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Review Article

The prospects of zero energy building as an alternative to the conventional building system in Bangladesh (A review)

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Abstract

Energy consumption in commercial and residential buildings worldwide accounts for about one-third of the world's energy and one-quarter of greenhouse gas emissions. If current trends continue, by 2025, buildings worldwide will be the largest consumers of global energy, using as much power as the transportation and industrial sectors combined. Recent studies have found that improving energy efficiency in buildings is the least costly way to reduce a large quantity of carbon emissions. By changing energy management practices and instituting technologies that enhance energy efficiency, building owners and managers can reduce energy consumption by up to 35%. However, energy efficiency efforts in buildings alone cannot address future demand for more energy by this sector. To achieve breakthrough solutions to this problem, it is evident that a coordinated effort in a whole-building systems approach that emphasizes the necessity of integrating renewable on-site or distributed generation and energy efficiency is required to design the buildings of the future. Several International Energy Agency (IEA) countries have adopted a vision of so-called 'net zero energy buildings' (NetZEBs) as the long-term goal of their energy policies. This NetZEB is very new in Bangladesh and it started building green buildings which will lead to NetZEB shortly. However, Bangladesh has to comply with the IEA and must accept the zero-energy building concept.

Introduction

In Bangladesh, due to extremely hot weather in recent years, the use of air coolers, refrigerators, and other similar household appliances has increased a lot thus increasing the energy requirement for buildings and contributing to the greenhouse effect. As such zero energy building concepts would be a great solution to lessen the greenhouse effect. With industrial growth in Bangladesh, especially in the garments sector the mid and low-income population has better earnings and can spend for a better living. So the use of air coolers, refrigerators, TVs, electric cookers, etc. has increased a lot. This leads to increased energy requirements from the building sector. As a consequence each year the country has to spend a huge portion of its annual budget to import fossil fuel. In this regard, NZEB can be a good approach to mitigate the fuel crisis as well as environmental issues.

According to the Energy Information Administration (EIA), the building sector consumed more than 20% of the delivered energy worldwide in 2015, and this proportion will remain the same in 2040 [1]. Meanwhile, building-related emissions have increased by 45% since 1990 [2]. In the United States, the building sector consumes more energy than any other sector — about 39% of the country's total primary energy use in 2017 [3]. However, these significant proportions of energy consumption and emissions harbor great potential to contribute to energy conservation and carbon emission reduction. Therefore, improving building energy efficiency and lowering the associated carbon emissions is a key strategy for addressing global issues such as energy consumption reduction, mitigating climate change, and reducing the carbon footprint of human activities.

Recently, Net-Zero Energy Buildings (NZEBs) have gained increased popularity in the building industry in many

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countries as a promising solution to reduce building energy consumption. The concept of self-sufficient and energy-autonomous construction has been popular for a long time for applications under severe conditions, such as solar-powered satellites in space or stand-alone construction in remote areas where facilities cannot be connected to power grids. Ionescu, et al. [4] reviewed the genesis of energy-efficient buildings in history. The first fully functioning passive house (a nearly zero energy building) was not a house, but a polar ship named the Fram of Fridtj of Nansen in 1893 [5]. In building science, the term "zero-energy building" also is not recent. As early as 1976, researchers in Denmark proposed the term "zero energy house" for the first time by conducting research on solar energy for heating buildings in cold winters [6]. The concept of an NZEB has been developed ever since, and recently it has become mainstream.

The present policy definition of NZEB needs modification for its acceptance by building owners and for its fruitful application. Otherwise building owners are losing interest. In many cases due to the imposed rules as asked by NZEB policies owners are buying and fixing equipment but those are not used and maintained afterwards. This paper will use the term "Net-Zero Energy Buildings (NZEBs)." To sustain against the rapid change of climate and global warming, Bangladesh must work on carbon emissions, which would be minimized by building most of the high-rise buildings as NZEBs by 2050. In the Bangladesh National Building Code (BNBC) it is found that solar panels are mandatory for all high-rise buildings to generate electricity, which must be supplied to the national grid.

Concept, definitions and other related terms

The convergence of the need for innovation and the requirement for drastic reductions in energy use and Greenhouse Gas (GHG) emissions in the building sector provides a unique opportunity to transform the way buildings and their energy systems are conceived. Given that about one-third of GHG emissions can be attributed to buildings and that buildings are estimated to account for around 40% of energy usage globally [7], ZEBs provide significant opportunities to reduce GHG emissions and to reduce energy usage. Demand abatement through passive design, energy efficiency, and conservation measures need to be simultaneously considered with the integration of solar systems and on-site generation of useful heat and electricity using a whole-building approach.

