International Journal of Advance Research and Innovation
Vol. 7(1), Jan-Mar 2019, pp. 49-61
Doi: 10.51976/ijari.711908
www.gla.ac.in/journals/ijari

Article Info

Received: 10 Dec 2019 | Revised Submission: 20 Feb 2019 | Accepted: 28 Feb 2019 | Available Online: 25 Mar 2019

Toward Zero Energy: Active and Passive Design Strategies to Achieve Net Zero Energy Building

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ABSTRACT

Buildingsare found to be an essential part of the needed transition towards energy sustainability. In the past few years, there have been growing interests in net zero energy buildings (NZEB) adapted worldwide. The minimized energy demand and airtightness of a passive house and the low energy buildings have provided in the past a step forward to the energy efficiency goal and the net-zero energy building. Implementation of proven energy efficiency technologies offers the world the fastest, most economical, and most environmentally benign way to alleviate threats. This paper will discuss Net Zero Energy Building definition and design strategies targeting for energy efficiency and environmental sustainability. The literature shows that to improve the integrated performance of the building and to achieve the goal of energy efficient and NZEB, appropriate active and passive design strategies should utilize. Also, energy demand should reduce to a minimum, through energy efficient building designs, leaving only a fraction of the energyrequired to be covered by renewable energy generation.

Keywords: *Net Zero Energy Buildings; Energy efficiency; Design Strategies; Renewable Energy.*

1.0 Introduction

Building are found to be an essential part of the needed transition towards energy sustainability [1]. Also, buildings are one of the leadingconsumers of energyandconsiderableproducers of greenhouse gases (GHG) [2]. Increased rate of infrastructure development has led to higher consumption of energy.

The consumption of energy by the building sector is continuously increasing because construction rate of buildings is faster than diminishing rate Moreover, buildings are responsible for more than forty percent of global energy use and production of a third of global greenhouse gas emissions, in developed as well as developing nations [3].

The impact of global warming, increase of energy demand and use of electrical energy are obliging international communities to propose future targets to deal with this threat, mainly through public awareness, new regulations and other useful measures [4].In construction sector energy is consumed during Manufacturing of Building component and Material (embodied energy), Transport of these material from plant to site (grey energy), construction of the building (induced energy), operation of the building (operational energy) and demolition of the building (recycling of building parts) [5]

To overcome these problems, Governments must take the lead by prioritizing the building sector in their national climate change strategies and putting in place some building blocks [2]. Reducing emissions from buildings will bring multiple benefits to both, the economy regarding growth in GDP and to the society by providing better houses and access to clean energy and water [6]. NZEB is a radical approach to the mitigation of the energy demand in the buildings sector [7]. This concept proposed in the literature as an evolution of very energy-efficient buildings, and it requires building with zero energy balance on an annual basis [2].

The United States of America and Canada implemented ZEB strategies and achieved the NZEB goal through the construction of several Commercial and residential Zero Net Energy Buildings. Furthermore, the European Energy Performance of

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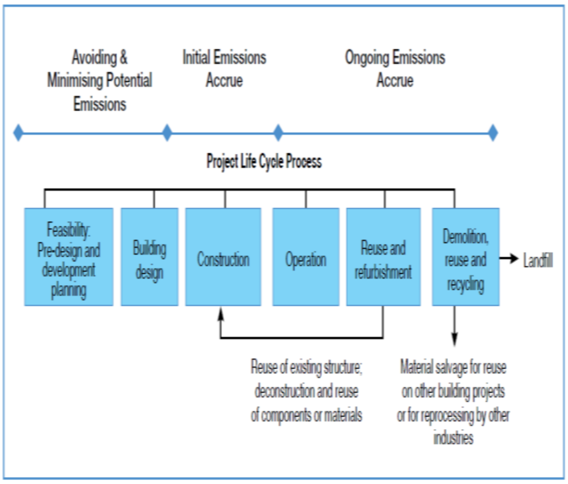
Buildings Directive 2010 (EPBD) requires all new buildings to be nearly Zero Energy Buildings (NZEB) by 31st December 2020 and all buildings acquired by public bodies by 31st December 2018 [8]. The European Union aims at drastic reductions in domestic greenhouse gas emissions by 80% in 2050 compared to the level in 1990[9].

