Sustainability Design Strategies and Tools in the Building Engineering Sector

Naddunuri Kumar
Dept. of civil engineering, M.Tech Building science Technology
School of Engineering and Technology, Jain University,
Bangalore, India

Abstract:- **Rapid growth of population and urbanization leads to enormous change in building industry. Building industry alone contributes 40% of carbon dioxide into the environment. Adopting sustainable design strategies and tools can reduce climate change impacts. Reduction in embodied energy, selection of building materials with ecological design principles cradle to cradle, cradle to grave, design for environment (DFE), design for deconstruction (DFD) and low impact development (LID) strategies using locally available materials designing with cardinal rules i.e. deconstructable, disassessment, harmless, recycling and less environmental impacts will bring down the carbon footprint level in the built environment. Life cycle assessment (LCA) is an important tool in assessing sustainability of new buildings existing buildings and of maintaining refurbishing and replacing the existing structures. Embodied energy and carbon associated with building construction, it is the energy required to construct a structure and the amount of carbon releases. Embodied energy is the energy required to extraction of raw materials, manufacturing of building components and transporting it to the construction site, installation and operation. So Design in way the nature it behaves thus bio mimicry are the primary sustainability strategies to follow.**

Consuming fossil fuels and conventional energy systems creates more problems in the built environment. Focus shifted to alternatives, renewable energy sources and integration of hybrid system makes buildings efficient. Lighting, Heating and cooling services have considered major energy consumers in buildings. Direct heating from geo thermal energy (ground coupling) and district cooling is environmentally optimized cooling solution with usage of local natural sources. And Passive cooling strategies like evaporative type cooling, and downdraught cooling, earth tunnel air-conditioning, chilled beam system etc. improves the whole building energy performance.

This article deals with possible solutions of sustainable parameters and integrated analysis of energy areas in the building services in mechanical, electrical and plumbing systems.

Keywords**: *Embodied energy, Lifecycle assessment, Carbon footprint, Low impact development (LID).***

INTRODUCTION

In recent times rapid growth of population and urbanization leads to enormous change in building industry. Due to construction of heavy structures (commercial, industrial, residential or other type of buildings) emits large amount of carbon dioxide and GHG's during the time of construction, operation and maintenance. These emissions from building sector contribute up to 40% of total world emissions.in India construction sector adds 30% of the GHG' emissions says 2007 report for `Indian climate change network assessment. So reduction strategies will bring down the environmental impacts as well as makes buildings more efficient. These strategies can be classified in different ways. Embodied energy, carbon footprint, lifecycle assessment in the built environment and construction &demolition waste handling, recyclable potential of materials, optimization in designing, passive design strategies, renewable sources utilization at the site, hybrid energy system design efficient use of building services (heating and cooling services with advanced controllers, lighting, water usage etc.) and low impact development methods.

Energy consumption = Fn (climate, density of population, occupancy schedule, orientation of building, internal loads)

Population density defines urbanism and results in large buildings in many ways with multi storied complexes then the term-embodied energy can be placed in origin to destination (O – D) studies.

Embodied energy in the built environment

EMBODIED ENERGY IS THE TOTAL ENERGY REQUIRED TO EXTRACT RAW MATERIAL, PROCESSING, MANUFACTURING, AND TRANSPORTING IT TO THE SITE AND FINAL INSTALLATION AT THE SITE.IN PRACTICAL THERE ARE DIFFERENT WAYS OF EMBODIED ENERGY TO ARRIVE BOUNDARIES OF THE STUDY. THE THREE MOST COMMON TYPES ARE CRADLE TO GATE, CRADLE TO SITE, AND CRADLE TO GRAVE.

1) A cradle-to-site study favours defining the embodied energy of individual building components. This includes the energy required to extract the raw materials, process them, assemble them into usable products and transport them to site. This definition is useful when looking at the comparative scale of building components and relates more to the 'good' in Cleveland & Morris's definition as it neglects any maintenance or end of life costs.

2) A ***cradle-to-gate*** model simply describes the energy required to produce the finished product without any further considerations.

