Zero Energy Buildings Concept-Definition Review for Latin America

Subjects: Others
Submitted by: Miguel Chen
Austin

Definition

In recent decades, European countries have developed concepts, definitions, and construction technologies for Zero Energy Building (ZEB) that are effective and correspond to their specific climates. Latin American countries are still trying to find adequate solutions which respond to the local climatic, cultural, social, technical, and economic context. As such, this paper aims to establish the basis of the minimum energy efficiency and the renewable threshold for the definition of ZEB in order to better understand the application in Panama, based on assessing the energy regulations implemented in Panama. To achieve this aim, a review concentrated on the concept-definition and implementation adopted by Latin American countries is presented first before the paper converges into defining a framework for application in Panama. Finally, a case-study-based theoretical framework proposing a ZEB definition for Panama is discussed. The results of this study showed a net primary energy balance, of which the range falls into a plus energy building definition, indicating that all of the cases studied could supply their electricity needs using Photovoltaic generation. All dwellings studied have the potential to become a plus energy building, depending on the available roof surface area. Finally, a strengths, weaknesses, opportunities and threats analysis is presented in order to assess and support the introduction of such a ZEB definition and framework.

1. Introduction

Climate change is a problem that has received substantial interest. To mitigate greenhouse gas (GHG) emissions, the cooperation of different sectors is important; alliances, such as Paris Agreement and the Marrakesh Agreement, and the 17 sustainable development goals have established goals for decreasing GHG emissions. This is because greenhouse gas emissions impact the economy, society, and the environment [1].

In recent years, the effects of climate change have been causing disasters in different countries. The effects of global temperature and greenhouse gas emissions have increased drastically. In the European Union (EU), the building sector is responsible for approximately 40% of the total energy consumption and the EU is forecasting additional expansion [2]. As such, techniques in the construction of residential, hospitals, offices, and commercial buildings can help to mitigate the impacts in the building sector. The European Community began implementing the concept of Net-Zero Energy Buildings (NZEB) and new policies for the construction of new buildings. European policies are focused on reducing energy consumption in buildings in order to achieve the EU 2020 goals [3], and by 2050, all major business sectors must operate in a state of zero carbon emissions [1]. According to the member states of the EU, the implementation of NZEBs represents one of the biggest opportunities for increasing energy savings and reducing greenhouse gas emissions.

The EU legislative framework has been significantly strengthened in recent years through changes to the Energy Performance of Buildings (EPBD, 2010/31/EU) and the Renewable Energy Directive (RED, 2009/28/EC). Both directives outline the conditions needed to achieve nearly Zero Energy Buildings (nZEB) by 2020, and all member states must integrate these requirements into national legislation, as well as setting appropriate market instruments and financial frameworks to allow for the wide implementation of these ambitious targets [4]. A minimum energy efficiency threshold has been implemented in European countries, using proposed indicators [5] to effectively move towards nZEB in a more robust framework.

The progress and implementation of NZEBs around the world have different indicator values depending on their climate, the concepts that have been developed, construction techniques. As such, there is still a gap concerning national NZEB definition.

Each country must develop its own NZEB concept. In this way, new designs can be developed to reduce the amount of energy used in new buildings. Different studies present definitions for NZEB [4][6][7][8], and these differ according to the regulations and climatic conditions of the country in question.

Some countries in Europe have not yet settled on a regulation or clearly defined concept of NZEB. Romania and Portugal both presented problems, such as the absence of professional knowledge in the design and construction of NZEBs, an absence of local construction materials to scope a high standard, and the absence of local HVAC equipment to allow for high energy performance [9].

In Greece, the contribution of a new Building Energy Performance Regulation (REPB) was analyzed in a case study focusing on two residential buildings: a single residence and building with multiple residences (15 apartments) [10]. Here, the requirements set before by the regulation of thermal insulation and after the application of the REPB for the four climates zones of Greece were examined. The assessment was based on a numerical analysis using the national calculation tool for building energy performance, “TEE KENAK”, and the Technical Guidelines of the Technical Chamber of Greece. The results show that the implementation of the REPB significantly reduced the required heating loads for space heating in all climate zones by 37% to 48% for both building types. This was mainly attributed to the reduction of heat transfer coefficient (U-value) of the building envelope. In addition, active strategies, such as the improvement of electromechanical systems performance by the installing of flat plate solar collectors for domestic hot water heating, produced significant energy savings, in the range of 51–58%.