This study aims to review various policies and studies that have been conducted to minimize current global climate problems through the implementation of NZEB. In addition to it, this paper discusses ZEB definitions, identifies ZEB strategies applied in different regions and gives an overview of the significant challenges of ZEB design.

Fig 1: Life Cycle Phases of Buildings



{Source :Garaham,P.(2013)[6]}

1.1 Net zero energy building

A ZEB does not have a clear and distinctive definition but its defined in several ways depending on the metric, boundary and the project goals [8.]A good net zero energy building definition should first encourage energy efficiency, and then use renewable energy sources available on site[7]. Summary of ZEBs definition has shown in table (1) .The U.S. Department of Energy (DOE) by National Institute of Building Sciences (Institute) established definitions for zero energy buildings which are as [10]-

1.2 Zero energy building (ZEB)

The Net Zero Energy building is an energy-efficient building which, the annual delivered energy is less or equal to the on-site exported renewable energy. On-site renewable energyincludes any renewable energy generated within the site boundary whereas the exportedenergy isOn-site renewable energy supplied via the site boundary and used outside the site boundary.

1.3 Zero energy campus

It is an energy-efficient campus where, on a source energy basis, the actual annual delivered energy is less or equal to the on-site renewable exported energy. Source Energyis thealgebraicsumofsite energy and energy consumed during extraction, processing, and transport of primary fuels.

1.4 Zero energy portfolio

An energy-efficient portfolio where, the actual annual delivered energy, on a source energy basis is less or equal to the on-site exported renewable energy.

Table 1: ZEB Definitions

Definition	**Pluses**	**Minuses**	**Other Issues**
Site ZEB	• Easy to implement • Verifiable throughon-site measurements • Conservative approach to achieving ZEB • Easy for building a community to understand and communicate. • Patronize energy efficient	• Need more PV export to offset natural gas. • Does not consider all utility cost (can have a low load factor) • Not able to equate fuel types • Does not account	

	building designs.	for non-energy differences between fuel type (supply availability, pollution)	
Source ZEB	• Able to equate energy of fuel types used at the site. • A better model for impact on the national energy system. • Easier Zero energy building to reach	• does not account for non-energy differences between fuel types • source calculation too broad • source energy use accounting and fuel switching can have a great impact than efficiency technologies. • It does not consider all energy costs(can have a low load factor).	• Require to develop the site to source conversion factors which require a significant amount of information to define.
Cost ZEB	• Allows for demand positively control. • Verifiable from utility bills. • It is easy to implement.	• It may not reflect impact to the national grid for demand since the generation of excess Photovoltaic could be more valuable for reducing demand with on-site storage than exporting to the grid. • Highly volatile energy rates make for difficult tracking over time. • Requires net metering agreements such that exported electricity can offset energy and non-energy charges.	• Net metering is not well established often with capacity limits and at buyback rates lower than retail rates. • Offsetting monthly service, and infrastructure charges, required going beyond ZEB.
Emission ZEB	• A better model for green power. • Account for non-energy differences between fuel type (pollution, greenhouse		• Need appropriate emission factor.

	gases). • Easier ZEB to reach.		

[Source: Torcellini, Pless and Deru, 2006]

1.5 Zero energy community

An energy-efficient community where, on a source energy basis, the actual annual delivered energy is less or equal to the on-site exported renewable energy.Kurnitski .et al. stated that Net zero energy requirement has the exact performance level of 0 kWh/m² primary energy. An NZEB is a grid-connected building with high energy performance which aims towards balancing energy use such that the primary energy feed-in to the grid equals the primary energy delivered to NZEB from energy networks.

Therefore, an NZEB produces energy when conditions are suitable, and uses delivered energy during rest of the time [11].

As per European ZEB definition, a nZEB should take into account the climate, building geometry, and usage conditions as follows :9

1.6 Geometry

Building geometry does not seem to be a striking argument for differences in energy requirements (e.g., in kWh/m2 per year) for the new buildings the requirements should be independent of geometry. On the other hand, for the existing building stock, geometry aspects should be further analyzed in order to avoid additional unfair burdening of the building owners.

1.7 Usage

All residential buildings should meet the same requirements as they typically have the same usage patterns. Non-residential buildings with a similar usage pattern as residential buildings may still have the same requirements as residential buildings.

The other non-residential buildings should have classified in a few categories as possible (following the main criteria of indoor temperature, internal heat gains, required ventilation, and so forth) and should have particular energy performance requirements.

