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Review of Influential Elements in nearly-Zero Energy Temporary Buildings from Energy, Building Envelope, and Fenestration Perspectives

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ABSTRACT

Buildings serve as essential shelters, providing safety and comfort for people. factors such as conflicts, natural disasters, urbanization, and economic instability contribute to homelessness. Additionally, Temporary buildings, with their rapid construction, sustainability, modularity, and portability, used in remote area, cost-effectiveness, play a critical role in addressing this situation. Temporary buildings include shipping containers, prefabricated building, container house or building, Industrial Building, and Lightweight Steel Frames. Building sector consume a significant share of global energy for construction and operation so making energy-efficient building performance a critical focus in energy policies. Consequently, the United States Department of Energy and the European Union have introduced the concept of nearly-Zero Energy Buildings (nZEBs). This literature review provides a comprehensive technical insight into the parameters of nZEBs, specifically focusing on temporary buildings. Accordingly, climate considerations, envelope, ventilation as a part of HVAC, and lighting are introduced to reduce energy requirements. Research was analyzed reveals that in climates, optimizing the building envelope with technologies like Thermal Insulation Layers (TILs) and Phase Change Materials (PCMs) as essential strategies for enhancing energy efficiency and most of them used EnergyPlus or DesignBuilder software.

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INTRODUCTION

In this century, population and technological have been rapidly expanding and it is forecast that the urbanization will grow up to 60% by 2030 and continue to 70% by 2050, which will lead to an increase in the need for energy consumption (Ohene et al., 2023) and the International Energy Agency (IEA) in World Energy Outlook (2014) approved it (Baydoğan & Özkantar, 2023). However, the majority of the energy produced up until now has come from fossil fuels such as coal, gasoline, diesel, and natural gas which it has caused environmental, security, social crises, energy price fluctuations (Ahmadi-Kaliji et al., 2023) and conflict (Zhou et al., 2023) issues. Jerry L. Holechek et al. investigate the feasibility of transitioning from fossil fuels to RESs by 2050, this study evaluates the effectiveness of eight distinct pathways to eliminate fossil fuel use completely by 2050, depending on whether energy demand remains constant at 2020 levels renewable energy production will need to be increased by up to 6-fold or increased

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50% from the 2020 energy demand level the production of renewable energy should be increased 8-fold (Holechek et al., 2022). Buildings, which include residential, commercial, administrative and entertainment facilities, fulfill the essential needs of humans such as shelter (Perrucci & Baroud, 2020) and housing, responsible for approximately 40% of global energy consumption and 28% of carbon emission (Clarke et al., 2023). This significant figure emphasizes the necessity and importance of reducing energy consumption in the building sector (Bjelland et al., 2024). To address this issue, researchers and governments have introduced new concepts such as sustainable building performance (Hafez et al., 2023) , Passive design building (Elaouzy & El Fadar, 2022), green building (Jahangir et al., 2022; Mohammed et al., 2023), zero energy buildings (Tirelli & Besana, 2023) and NZEB (Net Zero Energy Building) review articles (Christopher et al., 2023). The factors that influence energy consumption in buildings include building envelope (Wilberforce et al., 2023), occupant behavior (Ahmed et al., 2023) (Xu et al., 2023), indoor thermal comfort (Qin et al., 2023), building operation Heating, Ventilation, and Air Conditioning (HVAC) system (De Masi et al., 2023), and the climate conditions (Ismail et al., 2021). Additionally, using RESs, such as solar, wind and geothermal (Noye et al., 2022), can help achieve zero energy goals and reduce our reliance on non-renewable sources of energy (Jaysawal et al., 2022).

Buildings can be classified into two groups: permanent and temporary (Lines et al., 2022). Permanent (traditional) buildings often require more substantial investments of time, money, labor, spanning from pre-design stages to completion and constructed by masonry material, while temporary buildings are a flexible and versatile solution that can be offsite fabrication (Boafo et al., 2016) easily to transport, quickly assembled, disassembled, or relocated (Tumminia et al., 2018).

Prefabricated temporary buildings has increased due to their alignment with various features, which can generally be visualized by the principles of modular design (Ferdous et al., 2019b), reducing the environmental and energy footprint (Satola et al., 2020), cost-effective construction (Montalbano & Santi, 2023), trends migration (Ling, 2021), different application, isolated structures in remote areas (Albadra et al., 2020), providing immediate housing and shelter in response to emergencies (Paparella & Caini, 2022), such as natural disasters (Milovanović et al., 2022) or man-made conflict (Zhou et al., 2023).