In Portugal and Spain, the requirements for building renovation through the transforming of the existing buildings into nearly zero energy buildings (nZEB), were analyzed in relation to a three-story residential building through the use of numerical simulation [11]. In both countries, it was necessary to change the active systems in order to achieve nZEB requirements and to retrofit the envelope, achieving more restrictive U-values, for major renovations as good practice towards the decarbonization of the residential sector. The results showed that applying the nZEB standards to the renovation of the multi-family buildings in both countries significantly contributed to the decarbonization of the building stock for this type of building typology, with reductions of 80–96% of CO_2 emissions in Portugal and 71–94% in Spain.

2. Implementation of nZEB and NZEB in Latin America

In order to identify the different applications based on nZEB or NZEB concepts, an inspection of the literature has been carried out with the search strategy described below.

The procedure to select the final papers on this research includes five steps (**Figure 1**):

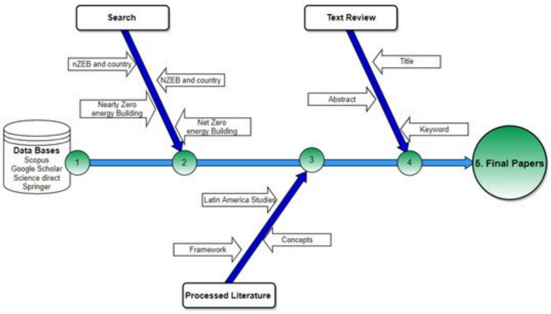

Figure 1. Search procedure for the inspection of the literature.

- To gather as many studies as possible, the use of scientific databases such as Scopus, Google Scholar, Science Direct, and Springer were selected.
- The search was performed in each of the scientific databases, applying the Boolean operators. The main co-word combinations were "nearly zero energy building," "net zero energy building," "nZEB," AND "country" OR "NZEB", in which the country represents each of the Latin American countries, with a total of 21.
- A complete review of the preselected articles in order to select those sources that provide information related to the ZEB framework, concepts, and Latin American studies.
- A full review of the title, abstract, keywords, and most relevant papers.

The criteria employed in the literature selection were: (i) Latin American studies regarding energy in building, (ii) zero energy building, and (iii) any experience in zero energy building for Latin America, with no limitation on the year of publication for the studies. The final step corresponds to the resulting list of documents. The final list of documents was analyzed by: (i) building energy efficiency regulations, and (ii) ZEB experience, with information collected on the country, climate type (city), type of ZEB, energy consumption, type of project (status), type of building, or building sector, energy-saving strategies, building area, U-values and energy generation.

Policies and regulatory measures regarding energy usage have been implemented over the last decade in Latin America. Their implementation generated a trend, which is shown in **Figure 2**. Oil and natural gas have been the principal resource supplying energy to buildings in Latin America. The residential energy consumption has increased through the years, with a 14,461 ktoe of oil, 12,349 ktoe of natural gas, and 67 ktoe of coal being consumed annually by 2017 [12][13].

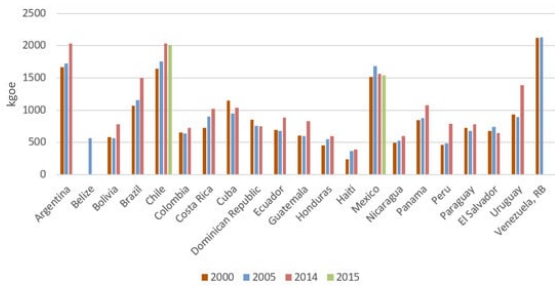

Figure 2. Energy use per year in Latin America [14].

One measure for decreasing energy consumption in buildings is the implementation of nearly zero energy buildings (nZEB) as the new building target [8]. Latin American countries, such as Costa Rica, Argentina, Brazil, Chile, Colombia, Ecuador, Paraguay, Peru, and Uruguay, have building energy efficiency regulations [15][16], and few local studies have focused on NZEB or nZEB. Sustainable building codes worldwide are on the rise, mainly because they are effective instruments to improve the efficiency of residential and non-residential buildings. The most demanding building energy codes in the world require buildings to be net-zero energy. In addition, renewable energy systems integration is being considered in these building energy codes [17][18]. **Table 1** gathers the countries in Latin America that have applied the nZEB or NZEB concept as either a preliminary study, academic study or finished project. The missing countries (Bolivia, Costa Rica, Guatemala, Honduras, Nicaragua, Paraguay, Republican Dominican, and Puerto Rico) do not appear in the literature using the nZEB or NZEB concept. In Venezuela [19] different factors were applied to compare to other cities, but the nZEB concept was not implemented in the final results.

Table 1. Countries in Latin America with experience in nZEB or NZEB.

