Zero Net Energy Buildings in India

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ABSTRACT

Energy helps man, machine to work as per human comfort considering the environmental aspects so that the human comfort will get achieved. Energy can be in any form such as solar energy, wind energy, geo thermal energy and many more. However, utilization of energy depends on application requirements, energy converters, source of energy and most important energy conversion and recovery system. The research paper deals primarily with how an existing building can achieve zero net energy consumption with systematic approach towards building energy consumption profile. The different factors affecting a building' s energy consumption were analyzed in classical way of looking energy profile. Some ways of integrating energy- efficient tactics into the different stages of construction namely the designing, construction and operation of buildings so as to improve and optimize the efficiency of buildings that already exist were discussed. These can decrease consumption of energy significantly.

Keywords: Zero Net Energy, Energy consumption, Active systems design, Passive design, renewable.

1. INTRODUCTION

Cities with Institutional, high rises residential & commercial buildings have become symbols and icons of progress and development for any country across the world. Old cities will continue to grow and new cities will come into being as the populations migrate into them in search of employment, new opportunities and a better life. With restrictions in space in the cities, buildings have grown vertically, higher and higher to meet ever increasing demands for commercial, office and residential requirements, with the result that they have, in no time become big consumers of energy. Buildings are, in fact, considered to be the primary energy consumers, and in big countries such as the United States, they account for 33% of global carbon dioxide emissions. The energy usage of the building sector is still on the increase to this date; mainly because construction of new buildings is faster than retirement of the old ones, and urban areas keep on increasing.

As a study approach, until buildings are designed in a way that they are able produce enough energy from renewable energy sources to balance the energy requirements of these buildings, energy consumption in the commercial building sector will be on the rise.With the increase in energy prices, and more importantly because of increasing effects of Climate change, it has become more and more urgent to decrease energy consumption and one way of doing so, is to target building energy use. The building sector can have major energy reductions by integrating energy-efficient approaches into the different stages of construction namely the designing, construction, and operation of buildings. This could also help to decrease the dependence on energy derived from non-renewable fuels. The main idea is that buildings can be made to meet all their energy demands from cheaper, easily available and clean renewable sources.

However, advancement in construction technologies and renewable energy systems are making Net Zero Energy buildings more and more achievable.

2. Zero-net energy building definition

A zero-net energy building (ZNE) is a building that has zero energy consumption. This means that the building makes use of renewable energy which is created on site and this energy is roughly equal to the total energy consumption of the building annually. For this type of building, one unit of energy must be generated for each unit of energy consumed by the building over a year.

Most of these buildings are still connected to the utility grid. This is done so that the building can use electricity from the grid in case the renewable energy generation is not enough to meet the electrical load of the building. However, when the generation of the energy on-site energy exceeds the load, the excess energy should be sent back to the electric grid. The energy which is in excess is then used in case of peak demands. This is why the energy consumption is said to be net zero.

3. Types of Zero Energy Buildings

Zero energy building can be divided into different categories. These categories are listed below:

1. Net zero Building energy: - The amount of energy produced at the same building should meet the energy demands of the building.

2. Net zero source energy the energy produced at the source should meet the demands of the building in terms of energy.

3. Net zero energy costs: - In a cost ZEB, the cost of purchase of energy is equaled to the amount money received for the sales of excess electricity to the supply company.

4. Net zero energy emissions:- The amount of energy produced from pollution producing energy sources is almost equal to the emissions-free renewable energy it produces.

4. Net zero site energy

This type of ZEB produces energy that it needs on site. The energy generated are mostly from Photovoltaic panels mounted on the roof and on other surfaces such as at the parking, solar hot water collector, small scale wind power and in some rare cases low impact hydro power.

- ### Net zero source energy

Source energy accounts for both the energy demand of the building as well as the energy required to transport the energy to the building. It takes into consideration the losses that occur during electrical transmission. The imported and exported energy should be multiplied by the required site-to-source conversion factors to obtain the building’s total source energy.