Building energy design is currently undergoing a period of major changes driven largely by three key factors and related technological developments:

1. The adoption in many developed countries, and by influential professional societies, such as ASHRAE, of net-zero energy [8] as a long-term goal for new buildings;
2. The need to reduce the peak electricity demand from buildings through optimal operation, thus reducing the need to build new central power plants that often use fossil fuels;
3. The decreasing cost of energy-generating technologies, such as photovoltaics, which enables building-integrated energy systems to be more affordable and competitive. This is coupled with increasing costs of energy from traditional energy sources (e.g., fossil fuels).

A key requirement of high-performance building design is the need for rigorous design and operation of a building as an integrated energy system that must have a good indoor environment suited to its functions. In addition to the extensive array of HVAC, lighting, and automation technologies developed over in the last 100 years, many new building envelope technologies have been established, such as vacuum insulation panels and advanced fenestration systems (e.g., electrochromic coatings for so-called smart windows), as well as solar thermal technologies for heating and cooling, and solar electric or hybrid systems and combined heat and power (CHP) technologies. A high-performance building may be designed with optimal combinations of traditional and advanced technologies depending on its function and climate.

There are four definitions of Net Zero Energy as follows: Net Zero Site Energy, Net Source Energy, Net Zero Energy Costs, and Net Zero Energy Emissions [9]. These brief definitions are:

1. ***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.
2. ***Net Zero Source Energy*:** A source ZEB produces at least as much energy as it uses in a year when accounted for at the source. Source energy refers to the primary power used to generate and deliver the energy to the site. To calculate a building's total source energy, imported and the appropriate site-to-source conversion multiply exported energy.
3. ***Net Zero Energy Costs*:** In a cost ZEB, the amount of money the utility pays the building owner for the energy the building exports to the grid is at least equal to the amount the owner spends the efficiency for the energy services and energy used over the year.
4. ***Net Zero Energy Emissions*:** A net-zero emissions building produces at least as much emissions-free renewable energy as it uses from emissions-producing energy sources.

Torcellini, et al. [9] indicate that the unit applied in the ZEB definition can be influenced by (1) the project goals, (2) the intentions of the investor, (3) the concerns about the climate and greenhouse gas emissions, and (4) the energy cost. Therefore, they propose four different ZEB definitions: site ZEB, source ZEB, emissions ZEB, and cost ZEB, respectively. The authors point out the advantages and disadvantages of each of the definitions i.e. easy implementation of 'zero site energy' and 'zero energy costs' definitions, more international and not regional features of the 'zero source energy' definition, and calculation complexity of the 'zero-energy emission'

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definition. The proposed distinction between different metrics is brought up and further discussed in several publications [10], Kilkis [11] states that the metric of the balance in the ZEB definition should address both the quantity as well as the quality of energy if we want to assess the complete building's impact on the environment. Therefore, he proposes a new definition for the term ZEB, in particular, a net-zero exergy building, and defines it as a building, that has a total annual sum of zero exergy transfer across the building-district boundary in the district energy system, during all-electric and any other transfer that is taking place in a certain period'. Mertz, et al. [12] and Laustsen [13] distinguish only two units of the balance: emissions and energy, however, without specifying delivered or primary energy. The definition of 'Near Zero Energy Building' from the EPBD [14] is clear and uses primary energy as the metric for the energy balance.

Many of the papers talk about using a mix by taking energy from the grid to supplement what the buildings cannot produce onsite [15]. Despite the ability to still be an NZEB if energy is taken from the grid, there is still a hierarchy. The developed hierarchy can be seen in Table 1.

Moreover, the hierarchy was also used to find the best option for NZEB with different purposes such as NZEB. Marszal, et al. [16] in their article highlighted the lack of a single definition for the term 'Zero Energy Building' and the inconsistencies in the way this term is applied. As an extension of this, they compare the differences in how the calculations of a ZEB are carried out. The main differences were identified as the inconsistencies in the source of energy generation (on-site vs. off-site), the inclusion of embodied energy, and the inclusion of GHG emissions.

Table 2 summarizes some of the key considerations of each NZEB or related concept model. The NZEB concept lacks a holistic, quantifiable, and widely accepted definition. Some of the risks associated with a lack of a common definition are that NZEBs could be poorly executed and risk becoming a status symbol for building owners rather than a practical goal in alleviating environmental, social, or ethical issues.

Table 1: NZEB supply options hierarchy [9].

Options	ZEB Supply-Side Options	Examples
1	Reduce site energy use through low-energy building technologies.	Daylighting, high-efficiency HVAC equipment, natural ventilation, evaporative cooling, etc.
On-Site Supply Options		
2	Use renewable energy sources available within the building's footprint.	PV, solar hot water, and wind are located in the building.
3	Use renewable energy sources available at the site.	PV, solar hot water, low-impact hydro, and wind are located on-site, but not on the building.
Off-Site Supply Options		
4	Use renewable energy sources available off-site to generate energy on-site.	Biomass, wood pellets, ethanol, or biodiesel that can be imported from off-site, or waste streams from on-site processes that can be used on-site to generate electricity and heat.
5	Purchase off-site renewable energy sources.	Utility-based wind, PV, emissions credits, or other "green" purchasing options. Hydroelectric is sometimes considered.

