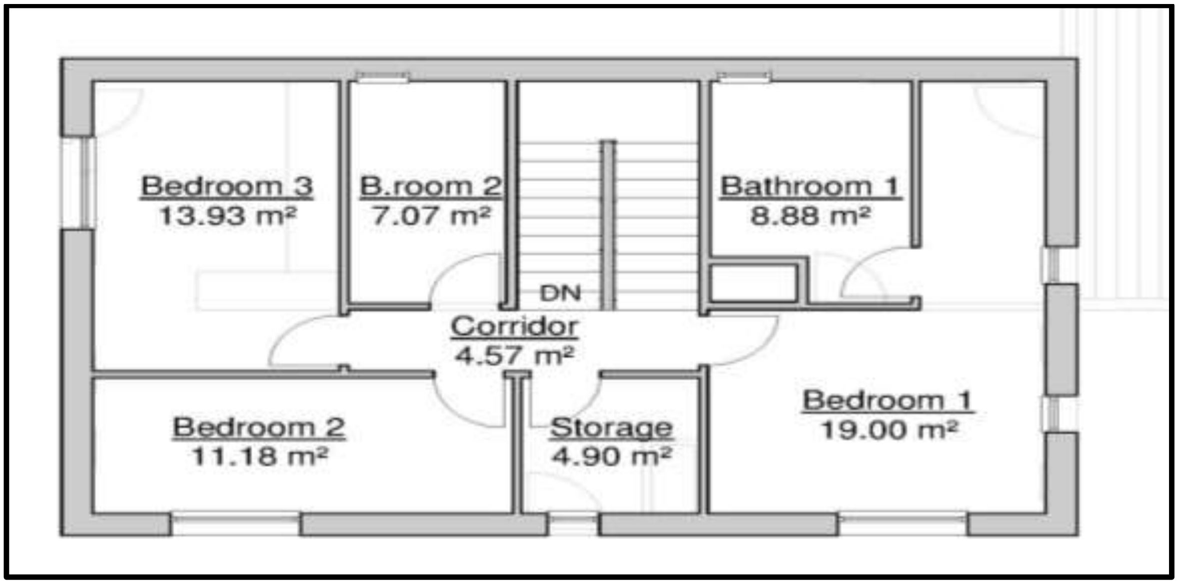


Fig: First floor

- **SURFACE/ VOLUME RATIO (S/V):**

  A compact building gains less heat during daytime and loses less heat at night. The Compactness of the building is measured using the ratio of surface area to volume.In hot-dry climate as a dominant season in Islamabad, the S/V ratio should be the minimum. We have designed double storey house to minimize the S/V ratio. This minimum ratio is also suitable for winters to minimize heat loss.

- **CEILING HEIGHT:**

  The increase in Ceiling Height of every 30 cm (1-foot) can reduce 0.3 degree centigrade for single storey buildings.In our house almost all spaces are designed keeping ceiling height 3.3m(11 ft).

- **COOL ROOF:**

  Roof slab is properly insulated .Half of roof is covered with PV panels. But parts which are exposed, white paint is done to reflect the light.

- **FALSE CEILING:**

  In the standard house when the roof slab gets hot, it radiates heat directly into the room below. A radiant barrier that is a false ceiling is an additional layer, provided underneath the slab to stop the heat from radiating into the room. The false ceiling may work by absorbing the heat, or reflecting the heat. There should be an adequate and ventilated air gap between the slab and the radiant barrier to be most effective.We have proposed false ceiling in upper floor. By providing false ceiling volume of room also decreases hence heating and cooling loads plus lighting requirements also decrease.

- **GROUND SURFACE:**

  Ground cover affects heat gain. The temperature on the hard surfaces such as concrete pathways can be more than 5 *degree* centigrade greater than on soft surfaces such as organic paving or vegetative areas.

  We have minimized the use of masonry materials, such as concrete patios and pavers on the south side of the house as they reflect heat into the house. Lawn is given in front of drawing room as grass, shrubs, and other low-growing vegetation help prevent overheating in summer.. Paved areas are basically reduced to lessen heat build-up.Color and type of paving is also considered .Paving with high reflectance color is used as it minimizes heat gain. Porous block pavement system is proposed.

49. AUTODESK ECOTECT

We have used Autodesk Ecotect for accurate analysis of different materials. Autodesk® Ecotect® Analysis sustainable design analysis software is a comprehensive concept-to - detail sustainable building design tool. Ecotect Analysis offers a wide range of simulation and building energy analysis functionality that can improve performance of existing buildings and new building designs. We used thermal analysis simulations for calculating heating and cooling loads for models and analyzing comparisons of different materials and weather tool to get the best orientation for the house.

