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Effective Techniques in Designing Net Zero Energy Buildings

Pravin Badarayani[1], Anshul Shrivastava[2] and Divyesh Arora[3]

[1]M. Tech Renewable Energy University of Petroleum and Energy Studies, Dehradun, India
[2]M. Tech Smart Grid University of Petroleum and Energy Studies, Dehradun, India
[3]M. Tech Renewable Energy University of Petroleum and Energy Studies, Dehradun, India
E-mail: [1]bpravin233@gmail.com, [2]anshu.shri91@gmail.com, [3]divyesh134@gmail.com

Abstract—*Net Zero Energy Building is the upcoming concept which will be mandatory in developed countries within a few years. In case of developing nations, it can be a viable solution to achieve the electricity demands of the buildings using renewable energy, esp. solar energy. This building is instrumented with automation and control systems for effectively monitoring the energy consumption of the building. The energy storage capacity of the building is also an important factor which plays a vital role in designing this type of building. The thermal comfort of the building should also be maintained. An optimal energy mix is required in order to achieve Net Zero Energy Building concept.*

The following paper reviews the different possible passive heating and cooling systems and the effective energy mix required for achieving this concept. The main focus of the paper is to review and suggest the requirements in designing a Net Zero Energy Building and how this concept can be a viable solution for developing countries like India.

Keywords: *passive cooling, zero energy, energy efficiency, sustainability, energy demand, passive heating.*

1. INTRODUCTION

The traditional buildings of the past are an excellent example of energy conscious buildings. In the past, the houses were built taking into consideration the actual needs and these were in harmony with the environment. However with the change in lifestyle, the architecture has also changed. The present day architects give more importance to aesthetics than the environmental aspect. People live in houses wherein inefficient lighting, inefficient heating and cooling systems and energy wastage can be observed. This transformation is leading to much serious environmental concerns. There is an increase in the energy consumption of the buildings day by day which is contributing significantly to global warming and greenhouse gas emissions.

According to the Fifth Assessment Report of Intergovernmental Panel on Climate Change (IPCC), buildings account for 32% of total global final energy use, 19% of energy related Greenhouse Gas Emissions (including electricity related). India ranks fourth in the current global primary energy demand. Buildings account for 35% of total final energy consumption in India today and building energy use is growing at a rate of 8% annually.

India's residential energy consumption growth is projected at 3.7% per year while the commercial consumption growth is projected at an average of 5.4% annually.

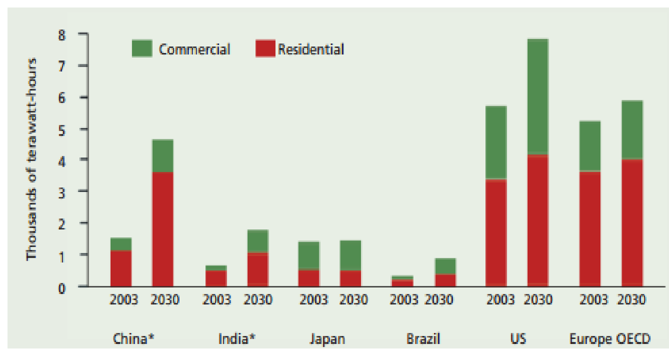

Fig. 1: Projection of Energy for buildings by regions, 2003-2030

Also space heating and cooling is the most energy consuming area with respect to buildings as shown below in Fig. 2.

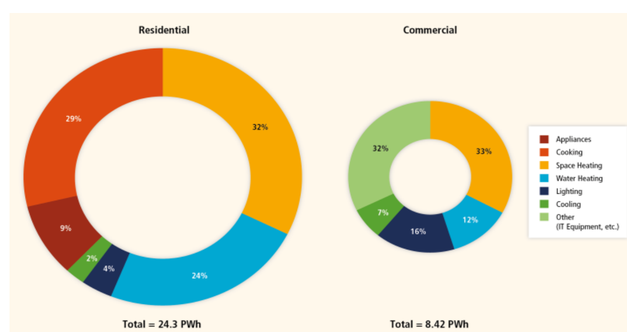

Fig. 2: Global Energy Consumption in residential and commercial buildings

The growing use of conventional air conditioning systems in commercial as well as residential buildings is having a large impact on the electricity demand. These are thus the significant areas wherein there is an opportunity to reduce energy consumption, reduce CO_2 emissions and improve energy security of the country.

The other factor which has an impact on the performance of the building is the climate of the region, especially hot and dry regions. There is difference in the day and night temperatures in such regions. Thus, the building materials absorb more heat and transfer the same to the inner compartments and make the environment uncomfortable due to increased temperatures. This promotes the use of air conditioning thus increasing the energy consumption.

Net Zero Energy Building (NetZEB) is one such concept which addresses this issue and passive techniques help in achieving this concept. Thus Net Zero Energy Building concept and passive systems go hand in hand to reduce the energy consumption in buildings.