Table 2: Summary of NZEB considerations per model.

Model	NZ Site Energy	NZ Source Energy	NZ Emissions Energy	NZ Costs Energy
Applies to new buildings	?	?	?	?
This applies to retrofitted buildings	?	?	?	?
Consideration of climate change	No	No	No	No
Encourages energy efficiency measures	No	No	No	No
Consideration of the energy generation method/ fuel source	No	No	Yes	No
Consideration of energy storage	No	No	No	No
Consideration of embodied energy	No	No	Yes	No
Recognition of cost-saving opportunities	No	No	No	Yes
Grid connection	Yes	Yes	Yes	Yes
Ease of measurement for end-users	Yes	No	No	Yes
Consideration of economic viability	No	No	No	Yes

Design strategy

When the design strategy of the NZEB model is considered, Lund-Andersen, et al. [17], suggested two things to consider, the first involving the methodology of zero energy building and the second involving the limitation of energy generation options. And Li, et al. [18], addressed two key approaches to be considered when implementing ZEBs. The first approach is to reduce energy consumption by limiting the amount of heat gain and loss, considering internal energy-efficient design and building facilities such as heating, cooling, and utilities. The second approach is to use renewable energy technology such as PVs, wind turbines, solar thermal, heat pumps, etc. Aelenei, et al. [19] proposed a common design strategy for the NZEBs in comparison to Li, et al. [18] and Singh and Verma [20], using 3 specific criteria. These design concepts are passive design strategies to minimize existing energy use typically associated with heating, ventilation, lighting, and equipment, then active design strategies to implement energy-efficient systems and, ultimately, the implementation of renewable energy systems. The basic 3-step process is known as 'Trias Energetica,' and Gvoz-denovi'c, et al. [21] have recently suggested an extension to the 5-step process.

It is unanimously agreed to prioritize energy-efficient strategies in a ZEB design and to address energy deficits through the application of renewable energy technologies. Torcellini, et al. [9] believe that the energy demand of NZEB should be met from low-cost, locally available, non-polluting, renewable energy sources. Although grid disconnection is desirable in this regard. However, Torcellini, et al. [9] assume that a grid connection is a valuable method for balancing electricity, believing that surplus energy will still be used by the grid, which may be false in times of high market saturation. Like Torcellini, et al. [9], Carrilho da Grac¸ et al. [22] described

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that although potentially desirable, a grid disconnection is not generally feasible as technologies are unable to cope with the 'seasonal mismatch' of energy demand versus supply. This idea could be increasingly out of date with advancements and additional availability of energy storage technologies. However, this problem of grid disconnection could potentially be mitigated by the implementation of renewable district energy generation systems using a wide range of renewable energy generation methods.

When considering renewable energy technologies to be implemented into NZEBs, Torcellini, et al. [9] proposed that a set of criteria be considered to rank technologies in terms of their potential to minimize environmental effects, reduce transport and conversion losses, and consider the durability of technology in terms of building life and technology availability. Good, et al. [23] studied PV technology and its impact on emission balances in buildings net-zero emission buildings. This research was limited to residential building types only. The research analyzed how the orientation of PV systems along with materials used can affect the energy efficiency of a building. Four PV system configurations were considered, which are all positioned on a flat-roofed home. Four different PV technologies were also considered, which were made up of different materials. Each system configuration was modeled using each of the different PV technologies to establish the energy yield and subsequently, which one is more efficient. Embodied emissions, avoided emissions, green-house gas payback return on investment, and the net emissions balance were also modeled for each case. The results show that the system with the largest area of high-efficiency Si-mono modules achieves the best lifetime emission balance.

When considering the load reduction strategies, Gagliano, et al. [24] and Evola, et al. [25] discussed strategies that result in high value in terms of financial investment. When considering a multi-story apartment building in Sicily, Italy, Gagliano, et al. [24] found that some of the most effective methods to achieve an 'enhanced saving building include optimizing the external wall insulation, reducing thermal bridging, and using low-E and reflective windows and green roofs. Similarly, Evola, et al. [25] stated that some techniques to reduce loads with minimal financial efforts in a Southern Italian terraced house may include increasing the insulation, using a very-low emissive coating on the inner side of the windows, implementing movable shading devices, and tilt-and-turn opening devices for natural ventilation. Despite providing useful guidance, Evola, et al. [25] inferred that these strategies are not a one-size-fits-all solution and particularly local climate must be considered to adjust individual design strategies accordingly. Further research into passive design and energy load reduction strategies is catalyzed in Europe by programs such as Horizon 2020, an initiative of the European Commission [26].