A considerable number of NZEB (Net Zero Energy Building) review articles (Garzón-Juan et al., 2022; Santos-Herrero et al., 2021; Wei & Skye, 2021), are devoted to permanent buildings or general definitions and a few also focus on nearly Zero Energy Temporary Buildings (nZETB) (Reddy et al., 2024). The purpose of this paper is to review the current standards, definitions and scientific contributions that address the nZETB.

METHODOLOGY

The purpose of this work review is to provide an explanation of the nZETB concept, its definition, and important parameters to achieve it. In general terms, two design approach are involved in nZETB: reducing the need for energy in temporary buildings and the other one incorporating Renewable Energy Source (RES). To conduct this review, scientific journals were searched using relevant keywords “Prefabricated Houses”, “Temporary Housing”, “Temporary Building”, “Temporary Habitation”, “Mobile Metallic Housing”, “Shipping Container”, “Temporary Shelters”, “Container House”, “Container Mobile Housing”, Lightweight Steel Frame (LSF)(Moga et al., 2022a), “Sea Containers”, “Industrial Building”, “Emergency House”, “Lightweight Relocatable Construction” (Atsonios et al., 2019a) by focused on NZEB or ZEB from year of 2016, but the most of them from year of 2020. In the keywords reviewed in the article, Shipping Containers (SCs) are more popular considering that they can be used in temporary buildings after their service life in transportation. Therefore, for a better understanding of SCs and their standards, a brief explanation is given. SCs have transformed the world of transportation (Bertolini & Guardigli, 2020), making it more efficient and cost-effective. They were designed to withstand impact forces, weather conditions, and provide durability, leading to increased growth in the industry after the 1950s (Álvarez-Feijoo et al., 2020). The lifespan of a SCs is designed to be approximately 10-15 years for transporting goods (Suo et al., 2023). After this time, they may have dents, scratches, or deformations, making them suitable for storage or repurposing. Approximately 300 million disused SCs worldwide (Álvarez-Feijoo et al., 2020), so it is essential to find new applications for them to save energy and reduce waste (Casson et al., 2020). SCs offer several advantages, including effective use of space, robustness, modularity, configurability, and recyclability. These characteristics make SCs (Paparella & Caini, 2022; Zafra et al., 2021) an attractive option for repurposed for various uses such as storage facilities, hotels, schools, residential homes, shopping centers, and more (Moga et al., 2022a). Philip Clark in 1987 filed a patent for the conversion used SCs into livable buildings, paving the way for hundreds of SCs homes around the world (Taleb et al., 2019). However, before converting a container into a livable home, it must be repaired and undergo changes to ensure proper air tightness, TIL, and other necessary modifications so lifespan can be extended over 50 years (Dara et al., 2019).

• **NZEB definitions:** As mentioned above, buildings, both permanent and temporary, are energy consumers all over the world, therefore, sustainable energy supply for buildings and their residents, especially temporary buildings are very importance. To reduce energy consumption in buildings, NZEB terminology have been defined (Pless & Torcellini, 2010). Research on NZEB began around 2000 (Wilberforce et al., 2023), and the first time was introduced in 1976 by Esbensen and Korsgaard at the Technical University of Denmark during research into solar energy utilization for domestic purposes in the cold season with the term "zero energy house (Feng et al., 2019). NZEBs have been developed for various purposes, such as environmental, economic, and energy efficiency goals. There are different common terminologies for this field explained by Wei W et al. (Wei & Skye, 2021).

• **Net zero site energy:** refers to the energy produced and consumed by the building is the same at the site, regardless of the source of that energy.

• **Net zero source energy:** refers to a condition where for every unit of energy consumed, an equivalent unit of energy is produced, considering both source energy losses and distribution losses.

• **Net zero emissions:** refers to buildings that produce no net carbon emissions. This is achieved by minimizing energy consumption, using renewable energy sources, and offsetting any remaining emissions.

• **net zero cost energy**: refers to the utility bills of buildings are free of charge. the building capable of achieving energy income by selling on-site generated energy to cover the paid energy expenses.