Country	Climate Type (City)	ZEB Type	Energy Consumption Limits (U Conventional)	Energy Consumption Limits (U Improved)	Type of Project (Status)	Type of Building or Building Sector	Energy Saving Strategies	Building Area (PV Area) m^2	Ref
1 Argentina	Not Specified	NZEB	Not Specified	Not Specified	policies	Not Specified	Not Specified	Not Specified	[20]
	Cfa (Llavallol)	NZEB	321.4 heating kWh m^{-2} y^{-1}	72.7 heating kWh m^{-2} y^{-1}	Research (Preliminary study)	Commercial Office	Passive Active	750–900	[21]
	Cfa (Resistencia)	nZEB	Depending on the case	Not Specified	Research (Preliminary study)	Residential	Passive	12,000	[22]
	Cfa (Buenos Aires)	nZEB	Depending on the case	Not Specified	Research (Preliminary study)	Residential	Passive	12,000	[22]
	BwK (San Juan)	nZEB	438,856 kWh y^{-1}	87,771 kWh y^{-1}	Research (Preliminary study)	Educational	Passive Active	(387)	[23]
2 Brazil	Not Specified	NZEB	Not Specified	-	Policies	Not Specified	Not Specified	-	[24]
	Cfa (Florianopolis)	NZEB	Depending on the case	Depending on the case		Office	Active	360–25,500	[25]
	As (Fortaleza)	NZEB	Depending on the case	Depending on the case		Office	Active	360–25,500	[25]
	Af (Curitiba)	NZEB		23% less	Research (Preliminary study)			60 (17)	
		NZEB			Research (Preliminary study)				

Country		Climate Type (City)	ZEB Type	Energy Consumption Limits (U Conventional)	Energy Consumption Limits (U Improved)	Type of Project (Status)	Type of Building or Building Sector	Energy Saving Strategies	Building Area (PV Area) m	Ref
		Cfb (El Salvador)		Not Specified	42% less		Residential	Passive	60 (17)	[26]
3	Chile	Csb (Santiago)		Not Specified	15–45 kWh m^{-2} y^{-1}	Research (Preliminary Study/ finished)	Residential	Passive	Not Specified	[27]
		BWk (Antofagasta) Csb (Santiago) Csb (Concepción) ET (Punta Arenas)	nZEB	Depending on the case	Depending on the case	Research (Preliminary Study)	Residential	Passive Active	50 106 1614	[28]
4	Colombia	Not Specified	NZEB	Depending on the case	Not Specified	Research (Preliminary Study)	Residential (social dwelling)	Passive	Not Specified	[29]
		Aw (Cartagena)	NZEB	3393	1901	Research (Preliminary Study)	Residential	Passive Active	3334	[30]
5	Cuba	Not Specified	nZEB	Not Specified	Not Specified	Research (Preliminary Study/finished/ Preliminary Study)	Hotels	Not Specified	Not Specified	[31]
		Not Specified	nZEB	Not Specified	30–40% LESS	Research (Preliminary Study/finished/ Preliminary Study)	Hotels	Passive	Not Specified	[32]
		Aw (La Habana)	nZEB	230 kWh m^{-2} y^{-1}	Not Specified	Research (Preliminary Study/finished/ Preliminary Study)	Hotels	Passive	Not Specified	[33]
6	Ecuador	Cfb (Quito	NZEB	7126–178,545 kWh y^{-1}	3377–176,825 kWh y^{-1}	Research (Preliminary Study)	Residential	Passive	49.77–6300	[34]
		Cfb (Quito)	NZEB	28,625 kWh y^{-1}	Not Specified	Academic (Preliminary Study)	Residential	Not Specified	600 (284.52)	[35]
		Not Specified	nZEB	Not Specified	Not Specified	Research (In progress)	Not Specified	Not Specified	Not Specified	[36]
7	El Salvador	Aw (San Salvador)	NZEB	Not Specified	Not Specified	Project (finished)	Laboratory	Active	Not Specified	[37]
8	Haiti	Aw (Mirebalais)	NZEB	Not Specified	Not Specified	Research (finished)	Hospital	Passive	17,187	[38]
9	México	Not Specified	NZEB	Not Specified	Not Specified	Policies (finished)	Not Specified	Not Specified	Not Specified	[39]
		Not Specified	NZEB	Not Specified	Not Specified	Gathered Consortium project (finished)	Residential Office commercial	Not Specified	20,000	[40]
10	Panama	Af (Los Santos)	NZEB	Not Specified	0.72 kWh m^{-2} y^{-1}	Research (finished/ Preliminary study)	Residential	Passive	213	[41]
		Aw (Ciudad de Panama)	nZEB	516.64	Depending on the case	Research (finished/ Preliminary study)	University	Passive	218	[42]
11	Peru	Not Specified	nZEB	Not Specified	Not Specified	Project (finished)	Residential office Commercial schools, hospitals,	Not Specified	Not Specified	[43]
12	Uruguay	Cfa	nZEB	Not Specified	17–19 kWh m^{-2} y^{-1}	Project (finished)	Residential	Not Specified	280	[44]