Steps Of Building Analysis in Ecotect Software

a. Setting User Preferences

User preferences are set i.e units in SI system etc

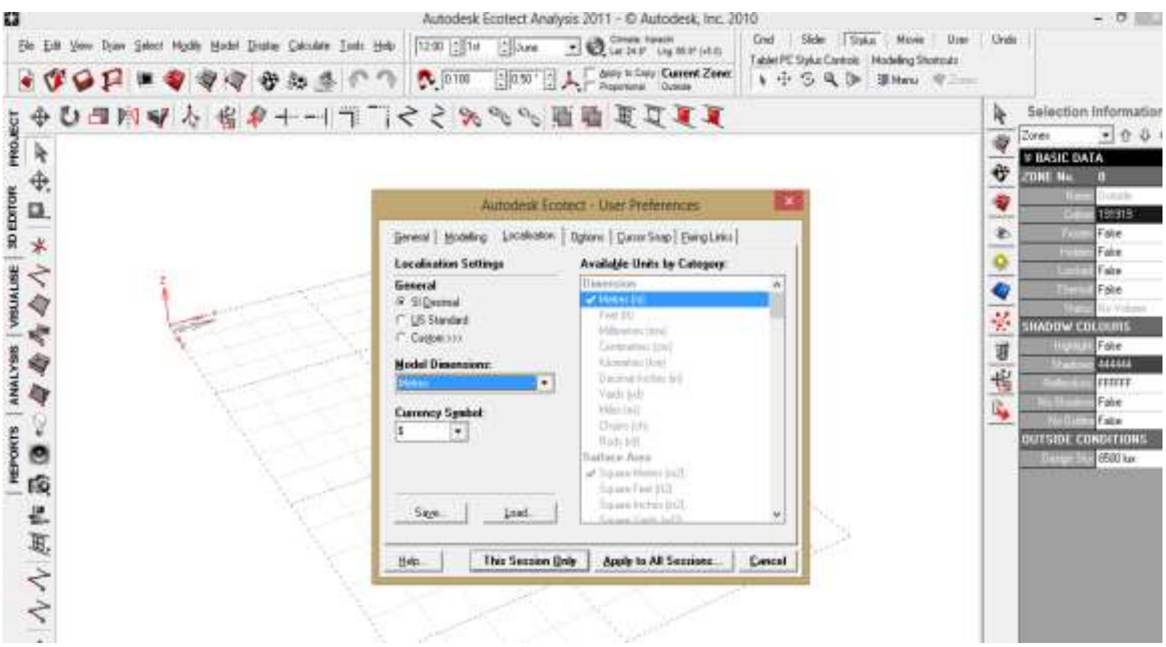


Fig:Set User Preferences

b. Setting the Grid

Settings regarding house orientation ,updation of climatic data etc is done in this step

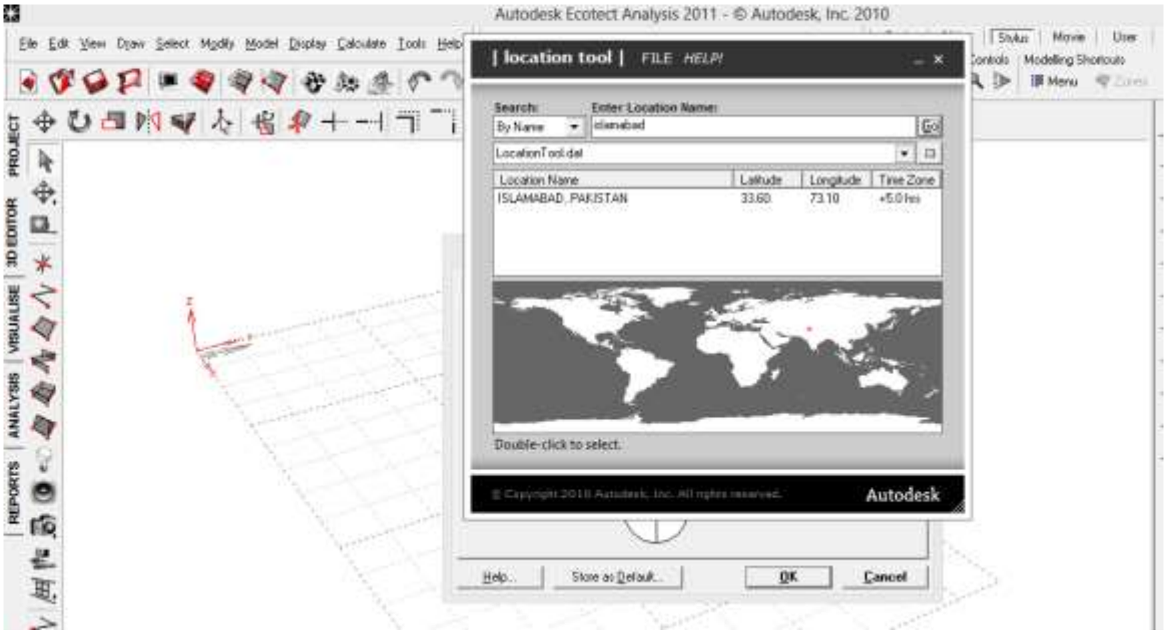


Fig: Setting the grid

c. Preparing the Model of Building

In this step, we prepared the model of the house. Model prepared on goggle sketch up is imported to ectotect software.