Characteristics impacting nZEB efficiency

Climate and Geographical Characteristics

The climate plays a crucial role for researcher, architects, and engineers in making informed decisions about building design (Jayalath et al., 2024) , strategy to energy efficiency of HVAC systems, and so to approach of nZEB and nZEBT (Skandalos et al., 2022). There are two main classification systems used to divide the Earth's climatic zones: the ASHRAE (Chu et al., 2022) and the Köppen (Gupta et al., 2023a). The Köppen classification system has five primary groups: tropical, arid, temperate, cold, and polar, coded as A, B, C, D, and E, respectively. These groups are further subdivided based on precipitation and temperature into categories such as desert, steppe, fully humid, summer dry, winter dry, monsoonal, hot arid, cold arid, hot summer, warm summer, cool summer, extremely continental, and polar frost, coded as W, S, f, s, w, m, h, k, a, b, c, d, and F (Congedo et al., 2021),(Gupta et al., 2023b). The ASHRAE 169–2020 climate classification divides the climate into eight main zones: Very Hot, Hot, Warm, Mixed, Cool, Cold, Very Cold, and Subarctic (Ashrae, 2021). These zones are defined by numbers and letters: the numbers signify thermal climate zones, while the letters represent the moisture zones. Table 1 presents the details of the climate classification used in the review articles.

Building envelopes function as boundaries and barriers between internal and external spaces, serving to block and control the negative effects of the external environment while providing comfortable conditions for occupants. The building envelope includes walls, roofs, floors, doors, windows, and other openings, each with specific thermo-physical properties. Thermo-physical phenomena, such as heat transfer, play a significant role in energy loss from the envelope, impacting the temperature and comfort thermal inside living spaces (Zheng et al., 2022). Therefore, strategies used to improve envelope such as absorb or reflect solar (thermal) by coating, paint, smart window (Chan et al., 2022), shading or thermal transfer such as TIL (Asghari et al., 2024), external living wall systems (LWSs) (Nan et al., 2020b), thermal bridge, air tightness, using high-performance glazing (De Masi et al., 2023). Dara et al. (Dara & Hachem-Vermette, 2019) focused on passive design parameters to improve the energy efficiency of the building envelope such as TIL, rate of changes in infiltration, window assemblies (triple pane, low-e, argon-filled), window-to-wall ratio (WWR), thermal mass, solar shading control with blinds and overhangs, building orientation, and PCM the improved case could reduced 79% in annual energy consumption.

The external wall, roof, and floor of a building constitute a significant portion of the building envelope, with approximately 30% of overall energy use attributed to heat loss from the exterior wall and 8-10% from the roof so heat transfer from external walls is a critical point for energy conservation in buildings. Several factors influence heat loss from the wall, such as the orientation, WWR, and thermal resistance of wall materials, fenestration, thermal bridge. Table 2 summarizes typical studies and the main conclusions on the energy saving of nZETB.

The best technique in the envelope for achieving NZEB is decrease the heat flow rate and Thermal Energy Storage (TES)by using TIL and PCM (Garzón-Juan et al., 2022). TIL and PCM can be installed alone or toghether on the envelope in different location such as outside, middle, and inner. Each position has its advantages and disadvantages. Table 2 depicated Various studies have evaluated different TIL and methods for container buildings.

- *opening*

Windows play a critical role in enhancing comfort conditions by providing desired levels of daylighting and ventilation. However, they also contribute to thermal losses, accounting for approximately 40% of the overall energy consumption in a building (Norouziasas et al., 2023). The material used in the frame and glaze (Zhang et al., 2021), glazing coated, double or multiple-pane, orientation (window placement) (Satola et al., 2020), and WWR are important factors reduce heat loss and energy-efficient windows. Opening placement is influenced by climate and location (Zhang et al., 2021).

Thermal bridges in a building reducing energy efficiency by allow heat to easily transfer from the inside to the outside or vice versa. Thermal bridge bypassing TIL and structural damage due to water vapor condensation on the interior (Milovanović et al., 2022). Numerical method showes the behavior of the thermal bridge, and Infrared Thermography (IRT) method for testing and finding thermal bridges in the envelope of built buildings (Tkalčić et al., 2023). It involves scanning the building envelope and identifying thermal bridges. IRT is a non-destructive method and can be performed in-situ.

Airtightness and ventilation

Airtightness refers to the prevention of air infiltration or exfiltration into the control