2. WHAT IS NET ZERO ENERGY BUILDING?

Net Zero Energy Building (NetZEB) concept can be defined as a building which is neutral over a year (i.e. the energy given to the grids is equal to that supplied from the grids) when energy efficiency measures are successfully combined with renewable energy resources. Thus, it can be achieved by the following two steps: first reduce the energy demand of building and second, generate electricity or other energy carriers, to get enough credits to achieve the desired energy balance. [1]

The successful implementation of this target depends on a variety of factors. From the designer and code writers' point of view, these include: balancing the cooling and heating requirements of the building by considering both the climate and the available energy mix; mainly renewables and also providing effective shade from the sun in summer and good daylight. Along with the theoretical advice and the different myths about the value of technologies, this new concept may play a key role in achieving the Net Zero Energy performance.

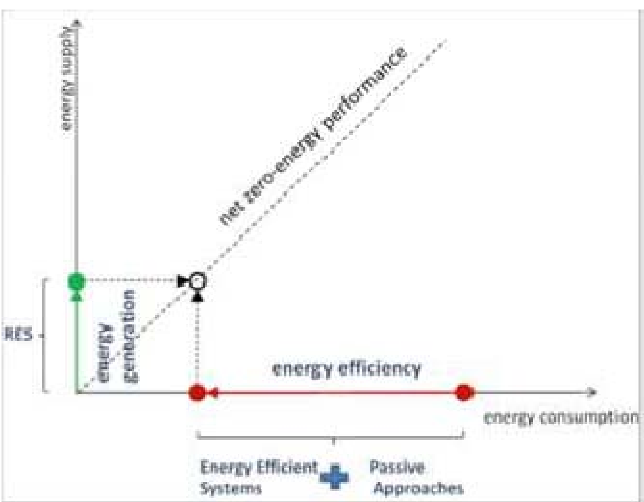

Fig. 3: Net Zero Energy Building Challenge

In a nutshell, to achieve the Net-ZEB concept, two key factors to be considered at the design stage are:

- To reduce the building energy demand by using energy efficient systems and passive strategies
- To meet the electricity demands through renewables and maintain the optimal energy mix. [14]

3. FROM PASSIVE DESIGN TO NET ZERO ENERGY BUILDING

Passive design is the design of the building in which the energy usage is minimized by maximizing the comfort and health of the humans in the building, taking into consideration the local climate and weather conditions. Local climate plays a key role in passive design of a building.

There is no exact approach to design a Net Zero Energy Building, however the best option is to start from the solar passive sustainable design of the building. Passive approaches play an important role in the design as they have a direct effect on the mechanical and electrical systems loads of the buildings, and hence devise for renewable energy generation options.

A passive solar building takes into account the building's site, climate, materials used, etc. in order to minimize the energy use. A well designed passive solar building will first lower the heating and cooling loads of the building through energy efficiency strategies and then devises a good system to achieve these loads with the help of renewables, mainly solar energy. [1]

4. ENERGY EFFICIENCY: PASSIVE BUILDING DESIGN TECHNIQUES

The solar design of the building integrates a number of measures as:

- **Use of solar gains**

For locations such as India, the solar energy can be utilized effectively if the buildings are oriented due south. The main building façade should be south oriented. If this façade is covered by windows and PV modules in equivalent proportions, then a large glazing area is achieved. This glazing area (nearly 46% of the south façade) interacts directly with the rooms which are permanently occupied and provide natural light and heat to these spaces. While designing the building, consideration of the winters is also taken by taking into account factors such as location, size and orientation (south) of the building. [2]

- **Louver shading devices**

A louvered shading device when placed in the south east façade of the building blocks the sun gain in summer and also allows wind to pass through it and cool the area. The shading is designed in such a way that it blocks the sun in summer and yet allows it to enter during the winter. [2]

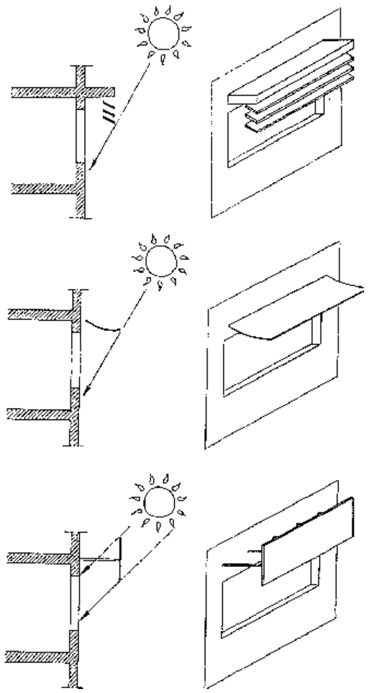

Fig. 4: The adjustment of louvers according to the season

- **Natural Lighting and Natural Ventilation**

The central skylight has to be the fundamental light distributor. Thus its location and dimension play an important role. As also the vents in the doors which communicate from north and south spaces to the corridor and the glazing areas over the entire building envelope. The adoption of these features in the building design drastically reduce the electric light consumption of the building. The natural ventilation is provided with the help of cross wind via openings in façade and roof level. [2]

