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Net Zero Energy Building – A design example of an office building

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Abstract

According to studies, buildings use around 40% of the total energy consumption in the world. Most of this consumed energy comes from fossil fuel, one of the sources of environmental pollution. The Net Zero Energy Building (NZEB) is an alternative to this alarming pollution the main objective of this research is to integrate the renewable energy sources (RES) and the utility grid with the electrical load of NZEB.

Keywords*-Zero Energy Building; Sustainable Construction; Green Building; On Site Energy Production; Solar energy applications in buildings*

I. INTRODUCTION

A net zero-energy building (ZEB) is a residential or commercial building with greatly reduced energy needs through efficiency gains such that the balance of energy needs can be supplied with renewable technologies. In the pursuit of energy efficiency and sustainability, net-zero energy buildings (ZEB) are an exciting next step. A ZEB is a residential or commercial building that consumes a net total of zero energy from non renewable sources (such as utility electricity, natural gas, or oil). These buildings are so energy-efficient that they can rely mainly on renewable energy generated on-site. They typically use non renewable energy at times of year when renewable energy does not meet demand. But at times when the on-site generation is greater than the building's needs, excess electricity is exported to the utility grid.

Buildings can be designed in such a way that a thorough application of energy-efficient design practices and technologies combined with photovoltaic (PV) on-site electricity generation might convert them from energy consumers to energy producers. The net-zero point, where as much energy is produced as used each year, lies at the heart of one definition of the zero-energy building (ZEB) concept. Choosing PV for on-site energy production is appealing, since the roofs of virtually all commercial buildings could be considered viable sites.

II. GLOSSARY OF IMPORTANT TERMS

Net Zero Site Energy: A site ZEB produces at least as much energy as it uses in a year, when accounted for at the site.
Net Zero Source Energy: A source ZEB produces at least as much energy as it uses in year, when accounted for at the source. Source energy refers to the primary energy used to generate and deliver the energy to the site. To calculate a building's source energy, imported and exported energy is multiplied by the appropriate site-to-source conversion multipliers.
Climate Responsive Design: An approach to energy efficient building design that considers the local climate.
Day lighting: The design of a building to use natural light to reduce the amount of electric lighting energy needed.
Integrated Design: An approach to building design that incorporates the interplay between location, layout, structure, systems, and anticipated use patterns.
Heat Recovery: A process of transferring heat between a building's exhaust air and the incoming fresh air. To reduce the amount of heating or cooling that needs to be applied to the fresh air.
High Performance Buildings: Buildings designed and operated in ways that reduce energy use.
Solar Thermal System: A system that absorbs solar energy for heating purposes, such as for domestic hot water.

III. ANLYSIS AND DESIGN OF A BUILDING

3.1 About the Building

The building considered for a design is an office building dealing with the construction related projects. The building shows respect towards Mother Nature and takes a step towards preserving it for the upcoming generations. Through this project and so from the building, we want to show how we can save our planet by using renewable energy.

3.2 Planning

Taking an area of 450 sq mt for the construction of the building and providing 250 sq. mt on GF and 200 sq. mt on FF. The shape of the building is staggered squares, as it would be easy to plan the building as well as it will be aesthetically good.
Since the building is designed for a total of 100 persons, out of them 60 persons are practicing, 20 persons are other employees & maximum 20 persons are visitors. Now, area occupied by a person in working area is 2 sq mt and area occupied by a person everywhere else = 1.5 sq mt So, the total area occupied by 60 persons is 120 sq mt And, area occupied by a person present everywhere else except the working area is 1.5 sq mt Therefore their occupied area is 60 sq mt.

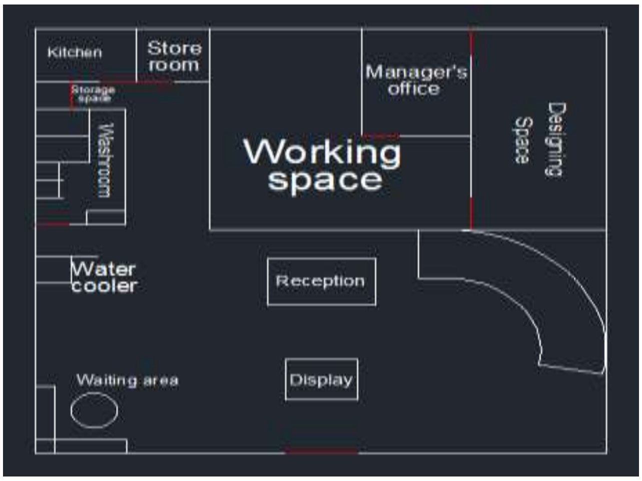

Fig. 1 Ground Floor Layout

The following calculations for the ground floor are done according to the book of anthropology and are shown in tabular form:

Table 1: Area Allocation on GF

Area	Area provided
Reception	3*1.75= 5.25 sq mt
Waiting space	4.5*0.5= 2.25 sq mt
Display area	1.5*2= 3 sq mt
Working space	42.375 sq mt
Ma n a g e r ’	4*3= 12 sq mt
Designing room	7.5*3.75= 28.125 sq mt
Washroom	4.3*2.5= 10.75 sq mt
Kitchen	2.81*2=5.62 sq mt
Store room	2*2= 4 sq mt

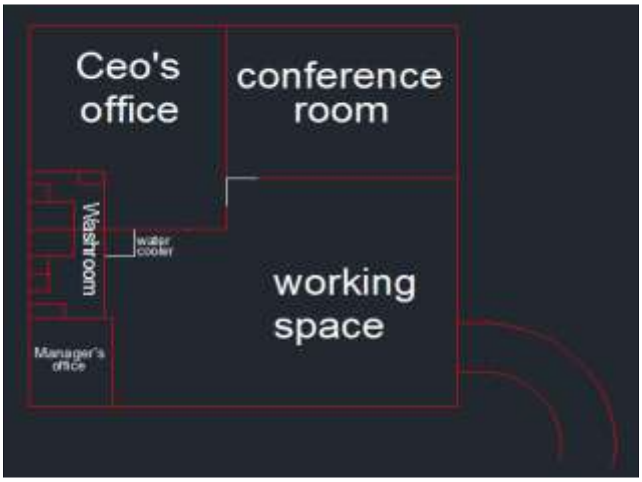

Fig. 2 First Floor Layout

And calculations for first floor are also shown in tabular form:

Table 2: Area Allocation on GF

Area	Area provided
C e o ’ s c a	7.54*6.5= 49 sq mt
Ma n a g e r ’ s	2.65*2.75= 7.2875 sq mt
Working space	47.25 sq mt
Conference room	6.65*7.65= 50.875 sq mt
Washroom	3.3*2.5= 8.25 sq mt
Water cooler	1*1= 1 sq mt

3.3 Calculations for Air Conditioning System

Ventilation is the process of changing or replacing air in any space to control temperature or remove any combination of moisture, odors, smoke, heat, dust, airborne bacteria, or carbon dioxide, and to replenish oxygen. Ventilation includes both the exchange of air with the outside as well as circulation of air within the building. It is one of the most important factors for maintaining acceptable indoor air quality in buildings. Methods for ventilating a building may be divided into mechanical/ forced and natural types. One of the mechanical techniques for ventilation is HVAC (heating, ventilation, and air conditioning).

Starting with the basic calculations, for designing an HVAC system, we first need to find out the air flow rate required by a person. According to the Indian standards And ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers), the air flow rate required by a person is 10 litres/sec. Taking the air flow rate as 12 litres/sec, air required by 100 persons will be =1200 litres/sec.

The HVAC system uses CFM (cubic feet per minute) as unit, and 1litre / sec = 2.11888 CFM. Thus for 1200 litres/sec air flow, CFM is = 2.11888*1200 = 2542.56 cfm.

For nominal cooling 400 CFM requires 1 tonne of cooling system. Taking 300 CFM, required capacity of cooling system is equals to 2542.56/300 = 8.43 ton (approx 8.5 – 9 ton) Thus, 8.5 – 9 ton of HVAC system may be provided.

As per BTU (British Thermal Unit, the amount of energy needed to cool or heat one pound of water by one degree Fahrenheit)

1 ton of cooling is equals to 12000 BTU

Area of both floor of the building = 450 square meter

Total BTU required for 450 sq mtrs = 100000

So, the required capacity of cooling system equals to 100000/12000 = 8.4 ton

Power consumption by HVAC

For our zero energy building, the HVAC system selected is packaged type. A packaged terminal air conditioner (PTAC) is a type of self-contained heating and air conditioning system commonly found in hotels and apartment buildings. One characteristic of PTAC is that condensate drain piping is not required because the condensate water extracted from the air by the evaporator coil is drawn by the condenser fan onto the condenser coil surface where it evaporates.

Now, according to ECBC 2005 table no 5.5, source IS 8148:2003 for a 9 ton HVAC system 31,500w = 31.5kw of power is consumed every hour.