Based on the literature, Figure 1 offers a prioritized list of broad design steps that should be used to create an NZEB. Although NetZero energy consumption could be achieved by reordering these principles, it is argued that this hierarchy will create a sustainable NZEB.

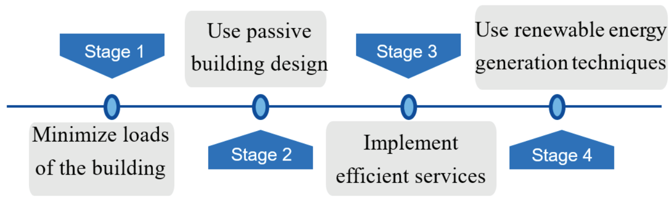

Figure 1: Hierarchical design strategy for NZEBs.

Case studies

Hoque [27] presented a study that compares two net-zero energy homes (based on annual energy consumption) in New Jersey and Vermont, United States. The home in New Jersey is powered mainly by solar and the Vermont example is mainly powered by wind. In this region of the United States, a major emphasis in NZEB design is placed on reducing the heating load of the homes, given the colder climate. Furthermore, net-zero energy homes can be attractive to homeowners in this region as the United States government incentivizes NZEB design with tax breaks and incentives. Although there are notable advantages to choosing net-zero energy homes some of the potential barriers encountered by homeowners may include high design and construction costs (implying potentially long payback periods), lack of knowledge about sustainable design concepts, difficulty claiming tax benefits, and lack of designer and builder expertise in this field. The two homes considered in the study are both constructed of main timber, are open plan, use foam insulation to maintain a humidity of around 40–45%, and are oriented south to maximize solar heating and daylight. Hoque [27] concluded that although both homes are well designed to significantly reduce energy usage, the success of both of these examples is reliant on the homeowners also being aware and conservative about their energy usage. In Table 3 some examples of established NZEBs are given for a better understanding of the implantation in this field.

S´anchez, et al. [28] compared 12 low-energy office buildings in Spain to conclude design solutions for future NZEBs. Low energy is diversely defined by S´anchez, et al. [28] with various buildings claimed to have features such as reduced energy consumption by more than 80% of a conventional building in the region, 'integration of solar technologies' and buildings using renewable technologies in conjunction reduced energy demand. In undertaking this study, S´anchez, et al. [28] realized that despite relatively specific net-zero energy goals as set out by the European Building Performance Directive, no office building in Spain could technically be considered net-zero energy and therefore they considered low-energy consumption buildings in their study. In this study, S´anchez, et al. [28] verified previous research that showed that as a building height increases, the feasibility of an NZEB decreases, as all buildings were relatively low rise with a maximum of 5 stories. Other consistent design features identified in the studied buildings included glazed windows, adequate insulation, and passive cooling and heating strategies. The most commonly used renewable energy technology is solar PV. The construction costs per area of the studied buildings were budgeted around

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Table 3: Samples of established NZEBs.

Building	Ref	Building	Ref
Nikini building, Colombo, Sri Lanka	[29]	Adam Joseph Lewis Center for Environmental Studies, Oberlin College, Ohio, USA	[32]
Institute of Technology building, Cork, Ireland	[30]	Zion National Park Visitor Center, Utah, USA	[33]
CSIRO Energy Centre, Newcastle, NSW, Australia	[31]	Mosaic Centre, Edmonton, Alberta, Canada	[34]
H1 Home, Lebanon, New Jersey, USA	[27]	Efficiency House Plus, Berlin, Germany	[35]
P-1 Home, Charlotte, Vermont, USA	[27]	SOLAR XXI, Lisbon, Portugal	[36]

40% higher than a standard Spanish office building and generally, actual construction costs were 25% higher than budgeted. This high construction cost and the fact that none of the studied buildings technically were NZEB, indicates that the NZEB industry needs significant advancement before NZEB is more realistic and feasible.

Ingeli andˇCekon [37] evaluated the energy consumption and design features of a Slovakian example of a net-zero energy house. By analyzing the thermal insulation used in this house, Ingeli andˇCekon [37] determined that airtightness plays an important role in low heat losses. The house researched in this paper is powered by a combination of solar and electric energy. Although the solar system is produced in the summer months and far exceeds the energy usage of the house, the most significant energy usage is during winter with around 10 times more energy used in winter than in summer. Ingeli andˇCekon [37] suggested that although this house has a net-zero energy usage when unused energy is commoditized in the summer months, the designer of this property could implement further measures such as batteries and other renewable technologies to further reduce electric energy consumption and to better customize the renewable energy production for the winter conditions. This example demonstrates that although a building is considered an NZEB, it doesn't necessarily mean that the building is capable of sustaining human activities off-grid. It also emphasizes that the consideration of the climate is vital to a sustainable NZEB. As well as considering the passive design and the implementation of current technologies, Wall, et al. [38] indicated that other factors that require consideration for ZEBs include building occupant behavior, future unpredictability in energy demand, and the integration of future renewable and energy storage technologies.