- **Integrated Photovoltaic- Thermal**

In addition to the direct solar gains through the windows, IPV-T system integrated in the south façade of the building can improve the indoor climate. During the heating season, in the daytime hours the heat released in the process of converting solar energy to power can be successfully recovered and also in winters, the air can be heated and circulated in the room by the IPV-T. This air can reach temperature as high as 30^0C. [2]

- **Insulation**

Passive design must include insulation to reduce heat loss or gain throughout the building envelope. Insulation acts as a barrier to the heat flow. Thus it prevents the heat loss from the room during winter and the heat gain into the room during summer. Hence, it helps to maintain the room cool during summer and warm during winters. Insulation is used in walls, ceilings and floors. [3]

- **Green Roofing**

Green roofing can be defined as the building roof covered by grasses or plants which lie over a waterproof membrane. It is regarded as the best method of insulation for a roof. Studies show that roof is one of the main solar heat gain areas in the building. So introducing green roofing will lead to reduction in heat conduction to the interior of the building. It will also be beneficial as for producing oxygen for the environment, reducing air temperature, etc. [2]

- **Indirect Radiant Cooling**

Another method for effectively reducing the temperature of the roof is radiant cooling. The radiant cooling occurs due to the net emission of electromagnetic waves from warm to cool objects. The process continues until both the objects reach the same temperature. A metallic plate radiator with an air space above it can be used as shown in Fig. 5. Thus the air is cooled by the long wave radiation entering through the roof in the heat exchanger (i.e. radiator). This air is then used to cool the room space. [2]

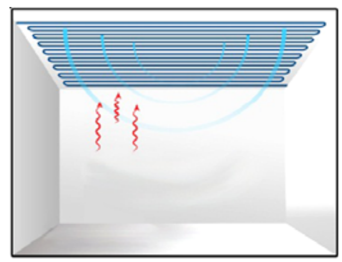

Fig. 5: Indirect Radiant Cooling

5. SOME NEW TECHNIQUES

a. Core Sunlighting System

Core sunlighting system is an alternative method for the illumination of the building. In comparison to the large glazing areas which provide the illumination only for the perimeter of the building, a core sunlighting system can effectively distribute the light over a wide area upto the core of the building.

It consists of two components: a sunlight collector which tracks the sun with the help of a motorized component and redirects this sunlight to a desired location, and light guides which guide the distributed light throughout the building. These collectors are installed above the windows on the façade where maximum sunlight is available. This system is able to offset the electrical illumination to a considerable extent. [4]

b. Passive Downdraught Evaporative Cooling System (PDEC)

Nearly 50% of the total energy consumed is utilized for space cooling purposes in buildings. In earlier times when the energy was not available in the form of electricity, building designers relied on the natural ways of ventilation of the building. The use of sustainable solutions for these purposes can lead to energy savings and also alleviate the environmental, social and economic problems.

PDEC is a cost-effective, energy efficient alternative to the conventional air-conditioning for the new buildings. It is based on evaporative cooling technique. When the decrease in dry bulb temperature is accompanied by increase in the moisture content of air, the process is commonly called as direct evaporative cooling. PDEC is an example of this process.

PDEC system consists of modified wind towers which guide the outside breeze over a row of water filled pots. As the air comes in contact with the water, it gives up its latent heat and vaporizes and descends down in the tower and finally to the interior space. It requires some auxiliary energy for its operation i.e. energy to operate pumps. Thus it is a low energy cooling technique.

Passive ventilation is a good technique which would offset the energy required by conventional mechanical cooling techniques. [5]

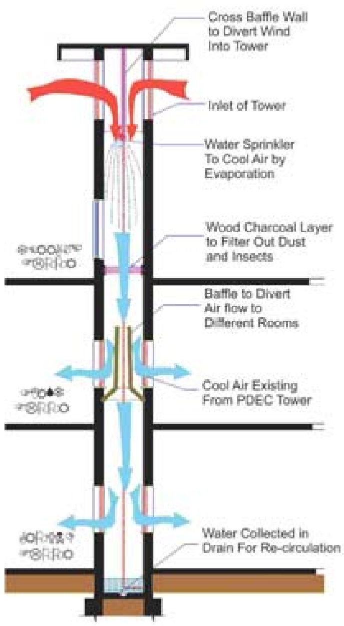

Fig. 6: PDEC System

6. ENERGY GENERATION

The integration of renewable energy systems in the building design is one of the major objectives to achieve Net Zero Energy Building. The building can be integrated with PV systems on the façade as well as rooftop PV systems which can contribute to the electricity demands of the building. The size and capacity of the PV systems will depend upon the electricity demand, space available and cost. The thermal solar collectors can also be installed for heating purposes.