Table 1. A summary of different location used to NZEBT study review

Autor Ref.	**Region**	**City**	**Climate Classification**	**Climate Code**
(Zafra et al., 2021)	Philippines	Tacloban	*	Cfa
(Song et al., 2023)	China	Nanjing	*	Dfa
(Sarmento et al., 2024)	1. Cuba 2. Canada 3. Russia	1. Punta de Maisi 2. Toronto 3. Yakutsk	Köppen	1. Aw 2. Dfa 3. Dfd
(Lingfan et al., 2024)	China	1. Lhasa 2. Harbin 3. Guangzhou	*	1. BSk 2. Dwa 3. Cfa
(Álvarez-Feijoo et al., 2020)	Spain	1. Alicanet 2. Bilbao 3. La Coruna 4. Las Palmas 5. Madrid 6. Valencia	Köppen	1. BSh 2. Cfb 3. Csb 4. BWh 5. Csa 6. BSk
(Shen et al., 2020)	European	1. Berlin 2. Stockholm 3. Rome	*	1. Cfb 2. Dfb 3. Csa
(Milovanović et al., 2022)	Croatia	1. Gospi´c 2. Zagreb Maksimir 3. Split Marjan 4. Hvar	Köppen	1. Cfb 2. Cfa 3. Csa 4. Csa
(Koke et al., 2021)	1. Germany 2. Sweden 3. Ethiopia	1. Berlin 2. Stockholm 3. Addis Ababa	ASHRAE	1. Cfb 2. Dfb 3. Cwb
(Taleb et al., 2019)	Egypt	Aswan	*	Bwh
(Suo et al., 2023)	China	Guangzhou	Chinese national standard	Cfa
(Jia et al., 2021)	China	1. Anda 2. Lanzhou 3. Kunming 4. Xiamen 5. Wuhan	Chinese national standard (GB50176-2016)	1. Dwa 2. Dfa 3. Cfb 4. Cfa 5. Cfa
(Tumminia et al., 2018)	Italy	Messina - Sicily	Meteonorm	Cfa
(Satola et al., 2020)	China	Shanghai	ASHRAE	Cfa
(Vega et al., 2022)	Chile	Antofagasta	Koppen	BWk
(Nan et al., 2020a)	China	Hangzhou	Koppen	Cfa
(Schiavoni et al., 2017)	Italy	Perugia	*	Cfa
(Kristiansen et al., 2021)	China	1. Guangzhou 2. Shanghai 3. Kunming 4. Lanzhou 5. Harbin	Koppen	1. Cfa 2. Cfa 3. Cwb 4. BSk 5. Dwa
(Naji et al., 2021)		1. Melbourne 2. Sydney 3. Perth 4. Mildura 5. Alice Springs 6. Darwin	Koppen	1. Cfb 2. Cfa 3. Csa 4. BSk 5. BWh 6. Aw
(Maracchini & D'Orazio, 2022)	1. Italy 2. Brazil 3. India	1. Ancona 2. Sao Paulo 3. New Delhi	Koppen	1. Csa 2. Cfa 3. CWa
(Nan et al., 2020b)	China	Hangzhou	Koppen	Cfa
(Ulloa et al., 2017)	1. Haiti 2. Yibuti 3. Uruguay 4. Russia 5. Chile	1. Port-au-Prince 2. Yibuti 3. Colonia 4. Yakutsk 5. Puerto	Koppen	1. Aw 2. Bwh 3. Csa 4. Dfa 5. Cfc
(Zukowski, 2022)	Poland	North-eastern	Koppen	Dfb
(Rapone et al., 2024)	Netherlands Italy	1. Amsterdam 2. Florence	Koppen	1. Cfb 2. Cfa

Continued Table 1. A summary of different location used to NZEBT study review

(Figaj et al., 2024)	1. Germany	1. Hamburg	Koppen	1. Cfb
	2. Netherlands	2. Amsterdam		2. Cfb
	3. Greece	3. Athens		3. Csa
	4. Spain	4. Barcelona		4. Csa
	5. Norway	5. Bergen		5. Cfb
	6. Germany	6. Berlin		6. Cfb
	7. Romania	7. Bucharest		7. Cfa
	8. Hungary	8. Budapest		8. Cfa
	9. Italy	9. Cagliari		9. Csa
	10. Denmark	10. Copenhagen		10. Cfb
	11. Poland	11. Krakow		11. Cfb
	12. Ireland	12. Dublin		12. Cfb
	13. Sweden	13. Gothenburg		13. Cfb
	14. Finland	14. Helsinki		14. Dfb
	15. Turkey	15. Istanbul		15. Csa
	16. Portugal	16. Lisbon		16. Csa
	17. UK	17. London		17. Cfb
	18. SPAIN	18. Madrid		18. BSk
	19. France	19. Marseille		19. Csa
	20. Italy	20. Milan		20. Csc
	21. Italy	21. Naples		21. Csa
	22. France	22. Paris		22. Cfb
	23. Czech	23. Prague		23. Cfb
	24. Italy	24. Rome		24. Csa
	25. Bulgaria	25. Sofia		25. Cfb
	26. Sweden	26. Stockholm		26. Dfb
	27. Finland	27. Tampere		27. Dfc
	28. Poland	28. Warsaw		28. Cfb
(Ye et al., 2022)	China	1. Guangzhou 2. Kunming 3. Shanghai 4. Beijing 5. Yinchuan	Chinese Standard Weather Data (CSWD)	1. Cfa 2. Cfb 3. Cfa 4. Dwa 5. Dwa
(Tong et al., 2022)	China	Beijing	Chinese national standard	Dwa
(Adilkhanova et al., 2021)	Kazakhstan	1. Nur-Sultan 2. Karaganda 3. Kokshetau 4. Almaty 5. Aktobe 6. Atyrau	Koppen	1. Dfb 2. Dfb 3. BSk 4. Dfa 5. Dfa 6. Bwk
(da Costa et al., 2023)	Brazil	1. Uberlândia	*	Aw
(Noaman & El-Ghafour, 2024)	Turkey Pakistan	1. Diyarbakir 2. Karachi	ASHRAE	1. BSk 2. BWh
(Dara et al., 2019)	Canada	Calgary	*	BSk
(Salvalai et al., 2020)	Switzerland Italy Burkina Faso	1. Zermatt 2. Lecco 3. Pô		1. Dfb 2. Cfa 3. Aw
(Asfour, 2019a)	Palestine	Gaza		BSh

