# Recent Development and Advances on Green Commercial Buildings: A Review

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**Abstract:** The world is advancing toward the utilization of various renewable sources of energy in different fields. The buildings are also need to be independent from energy generated through non-renewable sources. The step toward this idea was termed as Net Zero Energy Buildings or also called as Green Buildings. The various researches has undergone in this field for making buildings green. The commercial buildings like malls, schools, college, etc. are also need to make green building. The paper presents the researches carried out in the field of commercial green buildings and suggests the methods adopted to make the commercial buildings green or net zero energy building.

**Keywords:** Green buildings; Commercial Buildings; Net-zero energy; Buildings

## 1    Introduction

The shelter is the basic need of any living being. The building is basically a structure with roof. The building construction depends on various factors like weather condition, availability of building material, ground condition etc. The construction of buildings was started nearly around 18000 B.C. The buildings were previously made by humans for preventing himself from outside weather, animals, for comfortable living etc. But with the time, the buildings were not only made for shelter purpose but also for some other reasons like commercial purpose. The various types of buildings are shown in Fig. 1. Starting from the need of shelter the buildings now are made for various purposes like for education, commercial purpose, military base etc. With rapid urbanization and growth in population the need of commercial buildings also increases. So it becomes necessary to shift the focus on making such buildings green and sustainable.

Various researches has undergone in the field of residential, heritage and ancient buildings. Various devices have been developed till now that operates on solar energy that is the one of the renewable sources of energy like solar panels, solar water heater, solar pump etc. These devices make the building green and sustainable by fulfilling the energy demand which used to fulfill by energy generated through conventional sources. The buildings are made a Zero energy building by using both energy efficient measure and adopting renewable energy technologies [1].

Commercial buildings also need to be made green and sustainable as these consume nearly 7% of world energy consumption. About 60% of the energy is used for heating and cooling [2, 3]. Commercial buildings occupies nearly 20,000 $Km^2$ area of total land area in 2010 and this is increasing with a rapid rate due to growing population rate [4].

The paper gives the brief description of the researches in which the commercial buildings has been tried to make green and sustainable. The paper also presents the method that can be adopted to make the commercial buildings green and sustainable.
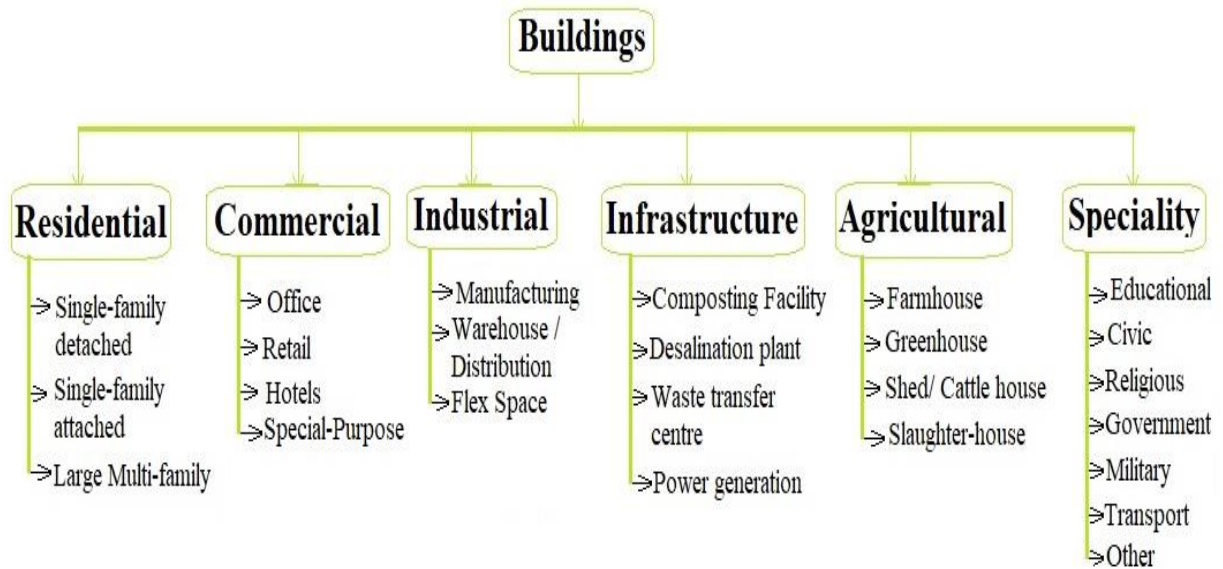


**Figure 1** Types of buildings

## 2 Researches toward Green commercial buildings

Linzi Zheng, Joseph Lai (2018) [5] carried out the case study on commercial building of Hong Kong for studying the air-conditioning system adopted during their retrofication. The economic evaluation of the AC systems was also carried out and the impact of the retrofication material on the environment was shown by the term 'carbon reduction efficiency'. The effect on performance of the AC system with its degradation with time was also studied. The methodology adopted by them can be used for determining the environmental and economic efficiency of the various energy saving measures adopted in the buildings.