3) A ***cradle-to-grave*** approach defines embodied energy as that 'consumed' by a building throughout its life. This definition is a far more useful one when looking at a building or project holistically.

Primary embodied energy: the energy required to initially produce the building. It includes the energy used for the abstraction, the processing and the manufacture of the materials of the building as well as their transportation and assembly on site.

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Recurring embodied energy: the energy needed to refurbish and maintain the building over its lifetime.
Demolition energy: the energy necessary to demolish and dispose of the building at the end of its life.

Note that the cradle-to-grave embodied energy, i.e. its life cycle embodied energy, does not include the operational energy required to utilize the final product. In other terms it does not account for the heating, cooling, lighting and power of any appliances that allow the building to serve its intended function.

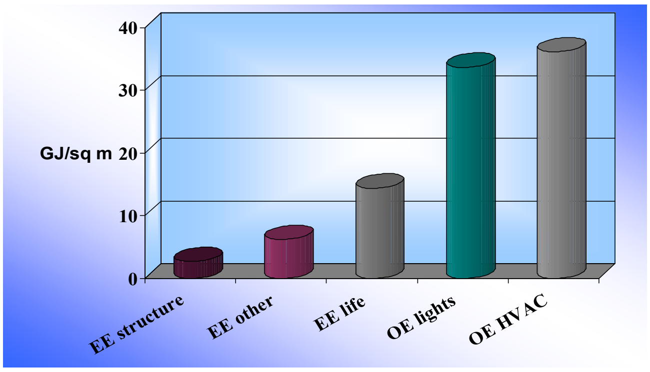

Fig.1. comparision of embodied energy and operational energy

How is embodied energy measured?
Embodied energy is measured as the quantity of non-renewable energy per unit of building material, component or system. It is expressed in mega joules (MJ) or gigajoules (GJ) per unit weight (kg or ton) or area (m^2) but the process of calculating embodied energy is complex and involves numerous sources of data.

Reducing embodied energy
Buildings should be designed and materials selected to balance embodied energy with factors such as climate, availability of materials and transport costs.
Lightweight building materials often have lower embodied energy than heavyweight materials, but in some situations, lightweight construction may result in higher energy use. For example, where heating or cooling requirements are high, this may raise the overall energy use of the building.
Conversely, for buildings with high heating or cooling requirements but where there is a large diurnal (day/night) temperature range, heavyweight construction (typically with high embodied energy) and the inclusion of high levels of insulation can offset the energy use required for the building.

- Durability of building materials
- How easily materials can be separated
- Use of locally available materials
- Use of recycled content materials
- Specifying standard sizes of materials
- Avoiding waste
- Selecting materials that are manufactured using renewable sources.

Why reduce embodied energy?
Energy consumption during manufacture can give an approximate indication of the environmental impact of the material, and for most building materials, the major environmental impacts occur during the initial processes.
The total amount of embodied energy may account for 20% of the building's energy use, so reducing embodied energy can significantly reduce the overall environmental impact of the building.

Embodied energy must be considered over the lifespan of a building, and in many situations, a higher embodied energy building material or system may be justified because it reduces the operating energy requirements of the building. For example, a durable material with a long lifespan such as aluminium may be the appropriate material selection despite its high-embodied energy.
As the energy efficiency of building increases, reducing the energy consumption, the embodied energy of the building materials will also become increasingly important.

How much embodied energy is typically found in buildings?

The amount of embodied energy in buildings varies considerably. Initial embodied energy consumption depends on the nature of the building, the materials used and the source of these materials (this is why data for a building material in one country may differ significantly from the same material manufactured in another country). The recurring embodied energy is related to the durability of the building materials, components and systems installed in the building, how well these are maintained, and the life of the building (the longer the building survives, the greater the expected recurring energy consumption).

The building envelope, structure and services contribute fairly equally and account for about three-quarters of total initial embodied energy. The finishes, which represent only 13% of the embodied energy initially, typically account for the highest increase in recurring embodied energy. Embodied energy may not be significantly different between building systems (e.g., wood versus steel versus concrete), however, the environmental impacts associated with one material versus another can be dramatically different.