Envelope

volume of from the building envelope. Air flow in or out of a building is one of the elements of heat transfer, and airtightness is the best and simplest choice for preventing air flow from the envelope, such as cracks and opening but ensure that improvements in airtightness do not adversely affect other factors such as ventilation and indoor air quality (Al Mindeel et al., 2024). Infrared thermography and blower door testing are two methods used for in-situ measurement of leakage from the building envelope. The blower door test, also known as the fan pressurization method, is used to calculate the amount of air leakage at 50 (Pa) and determine the level of airtightness. In one experimental study (Tanyer et al., 2018) the air leakage and thermal failures of four types of container homes commonly used in Turkey were examined using both blower door testing and infrared thermography. The study found that air leaks and thermal bridges from the junctions of the envelope, such as floor, wall, slab connections, and edges, as well as voids or holes in the envelope, can significantly impact the energy performanceof container homes. Moreover, in table 3, several papers were reviewed.

Table 2. A summary of assessment of envelop used to NZEBT studies review

Ref Author	**Type of Application**	**Analysis Method /BEPS tool**	**Strateg Assessment**	**Considered Criteria**	**Description and Main Findings**
(Salvalai et al., 2020)	Alpine Shelter Open lab Shelter	Simulation TRNSYS	TIL	Decrees u-value	The energy requirements for the students' lab, the Alpine shelter, and the emergency shelter were minimized to 14.13, 23.88, and 41.83 kWh/m^2 per year, respectively.
(Moga et al., 2022b)	Residential PTB	Experimental Simulation PSIPLAN	TIL	Linear thermal transmittance	TIL is the recycled-PET. Evaluate two-dimensional numerical the connections of the PTB envelope.
(Song et al., 2023)	Residential PTB	Simulation EnergyPlus	Materials TIL Air gap	• Types of materials • Types of TIL • Locations of TILs • Air gap thickness	Generate 1344 design schemes. Fiber cement and rock wool board are preferred for the outer and inner layers, respectively. Set a 30–40 mm air gap between the exterior and inner TIL.
(Ulloa et al., 2017)	First Aid Shower Refrigeration SCB	Simulation TRNSYS	Climate Application	• Q sensible emperature inside	Considered the values of thermal capacitances. Demand of heat and cold are analyzed. Q sensible and temperature inside in five location and three applications.
(Jia et al., 2021)	Unknown PTB	Simulation EnergyPlus	PCM	• Types PCM • Locations in wall • Direction • Thickness	Placing PCM inside the envelope is better. PCM on the west or east wall is better. Cetane PCM was the best among other kinds. Thicknesses of PCM were related with climate.
(Lingfan et al., 2024)	PTB	Simulation DesignBuilder	PCM Orientation	• Types PCM • Location in wall • Thickness • Orientations	Melting temperature12 to 32 °C. Thickness 15, 35, and 55 mm was considered. Positioning indoor PCM by melting temperature range of 18–22° C, better than external placement. Thicker PCM in warmer climates was employed. In moderate and cold climates, increasing the insulation thickness might prove more effective than adding a thick PCM layer. Orientation 0°, 90°, 180°, 270° didn't significantly affect. The maximum difference is around 2.5 %.