2.0 Net zero energy building- strategies

There are various ways to achieve Net Zero Energy balance in a building by incurring rational spending. Prevailing industry perceives the concept of zero energy to cost prohibitive and suitable only for large budgets; however, there is a mounting record that zero energy building has achieved within typical construction budgets [12]. Griffith, B. et al. [13] of NREL figured out that early prioritization of energy performance goal and integrated design could be used to achieve significant energy savings. In the same context, Griffith et al. estimated the portion of the commercial sector that could achieve zero energy with varying levels of energy savings relative to the minimum requirements of ASHRAE 90.1.2004 [13,14]. The first cost-effective strategy for net-zero energy is to maximize the reduction in energy demand and simultaneously produce renewable energy on-site to meet the future requirement[15]. This approach simplifies the design process and optimizes the potential of renewable energy technologies on any building initiative.

3.0 Passive Strategies

3.1 Reduce energy demand

Passive strategies include all the strategies that do not require energy for operation. Effectual employment of these strategies can provide buildings with low energy consumption. Typically, low-energy buildings will comprise a high level of insulation, energy efficient windows, high level of airtightness and natural/mechanical ventilation with efficient heat recovery to reduce heating/cooling needs [9.]Building energy demand can be reduced through Passive strategy by better architectural design and energy saving techniques.

3.2 Building design and architecture

Designing sustainable NZEB necessitates a delicate balance between energy generation/ consumption and social/environmental impact. Building architecture includes the exterior façade as well as structural elements. In addition to it, building orientation, massing, and layout can be designed to reduce building thermal loads without increasing construction costs [12]. Building layout planning, site planning, natural lighting, and ventilation are the most critical parameters that can have a high impact on the energy consumption of the building.

3.3 Building orientation

A building must be oriented in a way to take maximum advantage of natural light and prevailing winds while simultaneously reducing the need for artificial systems.

For instance, a rectangular floor plan works best for passive solar design, with the long (east-west) axis of the house oriented within 10 degrees of true south [16]. Similarly, a two-story compact house is better than a single-story house since its exterior building envelope is smaller per unit size of floor space [1].

Choi et al. [17] concluded that electricity consumption of plate-type buildings is lower than tower-type buildings. However, gas consumption of plate type buildings is much higher. Furthermore, from the perspective of a building's living type, mixed-use buildings generate more CO_2 than the general residential buildings.

At the same time, buildings with a simpler geometry tend to utilize lesser energy than the buildings with complicated geometry. Hence, for new buildings, differences in geometry do not seem to be a striking argument for differences in energy requirements (e.g., in kWh/m^2 per year) and the requirements should, therefore, be independent of geometry [9].

3.4 Natural daylighting

Generally, lighting systems utilize 30%-40%of a building's total energy consumption, thereby, making it a prime concern for net-zero energy discussions. National Renewable Energy Laboratory's (NREL's) proved that in net zero energy design, lighting systems in office facility should consume not more than 10% and less than 6% of the total building load when a data center or other equipment-heavy spaces are included [9].

Window arrangement is a crucial factor in determining daylight in the building. Tuning the window-to-wall ratio is one of the most effective strategies. Extra glazing adds material cost and increases HVAC system size without adding any benefit. Generally, net-zero projects have insulation values well beyond code.Daylighting should achieve in such a way that it reduces air infiltration through the use of a continuous air barrier to ensure the best performance under the design assumptions[15]. Therefore, the literature suggestsemploying layers of light for basic ambient light levels through daylight while providing occupants with additional lighting options to meet their needs.

Successful slashing facility lighting in the building can be achieved through the following goals in early project planning :18

3.5 By setting the maximum lighting power density goal

Lighting Power Density (LPD) is the electrical load of lighting per area lit, measured in watts per square foot. Overlit spaces (i.e., LPD too high), lead to wastage of energy as well as potential occupant discomfort.

3.6 By setting a daylight sufficiency goal

It specifies the amount of daylight needed to provide adequate light to perform typical tasks appropriate to each space, without additional electric lighting. It measures in lumens or foot-candles. It provides the appropriate balance between too little daylight (resulting in eyestrain or unnecessary electric light usage) and too much (resulting in excess glare or heat) to perform most tasks in the space.