Pascal Brinks, Oliver Kornadt, René Oly (2016) [6] carried out the research to develop the optimum-cost net zero energy building standards for industrial buildings in Germany. The two factors having the strong influence on the cost-effective insulation level were internal gains and minimum inside temperature. They classified the industrial buildings as low and normal temperature buildings. The Potsdam was used while defining the standards for nearly Net Zero industrial buildings. The heat energy in industrial buildings can be saved by increasing the air tightness, reducing thermal bridges and optimizing floor slab insulation. Their study is limited to German standards and for light steel industries.

R. Lapisa, E. Bozonnet, P. Salagnac, M.O. Abadie (2018) [7] optimized the design of low-rise commercial buildings according to the climatic conditions. The effectiveness of passive cooling strategy in thermal comfort and energy performance of the commercial building is also studied. NSGA-II

algorithm is used for optimization of building design. They suggested smaller skylight area, envelope with proper insulation and roof with high solar absorbing roof for northern region. While for southern regions, they suggested the buildings with reflecting cool roof, larger skylight area for maximizing natural cooling and lighting and non-insulated ground slab. Their methodology and results can be adapted for designing a new commercial building or improving the energy efficiency of the existing commercial building.

Joshua Kneifel (2010) [8] estimated the effectiveness of various energy saving measures in commercial buildings in terms of reduction in carbon emission, savings in energy and cost. For the study, the 12 buildings of 16 cities in U.S. were taken. It was observed that due to faulty envelope design, the energy demand of buildings increases resulting in installation of heavier and costlier HVAC system. He found that by adopting energy saving measures the energy demand get reduced by about 30% without any modification in the design of existing commercial buildings. It was also noticed that the carbon emission by building can be reduced by about 32% with these energy saving measures. The result of reduction in $CO_2$ emission in different type of building over 10 year of study is shown by Fig. 2.
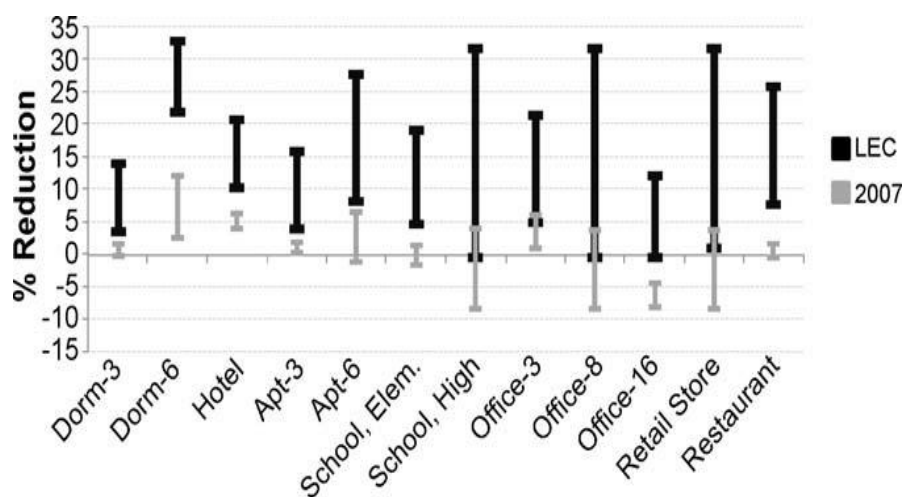


**Figure 2** Reduction in $CO_2$ emission in different types of buildings

Omid Ardakanian, Arka Bhattacharya, David Culler (2018) [9] carried out the research to estimate the occupant inside the building so as to reduce the energy wastage in empty or partially filled spaces. As HVAC system does not consider the occupancy and lot of energy get wasted in conditioning of empty and semi-filled spaces. In order to detect the occupancy of the buildings selected in 7 zones of U.S., non-intrusive time series analysis was proposed. Their designed schedule for each zone shows the energy saving of 38% in the selected commercial buildings.