(Figaj et al., 2024)	Residential Container Houses	Simulation TRNSYS	Modular Configuration	• Single Module • L-Shaped Module • Stacked Module	Analysis of the energy efficiency of various configurations in thirty European locations.
(Sarmento et al., 2024)	Residential PTB	Experimental Simulation EnergyPlus	Finishings Shading TIL	• Different finishing colors • Different thickness of TIL • Shading along the whole wall.	Different colors are painted on the envelope. Six different thicknesses Polyurethane (PUR). 1 m of shading with 30° of inclination. Energy savings with shading and finishing led to up to 32% in Cuba, 14% in Canada, and 2% in Russia.
(Milovanović et al., 2022)	Residential PTB	Numerical	Orientation	• Orientation north, east, south, west	Orientation related on the climatic conditions. Orientation affects transparent openings.
(Taleb et al., 2019)	Residential PTB	Simulation IES	TIL Glazing Green envelope	• Courtyard as a passive cooling • Double glazing • Green envelope	The annual cooling load was decreased from 21.8 MWh to 15.5 MWh by using a courtyard. Foam sandwich walls and Glass Reinforced Concrete had the same performance. Green envelope reduced the cooling load 13.5%.
(Kristiansen et al., 2020)	Residential SCB	Experimental Simulation IDA ICE	TIL Glazing	• Adding VIP • Glazing window	8 mm VIP adding wall & roof thermal transmittance from 1.0 to 3.7 m^{2}K/W and energy reduced 40 %. Increase thermal transmittance of the windows.
(Asfour, 2019b)	Residential SCB	Simulation DesignBuilder	Modular Configuration Finishing(color) TIL	• Joining SCB • Considering light and dark pain. • Different TIL	The solar absorption factor decreased from 0.6 to 0.3, temperature reduction of about 1.5 degrees Celsius in summer, with no change in winter. Consider on SCBs, then join 2 SCBs and last 3 SCBs to accommodate different family sizes.
(Ye et al., 2022)	Residential PTB	Simulation EnergyPlus	TIL PCM	• Thickness • Orientation and • Temperature	Effect of thickness of parameter related to different climates. In Beijing, the wall with 100 mm TIL and 90 mm TIL with 10 mm PCM provided thermal comfort for 803 hours and 1511 hours, respectively.
(Zafra et al., 2021)	Residential SCB	Simulation EnergyPlus	TIL Orientation	• R-value • Types of TIL • Orientation	Increasing the R-value of TIL and orientation of the SCBs had no effect on the internal thermal condition.
(Tong et al., 2022)	Office PTB	Experimental Simulation EnergyPlus	TIL	• Material of TIL • Thickness of TIL	Rock well (RW), XPS, PU VIP reduced heating energy by 21.4-32.8%.
(Satola et al., 2020)	Residential SCB	Simulation TRNSYS HOMER Pro	TIL Glazing	• R-value • WWR • Thermal transmittance and SHGC	Reducing: thermal conductivity of envelop to 0.1 W/m^{2}K, south-oriented glazing to 2.85 m^2, thermal transmittance of the windows to 0.71 W/m^{2}K, SHGC of the windows to 0.36, energy consumption reached heating 428(kWh) and cooling 643 (kWh)
(Vega et al., 2022)	Camp PTB	Simulation EnergyPlus	PCM	• Envelope	Reduction of energy consumption 52.8% in Antofagasta and 36.3% in Calama

Continued Table 2. A summary of assessment of envelop used to NZEBT studies review