The above suggested measures can be adopted which will reduce the electricity demand of the building. It is not possible that electricity is not at all required by the building. Some amount of electricity has to be taken from the grid to suffice the requirements.

A relevant indicator in the building energy generation and NetZEB is the load match index. The load match index allows to detail out the energy flows in the building depending upon the season, month, week, day, hours depending upon the level of preciseness required.

All generated power exceeding the load is considered as the grid power, hence the maximum load match index is 1 or 100%. This index is dependent on the time interval. With the increasing time interval, the excess production decreases.

$$f_{load,\,i} = \min\left[1,\ \frac{\text{on site generation}}{\text{load}}\right] \text{ x } 100\ [\%]$$

Where, i= time interval [1]

The calculation includes various aspects such as:

a. Distribution and storage losses
b. Share of heating demand and domestic hot water demand
c. Performance of the heat pump if used and the source and sink temperatures.
d. Yield of the solar thermal system depending upon the collector quality, slope end efficiency.
e. PV system efficiency considering mainly the inverter technology used and the shading.
f. Mismatch between energy demand and renewable energy generation.

7. BENEFITS OF NETZEB

a. Energy saving and Energy security
b. Cost savings, earnings and payback
c. Human Health Benefits
d. Addresses climate change issues
e. Green Job Opportunities

8. FINAL REMARKS

The global energy consumption is increasing every day and it is high time to make our systems energy efficient. In order to achieve sustainability of the environment, it is extremely important to consider the above techniques and pave a path for Net ZEB. The solutions suggested are cost effective and also address the climate change issues.

The techniques suggested above, i.e mainly passive heating and cooling techniques, natural ventilation along with the renewable energy systems will lead to an exemplary energy performance of the building. Thus the building will be Net ZEB.

Thus, it is important to consider the options while designing the building and achieve zero energy performance without significant efforts.

REFERENCES

[1] Laura Aelenei, Helder Goncalves, From Solar Building Design to Net Zero Energy Buildings, International Conference on solar heating and cooling for buildings and industry, 2013.
[2] Hanan Taleb, Using passive cooling strategies to improve thermal performance and reduce energy consumption of residential buildings, Frontiers of Architectural Research.
[3] Fabian Ochs, Georgios Dermentzis, Wolfgang Feist, Minimization of the residual energy demand of multi-storey passive houses- energetic and economic analysis of solar thermal and PV in combination with heat pump, International Conference on Solar Heating and Cooling for buildings and Industry, 2013.
[4] Sepideh Khosravi, Michele Mossman, Lorne Whitehead, Core Sunlighting System, 2013 ISES Solar World Congress.
[5] Mansi Jayswal, To examine the energy conservation potential of passive and hybrid downdraught evaporative cooling, SHC 2012.
[6] Ram Joshi, Maharshi Pathak, Decentralized Grid-Connected Power Generation Potential in India: From perspective of Energy Efficient Buildings, 2013 ISES Solar World Congress.
[7] Ursula Eicker, Romain Nouvel, Eric Duminil, Volker Coors, Assessing passive and active solar energy resources in cities, 2013 ISES Solar World Congress.
[8] Lavinia Tagliabue, Michela Buzzetti, Giorgia Marenzi, Energy Performance of Greenhouse for Energy Saving in buildings, SHC 2012.
[9] Milan Ostry, Pavel Charvat, Materials for Advanced Heat Storage in Buildings, 11^{th} Conference on Modern Building Materials, Structures and Techniques, 2013.
[10] Hicham Mastouri, B. Benhamou, H. Hamdi, Pebbles Bed Thermal Storage for heating and cooling of buildings, The Mediterranean Green Energy Forum, 2013.
[11] Macedon Moldovan, Ion Visa, Mircea Neagoe, Bogdan Burduhos, Solar heating and cooling energy mixes to transform low energy buildings in nearly zero energy buildings, SHC 2013.
[12] Julia Coma, Gabriel Perez, Cristian Sole, Albert Castell, Luisa Cabeza, New Green Facades as passive systems for energy savings in buildings, 2013 ISES Solar World Congress.
[13] F.Garde, A.Lenoir, D.Aelenei, D.Waldren, H.N.Rostvik, L.Aelenei, M.Tardif, S.Cory, M.Donn, Design of Net Zero Energy Buildings, The 6^{th} International Conference on Applied Energy, 2014.
[14] Francesco Causone, Salvatore Carlucci, Lorenzo Pagliano, Marco Pietrobon, A Zero Energy Concept Building for Mediterranean Climate, 6^{th} SEB, 2014.