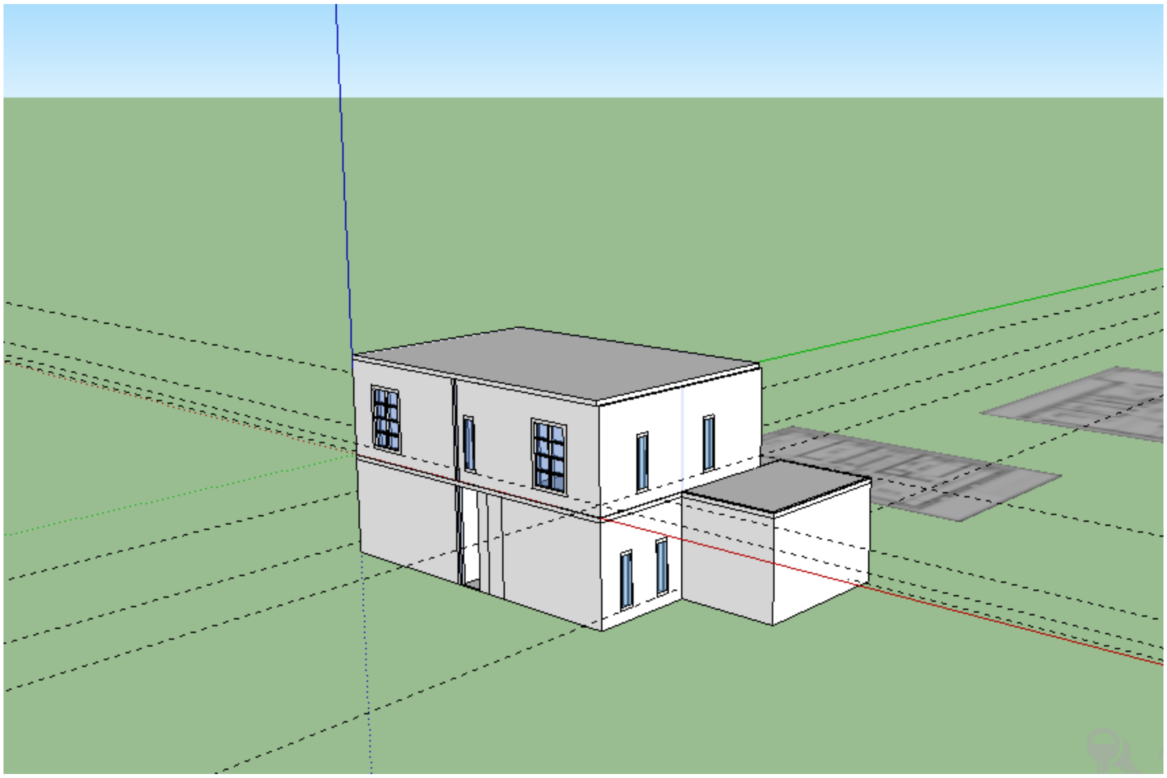


Fig:House Model

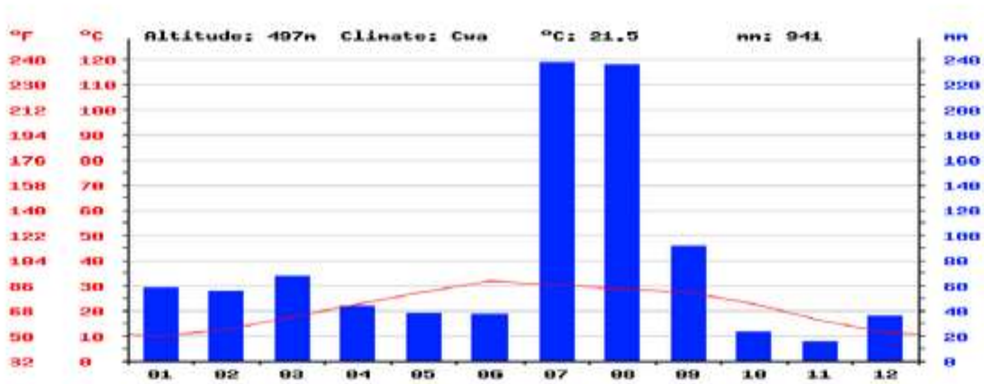
d. Analysis Part

(1) **Climatic Analysis**

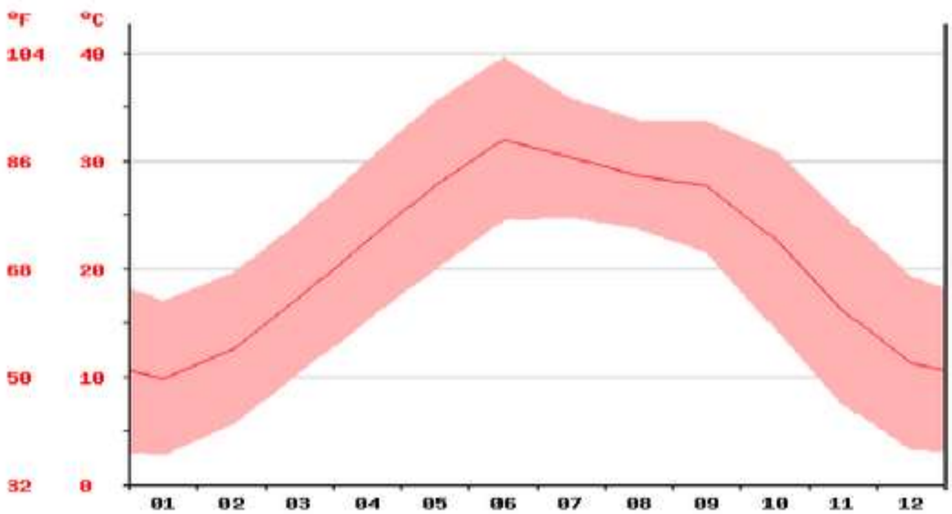
Whenever processing the energy-efficient buildings design, the site climate analysis should always be the first step in the early design stage.

The climate features a hot semi-arid climate with rainy, long and extremely hot summers, dry and cold winters, a monsoon and dust storms. The weather is extreme during the months of May, June and July, when the temperatures soar to 40-45 'C. From late June till August, the monsoon seasons starts, with heavy rainfall throughout the province. The months of December, January and February are the coldest months when sometimes the temperature falls below 2 degree Celsius. Sometimes there is a little amount of rain during the month of December.

Climate graph



Temperature graph



Climate table

month	1	2	3	4	5	6	7	8	9	10	11	12
mm	58	56	68	44	38	37	237	236	92	23	16	36
°C	9.8	12.5	17.3	22.6	27.6	32	30.3	28.6	27.6	22.7	16.2	11.3
°C (min)	2.7	5.5	10.4	15.3	19.9	24.5	24.8	23.6	21.6	14.5	7.5	3.3
°C (max)	17	19.5	24.2	29.9	35.4	39.5	35.8	33.7	33.6	30.9	25	19.3
°F	49.6	54.5	63.1	72.7	81.7	89.6	86.5	83.5	81.7	72.9	61.2	52.3
°F (min)	36.9	41.9	50.7	59.5	67.8	76.1	76.6	74.5	70.9	58.1	45.5	37.9
°F (max)	62.6	67.1	75.6	85.8	95.7	103.1	96.4	92.7	92.5	87.6	77	66.7

The difference in precipitation between the driest month and the wettest month is 221 mm. The average temperatures vary during the year by 22.2 °C.