2.1. ZEB Type and Energy Saving Strategies According to Climate

First, a classification of the type of climate has been implemented according to the Köppen climate classification. Each country presented a different climate type according to their cities. Even though there can be a variety of climate types in each country, the climate types presented here are only those that appear in the literature as having an experience with zero energy building in Latin America. Climate classification is a reference to compare with other countries and their experience, some construction materials, and regulations. In this sense, Panama can be compared to Brazil, Colombia, Cuba, Haiti, and El Salvador. The same applies to other countries with comparable climates. Panama also has another three types of climates (Cwb, Cfb, and Am), a fact which will allow for developing projects and comparing with other countries which share the same climate.

Table 1 shows ZEB's experience in Latin America in relation to the climate type, energy-saving strategies, and type of ZEB. **Table 2** and **Table 3** show, in more detail, the passive and active strategies implemented to achieve nZEB/NZEB. A tendency to apply passive strategies seems to be adopted regardless of the type of climate. This tendency follows the ZEB philosophy, as shown in **Figure 3**. In fact, it can be observed that NZEB can be reached by applying only passive solutions, regardless of the type of climate (**Figure 4**a) [22][26][27][29][32][33][34][38][41][42].

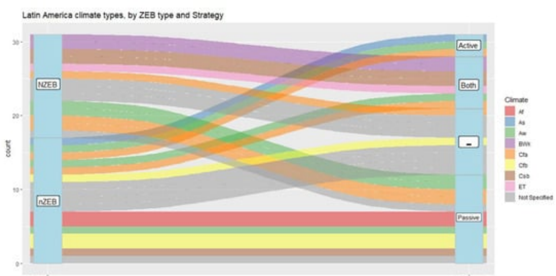

Figure 3. ZEB types arranged by climate type and strategy.

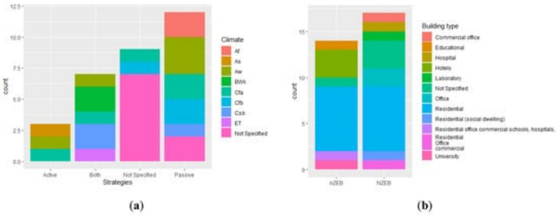

Figure 4. (**a**) Energy strategy according to climate type, and (**b**) building and ZEB type.

Table 2. Countries in Latin America Energy generation.

Country		Climate Type (City)	ZEB Type	Energy Generation	Passive Design Features	Other Active Design Features	Ref
1	Cuba	Not Specified	nZEB	Not specified	Natural ventilation	Lightning	[31]
				Solar thermal, photovoltaic systems. Small wind turbines			[32]
		Aw (La Habana)		Save 40% (92 kWh m^{-2} y^{-1})PV			[33]
2	Ecuador	Cfb (Quito)	NZEB	11,427–138,053 kWh y^{-1}	Passive solar, thermal insulation according to the climate, and high compactness	Reduced needs for heating and cooling	[34]
		Cfb (Quito)		PV	-	-	[35]
		Not Specified	nZEB	Not specified	-	-	[36]
3	El Salvador	Aw (San Salvador)	NZEB	PV	-	Lightning control	[37]
4	Haiti	Aw (Mirebalais)		PV	Light colored walls promote natural ventilation, and reflect solar radiation	Operable windows	[38]
5	México	Not Specified		Not specified	-	-	[39]
					-	-	[40]
6	Peru	Not Specified		Not specified	-	-	[41]
7	Uruguay	Cfa		PV	-	-	[44]

Table 3. Countries in Latin America U-values and energy generation.