- ### Net zero energy costs

The cost of purchase of energy is equaled to the amount money received for the sales of excess electricity to the grid. This occurs when the building has more energy than required hence it can sell the excess energy produced to the grid may be a challenge in future. Generally, in a drive to promote renewables across the world, Governments utilities offer higher costs for energy exported to the grid than that supplied from the grid but such revolution in India might be the next fold. Hence, in a building which has on-site renewable power generation, selling power to the utility grid fetches more than import from the grid. The net annual costs between power sold to the grid and consumed directly from the grid comes to zero or +ve.

- ## Net zero energy emissions

The emission of carbon from on-site or off-site fossil fuel use is almost equal to the amount of on-site renewable energy production. For example; if a building uses sources like as hydroelectric power or wind power, emissions are already zero and there is no need for any on- site renewable energy generation to balance the emissions. However, if that building requires natural gas for heating purposes, then it will have to balance emissions by producing and exporting enough emissions-free renewable energy.

On site measurements are used to check adequacy of a site ZEB whereas source energy or emissions ZEBs cannot be measured as easily since there are site-to-source factors involved.

Table 1: Energy generation options (on and off site)

On-Site Supply Options		
1	Use renewable energy sources available within the building's footprint	PV, solar hot water, and wind located on the building.
2	Use renewable energy sources available at the site	PV, solar hot water, low-impact hydro, and wind located on-site, but not on the building.
Off-Site Supply Options		
3	Use renewable energy sources available off site to generate energy on site	Biomass, wood pellets, ethanol, or biodiesel that can be imported from off site, or waste streams from on-site processes that can be used on-site to generate electricity and heat.
4	Purchase off-site renewable energy sources	Utility-based wind, PV, emissions credits, or other "green" purchasing options. Hydroelectric is sometimes considered.

- ## Factors affecting a building's energy consumption

For a new building, the most profitable way to obtain a reduction in the energy consumed usually occurs during the conceptual design process.

There are various factors that alter the energy demands in a building. These can be divided into three main categories namely; non-design factors and design factors. The design factors can be further divided into the passive design factors and the active system design.

Non-design factors are those affected by;

1. Occupancy and management,
2. Environmental Standards and
3. Climate and Building application.

Passive design can be further divided into

The use of the building's location and site to reduce the building's energy profile and the design of the building itself such as

- Size and shape,
- Orientation,
- Thermal mass,
- Day lighting,
- Passive cooling and heating and,
- Solar thermal collector.

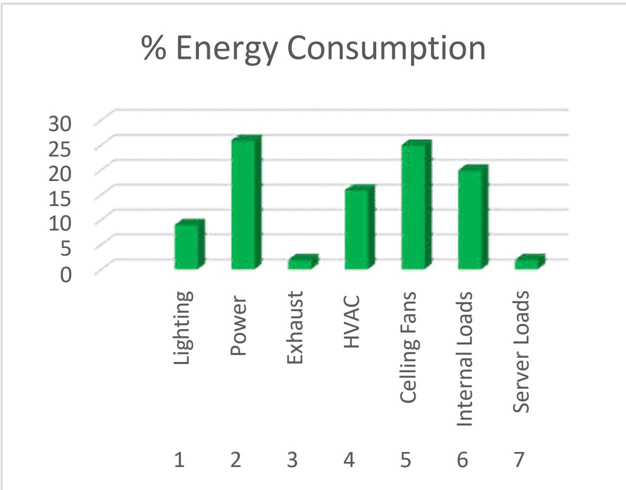
Active system design:

This consists in using mechanical and electrical use so as to decrease the building's energy demand. Some examples of mechanical systems include HVAC, extraction systems, Lifts & Escalators, pumps etc. The electrical systems include luminaires and electrical motors and equipment used in the building such as computers, servers, UPS, printers etc.