Wind Analysis

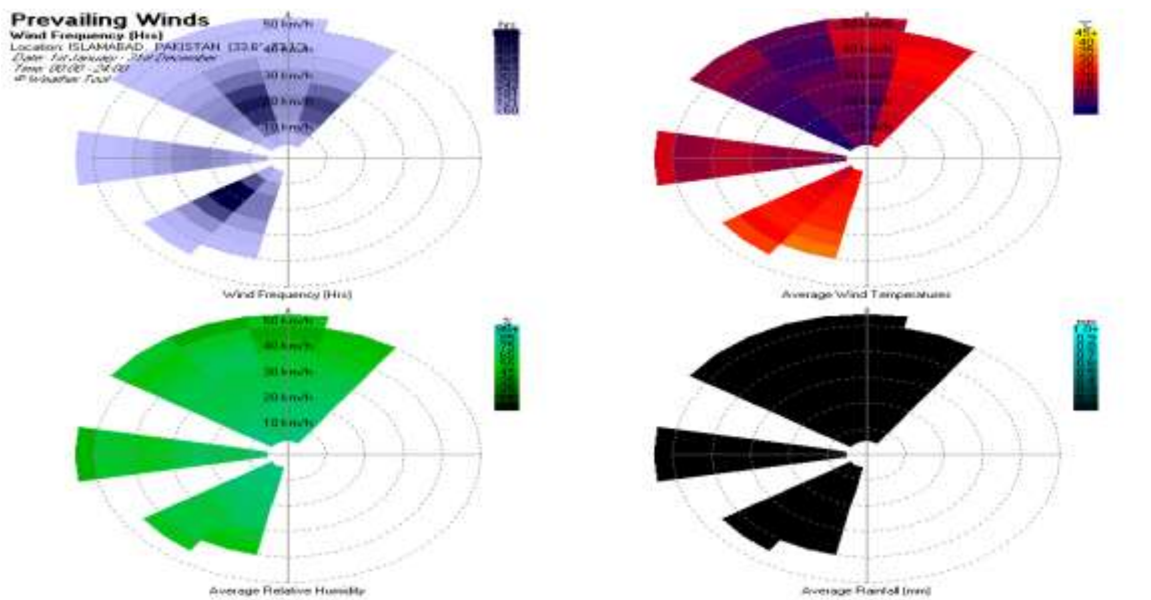


Figure: prevailing winds (ECOTECT)

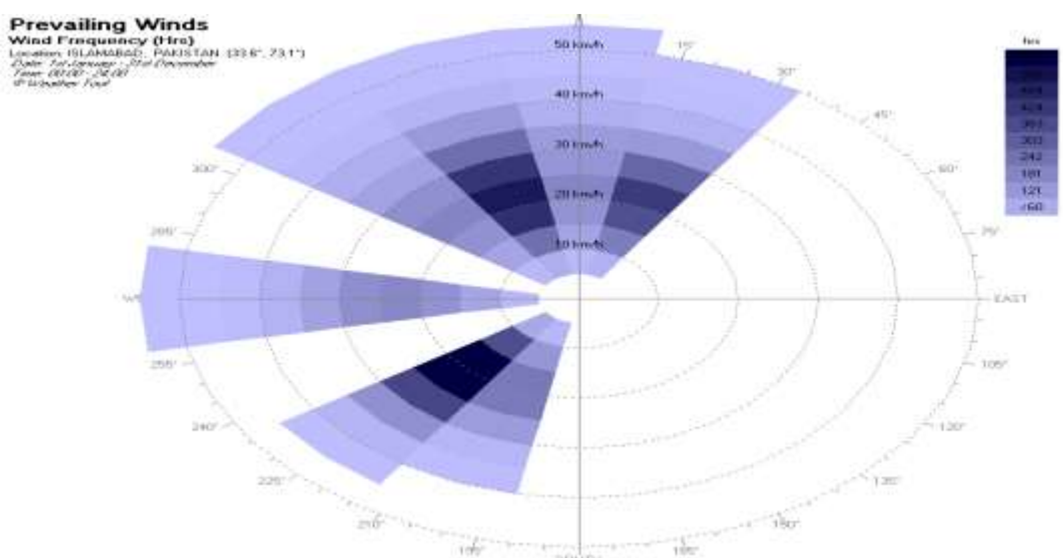


Figure : Annual wind rose all hours (ECOTECT)

Figure shows a wind rose map, it gives detailed information about wind direction and frequency for a whole year. The diagram reveals that the prevailing wind in islamabad comes from both northwest and southwest.,if it is properly utilized with cross ventilataion then it would affect the heating demand and cooling demand of the building.

Best Orientation

The best orientation of the building would be to the south as shown in results from ECOTECT (see below Figure). This is used to determine the most favorable range of orientations for passive solar heating, whilst still considering the effects of unwanted solar gains in summer. And also for the orientation of solar panels.

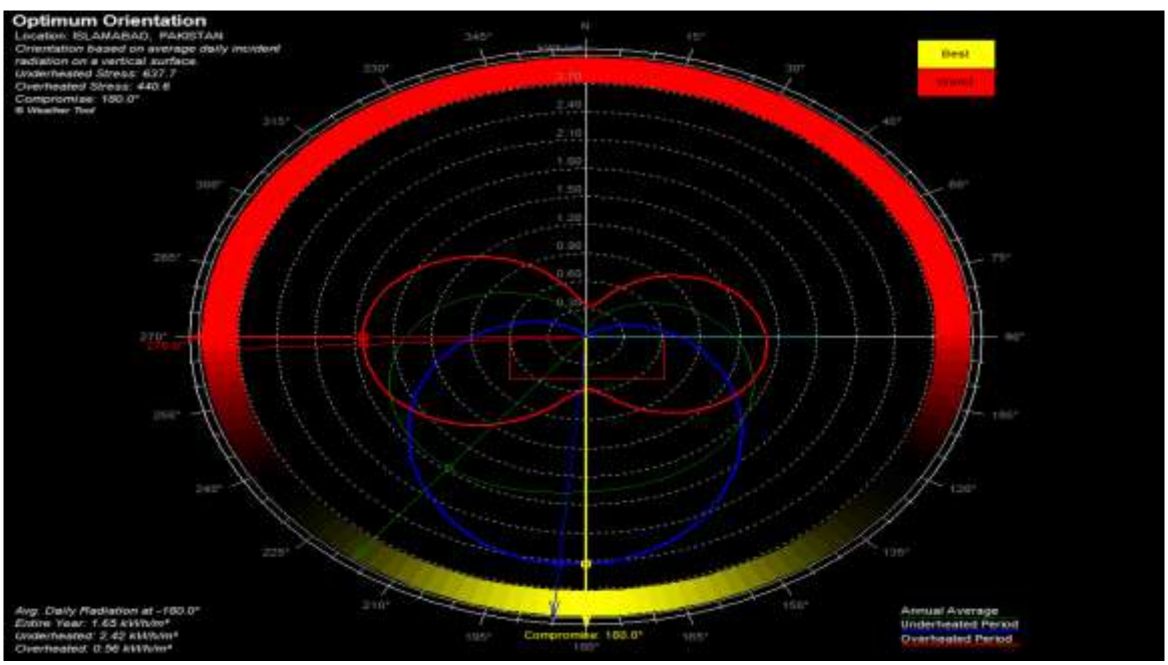
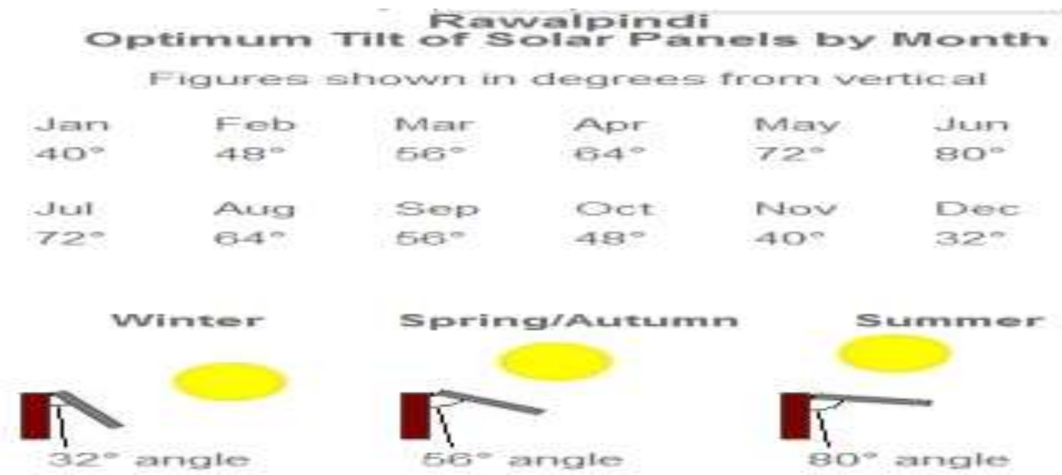