Country		Climate Type (City)	ZEB Type	U (W m^{-2} K^{-1}) Conventional or Original					U (W m^{-2} K^{-1}) Improved					Energy Generation	Passive Design Features	Other Active Design Features	Ref
				Ceiling	Walls	Doors	Window	Floor	Ceiling	Walls	Doors	Window	Floor				
1	Argentina	Cfa (Llavallol)	NZEB	1–7	1–3	1–7	3–6	2–3	0.12	0.12	1.86	0.8	0.5	PV and Thermal	Advance envelope	Rainfall water recovery	[21]
		Cfa (Resistencia)	nZEB	0.45–0.83	1–1.10	-	<4	-	-	-	-	-	-	182 kWh m^{-2} y^{-1}	Optimized shape, natural ventilation		[22]
		Cfa (Buenos Aires)		0.45–0.83	1–1.10	-	<4	-	-	-	-	-	-	173 kWh m^{-2} y^{-1}			
		BwK (San Juan)		-	-	-	-	-	-	-	-	-	-	PV 91,400 kWh y^{-1}	Solar shading, advance envelope, natural ventilation, occupant behavior	Advanced lighting controls, load management,	[23]
2	Brazil	Cfa (Florianopolis)	NZEB	2.42	2.47	-	5.82	-	0.25	3.1	-	1.67–1.68	-	PV	-	Window systems	[25]
		As (Fortaleza)		2.42	2.47	-	5.82	-	0.25	0.39	-	1.67–1.68	-		-		
		Af (Curitiba)		-	-	-	-	-	3.74	0.96	-	-	-	BIPV	Advance envelope, optimized shape, and orientation	-	[26]
		Cfb (El Salvador)		-	-	-	-	-	3.74	3.19	-	-	-			-	
3	Chile	Csb (Santiago)		-	-	-	-	-	-	-	-	-	-	No specified	-	-	[27]
		BWk (Antofagasta)	nZEB	0.84	4	3.35	5.8	-	0.84	2.1	3.35	5.8–0.75	-	Depending on the case	Envelope modifications	Mechanical Ventilation for air quality	[28]
		Csb (Santiago)		0.47	1.99	3.35	2.8	-	0.38	0.6	1.20	2.8–0.67	-				
		Csb (Concepción)		0.38	1.7	3.35	2.8		0.33	0.5	1	2.8	-				
		ET (Punta Arenas)		0.25	0.6	3.35	1.8		0.25	0.35	0.80	1.8	-				
		Not Specified		-	-	-	-	-	-	-	-	-	-	Wind and PV	Strategic orientation, natural ventilation	Energy efficient of systems	[29]

Country	Climate Type (City)	ZEB Type	U (W m K) Conventional or Original					U (W m K) Improved					Energy Generation	Passive Design Features	Other Active Design Features	Ref
			Ceiling	Walls	Doors	Window	Floor	Ceiling	Walls	Doors	Window	Floor				
4 Colombia	Aw (Cartagena)	NZEB	3.868	4.576	-	5.85–5.91	-	-	0.22	-	1.94	-	PV	Building orientation, wall insulation, air tightness, window efficiency, and ventilation	Shading system, Humidity control, lightning, and air conditioner	[30]
5 Panama	Af (Los Santos)		-	-	-	-	-	0.25	0.15	-	1.4	0.3	PV	Passive cooling, ventilation	Daylighting control	[31]
	Aw (Ciudad de Panama)	nZEB	0.25	3.86	-	0.49	0.25	0.25/ 0.25	0.15/ 0.36	-	1.40/ 0.49	0.25/ 0.23	Not specified	Passive cooling, envelope modifications, occupant behavior, and building orientation		[42]

However, the application of active solutions only also helps to reach NZEB, but this technique appears to be less common [23][37] (**Figure 4**a). Other studies have applied both passive and active solutions, but their results show that the NZEB was not as successful as when only one type of strategy was applied [21][23][28][30].

The results also show that researchers have favored studying the applicability of the ZEB concept (**Figure 4**b) in residential buildings, and residential buildings successfully reach the net-zero energy balance far more than any other building type. This is observed for different types of climates, which can be translated into the different amounts of energy generated even with the same technology. Depending on the climate, residential buildings tend to present lower energy demand, in general, which may make it easier to achieve a net-zero energy balance than in other complex types of building. However, other studies have showed that a successful net-zero energy balance can be reached for other building types.

In the following section, comparisons according to climate, U-values, and energy-saving strategies are introduced in order to understand more of each country.

2.2. Envelope Transmittance Values According to Climate

Although, most studies did not present transmittance values for the envelope (U-values), all seemed to converge, when modified, into an “improved” performance (improved case) with a lower U-value (**Table 3**). However, the U-values appeared to diverge with the type of climate.

For instance, both office buildings in [25] started with equal U-values for the roof, walls, and window, in two different types of climates (Cfa and As). Here, the improved case showed a difference only in the external walls’ U-value, resulting in significantly a lower U-value for the As climate type.

Similarly, in Brazil, in two residential buildings in different types of climates [26] (Af and Cfb), the improved case turned out to have the same roof U-values but different wall U-values, with the building located in Af being significantly lower. Moreover, residential buildings studied in Chile [28] in three climate types (BWk, Csb, and ET) started with different U-values. In the BWk climate, the original U-values for the roof, walls, doors, and windows were higher than the improved values. In the ET climate, the U-value for the roof and windows remained the same for both original and improved cases; for the walls and door, a lower value was reported for the improved case. On the contrary, different U-values were encountered for the Csb climate. In this case, the original U-values did not differ significantly with any envelope element; in fact, both windows and floor U-values were the same. The improved cases resulted in less difference, indicating that the same might help to reach same performance under the same type of climate for the same type of building (residential) [28]. In these three types of climates—even within the same building type (residential), where the higher U-values are from the BWk climate, followed by Csb, and the lower for the ET climate—all of the cases reached were classified as nZEB.