- **Energy Efficient Design**

The figure below gives an account of the amount of energy consumed by a building in terms of lighting, electric heat, gas heat, Air conditioning, Exhaust fan, HVAC fans and other internal loads. Figure 1 shows the amount of energy consumed by a building and Figure 2 shows the amount of energy that can be saved with energy efficient designs.

Figure 1: Amount of energy consumed



Passive Design

This section will be concerned with the different factors involved in the passive design.

- **Size and Structure:-**

The shape and structure of the building is vital as it determines the amount of solar energy that the building receives hence affecting its total energy requirements. Solar radiations can create an increase in energy requirements of up to 25%. The surface exposed to the outside also determines the energy losses. Ideally, the ratio between the outer surface and the volume of the building is related to a building's capacity to store or lose heat. To prevent heat loss or heat gain, the ratio between the outer surface and the volume should be small. The shape also defines the percentage of the building exposed at each cardinal point. A building, in the Northern Hemisphere, with less wall surface facing the South requires 8.2% more energy for heating.

- **Building Orientation:-**

The orientation of a building is measured using the meters. GPS is a way of measuring the angle of a surface from the true north.

Orientation, normally in the East-West direction, with the shortest lengths facing East and West would be ideal so as to:

Maximize natural daylighting and solar passive heating in cold climate countries

Maximize natural daylighting and minimize the air conditioning loads in hot climate countries

Some benefits of having optimal building orientation are:

- Low cost measure that can be implemented at the design stage of the project.
- Reduces energy demand.
- Reduces the need for complex passive systems.
- Increases amount of daylight hence reduces demand for artificial lighting therefore less contribution to internal heating of the building.
- Improves performance of solar collectors.

By knowing how the sun will interact with the building in the summer or in the winter, overheating and glare can be mitigated.

- **Thermal Mass:-**

It is the property of a material to take in and retain heat. There are two main parameters; heavy-weight and light-weight which are used to describe buildings with different thermal absorption abilities. Buildings constructed with heavy weight materials have the tendency to take in and store heat. A lot of energy is required to lower the temperature of high density materials like concrete, bricks and tiles. They are hence said to have high thermal mass. Wood or Ply which is a lightweight material has low thermal mass.

A building with high thermal mass will absorb, retain and radiate heat to the interior or exterior, whichever way is the thermal driver. Thus, in a hot country, this will impact on the internal comfort air conditioning cooling load and in a cold country; it will impact on the heating load.

Hence in hot countries, buildings should be more open and lightweight. In cold climates, buildings should have high insulation and little exposed thermal mass. When used properly, a combination of with passive solar design and appropriate thermal mass can play an important role in reducing energy use in active systems. It is important therefore for the architect to be well aware of the properties of the materials that will go into the construction of the building as well as insulation levels, as this will help to reduce energy consumption or the need for heating or cooling systems.

- **Day Lighting:-**

Natural external daylight intensity varies from 400 Lux at sunrise / sunset to about 120,000 Lux during periods of bright sunlight. Normally, an internal lighting level of 300 Lux is more than adequate for general office work. So, if ways and means could be found to make maximum use of natural daylight inside a building, this would reduce the need for artificial lighting and hence electrical power. Artificial light can take up to 35% of a building's cost. So, the use of natural daylight should help reduce these costs.

During the conceptual design of the building, this criterion has to be considered. A building laid out in the East – West orientation with glazing along the longer North and South facades would allow daylight with minimum sunlight on either the North or South facades depending on which hemisphere the building is located.

The architect can also use other means to shield the glazing from direct sunlight, such as fixed or adjustable architectural sun shadings on the facades or even special tinted glazing that would allow daylight into the room while preventing heat transmission into the occupied space.

- **Passive Cooling and Heating: -**

This type of cooling or heating uses a natural process to remove or absorb heat. Summer cooling as well as winter heating is important in a building. Unwanted summer heat includes direct solar impact on buildings, heat transfer and infiltration of outside air through elements of the structure and lastly the internal heat produced by lighting, equipment and appliances.