Figure : Best Orientation (ECOTECT)

Solar panel Tilt Angle

Solar panels will be tilted according to following angle to get the maximum solar radiations .Calculations are based on geographic data of the site and carried out using solar radiation calculator(online)



Passive Design Strategies

Passive design strategies are adopted to live in comfort zone without dependency on the active cooling techniques like fan, air conditioner etc. According to climatic data of Islamabad, comfort zone graph is as following showing the temp vs humidity graph.

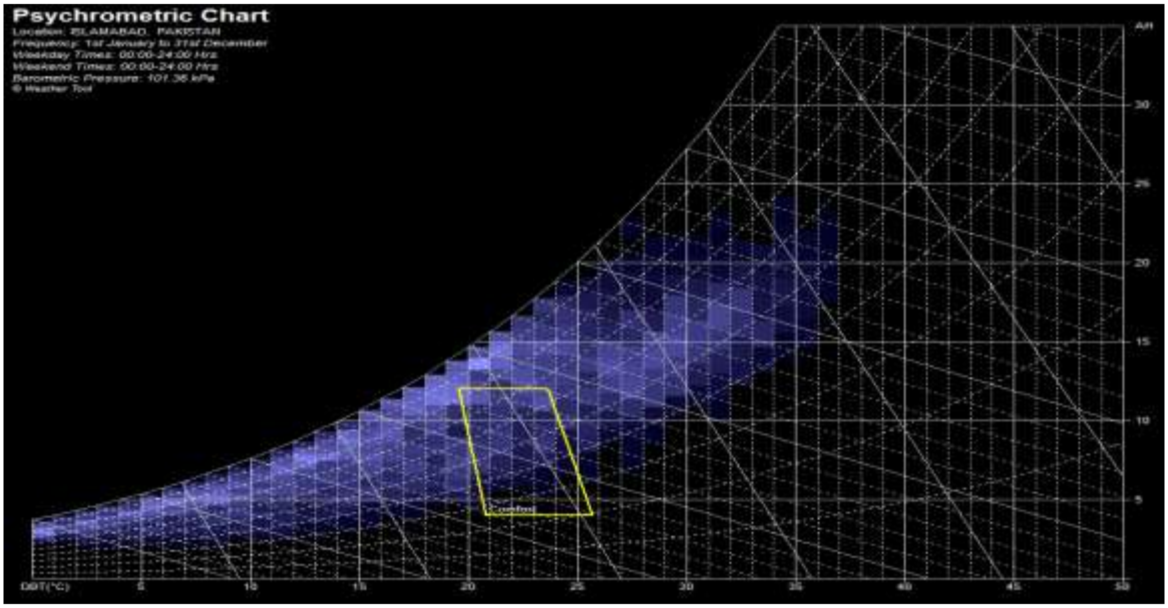


Figure: Comfort zone (ECOTECT)

Now, according to prevailing climatic conditions, we will require cooling techniques to live in comfort zone as shown in following figure.