Moreover, in Argentina, under the same Cfa climate, the same original U-value was encountered for reaching nZEB [22] for different building types, but to achieve NZEB the improved case presented U-values lower than the original [13] (**Table 3**). On the other hand, to achieve NZEB, the improved U-values differed significantly in studies based in countries with an Af climate, such as Brazil [26] and Panama [41] (**Table 3**), despite the same type of building being analyzed (**Table 1**). An agreement is encountered under the same type of climate, Aw [30][42], for the improved U-values in walls and windows, despite different building types, to achieve nZEB/NZEB (**Table 3**). No further analysis can be performed due to a lack of information.

Finally, as the U-values depend on the materials that are implemented, the discrepancies encountered between different climates and countries, or even within the same climate type for the same country, highlight the lack of a strong building performance energy regulation. However, the ZEB philosophy has been explored with encouraging figures. Although it is yet to become an accepted philosophy and achieve a consensus in Latin America, such as has happened in the EU, most studies are in the preliminary research project stage.

References

1. Attia, S. Net Zero Energy Buildings (NZEB): Concepts, Frameworks and Roadmap for Project Analysis and Implementation; Elsevier: Amsterdam, The Netherlands, 2018; ISBN 978-0-12-812461-1.
2. Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the Energy Performance of Buildings. Available online: https://eur-lex.europa.eu/legal-content/en/TXT/?uri=CELEX%3A32010L0031 (accessed on 10 May 2020).
3. D’Agostino, D.; Zangheri, P. Development of the NZEBs Concept in Member States, p. 47. Available online: https://ec.europa.eu/jrc (accessed on 10 May 2020).
4. Ecofys Germany GmbH; Danish Building Research Institute (SBi). Principles for Nearly Zero-Energy Buildings. Paving the Way for Effective Implementation of Policy Requirements. November 2011. Available online: https://www.bpie.eu/publication/principles-for-nearly-zero-energy-buildings/ (accessed on 10 May 2020).
5. Ecofys: Andreas Hermelink, Sven Schimschar, Thomas Boermans Politecnico di Milano/eERG: Lorenzo Pagliano, Paolo Zangheri, Roberto Armani University of Wuppertal: Karsten Voss, Eike Musall. Towards Nearly Zero Energy Buildings Definition of Common Principles under the EPBD. 14 February 2013. Available online: https://ec.europa.eu/energy/sites/ener/files/documents/nzeb_full_report.pdf (accessed on 4 June 2020).
6. Voss, K.; Sartori, I.; Napolitano, A.; Geier, S.; Gonçalves, H.; Hall, M.; Heiselberg, P.; Widén, J.; Candanedo, J.A.; Musall, E.; et al. Load Matching and Grid Interaction of Net Zero Energy Buildings. In Proceedings of the EuroSun 2010 Conference, Graz, Austria, 28 September–1 October 2010; pp. 1–8.
7. Sartori, I.; Napolitano, A.; Marszal, A.; Pless, S.; Torcellini, P.; Voss, K. Criteria for Definition of Net Zero Energy Buildings. In Proceedings of the EuroSun 2010 Conference, Graz, Austria, 28 September–1 October 2010; pp. 1–8.
8. Marszal, A.J.; Heiselberg, P.; Bourrelle, J.S.; Musall, E.; Voss, K.; Sartori, I.; Napolitano, A. Zero Energy Building—A review of definitions and calculation methodologies. Energy Build. 2011, 43, 971–979.
9. Attia, S.; Eleftheriou, P.; Xeni, F.; Morlot, R.; Ménézo, C.; Kostopoulos, V.; Betsi, M.; Kalaitzoglou, I.; Pagliano, L.; Cellura, M.; et al. Overview and future challenges of nearly zero energy buildings (nZEB) design in Southern Europe. Energy Build. 2017, 155, 439–458.
10. Gaglia, A.G.; Tsikaloudaki, A.G.; Laskos, C.M.; Dialynas, E.N.; Argiriou, A.A. The impact of the energy performance regulations’ updated on the construction technology, economics and energy aspects of new residential buildings: The case of Greece. Energy Build. 2017, 155, 225–237.
11. Monzón-Chavarrías, M.; López-Mesa, B.; Resende, J.; Corvacho, H. The nZEB concept and its requirements for residential buildings renovation in Southern Europe: The case of multi-family buildings from 1961 to 1980 in Portugal and Spain. J. Build. Eng. 2021, 34, 101918.
12. Kurnitski, J. How to Define Nearly Net Zero Energy Buildings nZEB. Available online: https://www.rehva.eu/fileadmin/hvac-dictio/03-