Table.1 Energy coefficient values

Material	**Energy, MJ Per Kg**	**Carbon Kg/Co2 Per Kg**	**Density Kg /M^3**
Aggregate	0.083	0.0048	2240
Concrete (1:1.5:3)	1.11	0.159	2400
Bricks	3.0	0.24	1700
Marble	2.0	0.116	2500
Cement mortar (1:3)	1.33	0.208	-
Steel general	20.1	1.37	7800
Timber	8.5	0.46	480-720
Laminated timber	12	0.087	-
Plywood	15	1.07	540-700
Ceramic tiles	12	0.74	2000
Paint (water based)	59	2.12	-

Source: Energy and carbon dioxide implications of building construction, by Andrew H. Buchanan and Brian G. Honey, Energy and Buildings, 20 1994. Elsevier Science.

Table. 2
Energy required Manufacture some common building material

Material	Unit	Energy coefficient MJ per unit
Timber rough	M^3	848
Timber form work	M^3	283
Plywood	M^3	9440
Gypsum board	M^3	5000
Glass	Kg	31.5
Structural steel	Kg	59
Aluminium	Kg	145

Source: Foot notes: Energy and carbon dioxide implications of building construction, by Andrew H. Buchanan and Brian G. Honey, Energy and Buildings, 20 1994. Elsevier Science.

While these figures will vary with the quality and quantity of recycled feedstock, as well as with the efficiency of the processing equipment used, they show that using recycled materials as raw material for manufacturing can result in substantial energy savings for at least a few frequently used materials.

- Reusing materials, or even reusing entire buildings by retrofitting them, reduce the total amount of embodied energy even more than using recycled materials. Although reusing materials often requires intensive cleaning, and frequently entails repair, it represents a means of attaining substantial embodied energy savings. Builders can save embodied energy by incorporating as many salvaged and reused building components as practical. Meanwhile, reducing the energy required at any stage of production can lower the embodied energy of a manufactured material.
- Choose durable, long-lived building materials. Durable materials, especially those with low maintenance requirements, tend to have a lower embodied energy than disposable or short-lived materials. Although less-durable materials may not involve as much energy in their manufacture, the need for frequent replacement, combined with the need to dispose of the product following removal, results in a higher total embodied energy over the life of the structure.
- Use indigenous, or local, materials. Besides lower transportation energy costs, indigenous materials usually involve less processing energy than conventional construction materials. Using materials such as local stone for patios involves less embodied energy than using concrete or treated wood for patios and decks. Some builders build entire structures of indigenous materials.

Life cycle assessment (LCA) for Building components

LCA methodology is based on ISO 14040 LCA is a technique for assessing the environmental aspects and potential impacts associated with a product by compiling an inventory of relevant inputs& outputs of product system. And evaluating the potential environmental impacts associated with those inputs&outputs.and interpreting the results of the inventory analysis and impact assessment phases in relation to the objective of study.

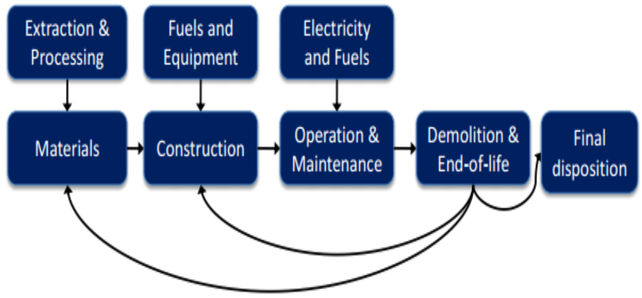

Fig.2.LCA process

Considerations in LCA framework

Energy use global warming, clinical change, resources waste and recycling. Pollution and hazardous substances. Internal environment planning land use and conservation.
More selective of building material use of recycled materials, reusability of materials and recyclability of materials and items.