The building should be designed in such a way that sunlight striking the external surfaces is minimized. Painting the external surfaces with light colors e.g white would reduce heat absorption by reflection of direct sunlight at the surface. The heat from surrounding outside areas should also be prevented from re-radiating and reflecting back into the building.

The laws of nature are used in to carry out passive cooling: hot air is less dense and rises naturally, so this natural principle could be used in a building with external air entry at a lower level and extraction of warmer air at roof level.

Many of the techniques used for passive cooling, like for example insulation of the walls will also prevent heat loss in winter.

- **Solar thermal Collector:-**

Solar water tubes are passive heat absorption which collects beaming heat from the sun to heat up water which is circulated through tubes in the collector for use as canteen or domestic hot water in the building and also as pre-heated water for the general building heating in cold countries.

Solar thermal collectors are usually located at the roof to the inclination as necessary. An efficient Solar Thermal Collection, which is a green source of energy, can help reduce utility bills in a building considerably.

- **Active Design**

This section will be concerned with the different electrical and mechanical systems involved in the active design.

- **Cooling System:**

For general comfort of the occupants in a building, it is required to have a cool and clean internal environment. This is the key towards employees' satisfaction, good health, happiness and maximum productivity.

To achieve such internal comfort conditions, it is generally required to treat, cool and circulate the air supplied to the occupied areas mechanically by means of Air Conditioning systems which may include Central water chillers, air handling units, air supply and return ducts, Variable air Volume (VAV) terminals, fan coil units, split air conditioning units, supply fans, return fans etc.

These mechanical components usually run on electrical power and in a building, it has been found that the air conditioning power load turns out to be more than 50% of the total electrical power consumption. Hence, it becomes important to find ways and means to reduce the electrical power consumption so that building can achieve a Net Zero Energy status.

Few Methods to reduce the power consumption HVAC in a building are as follows :-

- Use of star rated water chillers with high Coefficient of Performance (COP), having Variable speed Condensing fans and with an ability to modulate its cooling capacity as per the demand in the building, etc.
- Use of variable speed pumps in the circuit so that the flow of chilled water varies as per cooling load requirements.
- Use of highly efficient Variable Refrigerant Flow (VRF) systems for mini central systems.
- Use of high-efficiency inverter type air conditioners, with high COP's and very low power consumption.
- Use of highly efficient variable speed fans for air supply, return, and extraction.
- Balancing the peak electrical loads.

As Above, it is mean that the air conditioning power load which adds on to the general power load during the day is shifted to the night. In this way, the electrical power consumed in the building remains balanced at a low average and does not have peaks which would penalize the user over an extended period as regards electricity tariffs.

Shifting the air conditioning electrical load to night time may also be beneficial if the electricity cost is lower at night. This is the case in many countries such as the USA or well-developed countries.

A highly Intelligent Computer Control system for the air conditioning system could be used to provide the required exact cooling at any time by controlling each element in the system, thus avoiding any wastage.

- **Lighting System:-**

Lights in a building consume about 20% of the overall electrical power consumed in the building.

It has become crucial therefore to find ways and means to minimize this load without compromising the lighting levels that are required for the different tasks being carried out in the building.

The latest in lighting is the LED light, which is Light Emitting Diodes. LED operates at the atomic level to give off photons of light in the presence of an electrical charge. A normal 100W incandescent lamp could be replaced by a 24W CFL lamp or 18W LED lamp. The LED lamp does not give off much heat; hence there is less load on the air conditioning system. Also, the LED light typically has a 30,000 hours lifetime compared to 10,000 for CFL and 1000 for Incandescent lamps.

