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Net Zero Energy Buildings Initiatives - A Review

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Abstract

Buildings are one of the major energy consumers globally. The climate change and global warming are symptoms of increasing Green House Gases emissions because of growing energy consumption. Majority of electricity produced from fossil fuels, coal, which are the source of GHG emission. Here renewable energy and efficient measure of energy consumption reduction can give the opportunity to do save our earth by reducing GHG emission level. The integrated solution of energy demand and environmental impact for building is the net zero energy buildings. This paper reviews the NZEBs initiative around the world in a different perspective such as passive design of building, active approach incudes energy efficient measures and electricity production by renewable energy particularly for buildings. Further this paper highlights, optimizing and modelling using different tools and software used for implementing NZEBs. This paper suggests the possible ways of implementation of NZEBs and its benefits in residential, commercial and educational buildings for various climate zones and recent case studies results.

1. INTRODUCTION

As global warming and climate change threatening the future of the earth, the remedial actions has to be taken with immediate effect. On the other hand energy demand increasing, fossil fuel and coal also deployed constantly may lead to energy crisis. Electrical energy is one of the important source for industries, factor of GDP growth, and basic need for comfortable and happy living in the modern technology era. To fulfill the need of energy demand and rectify the environmental impacts such as climate change and global warming due to GHG emissions, the individual participation is the need of the hour by everyone including industries, commercial buildings, institutions, residence in their houses, etc. The involvement can be using renewable energy for producing electricity and other needs which fulfilled by fossil fuel generated electricity. And also energy should be utilized in an efficient manner, energy should not be wasted rather has to be conserved. To solve the above described issue with the balanced manner the opportunity evolved is called Net Zero Energy Buildings (NZEBs) will be defined in the following section and different approaches, possibilities of using renewable energy with storage systems, modelling and optimization using software, conclusion are discussed further as different sections.

2. NET ZERO ENERGY BUILDINGS-DEFINITION

In general net zero energy buildings can be defined as the building produced the energy as much as consumed over a period of year using renewable energy.

The measures has to be taken before electricity production on site, to reduce energy consumption using passive design approaches and effective measures to save energy using efficient energy appliances.

The net zero energy can be expressed mathematically (B. Singh, S. K. Sharma, and Syal),

$$\sum E_d - \left(\sum E_{ee} + \sum E_{re}\right) = 0$$

Where,

$\sum E_d$ = Energy demand in kWh for one year

$\sum E_{ee}$ = Reduced energy demand by taking energy efficiency measures in kWh for one year

$\sum E_{re}$ = Generated energy by renewable sources in kWh for one year

Apart from this net zero energy building can be defined based on source, site, emission and cost (Crawley, Pless, and Torcellini) (D'Agostino and Mazzarella).

In India, the net zero energy building (shunya) rating given based on Energy Performance Index (EPI) for buildings according to Energy Conservation Building Code by BEE India

(If EPI is between 0-10, shunya rating will be given the buildings.)

EPI can be determined by,

$$EPI = \frac{Annual\ Energy\ Consumption\ in\ kWh}{Total\ built-up\ area (excluding\ unconditioned\ basements) in\ square\ meter}$$

3. VARIOUS APPROACHES TO NZEBs

Some of the initiatives in the general approach to achieve net zero energy buildings passive design it mainly concentrates on building design perspective to utilize the available natural sources such as sunlight, heat, flow of wind, cooling of night and seasons. (B. Singh, S. K. Sharma, and Syal) The windows, exterior wall design, roof top, glasses to get sunlight and natural daylight, materials, etc is focused for extracting more natural energy. For new buildings it can be considered while designing and for existing buildings possible and adequate measures can be taken to achieve net zero target. Stritih et al. used the phase change materials to absorb and release the heat as per requirement and analyzed the effect of composite wall by different phase changing materials. (Stritih et al.)