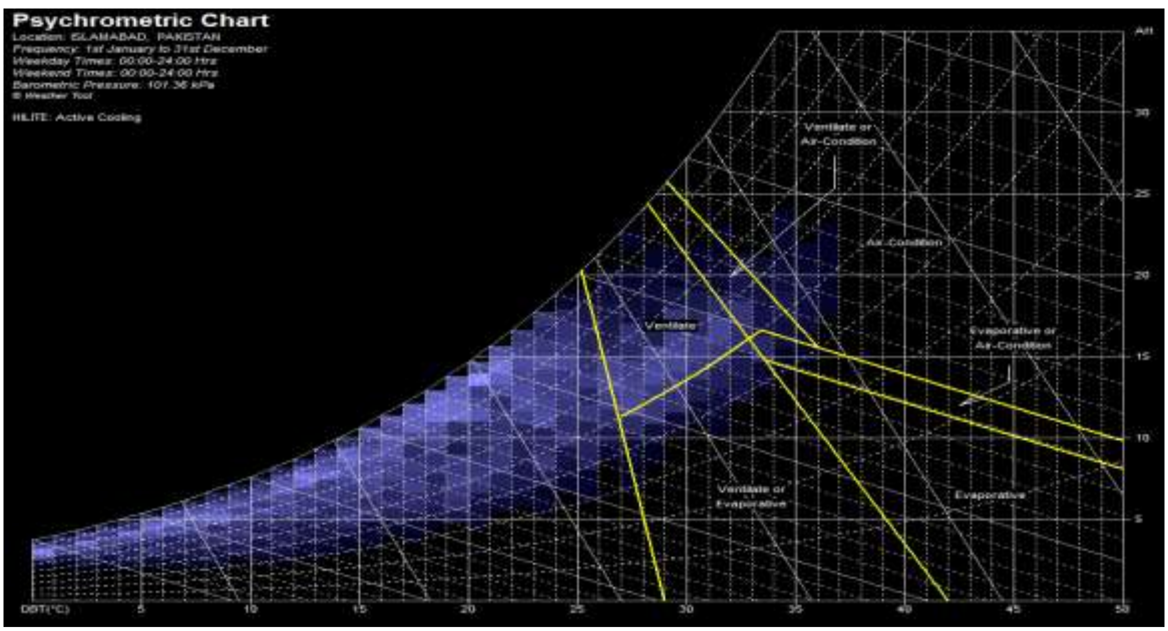


Figure: Active Cooling techniques

ECOTECT provides an initial analysis of passive design strategies based on Islamabad Climate data. From Figure, we could see that through applying these passive strategies such as passive solar heating, thermal mass and natural ventilation, the thermal comfort percentage (red color) has been improved approximately thrice compared to before which is shown in the yellow color.

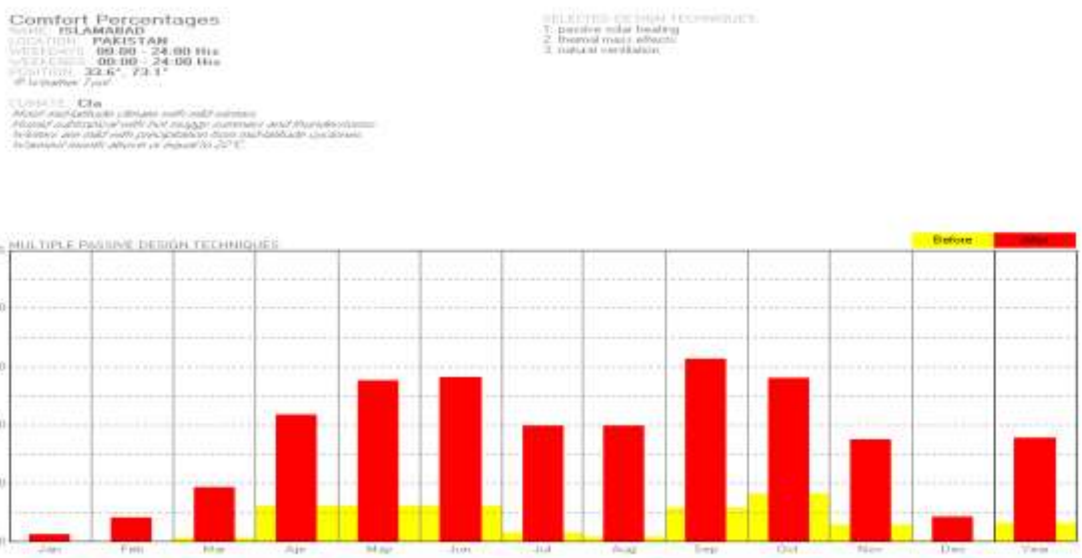


Figure: Expanded comfort zone due to passive strategies (ECOTECT)

50. **Window size Analysis**

(a). Experiment No 1 & 2.

- → 3.0 M height Room with Single row of window with window height *1.3 m and width 1.0 m*
- → 3.0 M height Room with 2 row of window with window height *600 mm and width 1.0 m*

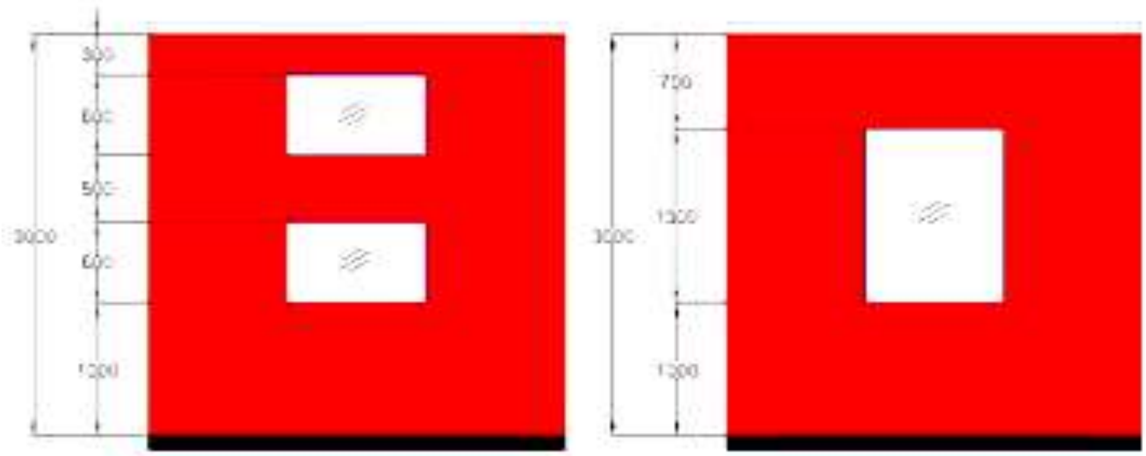
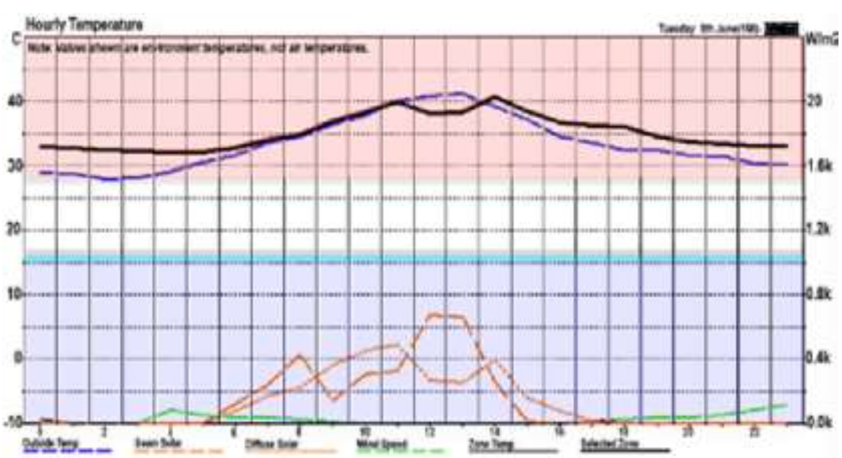