Other recent advances of interior lightings are Computer Controlled Intelligent dimmer type LED lightings with occupancy sensors. These help to dim the natural daylight intensity in the room, usually set to 300 – 400 Lux, and also switch off when there is no movement in the room i.e the occupant is absent. This system is usually connected to a Building Management System (BMS). Figure 3 shows a small comparison between different types of light bulbs

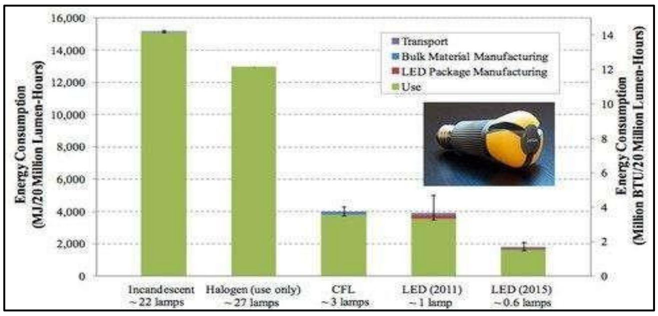


Figure 3: Comparison between different light bulbs

The figure above is an example to show a comparison between different bulb types. It can be concluded from the bar graph that LED lights are more efficient.

Energy generation from solar, wind, and biomass have advantages and disadvantages.

- **Photo Voltaic (PV) Electricity Generation**

These are flat plate photon collectors (PV) placed at roof level to convert the light from the sun into electrical energy. A number of the PV panels can be installed at the roof at the required inclination for maximum solar exposure, together with solar thermal collectors for production of hot water.

PV collectors come also as architectural panels, which can be placed on the façade in the direction of the sun as sun blinds, where they act as both sun blinds to prevent direct sunlight through the windows and electricity generators. In the Northern hemisphere, the sun blinds should be placed on the South facades and in the Southern hemisphere, the North facades. A further improvement in the inclination of the PV collectors is to have them automatically oriented to be always perpendicular to the sun rays, so that they get the maximum power from the sun.

With all the energy savings features incorporated in a building, the power produced by the PV panels could in fact meet the demand of the building or even be in excess so that it can be exported back to the mains grid. If the building is connected to the grid, then the excess power produced by all the PV panels can be exported to the grid during the day while at night, electricity is obtained from the grid.

Thus, with a careful yearly monitoring, the balance on an annual basis can become zero.

- **Proposal for Zero Net Energy Building BVP PUNE AS CASE STUDY**

In India, buildings both commercial and residential use up to 48% of the electricity generated. Many Buildings in India now a days are the Zero Energy Building and in operation efficiently since from many years. The Net Zero buildings cost 20 to 30 percent more than a normal building. The purpose of building this zero net energy building was to improve energy efficiency in building design and uses. Clean renewable energy generation and extensive energy efficiency strategies were used so as to achieve a zero-energy related cost.

Some of the energy saving strategies includes double pane windows to reduce heat gain while at the same time providing natural light, high efficiency pumps and fans, office equipment that require less energy and lastly harvesting rainwater to provide for its water needs such as gardening or cooling the condenser.

All these features helped to decrease the energy usage of the building by 45% as compared to a conventional Indian Institutional office building. Proposed Building is the BVP academic engineering Building having 2 Blocks. The Energy saving report and the scope/ energy saving given in below summery and calculations.

The energy saving opportunities are mostly through Energy Efficient LED Lightings having efficacy more than 120 Lumen per watt. Replacement of conventional celling fans with Brushless DC Fans which are available at 25 to 32 watt and are the replacement of 80Watt (1200mm) Fans. The speed control can be achieved through remote control so fan regulators are not required. External street lights are proposed to replace with 48-Watt LED lamps at required color temperature.

These types of building are therefore becoming more of a realism nowadays.

- **Conclusion:-**

The Old buildings serving to society can be looked as an NET Zero energy efficient Buildings. The Institutional, Banking, Offices and Hospitals in old buildings can be converted in net zero Building with case-to-case study. The BVP Pune campus can be converted to net zero building replacing non efficient building accessories in to star rated fans, Lamps, implementing solar PVs and accessories. Considering the present scenario the complete campus can be free with external energy supply and building can 100% Net Zero self-energy dependent institute. This building could be the first project converted to Net Zero institute in India.

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