Notable national and international policy support for promoting NZEBs

Worldwide, there is relatively advanced policy support for NZEBs in regions such as North America and the European Union. Notable policies include the 2007 Energy Independence and Security Act in the USA and the 2010 European Performance of Buildings Directive, which both actively promote NZEB goals. The initiative, these regions with relatively good policy support coincide with more advanced research and progression towards creating NZEBs. Vasquez, et al. [39] indicated that although the existing regulations might lead to the 20% energy efficiency goal by 2020, they are not sufficient for the 2050 energy and GHG-emission goals, showing that further research and development are still required.

Table 4 summarizes the current policies and regulations for NZEBs in various countries. Most are promulgated in Europe and the United States, leading to the rapid and large-scale development of NZEB projects in these areas. Whereas Bangladesh includes in BNBC only for buildings of occupancy A shall use Solar or other renewable sources of energy to power 3% of the total electric load of the building.

Worldwide current status of zero-energy building

As a response to global warming and increasing greenhouse gas emissions, countries around the world have been gradually implementing different policies to tackle ZEB. Between 2008 and 2013, researchers from Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Italy, the Republic of Korea, New Zealand, Norway, Portugal, Singapore, Spain, Sweden, Switzerland, the United Kingdom and the US worked together in the joint research program called "Towards Net Zero Energy Solar Buildings". The program was created under the umbrella of the International Energy Agency (IEA) Solar Heating and Cooling Program (SHC) Task 40 / Energy in Buildings and Communities (EBC, formerly ECBCS) Annex 52 with the intent of harmonizing international definition frameworks regarding net-zero and very low energy buildings by diving them into subtasks [60]. In 2015, the Paris Agreement was created under the United Nations Framework Convention on Climate Change (UNFCC) with the intent of keeping the global temperature rise of the 21st century below 2 degrees Celsius and limiting temperature increase to 1.5 °C by limiting greenhouse gas emissions [61]. While there was no enforced compliance, 197 countries signed the international treaty, which bound developed countries legally through cooperation where each party would update its INDC every five years and report annually to the COP [62]. Due to the advantages of energy efficiency and carbon emission reduction, ZEBs are widely being implemented in many different countries as a solution to energy and environmental problems within the infrastructure sector [63].

In Australia, researchers have recently developed a new approach to the construction of visually clear solar energy harvesting windows suitable for industrialization and applications in net-zero energy buildings [64]. Industrial production of several prototype batches of solar windows started in 2016 [65]. Up to December 2017, the State of Queensland has more than 30% of households with rooftop solar photovoltaic (PV) systems. The average size of the Australian rooftop solar PV system has exceeded 3.5 kW. In Brisbane, households with a 6 kW rooftop PV system and reasonable energy rating, for example, 5 or 6 stars for the Australian National House Energy Rating can achieve a net-zero total energy target or even positive energy [66].

After the April 2011 Fukushima earthquake followed by the up with Fukushima Daiichi nuclear disaster, Japan experienced a severe power crisis that led to the awareness of the importance

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Table 4: Summary of current policies for NZEBs in different countries and regions [40].