The heating, ventilating, air-conditioning (HVAC) process consuming more energy primarily, so the efficient measures can be taken for using energy efficient appliances for this area. The integration of HVAC and PV, cost analysis carried in United States for different climate zone along with heat recovery ventilator and air recovery ventilator comparison, and also air source heat pump and ground source heat pump comparison (Wu and Skye, "Net-zero nation: HVAC and PV systems for residential net-zero energy buildings across the United States"). The integrated and separated study of Earth-air heat exchanger, Underground tank, solar thermal collector to save energy and reduce CO_2 emissions in Algeria. (Benzaama et al.) .The energy can be conserved by using energy efficient measures by replacing LEDs in lighting systems, replacing efficient appliances in the place of old machines, fans, transformer, Air-conditioner and Refrigerator, can give desired improvement in the path of net zero energy buildings. (Rupal, Syal, and S. Sharma) (Syal and A. Singh) The Bureau of Energy Efficiency (BEE) has established star ratings for appliances, one to five star based upon energy saving capacity of the appliances.

4. POSSIBILITIES - RENEWABLE ENERGY AND STORAGE SYSTEM

Various integrated studies held in renewable energy and storage system to achieve net zero energy buildings. Solar is the feasible solution while thinking for renewable energy sources. For sea shore areas wind energy can be utilized to generate electricity, and other renewable energy sources such as bio energy, hydro, heat pumps also can be used separately or combined manner based upon availability, need, efficiency. (Ahmed et al.) The hybrid system can be a solution for seasonal availability of renewable sources. Solar- hydro-fuel cell system and hydrogen storage helps in uncertainty of one renewable source and will give the possible reduction cost and carbon dioxide emissions. (Mehrjerdi et al.) solar tracking option to utilize maximum light, will give the better result than the fixed solar system. (D et al.) In residential buildings, the renewable source used along with passive design and efficient measures such as HVAC systems, phase change material, building envelope design, will give better result. (Wu and Skye, "Residential net-zero energy buildings: Review and perspective") (Abdou et al.) (Reda and Fatima)

5. ENERGY MODELLING AND OPTIMIZATION SOFTWARE

Energy modelling is the method to get the virtual solution before implementation using different software and tools. The data related to building area, structure, energy consumption, possible strategies, involving renewable energy can be simulated, better feasible options and suggestion can be derived. Using optimization techniques and software models can be generated. The various simulation software and optimization techniques used are discussed in this section. The Building Information Model (BIM) is a software tool which can be used to design a building as well as create a template for energy calculation for Net Zero Energy Buildings (Kaewunruen, Rungskunroch, and Welsh) (Sayary and Omar). The BEopt tool which is running by energy plus simulation engine, used for creating cost based building design as optimised model for single family homes in california (Wei et al.). The TRNSYS simulation used to get model with energy demand for space cooling and heating and gives energy outcomes, TRNBuild used to configure building envelope for residential building. (Abdul-Zahra and Jubori, "Potential evaluation and analysis of near-to-net zero energy building in hot and dry climate") Design Builder software as effective retrofitting design tool, non-dominated sorting genetic algorithm(NSGA-II) as optimizing tool to reduce load for cooling and heating, JEPlus tool for calculating cost for different weather conditions together used to design a optimized model for future weather. (Aram, Taherkhani, and Šimelyt) The hybrid optimization model for electric renewables (HOMER) is a software tool used to create a model NZEB with grid connected solar based on initial cost in an educational building in Egypt (Abdul-Zahra and Jubori, "Potential evaluation and analysis of near-to-net zero energy building in hot and dry climate"). eQUEST is the energy modelling open source software which can be used to simulate whole building design by giving data inputs, and some of the other tools are, green building studio(GBS), Energy pro, etc. (Punia, S. K. Sharma, and Syal) Many energy modelling software and optimization techniques used for different buildings such as institutions, industries, residential buildings, businesses etc.

6. CONCLUSION

By considering the current crisis in the world the NZEB initiated in different aspects which discussed in this paper. The renewable energy and eco-friendly technologies has to be utilized in an efficient manner to save the earth for future generations. The simulation and optimization techniques in the field of energy, will be a great help to initiate by suggestive models, templates for energy, for individual participation in the race of energy and environment saving as NZEB to everyone. The merits and demerits may be in each initiatives, the research will continue to solve the issues by considering various factors such as cost, comfort, climate, complexity and consistency. The embodied carbon for the building material has to be reduced f by different models as further work.

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