Considering 8 working hrs per day, therefore, power consumed by the HVAC system is = 31.5Kw power * 8 hrs = 252 Kw/day.

3.4 Requirement of Electricity

For consideration of day lighting the most important factor to be considered is DAYLIGHT FACTOR (DF).

The daylight factor is given by the formula:

DAYLIGHT FACTOR (DF) = 100 * internal illuminance / external sky Illuminance. According to ECBC 2007 the daylight factor for an office building with drawing and typing specifications is equal to 3.75. According to is NBC 2005 for a region having hot and dry climate the average sky design illuminance is equal to 10,500 lux. Hence the internal illuminance required for our office is:

Internal illuminance = 3.75 * 10500/100 = 393.75 lux ~ 400 lux.

Basic dimensions of our building regarding day lighting helpful in the calculation of daylight factor and internal illuminance:

WWR ratio = 50% (max 60% as per NBC 2005)

Total fenestration area for ground floor = 117.87 sq mt.

Total fenestration area for first floor = 106.52 sq mt.

Areas like restrooms, store etc are avoided for fenestration.

total area considering floor ,ceilings and walls :
for ground floor = 752.96sq mt & for first floor = 626.24 sq mt.
According to the multiple reflection formula and the data obtained by International Daylight Measurement Program (IDMP) the total internal flux is given by:
$[M.E_O.F.A.R_{AV}] / [100.A_{r.} (1-R_{AV})]$ = total internal flux.
Where,
E_O → Illuminance on window plane which is obtainable from IDMP data
A →Floor area of room
A_r →Total internal surface area of room
R_{AV}→Average reflectance of room
M →Reduction factor due to glass transmittance, maintenance and reduction due to louvers and reduction due to area obstructed by window sashes.
F → Fenestration (window opening) as percentage of floor area
Placing the values as:
Eo = 7000 lux (taking avg, obtained lux is 10500 lux)
Rav = 0.6
M = 0.62 (for double glazed glass with air gap.)
F = 47.14% GF, 53.26% FF.
Internal flux (ground floor) = 0.62 X 7000 X 47.14 X 250 X 0.6 / 100 X 752.96 X (1-0.6)= 1018 lux.
Internal flux (first floor) = 0.62 * 7000 *53.26 *250 * 0.6 / 100 * 626.24 * (1-0.6) = 1380 lux.
In accordance to the NBC 2005 table 4 *(*Clauses 4.1.3, 4.1 .3.2, 4.3.2 *and 4.3.2.1)*
The total internal lux of our office is above the minimum requirement.
Hence our assumptions and designs are effective for generating day lighting For better illuminance in bad weather conditions the artificial lighting to be integrated along with day lighting are as follows:
40 nos of 25 watt CFL (for ground floor)
45 nos of 25 watt CFL (for first floor)
Hence total power consumed by artificial lighting = 85*0.25*8 Hours = 170 kw/day.

Table 3: Other Requirement

Instruments	Energy used (watt/hr)	Total No	Hr used	Total energy (kw)
Fan	200	20	5	20
Refrigerator	900	3	24	64.8
Computers	120	60	8	57.6
Coffee maker	1000	1	1	1
Vacuum cleaner	1200	2	2	4.8
Pumps	500	1	1	0.5
Water cooler	1200	5	12	72
Total				220.7

Therefore, total energy consumed = 220.7+ 170 = 390.7 kW/Day

3.5 Calculation of total energy produced by solar panels

Total area of solar panels is 293 sq mts. Here it is assumed each solar panel to be of 1000w and of 1 mt sq dimension.
Assume average daily solar radiance for the vadodara City as 5.29 $kw/m^2/day$.
Hence each panel produces power = 5.29 $kwh/m^2/day$
Taking efficiency of each panel to be 17%
Hence each panel produces 5.29*0.17 = 0.8993 $kwh/m^2/day$.
There are 293 such panels installed.
Hence, total power produce = 293*0.8993 = 263.49 kwh/day.
Hence a total of 263.49 kwh/day of power is generated by the solar panels installed on the roof of the building.
Assuming effective 10 hours total energy produced per day will be 263.49 X 10 = 2634.9 kW/day

IV. Conclusive remarks

The above example is based on the theoretical values only and it can be practical if great care and efficiency is to be maintained throughout. Here, the production of energy is much higher than the consumption so the remaining energy can be sold and during hours of none or less production i.e. rainy days etc the energy can be purchased from the outside source. This design is efficient, sustainable and nowadays concern due to the positive impact on the environment.

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