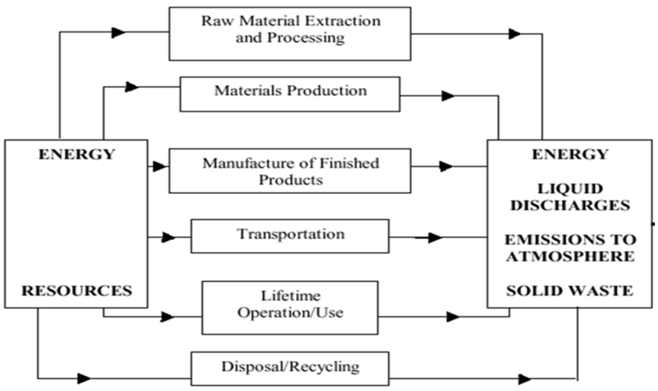

Fig.3. Graphical representation of the Inventory Analysis step.

LCA consists of four components or steps:
(1) Goal and Scope Definition,
(2) Inventory Analysis,
(3) Impact Assessment, and
(4) Interpretation.

Goal and Scope Definition

In this phase the product services are assessed and defined a functional unit is chosen and then required level of detail is defined. And set of data that needs to be collected are identified.

Inventory analysis

In this step, the energy and raw materials used; the emissions to atmosphere, water, and soil; and different types of land use

are quantified for each process then combined in the process flow chart and related to the functional basis.
As an example, the inputs may include water consumption and the outputs may include sulfur oxides (SOx). Thus, products and processes can be compared and evaluated using Life Cycle Inventory (LCI) results

Impact Assessment
The impact assessment translates the *emissions* from a given product or process into impacts on various human and terrestrial eco-systems. To aid in the understanding of impacts, the effects of the resource use and emissions generated are grouped and quantified into a limited number of impact categories, which may then be weighted for importance. Data from the inventory analysis is attributed to an appropriate impact category.

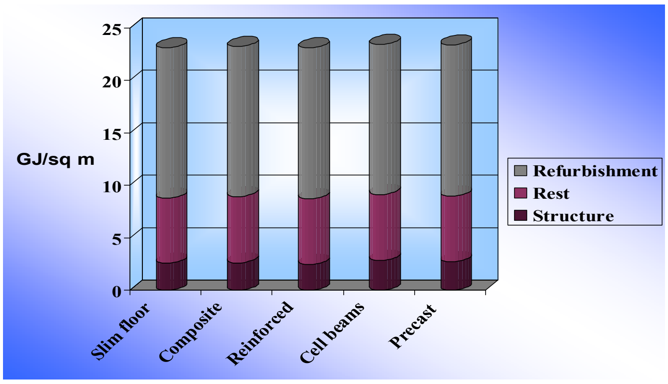

Fig. 4.Life cycle embodied energy

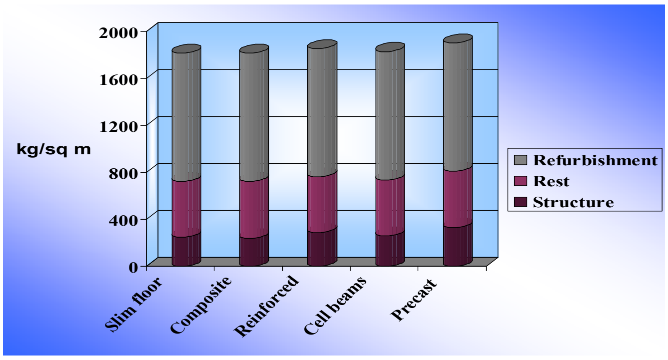

Fig. 5.Life cycle embodied CO2

Interpretation
LCA results are reported in the most informative way possible and the need and opportunities to reduce the impact of the product(s) or service(s) on the environment are systematically evaluated. In this step, the results are often presented in the form of tables or graphs, which is especially helpful when comparing two competing design options or products. The outcome of this step is directly useful in making environmentally friendly decisions. Like any other design feedback tool, LCA can be an iterative process. The interpretation of the LCA can lead to changes in the proposed design.