Country/ Region	Organization	Program	Content	Year	Ref
Europe	Directive on energy performance of building (EPDB)	ZEBRA 2020	New buildings are to be nearly zero energy from 2020	2010	[41]
Belgium	Brussels capital region Ministry of environment	Brussels Passive House Law 2011	New construction or major renovation of a dwelling, office, or school must comply with the passive standard 9nearly zero energy) from 2015	2011	[42]
Germany	EPDB	Act on the promotion of renewable thermal energy	Aim of achieving an almost climate-neutral building stock by 2050	2010	[43]
France	Ministry of environment, energy, and the sea	Act on energy transition for green growth	New buildings should be energy-positive by 2020	2015	[44]
Denmark	The ministry for climate, energy, and buildings	Building class 2020	Public buildings and private buildings are to be nearly zero energy buildings by 2018 and 2020, respectively	205	[45]
USA	Office of the Law Revision Counsel	The energy independence and security act of 2007	50% of new commercial buildings by 2040 and all new commercial buildings by 2050 should be zero energy	2007	[46]
USA	US Department of Energy (DOE)	The Building Technologies Program	Realize NZEBs at low incremental costs by 2025.	2008	[47]
USA	The California Public Utilities Commission (CPUC)	Zero Net Energy Action Plan	New residential and commercial construction will be NZEBs by 2020 and by 2030, respectively. 50% of commercial buildings will retrofit to be NZEBs by 2030, and 50 of new major renovations of state buildings will be NZEBs by 2025.	20`5	[48]
USA	The New York state energy research and development authority	Ultra-low-energy buildings in a high-density urban environment	Beginning in 2025, all new buildings would required to be built to very low energy design targets.	2014	[49]
Canada	British Columbia Energy Step Code Council	BC energy step code	New buildings must be 'net-zero energy ready' by 2032	2017	[50]
Canada	The city planning division of Toronto	Zero Emissions Buildings Framework	The municipality committed to adopting Tier 2, 3, or 4 for all city-owned development with nearly zero emissions standards by 2026	2018	[51]
UK	Ministry of Housing, Communities and Local Government	National Planning Policy Framework	All new homes should be zero carbon from 2016, and all other buildings from 2019	2012	[52]
Japan	Ministry of Economy, Trade and Industry (METI)	Strategic Energy Plan 2014	Newly constructed public buildings and standard houses are to be zero-energy buildings voluntarily by 2020. Newly constructed buildings and houses are to be zero-energy buildings voluntarily by 2030.	2015	[53]
Korea	National energy roadmap and zero energy building certification	Building an energy efficiency program	New building constructions should have net-zero energy consumption and non-residential buildings should have an energy-saving rate of 60% by 2025	2012	[54]
South Africa	C40 and sustainable energy Africa (SEA)	C40 South Africa Buildings Program	Energy efficiency policies and programs towards a net-zero carbon performance for new buildings in South African cities are to be developed and implemented by 2020	2018	[55]
Sweden	Stockholm	Buildings in the context of a fossil fuel-free city	All development on city-owned land must comply with a maximum energy use intensity, or specific purchased energy, of 55 kW-hours per square meter per year. Buildings this efficient can be considered to be zero or nearly zero energy buildings by 2040	2010	[56]
China	Ministry of Housing and urban-rural Development	The 13th five-year plan for building energy conservation and green building development	The construction of demonstration projects of ultra-low-energy and near-zero-energy buildings will reach more than 10 million square meters by 2020	2017	[56]
Australian	National strategy for energy efficiency	ZCA Buildings plan	Australia's emission goal is to reduce emissions to 26%-28% of 2005 levels by 2030	2009	[57]
Singapore	Building and construction authority	Building energy efficiency (BEE) R&D Roadmap and Solar PV Technology Roadmap	BEE to achieve improvements in the energy efficiency index (EEI) by 40%-60% over 2013 best-in-class buildings by the year 2030, super low energy (SLE) to achieve improvements in the EEI by 60% over 2005 industry levels by 2018, and 80% by 2030	2014	[58]
Malaysia	The Sustainable Energy Development Authority Malaysia	Zero energy building facilitation program	Intends to reduce its greenhouse gas (GHG) emissions intensity of GDP by 45% by 2030 relative to the emissions intensity of GDP in 2005.	2018	[59]
ASIAN	The ASEAN Member states	ASEAN Energy Awards	Zero energy building added to ASEAN Energy Awards 2019		[59*]

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of energy conservation. In 2012 Ministry of Economy, Trade, and Industry, the Ministry of Land, Infrastructure, Transport and Tourism and the Ministry of the Environment (Japan) summarized the road map for a Low-carbon Society which contains the goal of ZEH and ZEB to be standard of new construction in 2020 [67]. The Mitsubishi Electric Corporation is underway with the construction of Japan's first zero-energy office building, set to be completed in October 2020 (as of September 2020) [68]. The SUSTIE ZEB test facility is located in Kamakura, Japan, to develop ZEB technology [68]. With the net-zero certification, the facility projects to reduce energy consumption by 103% [69]. Japan has made it a goal that all new houses be net-zero energy by 2030 [70]. The Developing Company "Sekisui House introduced its first net-zero home in 2013 and is now planning Japan's first zero-energy condominium in Nagoya City, it is a 3 story building with 12 units. There are solar panels on the roof and fuel cells for each unit to provide backup power.