(Marin et al., 2016)	PTB	Simulation EnergyPlus	PCM	• Envelope	PCM increased the performance of energy demand. The board is filled with 18% microcapsules.
(Nan et al., 2020b)	* PTB	Experimental	LWSs	• Orientation and quantity of LWS. • Different plants.	External LWSs improve the energy efficiency and indoor thermal environments. The plants and soil-filled planter pots played the role of TIL.
(da Costa et al., 2023)	Residential SH	Simulation eQuest	TIL	• Type of TIL	TIL used in the inner of the wall. Mineral wool reduced cooling load. In Uberlândia city, PET reduced the consumption of electricity by 30.98%, while with mineral wool achieved an annual reduction of 42.80%. In Macaé city, the reduction in electricity consumption with PET wool was 28.69%, and with mineral wool was 44.99% within a year. PET wool better than mineral wool.
(Trancossi et al., 2020)	Residential PTB	Simulation TerMusG RetScreen Parasol v.6.7	TIL Glazing solar-Thermoelectric heat pump	• Material TILs • Thickness TILs • Configurations of window openings • Solar Shading • Trombe wall	The best solution incorporating sandwich walls with high-performance VIP. Seasonal shading optimized transparent elements. High performance window is adopted. Methods were considered: 1. solar heating. 2. NVS with solar heating. 3. Heat is stored in the thermal mass. 4. Reduce heat transfer by lowering the temperature of the storage wall.
(Shen et al., 2020)	Residential container	Simulation EnergyPlus	Glazing	• Low-mass construction	passive solar direct gain by using the low-mass construction material and windows sun shading.
(Suo et al., 2023)	Residential container houses	Simulation EnergyPlus	TIL Glazing Orientation	• Material TILs • WWR • Orientation	Mineral wool performed better in response to future climate conditions compared to expanded pearl and vermiculite of TILs.
(Noaman & El-Ghafour, 2024)	Residential SCB	Simulation DesignBuilder	Envelope Glazing Shading	• Different material envelope • WWR • Windows opening ratio • Glazing type • shading	In hot climates, use TIL and thermal mass, but avoid using them in mixed climates. Overhangs are used on south-facing windows, and vertical fins are used on north and west-facing windows. The ratio of window openings was reduced from 100% to 5%. Glazing was changed to double and triple, altering the SHGC and U-value. Internal venetian blinds were applied for windows.
(Dara et al., 2019)	Residential PTB	Simulation EnergyPlus	PCM TIL ACH Glazing Overhang	• Adding PCM • Decrees ACH • Increase WWR • Increase overhang	Incorporating 30% paraffin wax of PCM with in gypsum board of the walls and ceiling. Incorporating 100mm concrete slab on the main floor as thermal mass improving TIL for roof and wall assembly ACH 2.5 decrease to 0.6 at 50 Pa. Increasing the glazing on south façade to 40%. Introducing window overhangs and interior blinds. Total energy consumption SCB (71,514 to 25,672 and in Lightwood from 73,678 to 26,329 (kWh)
(Adilkhanova et al., 2021)	Residential PTB	Experimental Simulation DesgnBuilder	PCM	• Different type of PCM	PCM PTB combined with the natural ventilation. PCMs with melting temperature of 26°C, 28 °C, 30 °C, and 32 °C, the latent heat of is 219 kJ/kg. PCM 26 + NV showed the investigation revealed that RT 26 + NV was the most efficient in all cities the best performance achieving efficiency values were up to 39.1%.
(Maracchini & D'Orazio, 2022)	PTB	Simulation DesignBuilder	• Passive cooling • Shading	• Shading • Thermal buffering • Cooling roof	The efficacy depends on climate, NVS, cool roofs, or blinds. Consider the best trade-off between feasibility, costs, and thermal comfort.
(Schiavoni et al., 2017)	SCB	Simulation Designbuilder DIALux	External coating	• Corian • Corten • Plywood	Increasing the volume of SCB, increases energy consumption. The ratio of surface to volume influenced the thermal behavior. Plywood could provide high performance.
(Zukowski, 2022)	Residential PTB	Simulation Designbuilder	Shading Glazing Orientation	• Overhang on the south. • WWR	The PVs and sliding structure provide shading. Air-to-air heat pumps and GSHP are used for ventilation and heating. SHGC are reduced by up to 30% with overhangs on the south. Insulated frames, triple-glazing, and low-emissivity coatings were considered.
(Rapone et al., 2024)	Residential PTB	Simulation Designbuilder	• TIL • PCM • Coatings	• Type PCM	Electrochromic Coatings wall and window VIP increases Three different melting points PCM. Thermochromic Coatings wall and window. Electrochromic Coatings Wall and Window.