2011/How_to_define_nearly_net_zero_energy_buildings_nZEB.pdf (accessed on 10 July 2020).
13. WORLDBAL_Documentation.pdf All Rights Reserved. Available online: https://iea.blob.core.windows.net/assets/fffa1b7d-b0c5-4e64-86aa-5c9421832d73/WORLDBAL_Documentation.pdf (accessed on 8 May 2020).
14. Energy Use (kg of Oil Equivalent per Capita)–Latin America & Caribbean, Argentina, Bolivia, Brazil, Chile, Colombia|Data. Available online: https://data.worldbank.org/indicator/EG.USE.PCAP.KG.OE?end=2014&locations=ZJ-AR-BO-BR-CL-CO&start=2014&view=bar (accessed on 8 May 2020).
15. Hoque, S. Net Zero Energy Homes: An Evaluation of Two Homes in the Northeastern United States. J. Green Build. 2010, 5, 79–90.
16. Reus-Netto, G.; Mercader-Moyano, P.; Czajkowski, J.D. Methodological Approach for the Development of a Simplified Residential Building Energy Estimation in Temperate Climate. Sustainability 2019, 11, 4040.
17. Asadi, S.; Nazari-Heris, M.; Nasab, S.R.; Torabi, H.; Sharifironizi, M. An updated review on net-zero energy and water buildings: Design and operation. In Food-Energy-Water Nexus Resilience and Sustainable Development; Springer: Berlin/Heidelberg, Germany, 2020; pp. 267–290.
18. Layke, J.; Mackres, E.; Liu, S.; Aden, N.; Becqué, R. Accelerating Building Efficiency: Eight Actions for Urban Leaders. 2016. Available online: https://www.wri.org/research/accelerating-building-efficiency (accessed on 24 May 2021).
19. Harkouss, F. Optimal Design of Net Zero Energy Buildings under Different Climates. 2018. Available online: https://tel.archives-ouvertes.fr/tel-01891916 (accessed on 11 July 2020).
20. Transparency, C. The G20 Transition Towards a Net-Zero Emissions Economy. Argentina. 2019. Available online: https://www.climate-transparency.org/wp-content/uploads/2019/11/B2G_2019_Argentina.pdf (accessed on 15 June 2020).
21. Daniel, J.; Fernanda, A. Edificio de Oficinas de Baja Energía en Llavallol, Buenos Aires. Una Experiencia Universidad—Empresa. 2015. Available online: https://idus.us.es/bitstream/handle/11441/48621/56.pdf?sequence=1 (accessed on 15 June 2020).
22. Camporeale, P.E.; Mercader-Moyano, P. Towards nearly Zero Energy Buildings: Shape optimization of typical housing typologies in Ibero-American temperate climate cities from a holistic perspective. Sol. Energy 2019, 193, 738–765.
23. Arballo, B.; Kuchen, E.; Frank, A.; Alamino, Y. Estrategias de Ocupación, Operación y Gestión de Energía Casi Nula para el Edificio de Rectorado UNSJ, San Juan, Argentina. Construible, 2016. Available online: https://www.construible.es/comunicaciones/estrategias-ocupacion-operacion-gestion-energia-casi-nula-edificio-rectorado-unsj-san-juan-argentina (accessed on 15 April 2020).
24. Transparency, C. The G20 Transition Towards a Net-Zero Emissions Economy. Brazil. 2019. Available online: https://www.climate-transparency.org/wp-content/uploads/2019/11/B2G_2019_Brazil.pdf (accessed on 15 June 2020).
25. Didone, E.L. Parametric Study for Net Zero Energy Building Strategies in Brazil Considering Semi-Transparent PV Windows. Ph.D. Thesis, Department of Architecture-Karlsruhe Institute of Technology, Karlsruhe, Germany, 2014.
26. Domingos, R.M.A.; Gabriel, E.; Guarda, E.L.A.; Pereira, F.O.R. Assessment of technical-financial analysis of a zero energy building for Brazilian hot and temperate tropical climate. IOP Conf. Ser. Mater. Sci. Eng. 2019, 609, 072013.
27. Piderit, M.B.; Vivanco, F.; Van Moeseke, G.; Attia, S. Net Zero Buildings—A Framework for an Integrated Policy in Chile. Sustainability 2019, 11, 1494.
28. Besser, D.; Vogdt, F.U. First steps towards low energy buildings: How far are Chilean dwellings from nearly zero-energy performances? Energy Procedia 2017, 132, 81–86.