3.7 Natural ventilation

The basic principle in a tropical climate is to have rooms allowing air to blow through, by having opposite exterior facades with a porosity higher than 20%[19].

A case study carried out by Shan.R. et al.[20] in severe cold climate in China shows that building energy performance is mostly influenced by climate. According to his research, the annual total building energy consumption was much smaller than a traditional office building given almost no cooling or lighting load for the SGZEB.

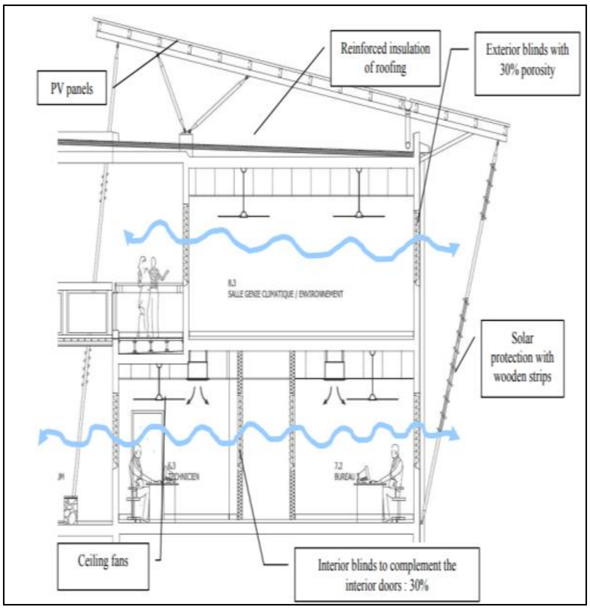
He also suggested that the mechanical ventilation load was significantly reduced by applying natural ventilation strategies. Simulation result provided by Energy Plus which shows that the annual energy consumption (195505 kBtu or 57297 kWh), is contributed mostly by the heating load in the extremely cold winter time [20].

It is possible to recycle the air at a rate of 40 to 100 vol/h with interior speeds of 1 m.s-1 for wind speeds of approximately 2 m.s-119.

As stated by Gard [19], few architectural innovations such as interior blinds, wall lights, using air fans, improved management and intelligent dimensioning of the building systems and it is possible to create a building which uses a third of the energy of a standard building with an additional cost of 2% 19.

The natural Airflow design of a building is shown in figure 2.

Fig 2: Technical Solution for the Thermal and Airflow Design of the Building



[Source: Gard, F.et.al. 2006]

4.0 Passive Energy Conservation Techniques

4.1 Building envelop

Building Envelope is an essential component of NZE design, especially for buildings with large heating loads. An energy efficient building must be tightly insulated and carefully constructed to prevent air infiltration and heat transfer through the building envelope. Thermal zoning and ventilation setback can yield energy savings up to 23% when troops are deployed 21. insulation is the primary material in the thermal control system. The thermal resistance of the installed insulation as quantified by the R-values. Achieving high R-values is a necessary part of any high-performance enclosure design strategy. Pettit,B.et.al.2015 presented design R-values of the insulation for the net zero residential test facility which is shown in table (2)22.

Table 2: Insulation R-Values by Component

	Sub-Slab	Fdn Wall	Ext Wall	Windows	Roof
Prescriptive 2012 IECC nominal R-value[m2.K/W (ft2.h.°F/Btu)]	1.8 (10)	1.8 (10)	3.5 (20)	0.5 (2.8)	6.7 (38)
NZERTF nominal R-valuem2.K/W (ft2.h.°F/Btu)]	1.8 (10)	4.1 (23)	7.9 (45)	0.9 (5.2)	12.7 (72)

[Source: Pettit,B.et.al.NIST.2015]

Climatic conditions influences building envelope design23.Kolokotsa, D.et.al.(2018) investigated design and energy technologies of a zero energy school in Greece and analyzed energy performance of the zero energy building and showed a significant 68% reduction of the energy demand by improvement of the indoor thermal comfort through the zero energy building design24.

Thermal mass plays a dominant role in the design of passive solar houses by allowing for more heat to be captured and modulating heat distribution thereby enabling less temperature swings in the house. The optimal amount of thermal mass required depends on the amount of glazing and mass location. Mass heated indirectly by warm air from the living space is reported to require roughly four times more area as the same mass in direct sun to provide the same thermal effect 16.

New building material production methods lead to better control of heat and mass flux by the building envelope including foundation, roof, walls, doors, windows 25.