The Canadian Home Builders Association - National oversees the Net Zero Homes [71] certification label, a voluntary industry-led labeling initiative. In December 2017, the BC Energy Step Code entered into legal force in British Columbia. Local British Columbia governments may use the standard to incentivize or require a level of energy efficiency in new construction that goes above and beyond the requirements of the base building code. The regulation is designed as a technical roadmap to help the province reach its target that all new buildings will attain a net zero energy-ready level of performance by 2032. In August 2017, the Government of Canada released Build Smart - Canada's Buildings Strategy [41], as a key driver of the Pan Canadian Framework on Clean Growth and Climate Change, Canada's national climate strategy. The Build Smart strategy seeks to dramatically increase the energy efficiency of Canadian buildings in pursuit of a net zero energy-ready level of performance. In Canada, the Net-Zero Energy Home Coalition [72] is an industry association promoting net-zero energy home construction and the adoption of a near net-zero energy home (nNZEH), NZEH Ready, and NZEH standard. The Canada Mortgage and Housing Corporation is sponsoring the Equilibrium Sustainable Housing Competition [73] which will see the completion of fifteen zero-energy and near-zero-energy demonstration projects across the country starting in 2008. The EcoTerra House in Eastman, Quebec is Canada's first nearly net-zero energy housing built through the CMHC Equilibrium Sustainable Housing Competition [74], The house was designed by Assoc. Prof. Dr. Masa Noguchi of the University of Melbourne for Alouette Homes and engineered by Prof. Dr. Andreas K. Athienitis of Concordia University [73]. In 2014, the public library building in Varennes, QC, became the first ZNE institutional building in Canada [75]. The library is also LEED gold certified. The EcoPlusHome in Bathurst, New Brunswick. The Eco Plus Home is a prefabricated test house built by Maple Leaf Homes with technology from Bosch Thermotechnology [76]. Mohawk College will be building Hamilton's first net Zero Building.

With an estimated population of 1,439,323,776 people, China has become one of the world's leading contributors to greenhouse gas emissions due to its ongoing rapid urbanization. Even with the growing increase in building infrastructure, China has long been considered a country where the overall energy demand has consistently grown less rapidly than the Gross Domestic Product (GDP) of China [77]. Since the late 1970s, China has been using half as much energy as it did in 1997, but due to its dense population and rapid growth of infrastructure, China has become the world's second-largest energy consumer and is in a position to become the leading contributor to greenhouse gas emissions in the next century [77]. Since 2010, the Chinese government has been driven by the release of new national policies to increase ZEB design standards and has also laid out a series of incentives to increase ZEB projects in China [63,78]. In November 2015, China's Ministry of Housing and Urban-Rural Development (MOHURD) released a technical guide regarding passive and low-energy green residential buildings [63]. This guide was aimed at improving energy efficiency in China's infrastructure and was also the first of its kind to be formally released as a guide for energy efficiency [63]. Also, with rapid growth in ZEBs in the last three years, there is an estimated influx of ZEBs to be built in China by 2020 along with the existing ZEB projects that are already built [63]. As a response to the Paris Agreement in 2015, China stated that it set a target of reducing peak carbon emissions around 2030 while also aiming to lower carbon dioxide emissions by 60% - 65% from 2005 emissions per unit of GDP [79]. In 2020, Chinese Communist Party leader Xi Jinping released a statement in his address to the UN General Assembly declaring that China would be carbon neutral by 20% pushing forward climate change reforms. With more than 95% of China's energy originating from fuel sources that emit carbon dioxide, carbon neutrality in China will require an almost complete transition to fuel sources such as solar power, wind, hydro, or nuclear power. To achieve carbon neutrality, China's proposed energy quota policy will have to incorporate new monitoring and mechanisms that ensure accurate measurements of the energy performance of buildings [80]. Future research should investigate the different possible challenges that could come up due to the implementation of ZEB policies in China [80]. One of the new generation net-zero energy office buildings successfully constructed is the 71-story Pearl River Tower located in Guangzhou, China [81]. Designed by Skidmore Owings Merrill LLP, the tower was designed with the idea that the building would generate the same amount of energy used on an annual basis [81] while also following the four steps to net zero energy: reduction, absorption, reclamation, and generation [82]. While initial plans for the Pearl River Tower included natural gas-fired microturbines used for generation of electricity, photovoltaic panels integrated into the glazed roof and shading louvers and tactical building design in combination with the VAWT's electricity generation were chosen instead due to local regulations.

In the US, ZEB research is currently being supported by the US Department of Energy (DOE) Building America Program [83], including industry-based consortia and researcher organizations at the National Renewable Energy Laboratory (NREL), the Florida Solar Energy Center (FSEC), Lawrence Berkeley National Laboratory (LBNL), and Oak Ridge National

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Laboratory (ORNL). From the fiscal year 2008 to 2012, DOE plans to award $40 million to four Building America teams, the Building Science Corporation; IBACOS; the Consortium of Advanced Residential Buildings; and the Building Industry Research Alliance, as well as a consortium of academic and building industry leaders. The funds will be used to develop net-zero-energy homes that consume 50% to 70% less energy than conventional homes [8]. DOE is also awarding $4.1 million to two regional building technology application centers that will accelerate the adoption of new and developing energy-efficient technologies. The two centers, located at the University of Central Florida and Washington State University, will serve 17 states, providing information and training on commercially available energy-efficient technologies [8]. The U.S. Energy Independence and Security Act of 2007 created 2008 through 2012 funding for a new solar air conditioning research and development program, which should soon demonstrate multiple new technology innovations and mass production economies of scale. The 2008 Solar America Initiative funded research and development into the future development of cost-effective Zero Energy Homes for $148 million in 2008 [84,78]. The Solar Energy Tax Credits have been extended until the end of 2016. By Executive Order 13514, U.S. President Barack Obama mandated that by 2015, 15% of existing Federal buildings conform to new energy efficiency standards and 100% of all new Federal buildings be Zero-Net-Energy by 2030.