Maite Gil-Báez, Ángela Barrios-Padura, Marta Molina-Huelva, R. Chacartegui (2017) [10] carried out the comparative assessment of mechanical ventilation system with the natural ventilation system provided in the school buildings of southern Spain. For this purpose, three school buildings were selected. The two buildings were ventilated by mechanical ventilation system while the one building is

ventilated by natural ventilation system. The inside air temperature, humidity and $CO_2$ mitigation is analyzed with the occupancy inside the school building in both the cases. The result shows that the natural ventilation system saves energy by about 18 to 33% along with maintaining the classroom thermal comfort level.

Amit Garg, Jyoti Maheshwari, P.R. Shukla, Rajan Rawal (2017) [11] carried out the research by surveying 197 small commercial establishments in Gujrat, one of the developing state of India. The connected electrical equipment and their energy usage were studied during winter and summer season. It was observed that appliances running by conventional source of energy are replaced by more energy efficient devices like LED bulbs, star rated AC etc. The energy consumption by these establishment is observed by dividing them into two categories that is low and high income. Also eight shopping malls and ten educational institutes were surveyed and observed. Drastic growth was observed towards the utilization of energy efficient devices in small as well as in large establishments, helping in reducing energy demand.

Khoa N. Le, Cuong N. N. Tran and Vivian W. Y. Tam (2018) [12] developed the model to determine the quantity of energy consumed and greenhouse gas emitted by the commercial buildings in Australia. To show the relationship between the energy consumption and greenhouse gas (GHG) emission, the GaBi 8.1 platform was used. The paper suggested considering the inverse relation between the R-value of building envelope with GHG emission and energy consumption. The paper also reported that the building having higher R-value will utilize lesser energy. They suggested to utilize their model as a reference for the new commercial construction in Australia.

Maria Kapsalaki and Vitor Leal (2011) [13] presented the progress in the net zero energy buildings in Europe. The paper highlights the development in defining the NZEB, changes carried out in design strategies and the utilization of technologies in making buildings energy efficient. The technical features used in the net zero commercial buildings in European countries are shown in table 1. The Fig. 3 shows the concept of net zero energy building.
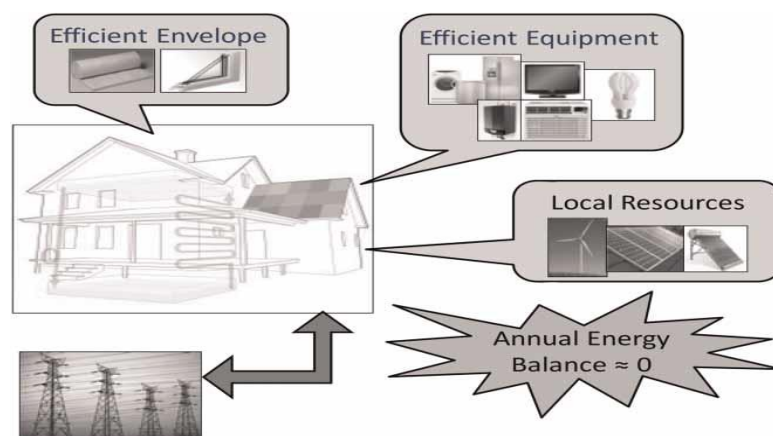