To determine the quantity of thickmass, Chiras,D. (2002) suggested using three glass-to-mass ratios 16:

a. South-facing windows stretching beyond 7% of floor space requires an additional 5.5 m2 of uncovered and sunlit floor mass.
b. In case themass is not in direct contact with the sunlight, but in the same room, an additional 40 m2 of mass is required per additional square meter of south-facing glazing above 7%.

Therefore, the optimal amount of glazing depends on the total heated floor area, total thermal mass, and other design parameters 16.

A study carried out by Bajc,T.et al. (2015) on the impact analysis of the building energy demand of a passive house with the Trombe wall considering the Belgrade weather showed that the trombe wall increased the cooling demand in summer and efficient heating energy-saving in winter 26.

The most cost-effective steps toward a reduction in a building's energy consumption can occur during the design process.

Griffith, B.et al. NREL (2006) recommended strategies for the design of NZEB with controlled cost and highlighted action is summarized in table 3 [13.]

4.2 Design of energy efficient lighting

A standard building has lighting from three 4x18W installations, giving a total power of 216 W and a rate of 11W/m² 19. In areas having grid electricity, energy efficient lighting design can be achieved by replacing incandescent light bulbs with compact fluorescent bulbs, which last four times longer and use one-quarter of the electricity 27. Stated by Della Cava et al.2004 that the official efficiency standard for lighting energy in new buildings in China, sets mandatory limits on wattage per m2 and recommends using natural daylight and controlling the use of electric lighting 28.

5.0 Produce Unmet Energy Demand –Active Strategy

The active strategies mainly represent ways to reduce building energy consumption through energy production.

5.1 Renewable energy

The term renewable energy refers to energy which flows naturally through the environment on a continual basis 29. Renewable energy sources are a necessity for achieving NZEB and beyond 9. Renewables are the second largest contributor to global electricity production.

RE accounted for 23.8% of world generation in 2016 29.

.2 Hydroelectric power

The power of falling water – has been used by human civilization for centuries to carry out mechanical work milling, grinding, or merely irrigating agricultural lands.

Hydroelectric installations are characterizedas either small or in the large scale.

Schemes with 10 MW and less are smallscales and those of installed capacity of more than 10 MW are usually consider ed to be large scale 31, hydro provided 2.5% of global production in 2016.

To support and operate renewable energy technologies and for better RE management, backup systems required and it should fully installed and commissioned 34.

Table (4) shows a summary of technologies used in NZEB.

Source: Maria, K and virot, L.(2013) 35

Table (3): NZEB Cost Effective Design Strategies

	Design strategies			
Audience	**Integrate simple and passive strategies**	**Consider life-cycle cost impacts**	**Allow for cost tradeoffs across disciplines**	**Leverage value added benefits**
Architects and Design Engineers	• Lev erage orientation, massing, and layout to reduce thermal loads without increasing cost. • Inte grate efficiency strategies with the building envelope and structure. • Avo id unnecessary control and moving components. • Con sider strategies that minimize the need for ongoing calibration.	• Use energy modeling and life cycle analysis to identify integrated design packages that are favorable long-term investments. • Consid er long-term maintenance requirements when comparing strategies. • Monit or and evaluate the operational performance of past design to provide insight into reliability, maintenance, and other operational consideration. • Evalua te efficiency investments using an avoided cost of renewables metric.	• Righ t- size HVAC systems to account for the load reductions provided by other efficiency strategies. • Leve rage cost saving from HVAC system capacity reduction to invest in other improved efficiency packages. • Use energy modeling early and often to evaluate interactions between building systems and design choices and maximize cost tradeoff benefits.	• Docum ent and emphasize non-energy benefits (comfort, aesthetics, productivity, flexibility, etc) of effective strategies to secure decision-maker buy-in. • Align efficiency strategies with the organizational mission to increase the willingness of decision-makers to sign off on emerging or un-conventional strategies.
Owners and developers	• Co mmunicate maintenance capabilities and operational priorities to the design team.	• Explor e robustlong-term investment options before screening by the first cost.	• Reco nsider typical discipline- centric budget allocations to enable fluid cost tradeoffs.	• Consid er the values of efficiency strategies beyond energy cost saving.
Contrac tors and subcontractors	• Iden tify opportunities for reducing the first cost with a simplified construction.	• Inform team members of construction considerations that can affect life-cycle cost.	• Infor m team members if options involve tradeoffs between material and installation costs.	• Comm unicate value-added benefits related to construction processes.