Global Warming Potential (GWP)
Global Warming Potential, or GWP, has been developed to characterize the change in the greenhouse effect due to emissions and absorptions attributable to humans. The unit for measurement is grams equivalent of CO2 per functional unit of product, Buildings accounts for 39% CO2 emissions.

Table.3. GWP Potentials of few common gases

Gas	Global warming potential (GWP)
CO_2	1
(CH_4)	21
N_2O	310
SF_6	23900

The commercial and residential building sector accounts for 39% of carbon dioxide emissions in the United States per year more than any sector.U.S buildings are more responsible for the more CO2 emissions than those of any other country except china. Most of these emissions come from the combustion of fossil fuels to provide heating, cooling and lighting and to power appliances and electrical equipment.by transforming the built environment to be more energy efficient and climate friendly. The building sector can play major role in reducing the threat of climate change.
Green buildings provide abundant opportunities for saving energy and mitigating CO2 emissions
Building Co2 emissions while improving the bottom line though energy and other savings. Examples of measures than can be taken to improve building performance.

- Incorporating the most efficient heating ventilation and air-conditioning system. Along with operations and maintenance and such systems to assure optimum performance.
- Using state of the art lighting optimizing day lighting.
- Using recycled content building and interior materials
- Reducing potable water usage.
- Using renewable energy.
- Implementing proper constructions waste management.
- Siting the building near public transportation.
- Using locally produced building materials.

Low carbon refurbishment
Is done in 4phases i.e. prepare, design, construct and use Building refurbishment' describes activities ranging from minor works to replacement of services and facades, which alter the interior and/or exterior of a building but fall short of demolition and rebuilding. As well as structural repairs and improvements to the external and internal appearance, refurbishments enhance the occupied space

The drivers for low carbon refurbishment include

- Reduced cost of operating facilities with lower energy use
- Reducing risk dye to future energy cost and supply uncertainty
- Better comfort and satisfaction and productivity for occupants.
- Setting a carbon emission target for the refurbished building.

Low carbon design must be integrated into the general building design

- Most aspects of a building can make difference to energy performance for example,
- Insulation to the envelope
- Low energy lighting fitted, zoned and controlled to regulations.
- The heating and cooling plants chosen for maximum efficiency
- Ventilation system designed to reduce energy usage.

Construction & demolition waste

Construction and demolition waste is general term for a diverse range of materials that when segregated, can include high value materials and resources for new construction. C&d waste is produced by demolition and building activities.

C&D waste comprises of concrete, plaster, bricks, metal wood plastic etc.it is estimated that construction industry in India generates 10-12 million tons of waste annually. There is huge demand in aggregates in the building industry but there is a significant gap in demand and supply. Which can be reduced by recycling construction and demolition waste to certain specifications. While some of the items like bricks tiles, wood metal etc. Are reused and recycled. Concrete and masonry constituting about 50% of the C&D waste is not currently recycled in India

When considering a reusable and recyclable material three major areas need to be taken into account are

- Economy,
- Compatibility with other materials
- Material properties

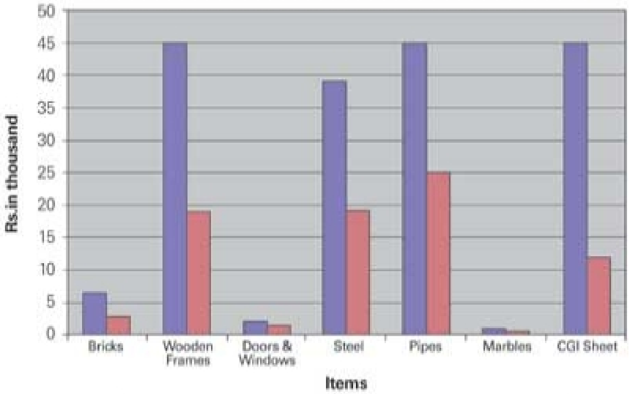

Fig.6.Cost comparison between new and old building materials

Table.4.C& D Production in India

Constituent	Quanity generated In million tons p.a
Soil sand and gravel	4.20 - 1.54
Bricks and masonry	3.60 – 4.40
Concrete	2.4 – 3.67
Metals	0.60 – 0.73
Wood	0.25 – 0.30MT
Others	0.10 - 0.15MT

Source: Technology information forecasting and assessment constituent

Recycling of C and D Waste

C and D waste management can be defined as the process related with the proper storage, collection and transportation, recovery and recycling, processing, reusing and disposal of C and D wastes in a manner that is in consensus with the principles of human wellbeing, economic, engineering and other environmental considerations.