Fig: Experiment 1 & 2

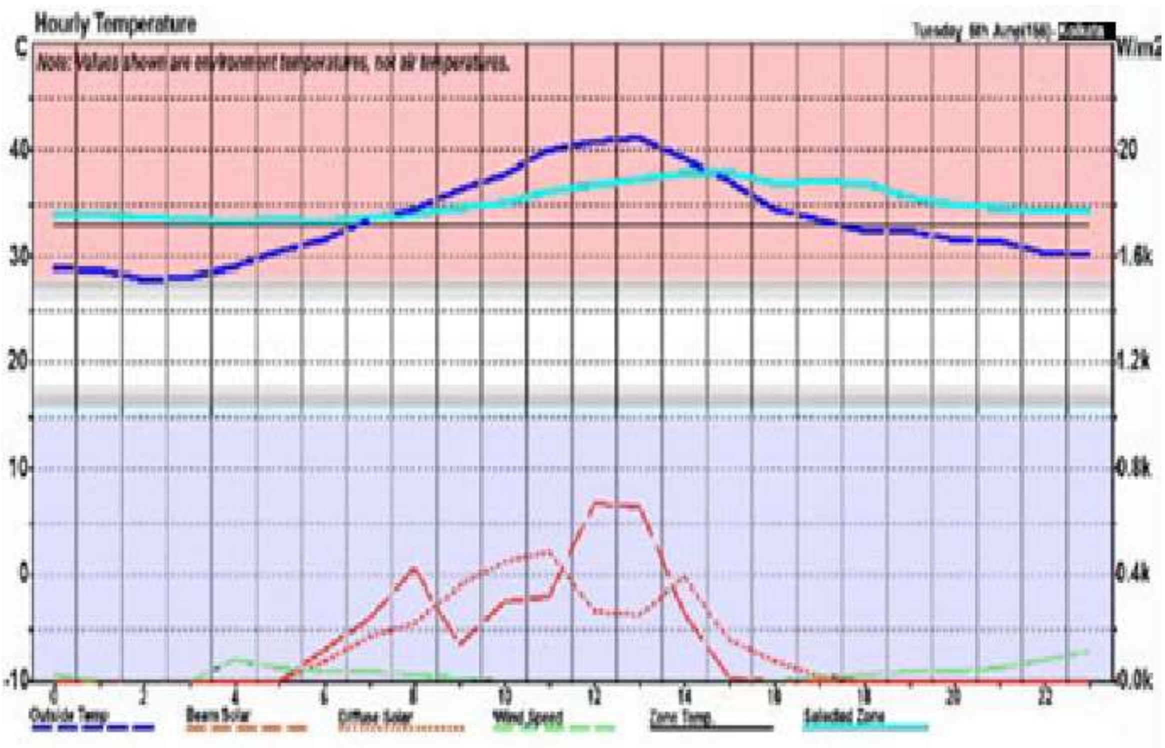
Experiment 1 results



<u>Fig Analysis Of experiment 1</u>

HOUR(C)	INSIDE (C)	OUTSIDE (C)	TEMP.DIF (C)
00	32.9	29.0	3.9
01	32.8	28.8	4.0
02	32.5	28.0	4.5
03	32.4	28.2	4.2
04	32.1	29.2	2.9
05	32.1	30.6	1.5
06	32.8	31.6	1.2
07	34.0	33.5	0.5
08	34.9	34.5	0.4
09	36.9	36.4	0.5
10	38.3	37.8	0.5
11	39.9	40.0	-0.1
12	38.2	40.9	-2.7
13	38.4	41.2	-2.8
14	40.7	39.3	1.4
15	38.5	37.3	1.2
16	36.7	34.6	2.1
17	36.3	33.5	2.8
18	36.0	32.4	3.6
19	34.5	32.5	2.0
20	33.7	31.7	2.0
21	33.4	31.5	1.9
22	33.1	30.4	2.7
23	33.1	30.3	2.8

Experiment No 2 Results



Hour	Inside temp (°C)	Outside temp (°C)	Temp Diff(°C)
0	34.1	29	5.1
1	34	28.8	5.2
2	33.7	28	5.7
3	33.6	28.2	5.4
4	33.4	29.2	4.2
5	33.5	30.6	2.9
6	33.4	31.6	1.8
7	33.7	33.5	0.2
8	34.1	34.5	-0.4
9	34.7	36.4	-1.7
10	35.2	37.8	-2.6
11	36.3	40	-3.7
12	36.9	40.9	-4
13	37.3	41.2	-3.9
14	38	39.3	-1.3
15	38.1	37.3	0.8
16	37.1	34.6	2.5
17	37.2	33.5	3.7
18	37.1	32.4	4.7
19	35.7	32.5	3.2
20	35	31.7	3.3
21	34.7	31.5	3.2
22	34.3	30.4	3.9
23	34.4	30.3	4.1

51. WALL ASSEMBLIES

A well-designed and constructed wall system represents the greatest opportunity to protect the building envelope against energy loss. The R-value, a measure of a material's ability to stop the flow of heat, is used to compare the insulating values of building materials. The higher the R-value, the greater the material will protect against energy loss.