[Source: Griffith, B.et al. NREL (2006)]

Design strategies (continue)			
Audience	**Maximize use of modular design strategies**	**Size Glazing area for Daylighting, Views, and efficiency**	**Consider alternative financing for higher cost systems**
Architects and Design Engineers	• Leverage the replicability of modular elements to reduce design and construction costs. • Standardize building construction (punched windows, exterior wall panels and so forth) to reduce cost through economies of scale. • Use modular elements to increase space efficiency and reduce footprints. • Reinvest space efficiency cost saving into efficiency strategies. • Leverage modular floor plans to simplify mechanical and electrical system design.	• Size glazing area to balance daylighting, thermal performance and architectural amenities. →First specify the amount of daylighting glazing necessary for the projects daylighting goals. →Then identify key opportunities for implementing view glazing that improves the interior environment while minimizing thermal gains. →Limit east and west facing glazing to the extent possible. →Eliminate unnecessary glazing to decrease overall envelope costs and improve thermal	• Consider leveraging alternative financing to take advantage of tax deductions, credits, and local utility rebates that are available to third-party commercial entities. • Take advantage of demand-side rebate programs provided by local utilities to help defray the cost of efficiency investments. • Consider a PPA for renewable energy systems if adequate funds cannotbe freed through other cost-saving strategies. • When direct purchase and financing options are both feasible, evaluate the life cycle cost, mission impacts, and other value added for each scenario.
Owners and developers	• Encourage designers and construction contractors to pursue innovatively, cost-saving modular design and construction strategies.	• Recognize that glazing has a wide range of implications beyond aesthetic and that careful design can optimize benefits.	• Provide input during evaluations of how alternative investment scenarios align with owner goals and constraints.
Contractors and subcontractors	• Identify opportunities to modularize specific building constructions.	• Communicate energy performance implications of glazing constructions (e. g. thermal breaks in frames).	• Relay to owners any construction cost considerations, such as system sizing or construction schedule.

The global production of renewable sources in 2016, such as solar PV, wind, solar thermal, geothermal, kept on expanding at a fast pace (+31.1%, +14.2%, +3.2%, +4.0%, respectively) but still accounted for less than 2% of global primary energy production together 30.

In selecting a renewable-energy technologies for a building, the site-capacity from the energy model can be used for determining energy sources which will be able to meet the demands of the building within the constraints of the site, budget, timeline, and performance goals.

The most common renewable systems arePhotovoltaics, Wind power, Geothermal systems, Hydroelectric power, andBiomass 9.

- The photovoltaic systems convert sunlight directly into electricity using the PV effect through which light causes matter to emit electrons.The photovoltaic technology generates electricity on a completely different physical basis than either conventional generation or other kinds of renewable energy generation 31.

- For existing infrastructure, the PV can be easily installed economically. The solar panels can produce the equivalent of 2.5 times the building's energy use 19.
- Ground-based or roof-mounted wind turbines can be a potential source of renewable energy in the areas having high wind velocities. Cao et al. (2017) evaluated the wind power resource around the 1000-meter scale of mega-tall buildings and showed that the technical performance of the wind turbine system was seen to be the best when at distances of 300 and 200 m from the ground, and when the building orientation is north and south 32.
- Geothermal systems harness the power of underground heat. They are expensive at small scale and are not an option on most sites.Geothermal energy is most useful when it occurs in the hydrothermal form: springs of hot pressurized water or steam known as aquifers. High-velocity steam made from exploiting geothermal energy by converting water to highly pressurized steam is used to create electricity 31.
- Bioenergy or biomass is the energy recovered from biomass that is from the chemical bonds formed via photosynthesis in the living matte.it is a single most significant source of energy in the developing countries providing 35% of total primary energy supply 33.

The primary source of biomass fuels is wood also, sources of biomass includes animal residues, agricultural residues, urban refuse, sewage sludge, industrial waste, and energy crops 31.