C and D waste management includes following steps.

1. Storage and segregation: C and D wastes should be deposited/collected at source or place of generation. If they are Separation can be carried out at source during C and D activities or it can be achieved by processing the mixed material to remove the solid wastes. Separation at source is most efficient in terms of energy utilization, cost and time. Additional segregation is required for reuse/recycling of materials like timber, glass, and steel, plastic, plaster board and so on before demolition.

2. Collection and transportation: The time taken for handling (loading and unloading) large volumes of wastes should be kept to minimum by using front-end loaders and trucks.

3. Recycling and reuse: The growing population and requirement of land has reduced the availability of land for C & D waste disposal. C and D waste is not suitable for the disposal by incineration or by composting methods. Reuse and recycling are important strategies for management of waste. Other reasons that support the adoption of these strategies are reduced extraction of raw materials, reduced transportation cost, improved profits and reduced environmental impact. To conserve the conventional natural aggregate for other important works, all-fast exhausting sources of conventional natural aggregate has demanded the use of recycling/ reuse technology

4. Disposal: C and D waste does not create chemical or bio-chemical pollution. Hence maximum greater portion of the C & D wastes can be reused and recycled. The material can be used for filling or leveling of low-lying areas. In the developed countries, special landfills are created for inert waste, which are normally located in abandoned areas.

The waste management system should be planned and implemented which is holistic, integrated and sustainable. The plan should also target for waste diversion and recycling through implementation of new policies, information technologies, and awareness and waste management facilities. Waste minimization, reuse and recycling should be managed. The 3R strategy Reduce, Reuse and Recycle should be adopted to minimize C & D waste. Highly useful in handling of construction and demolition waste

Bio mimicry

Bio mimicry "innovation inspired by nature" that studies nature's best ideas and then imitates these designs and processes to solve human problems in the built environment. Studying a leaf to invent a better solar cell is an example domes at green which London where the lotus effect is used to create self-cleaning surfaces. A drop of water on a lotus leaf stands proud and spherical, as the microscopic surface contours do not allow the drop to spread out. If buildings are designed in such manner then rainwater just rolls off, taking dirt with it.

Day lighting and visual comfort

It can be very difficult to get consistent daylight and control glare from east and west windows. However, the side of the building facing the sun's path (the equator-facing side) can generally be easily shaded with overhangs, light shelves, or louvers, and the side of the building facing away from the sun's path gets little or no glare.

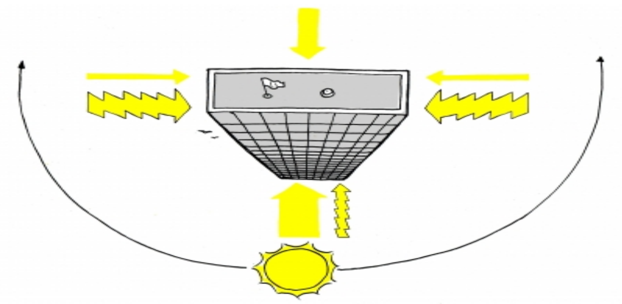

Fig.7.Useful daylight (straight arrows) and unwanted glare (jagged arrows) on different faces of a building.