Thermal bridge

Table 3. Comparative results of container airtight-ventilation studies reviewed

Ref. **Author**	**Type of Application**	**Strategy Assessment**	**Finding**
(Lin & Cheng, 2020)	Residential *	NVS	Openings of the asymmetric window had the best NVS effect.
(Tanyer et al., 2018)	Office *	Airtightness	Improve thermal bridge and airtight with tapes seal of junctions and edges. Total energy consumption was reduced9.3%.
(Suo et al., 2023)	Residential *	ACH	An ACH range of 0.5 to 1.5 is explored for future climates in the 2050s and 2080s.
(Noaman & El-Ghafour, 2024)	Residential PTH	NVS	Opening ratio of 35% with a WWR of 9%-25% for south and north facades, and 6%-12% for west façade
(Ye et al., 2022)	Residential PTH	NVS	ACH considered 0, 2, 4 ,6, 8, 10 Higher ventilation rates increased thermal comfort and reduced energy demand in Guangzhou, but not in Kunming.
(Maracchini & D'Orazio, 2022)	* PTB	NVS	Occupants manually control the opening of the windows. The performance results are better in São Paulo with high wind speed, New Delhi with high thermal gradient and worst in Ancona with low wind speed.
(Zafra et al., 2021)	Residential SCB	NVS	Effect of Fully closed, open or scheduled opening Checked. Scheduled NV, or closed windows increases both the indoor temperature and indoor relative humidity.
(Milovanović et al., 2022)	Residential PTB	Thermal Bridge	The U-value with steel studs rises from 28.4% to 41.6%, so it is covered by TIL. For free moisture condensation, the values are below 0.1 W/(m·K) in all cases. Thermal bridges have a significant impact on heating energy demand, but not on cooling energy demand.
(Atsonios et al., 2019b)	* PTB	Thermal Bridge	Calculated all linear and point thermal bridge configurations and VIPs decrease 50% thermal bridge by metal studs and reduces condensation inside the envelope.
(Zukowski, 2022)	Residential PTB	NVS	With NV rates of 0.2 and 1.2 ACH, the indoor temperature dropped by 10°C and 3°C, respectively.
(Adilkhanova et al., 2021)	Residential PTH	NVS	8 ACH rate was considered PCMs +NV increase the period of comfort hours. During summertime, PCM+NV showed an optimum configuration, reducing the discomfort conditions.
(Rapone et al., 2024)	Residential PTH	NVS	ACH rates were from 0.7 to 2, 3 and 4.
(Kristiansen et al., 2020)	Residential SCB	NVS MVS HVS	NVS provided indoor air quality comparable to MVS through thermal recovery, with a 7% higher annual energy demand for HVAC. HVS had the lowest energy demand, with an 11% change compared to NVS in a subtropical climate.

Conclusions and suggestions for future works

The ventilation system in buildings is essential for maintaining adequate Indoor Air Quality (Su et al., 2023). Ventilation systems serve several purposes, including providing fresh air with oxygen for occupants, diluting bioeffluent and harmful chemical concentrations, promoting a healthy environment and comfort through proper air distribution, controlling indoor humidity, temperature and controlling the concentration of aerosols (Mata et al., 2022). Assessing CO_2 concentrations is crucial, and it is recommended that they remain below 1,000 ppm to improve residential performance (López et al., 2023). Heat recovery can minimize heat loss from air extraction to the atmosphere and increase fresh air supply (Liu et al., 2023).Ventilation systems can be categorized into three types: Natural Ventilation System (NVS), Mechanical Ventilation System (MVS), and Hybrid Ventilation System (HVS) (Tognon et al., 2023). Lin et al. studied the effect of air change rate by position of openings with CFD simulations on eight basic models (Lin & Cheng, 2020). Moreover, in table 3, several Ventilation systems consider in paper were reviewed.

nZEBs represent a forward-thinking approach to minimizing energy consumption. Buildings can be categorized into two main groups: permanent and temporary. The purpose of this literature review is to explore the concept of nZETBs. The main findings of this literature review and recommendations for future research can be summarized as follows:

- Temporary building offers many benefits over traditional building, including high strength and durability, cost-effectiveness, energy conservation, environmental protection, and ease of installation, disassembly, and movement.
- Temporary buildings serve as safe and secure spaces for homeless people during natural disasters, conflicts, rapid urbanization, crises, and economic problems. They can be adapted from hotels, schools, residential homes, shopping centers, offices, and more.
- Climate plays a crucial role in designing energy-efficient buildings. Proper analysis and modeling of climatic conditions enable architects and designers to make informed decisions and optimize building performance strategies. Most research has focused on the Cfa (25 cases) and Cfb (24 cases) climate classifications, while the least amount of research has been conducted on the Dwa, Dfa, Aw, and Bwh classifications, each represented by a single case study.
- Optimizing the building envelope with techniques like TILs, PCM depends on factors such R-value, melting temperature, thickness, and position. These optimizations have led to energy reductions of up to 45% with TILs and 53% with PCM.
- Openings are a critical element of heat loss from buildings. The materials used in the frame and glazing, sunlight, orientation, and WWR are important factors that influence heat loss.
- Thermal bridges in a building allow heat to easily transfer from the inside to the outside or vice versa. Proper insulation, air sealing, and the use of thermal break materials can minimize their impact.
- Airtightness is the best and simplest choice for preventing air flow from the envelope and has been investigated up to 10 ACH. Infrared thermography and blower door testing, can be used to measure and improve airtightness.

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CONFLICT OF INTEREST

The authors declare that there is not any conflict of interests regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/ or falsification, double publication and/or submission, and redundancy has been completely observed by the authors.

LIFE SCIENCE REPORTING

No life science threat was practiced in this research.

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