29. Pinto, G.A.O.; Nova, D.A.S.; Calderón, N.C.B.; OrdonezPlata, G. Energy considerations of social dwellings in Colombia accotding to NZEB concept. DYNA 2015, 82, 120–130.
30. Tewari, R. Net-Zero Energy Housing Virtual Article 6 Pilot. 2020. Available online: https://newclimate.org/2020/01/29/net-zero-energy-housing-virtual-article-6-pilot-net-zero-energy-buildings-in-cartagena-colombia/ (accessed on 11 July 2020).
31. Collado, N.; Himpe, E.; González, D.; Rueda, L. Retos para una Definición de ‘Edificios de Consumo Energético casi Nulo’. Challenges for a Definition of Nearly Zero Energy Buildings. Rev. Ing. Constr. 2019, 34, 321–329.
32. Baldoquin, N.C.; Guzman, L.A.R.; Couret, D.G.; Janssens, A. Teaching about Nearly Zero Energy Buildings in the Architecture Curriculum in Havana, Cuba. 2018. Available online: https://biblio.ugent.be/publication/8589635 (accessed on 11 July 2020).
33. Baldoquin, N.C.; Guzmán, L.A.R.; Couret, D.G. Hoteles de Consumo Energético Casi Nulo. Potencialidades y Restricciones para Cuba. 2018. Available online: https://www.researchgate.net/publication/330542847_HOTELES_DE_CONSUMO_ENERGETICO_CASI_NULO_POTENCIALIDADES_Y_RESTRICCIONES_PARA_CUBA (accessed on 12 July 2020).
34. Ordoñez, E.; Mora, E.; Gaudry, K. Roadmap Toward NZEBs in Quito. IOP Conf. Ser. Mater. Sci. Eng. 2019, 609, 072040.
35. Montalvo, M.E.B. Estudio de Factibilidad Económico y Financiera Utilizando Tecnología Net Zero Energy para un Proyecto de Vivienda Familiar de Clase Media Urbana en la Ciudad de Quito. 2016. Available online: http://bibdigital.epn.edu.ec/handle/15000/15285 (accessed on 12 July 2020).
36. Pérez Pérez, M.; Márquez Pérez, L.A. Ecoinvolúcrate, la Estrategia de Ecuador para la Construcción de Edificios de Energía Casi Nula. Construible, 2016. Available online: https://www.construible.es/comunicaciones/ecoinvolucrate-estrategia-ecuador-construccion-edificios-energia-casi-nula (accessed on 14 April 2020).
37. NZEB-El Salvador: El Edificio de Cero Energía Neta de US$400.000. Revista Construir, 5 March 2020. Available online: https://revistaconstruir.com/nzeb-el-salvador-el-edificio-de-cero-energia-neta-de-us400-000/ (accessed on 16 April 2020).
38. Guenther, R.; Vittori, G. Sustainable Healthcare Architecture; John Wiley & Sons: Hoboken, NJ, USA, 2013; ISBN 978-1-118-08682-7.
39. Transparency, C. The G20 Transition Towards a Net-Zero Emissions Economy. Mexico. 2019. Available online: https://www.climate-transparency.org/wp-content/uploads/2019/11/B2G_2019_Mexico.pdf (accessed on 15 June 2020).
40. México, E. Edificios Certificados con Energía Cero. 2018. Available online: https://www.revistaequipar.com/mexico/contenido-editorial/edificios-certificados-con-energia-cero (accessed on 21 April 2020).
41. Hoque, S.; Iqbal, N. Building to Net Zero in the Developing World. Buildings 2015, 5, 56–68.
42. Mora, D.; Araúz, J.; Austin, M.C. Towards Nearly Zero Energy Buildings in Panama through Low-Consumption Techniques: A Numerical Study. In Proceedings of the 74th ATI National Congress Italie-AIP Conference Proceddings, Modena, Italy, 11–13 September 2019; p. 020114.
43. Proposals—APEC Nearly (Net) Zero Energy Building Roadmap. 2016. Available online: https://aimp2.apec.org/sites/PDB/Lists/Proposals/DispForm.aspx?ID=1942 (accessed on 21 April 2020).
44. BSUsolar. Proyecto Destacado—Residencia Nzeb en Uruguay. 2019. Available online: https://5b00fd61-12f8-440c-80b9-098f6e1bc274.filesusr.com/ugd/a1167a_d3e9d85fdcc048c0a9a95fc08f1cced9.pdf (accessed on 16 June 2020).

Keywords

Zero Energy Buildings;nZEB;NZEB;Latin America