Passive Design Strategies

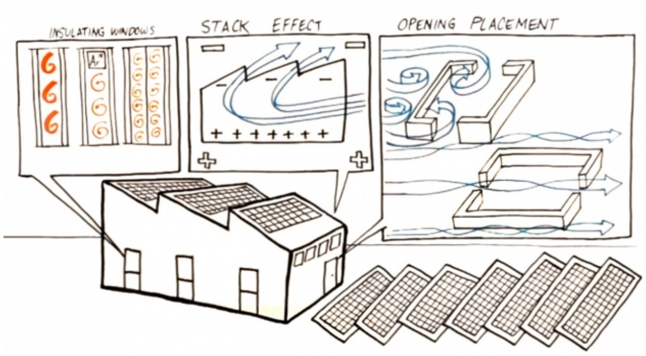

Fig. 8.passive cooling strategies incorporation in building

The right combination of passive and active design strategies Use the right blend of passive and active design strategies to minimize energy, materials, water, and land use.

Passive design strategies use ambient energy sources instead of purchased energy like electricity or natural gas. These strategies include day lighting, natural ventilation, and solar energy.

Active design strategies use purchased energy to keep the building comfortable. These strategies include forced-air HVAC systems, heat pumps, radiant panels or chilled beams, and electric lights.

Hybrid systems use some mechanical energy to enhance the use of ambient energy sources. These strategies include heat recovery ventilation; economizer ventilation, solar thermal systems, radiant facades and even ground source heat pumps might be included in this category.

Passive cooling strategies

Utilizing passive cooling strategies like natural ventilation, air-cooling, and shades can reduce your demand for mechanical cooling while maintaining thermal comfort.

- ***Natural ventilation***

Natural ventilation, also called passive ventilation, uses natural outside air movement and pressure differences to both passively cool and ventilate a building. It can include design strategies like wind ventilation, the stack effect, and night purge ventilation.

- ***Massing strategies for passive cooling***

Thinner buildings increase the ratio of surface area to volume. This will make utilizing natural ventilation for passive cooling easy. Conversely, a deep floor plan will make natural ventilation difficult-especially getting air into the core of the building and may require mechanical ventilation.

- ***Trombe wall***

A Trombe wall is a system for indirect solar heat gain and, although not extremely common, is a good example of thermal mass, solar gain, and glazing properties used together to achieve human comfort goals passively.

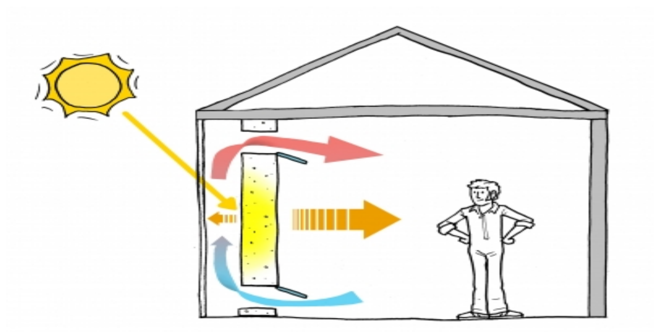

Fig. 9.hot air convection with Trombe wall

The glass prevents the escape of radiant heat from the warm surface of the storage wall. The heat radiated by the wall is therefore trapped within the air gap. Further heating the wall surface. For a 40cm (16") thick Trombe wall, heat will take about 8 to 10 hours to reach the interior of the building. This means that the room behind remains comfortable through the day and receives slow, even heating for many hours after the sunsets. Such designs are ideal for use in residential living areas and bedrooms.

- ***Evaporative type cooling***

Evaporative cooling is a very common form of cooling buildings because it is relatively inexpensive and requires less energy than many other forms of cooling. Unfortunately, evaporative cooling requires an abundant water source, and is most effective in climates with low humidity. In arid climates, homes and small business use direct evaporative cooling systems.

❖ ***District cooling system (D.C)***

D.C is the centralized production and distribution of cooling energy. Chilled water is delivered via an underground-insulated pipeline to office, industrial and residential buildings to cool the indoor air of the buildings within a district. Specially designed units in each building then use this water to lower the temperature of air passing through the building's air conditioning system.

The output of one cooling plant is enough to meet the cooling-energy demand of dozens of buildings. District cooling can be run on electricity or natural gas, and can use either regular water or seawater. Along with electricity and water, district cooling constitute a new form of energy service.