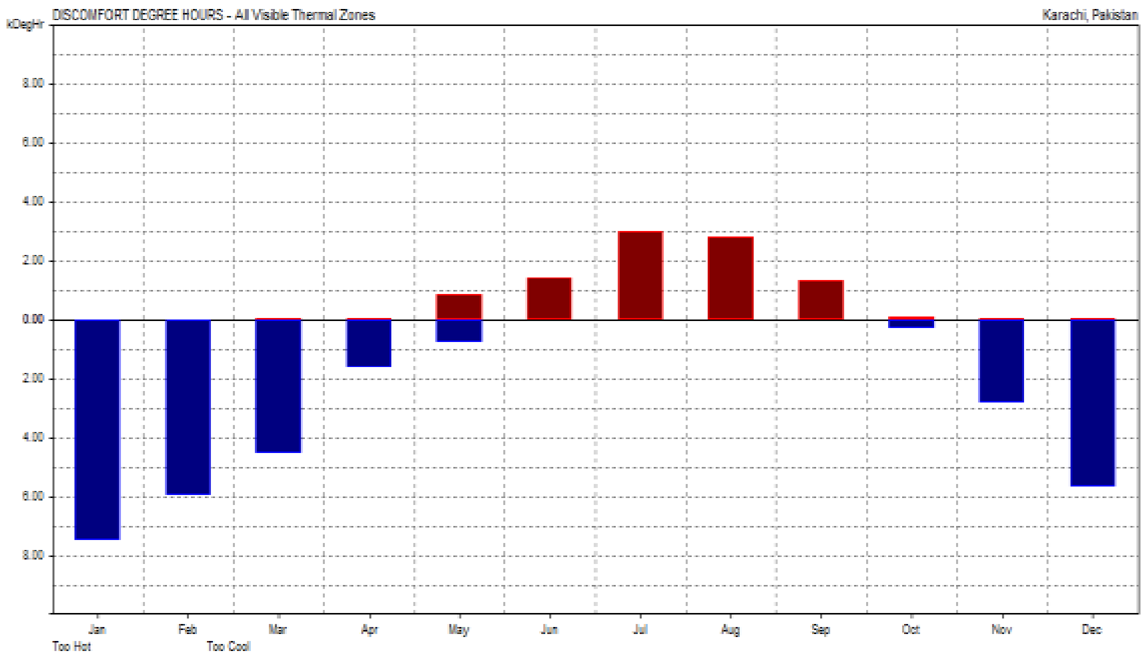


Fig: Cooling/Heating Hours (Brick Wall)

DISCOMFORT DEGREE HOURS
Simple Brick wall
All Visible Thermal Zones
Comfort: Adaptive - Average (± 1.75)

MONTH	TOO HOT (DegHrs)	TOO COOL (DegHrs)	TOTAL (DegHrs)
Jan	0	7479	7479
Feb	0	5996	5996
Mar	0	4533	4533
Apr	13	1653	1665
May	824	772	1596
Jun	1399	1	1400
Jul	2968	0	2968
Aug	2785	0	2785
Sep	1333	5	1339
Oct	79	289	368
Nov	10	2821	2831
Dec	0	5702	5702
TOTAL	**9411.1**	**29250.8**	**38661.9**

In fact what we concluded in our materials study is that cavity provides best insulation when it is left with an air gap without any insulation. We studied the wall assemblages using locally available materials and with the help of Ecotect compared the total cooling hours.we went for 110mm double brick plus 50mm cavity, with 10mm plaster.

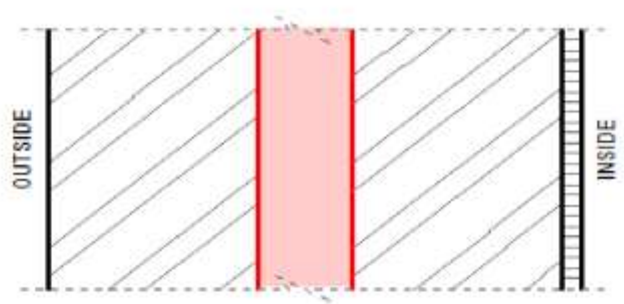


Fig: Cavity Wall

DISCOMFORT DEGREE HOURS
Cavity wall
All Visible Thermal Zones
Comfort: Adaptive - Average (± 1.75)

MONTH	**TOO HOT (DegHrs)**	**TOO COOL (DegHrs)**	**TOTAL (DegHrs)**
Jan	0	7019	7019
Feb	0	5096	5096
Mar	0	3433	3433
Apr	14	953	967
May	524	472	1396
Jun	1099	1	1200
Jul	2368	0	2468
Aug	2185	0	2185
Sep	1033	4	1037
Oct	59	189	248
Nov	8	2221	2229
Dec	0	5402	5402
TOTAL	**7290**	**24790**	**32680**

Difference in cooling hours = 38661.9 – 32680

= 5981.9

Percentage Reduction =15.47 %

52. ROOF ASSEMBLIES

CONCRETE SLAB ROOF ASSEMBLY:

For the roof we decided to go for concrete slab roof assembly used in local houses. Because of their thermal mass and ability to retain heat, concrete slab roofs are ideal for passive solar home designs. When homes are built to take advantage of solar radiation entering through windows in the winter months, concrete will absorb the heat from the direct sunlight and release the stored heat as needed at night to keep rooms warmer. Conversely in the summer and in hot climates, concrete shielded from the sun will stay cool longer and can actually help lower air-conditioning costs. It has the following layers

- Brick, medium weight
- Mud Phuska
- Insulation
- Asphalt cover
- Concrete slab
- False ceiling

To make it energy efficient we used Jumbolon as insulation.

53. **WINDOWS:**

We have used double glazed windows with 1" cavity in between which is filled with radon gas. Double glazed windows use two sheets of glass with a gap between them which creates an insulating barrier.

BENEFITS OF DOUBLE GLAZING

The benefits of double glazing windows are;

- Smaller energy bills
- Smaller carbon footprint
- More comfortable
- Peace and quiet
- Reduced condensation

Difference in cooling hours = 52328432-37014444

= 15313988

Percentage reduction = 29.3%

INSULATION:

Insulation is used only in the roof assembly. In walls, cavity works best when it is filled with air gap.

RESULT

By applying all the energy efficient thermal envelope elements we achieved a net percentage increase in comfort level as follows:

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