**Figure 3** The concept of net zero energy building

**Table 1.** Technical features of the some net zero commercial buildings in European countries [12]

| Commercial case studies | Main Technical Features | | | | | |
|---|---|---|---|---|---|---|
| | Heat Gain/ Loss through Envelope | Heat Loss through Ventilation | Heating/ Cooling and Hot Water | Lighting And Appliances | Electricity Production | Intelligent Energy Management Systems |
| Aldo Leopold Legacy Center | High performance windows Daylight harvest High levels of insulation High performance windows Increased daylight penetration | Mechanical ventilation with heat recovery Natural ventilation | Ground-source heat pumps Wood burning stoves Earth tubes to preheat or pre-cool | Energy efficient lighting and appliances | 39.6kW PV array | --- |
| Adam Joseph Lewis Center | Wall U-value 0.4 $W/m^2K$ Triple pane, argon filled, low-e glazing South-facing curtain wall Thermal mass through concrete floors Exposed masonry walls Window shades | Mechanical ventilation with HR | Closed loop geothermal wells | Energy efficient lighting and appliances | Roof integrated 60kW + 100kW PV system | Monitoring of Building systems Occupancy sensors Photoelectric daylight sensors Carbon dioxide sensors Automated Operable windows |
| Science House in Minnesota | Wall U-value 0.14 $W/m^2K$ Roof U-value $0.2W/m^2K$ High performance windows 1.21m overhangs (south) Maximum daylight | Mechanical ventilation with heat recovery Multi-modal natural ventilation | Premium efficiency ground source heat pumps Heat pump Assisted DHW Electric resistance back-up | Energy efficient lighting and appliances | 8.8kW PV system | Daylight dimming controls Occupancy sensor controls Continuous computer monitoring Control of mechanical systems |
| Hawaii Gateway Energy Center | Walls U-value $0.9W/m^2K$ Roof U-value $0.23W/m^2K$ | Passive thermal chimneys | Deep seawater pumping for passive cooling | Energy efficient lighting and appliances | 20kW PV system | Occupancy and photosensors |
| IDeAs $Z^2$ Design Facility | Highly rated insulation High efficiency windows Skylights Daylight harvesting | -- | Highly efficient HVAC system Radiant heating and cooling Ground-source heat | Energy efficient lighting and appliances | 30kW roof membrane integrated PV system | Occupancy sensors Automatic controls Monitoring equipment |

Jing Liang, Yueming Qiua, Ming Hu (2019) [14, 15] carried out the research to determine the energy performance gaps in green commercial buildings in order to make buildings energy efficient and sustainable for longer periods. From the analysis of 117 survey data, the various factors responsible for the energy performance gap were grouped under three categories viz, the organizational, behavioral and engineering factors. Fig. 4 shows the various factors effecting energy performance gap. They suggested

some solutions to encounter this problem like giving incentives to facility managers, commissioning, energy performance contracting and occupants behavioral change.
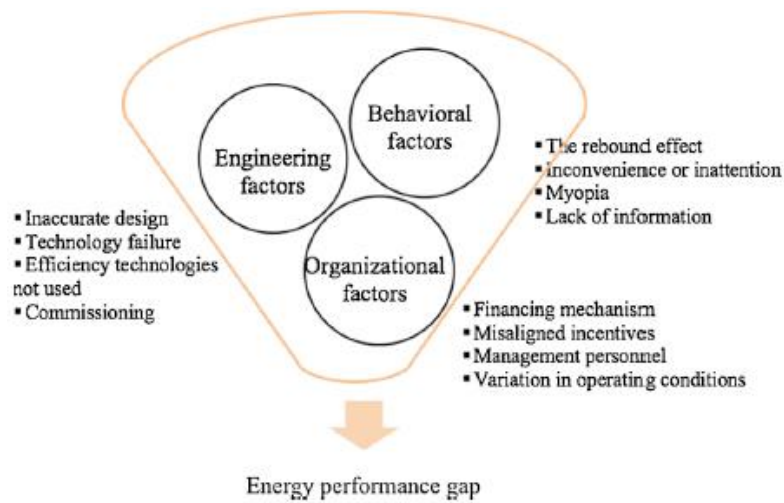


**Figure 4** The factors responsible for energy performance gaps

# 3    Conclusion

Various steps have been taken to reduce the impact of rapid urbanization on the environment. Zero energy buildings or Green buildings are also a step for reducing the negative impact of building during its entire life-span. The researchers are trying to find the alternative of the construction materials proving the better or same strength and having lesser or negative impact on the environment.

Various energy efficient measures like LED bulbs, star rated appliances etc. have been adopted in most of the residential buildings and also the people are progressing towards the utilization of renewable energy technologies like solar panels, solar water heaters etc.

The commercial sector also needs to be become energy efficient. The buildings made for commercial purposes needs to be made green and sustainable. Various researches have undergone around the globe to make the commercial buildings green. Some of the methods to make the commercial building energy efficient are as follows:

- Using energy efficient measures as it reduces usage of energy by 20-30% without any modification in existing building.
- The concrete structures emit low greenhouse gases in comparison to brick and concrete combination.
- Structures combining timber with other material have lesser impacts on environment than those using metal, brick or concrete.
- Higher R-value structure reduces the energy demand of the building.
- Monitoring and operating the devices as per the occupancy inside the building.

- Using renewable energy technologies like solar PV panels, solar water heaters etc. for lightning, heating and cooling purposes.
- Using natural ventilation system instead of energy consuming heavy HVAC system.

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