Future directions and research needs

Recently, we have seen significant technological developments in key technologies, such as photovoltaics, together with dramatic cost reductions that make it more cost-effective to achieve net-zero energy. However, the integration of PV and other technologies, such as heat pumps, with buildings and with other technologies still has a long way to go before similar cost reductions at a system level can be achieved. The integration of new technologies will lead to the development of new multifunctional building products, such as prefabricated BIPV/T walls and roofs, semitransparent PV windows, windows with integrated automatically controlled shading and daylighting devices, advanced building-integrated thermal storage systems, solar cooling systems integrating PV and heat pumps, and smart building operating strategies.

Human factors in the operation of Net ZEBs are seen as increasingly important as evidenced by the four case studies. Operating strategies need to be designed that take into account the possible scenarios due to human behavior and its impact on comfort and energy performance. The three main approaches to mitigating the uncertainty of occupants are as follows:

1. Carefully selecting building materials and geometry (i.e., passive techniques) that decrease the frequency of discomfort.

2. Smart controls for providing comfort with the possibility of learning controls that learn from occupant preferences and adapt accordingly (e.g., controllers that learn occupant preferences, habits, and schedules).

3. Building performance dashboards and other behavior-shaping design features or strategies. Research has shown that informing occupants of their building's energy performance can have a significant impact on their behavior. For the case of net-zero energy buildings, there is a defined performance target. Occupants should be informed of real-time and annual building performance so they can verify that the target is being achieved.

For Net ZEBs to become widespread the next step is to consider optimal design configurations for clusters of buildings and neighborhoods while considering interaction with electricity grids/microgrids. While net-zero energy buildings place considerable emphasis on individual buildings, we cannot lose sight of the bigger picture. Grid-tied Net ZEBs still have considerable upstream impacts on the environment and energy-supply infrastructure because of their diurnal and/or seasonal dependence on a centralized energy supply. Future research and development must recognize the complex interactions between individual buildings, the community, and the larger scale (e.g., urban and grid-wide). Through integration, the net-zero energy goal can be achieved at the community level, while allowing significant design flexibility at the individual building level. Different pathways for achieving net-zero energy balance at the community level need to be studied, including solar optimization of building form, density, and mix of solar and energy efficiency technologies (e.g., BIPV/T and heat pumps, thermal storage, and possibly some district heating). One possible scenario suggests that buildings can be integrated into traditional street patterns while ensuring that one or more large planar surfaces are optimally oriented to capture solar energy. There is also the possibility of integration with seasonal heat storage and district heating systems for cold climates. The optimal mix of technologies, their integrated design, and operation will depend on climatic conditions and local conditions, including cost and incentives. Plug-in hybrid and electric vehicles can be integrated into the community energy concept, serving as electrical storage and load management devices, but also providing backup power to the houses during emergencies such as earthquakes. In closing, this article has demonstrated that Net ZEBs are a viable design objective for most climates through four detailed, high-quality case studies. Modeling and design issues for the most common and appropriate technologies, systems, and strategies for Net ZEBs were outlined. It is clear from this research and demonstration projects that attention to detail from early-stage design to operation and use of appropriate modeling and simulation tools is essential.

Conclusion

In conclusion, we decided that for our Zero Energy Project using solar energy is the best energy source in regards to saving energy and cost efficiency. After brainstorming and researching we agreed that photovoltaic solar panels are the best solution for generation of the electricity. The installation of solar panels initially would be costly, but in the long run, the owner of the building would save money on their energy

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bill. More importantly, in the scarcity of natural resources, we would be providing a self-sufficient, energy-saving, non-polluting, Zero Energy building. The solar panels that would be installed would be on the back side of the building, which would be facing south. This would allow for the most direct sunlight to be absorbed by the panels. So according to us it is most efficient to install the PV Solar system. Using most of the sunlight for the buildings would be another option to save energy. Bangladesh is stepping forward to incorporate solar panels, use of most sunlight for lighting spaces, and solar heating systems to heat water and discourage AC usage in residences or commercial buildings. Besides BNBC, Bangladesh should have a master plan and approved policy for NetZEBs so that we feel safe and thereby contribute to eliminating carbon emissions for the globe.

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