Table 4:Main technologies for use in ZEBs

	Proven and stabilized technologies	**Still developing technologies**	**Technologies on the horizon**
Thermal insulation	Low conductivity materials	Reflective roofs, green roofs, exploring new material for thermal insulation	Smart, reflective roofs, cool colored paints(with IR reflective pigments), exploring new materials for thermal insulation (nanomaterials), highly insulation façade systems
Windows	Multi-layer windows Low-e-grazing Gas-filled air gaps Thermal break frames	Glazings with dynamic properties(e. g. electrochromic)	BIPV glazings, solar glazing, solar curtain walls
Lighting	CFL, LED, daylight harvest through transparent envelope	CFL, LED, intelligent, dynamic and light-re-directing facades with automated lighting controls	Intelligent, dynamic and light-redirecting façades combined with automated lighting controls, intelligent natural daylighting distributing systems
Heating and	Condensing gas boilers Biomass boilers High EER chillers Heat pumps(	Micro-combined heat and power	Solar combined heat, cooling, and power, thermally activated heat pump (HP), thermoelectri

	ground and air source)		c cooling, frostless HP, distributed refrigeration/ water-source HP
Ventilation	Mixed mode natural and mechanical with heat recovery (HR), night cooling, stack effect ventilation	Hybrid ventilation systems with automatic controls displacement ventilation	Heat recovery widows personalized ventilation
Renewable technologies	Thermal solar, biomass heating, PV systems, PV thermal solar systems, air solar collectors	PV system (increased efficiency) BIPV systems, wind turbines(WT) and micro WT	BIPV systems, WT, and micro
Building energy management systems	Sensors, energy control (zone cooling and heating) and monitoring systems	monitoring and control systems running on IP communication infrastructure	Improved management systems with grid/ consumer supply-demand integration

6.0 Conclusions

A significant rise in the water level of oceans and precipitation changes in the desert are visible changes brought due to the impact on climate. Climate change has all the necessary ingredients to prove to be a global threat.

Theliterature demonstrated that environmental sustainability canbe achieved through designing sustainable and energy efficient buildings by the help of NZEB technologies.Since, the energy consumption, especially in the building sectors associated with climate change therefore, focusing on energy efficiency in buildings must allow to meet goals for reduction of greenhouse gas emission. forthat, the energy efficient buildings would be an immediate option for a Secure, Clean, and Healthy Future.

In order to design an NZEB, a professional, having expertise in energy and comfort must involveto the design team at the earliest phase of the design process.

A design team must consist of experts in building Physics, architects and Mechanical engineers so that they work concurrently toward this approach to achieve NZEBs.

Many research has been conducted in the area of ZEB for past few decades, yet only a few zero-energy buildings (ZEBs) exist limiting mostly to USA, Canada and a few European and Asian countries, which shows that there are many socio-economic factors which are hindering the design, construction and operation of NZEBs.

Primarily, the energy demand for new buildings is higher than the old buildings, and most of this energy tends to get waste due to inappropriate architectural design which shows that architects have to modify their approach and follow the ZEBs strategies to obtain better services with lower energy need.

Simultaneously, mechanical engineers must change their conventional approach of building oversizing plants and systems and must look into the economic as well as environmental concerns of the design.

References

[1] PFG Bancll, ADPeacock. Energy efficient new housing. The UK reaches for sustainability,Building Research & Information. 35(4), 2007, 426.

[2] P De Wilde, D Coley.The implications of a changing climate for buildings. Build Environ.55, 2012, 1-7.

[3] UNEP-DTIE Sustainable Consumption & Production Branch. Buildings and Climate Change. Summary for Decision Makers**.** United Nations EnvironmentProgram. 2009.

[4] IEA. Energy performance certification of buildings: A policy tool to improve energy efficiency. Paris:OECD/IEA, 2010.

[5] UNEP. Buildings and climate change. summary for decision makers. United Nation Environment Program, sustainable building and climate initiative 2009, 10-11.

[6] P Graham. Building Ecology: First Principles for a Sustainable Built Environment Blackwell, Oxford, UK 2003.

[7] P Torcellini, S Pless, M Deru, D Crawley. Zero Energy Buildings: A Critical Look at the Definition, National Renewable Energy Laboratory (NREL), Pasific Grove, CA, 2006.

[8] European Parliament. Energy performance of buildings (recast)', Official Journal of the European Union, 53, 2010, L153/1–L153/35

[9] T Boermans. Principles for nearly zero energy building, Buildings Performance Institute Europe and Danish Building Research Institute, 2011.