❖ ***Chilled beam system***

Chilled beams are predominantly used for cooling and ventilating spaces, where a good indoor environment and individual space control is valued. Chilled beams use water to remove heat energy from a room and are located in the room space. Chilled beams are primarily used in locations where the humidity can be controlled.

Chilled beams provide excellent thermal comfort, energy conservation and efficient use of space due to the specific heat capacity of water being so good when used as heat transfer medium (typically four times better than air). Chilled beam operation is simple and trouble free due to having minimum maintenance requirements. Chilled beams also supplement the flexible use of available space, at the same time as the high temperature cooling and low temperature heating maximizing the opportunity for free cooling and heating. Operation of the chilled beams is used where the internal humidity loads are moderate, the primary air is dehumidified and any infiltration through the building is limited and controlled.

Renewable sources integration

❖ ***Intermittence and energy storage***

Sun only shines during the daytime, and sometimes-cloudy weather obscures the sun. Thus photovoltaics can only be counted on to generate power intermittently, and systems must be sized to generate extra power when the sun is shining, to meet the building's needs when it is dark. Additionally, wind is also intermittent.

The amount of extra power required depends on whether the building is connected to the local electrical grid, or if it is off the grid.

❖ ***Passive solar energy systems***

Passive solar energy systems rely upon the original or retrofitted design features and budding materials of a structure to enhance the use of natural forces including solar radiation, winds and nighttime coolness to provide heating or cooling within a residential, commercial, institutional or industrial building. Such systems are not primarily dependent upon mechanical power for operation, although they may make use of fans to enhance thermal distribution. Passive solar energy systems may also provide hot water, most commonly for residential purposes.

Wind power

Wind power may be useful for locations that have very strong winds and do not have enough sunlight for photovoltaics. Although large-scale wind power is usually less expensive than solar, small-scale wind power is usually much more expensive than solar Wind per kilowatt-hour of electricity generated.

Any commercial wind turbine will have a specification sheet showing a graph of energy generation vs. average wind speed. This is what should be used to judge energy generation, not the maximum power rating.

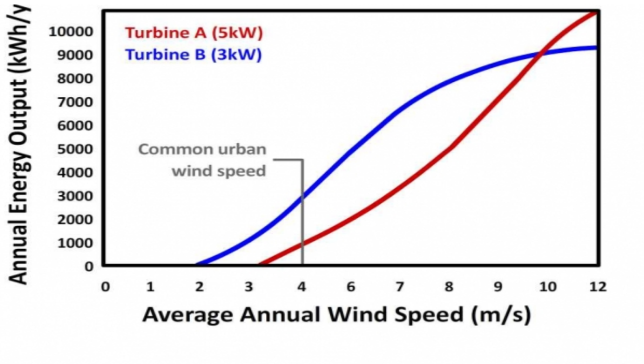

Fig. 10.Annual energy consumption

Hybrid energy systems

Hybrid energy systems have been designed to generate electricity from different sources, such solar panels and wind turbines.

Hybrid energy systems often consist of a combination between fossil fuels and renewable energy sources, and are used in conjunction with energy storage equipment (batteries).

This is often done either to reduce the cost of generating electricity from fossil fuels or to provide back up for a renewable energy system, ensuring continuity of power supply when the renewable energy source fluctuates.

One of the biggest downfalls of renewable energy is that energy supply is not constant. Sources like solar and wind power fluctuate in intensity due to the weather and seasonal changes.

Therefore, a reliable backup system is necessary for renewable energy generating stations that are not connected to a national power grid.

ACKNOWLEDGE & CONCLUSION

The challenge of sustainable development is the challenge of achieving environmental conservation and resource management without compromising the targets of growth and development. The objectives of this paper were: Sustainable development, when applied to the development of a system, creates complexity, which ensures that the cost to environment. The construction industry puts a high burden on the environment, using sustainable construction methods save money by reducing a buildings carbon output and running costs. This concludes that Sustainable development concepts to protect the environment from degradation. And Moving towards sustainable development presents tremendous challenges. The shift of paradigm from present practices to holistic thinking and strategic actions that link immediate to long-term needs and priorities depend on the successful implementations and human intellectual resources.

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