[10] National Institute of Building Science. A Common Definition for Zero Energy Buildings U.S. Department of Energy, 2015 .

[11] J Kurnitski, F Allard, D Braham, G Goeders. How to define nearly net zero energy buildings. Rehva proposal for uniformed national implementation of EPBD recast, 2011.

[12] National renewable energy laboratory. Cost control strategies for zero energy buildings. High performance design and construction on a budget. 2014, NREL/BR-5500-62752

[13] B Griffith, P Torcellini, N Long, D Crawley, J Ryan. Assessment of the Technical Potential for Achieving Zero-Energy Commercial Buildings. National Renewable Energy Laboratory. California NREL/CP-550-42144, 2006.

[14] ASHRAE. 2004. ANSI/ASHRAE/IESNA Standard 90.1. Energy Standard for Buildings Except Low-Rise Residential Buildings, Atlanta, GA, 2004

[15] AIA continuing education, Sustainable design. Net zero energy design and the living building challenge, 2016, 48.

[16] D Chiras.The Solar House: Passive Heating and Cooling. White River Junction, VT: Chelsea Green Publishing, 2002.

[17] IY Choi, SH Cho, JT Kim**.** Energy consumption characteristics of high-rise apartment buildings according to building shape and mixed-use development.46, 2012, 123–131.

[18] GSA. Office of Federal High Performance Green Buildings saving energy through lighting and daylighting strategies. https://www.gsa.gov/about-us/organization/office-of-governmentwide-policy/office-of-federal-highperformance-buildings/resource-library/energy-water/the-fort-carson-energy-research-project.

[19] F Garde, A Bastide, D Bentaleb, AH Fakra, F Ottenwelter. The construction of a zero energy building in Reunion island. Presentation of a new approach to the design studies. IASTED. MSO, Modelling, Simulation and Optimisation. , 2006,1-8.

[20] R Shan, M Carol,S Tiemao. Design Strategies for a Net Zero Energy Building in Severe Cold Climate: A Case Study for China. https://www.researchgate.net/publication/293816833, 2016.

[21] GSA. Strategies to achieve net zero energy. The fort carson energy research project General Services Administration. GSA, 2014.

[22] B Pettit, C Gates, A Fanney, M Healy.Design Challenges of the NIST Net Zero Energy Residential Test Facility. National Institute of Standards and Technology (NIST). Technical Note 1847, 2015, 25.

[23] L Yang, JC Lam, CL Tsang. Energy performance of building envelopes in different climate zones in China. Appl Energy, 85, 2008, 800-817.

[24] D Kolokotsa, V Vagias, L Fytraki, K Oungrinis. Energy analysis of zero energy schools: the case study of child's asylum in Greece. Advances in Building Energy Research, 2018, 11.

[25] S Hoque. Net Zero Energy Homes: An Evaluation of Two Homes in the Northeastern United States. Journal of Green Building, 5(2), 2010, 85.

[26] T Bajc, MN Todorovi´c, J Svorcan.CFD analyses for passive house with Trombe wall and impact to energy demand. Energy Build. 98, 2015, 39-44.

[27] L Richard, Ottinger. Energy Efficiency: The Best Immediate Option for a Secure, Clean, and Healthy Future, Strategic Planning for Energy and the Environment, 2010, 28.

[28] MFDellaCava, S Weil, P DuPont, SR Na Phuket, S Constantine,JE McMahon. Ministry of Construction Gazette N° 247. 2000 30(2), 2004, 43

[29] International Energy Agency. Renerable information. IEA. Renewable information: overview 2018, 5.

[30] International Energy Agency. World energy balance. IEA: overview edition, 2018, 3.

[31] T Jackson. Renewable energy sources. Center for environmental strategy, University of surrey. United Kingdom, 2000.

[32] J Cao, X Man, J Liu, L Liu, T Shui. Preliminary assessment of the wind power resource around the thousand-meter scale megatall building. Energy Build, 142, 2017, 62–71.

[33] WEC. New Renewable Energy Resources.A guide to the future, World Energy Council, Kogan Page, London, 1994

[34] Department of Housing, Planning and Local Government of Ireland. Conservation of Fuel and Energy Buildings other than Dwellings, Building Regulations. part L, 2017,17.

[35] K Maria, L Virota. Recent progress on net zero energy buildings. Advances in building energy research, 2018, 158.