Zero Energy Building: Systematic Literature Review
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1. Introduction

The concept of Zero Energy Building drew international attention over the past few years and is currently considered a future target for building design. Zero Energy Building is a construction that is energy self-sufficient. This means that it generates as much energy as it consumes throughout the year, using only renewable sources.

The construction of zero energy buildings is economically beneficial. Zero Energy Buildings have improved energy efficiency, which allows to reduce total cost of ownership. Thanks to the use of renewable energy sources, owners are protected from future increases in energy prices. When reselling a building, the owners receive more than the original cost of the construction because at the moment the supply for the Zero Energy Building is lower than the demand.

Nowadays, one of the global problems is climate change. Commercial and residential buildings are among the most powerful consumers of energy. The energy consumption of buildings increases because of the development of the residents' needs. Zero Energy Building uses renewable energy sources therefore Zero Energy Buildings have advantages in the field of environmental care because of the mitigation of CO2 emissions and the decrease of energy use in the building sector. The deposits of fossil fuel deplete at a high rate. The new deposits are extremely hard to find and if they are discovered are smaller than already used ones. Therefore, Zero Energy Buildings are the solution for this problem because they do not depend on fuel.

2. Articles categorization (we will use it for SLR)

Category	**Articles**
1. Definitions, Building energy codes, ZEB achieving, Designs, Policies, Clusters	
a) Thermal comfort	**[15], [16], [19], [20]**

b) Costs, Economic optimization	**[13], [14], [18]**
c) Materials	**[13]**
d) Performance Analysis, Clusters optimizations, control	**[11], [12],**
e) Design	**[13], [14], [15], [16], [38]**
2. Countries, Different climates	
a) USA	**[14]**
3. Renewable energy (production), Load matching analysis, Grid analysis	**[11], [12], [15], [17], [18], [36], [37], [39], [40]**
4. Comparison with other buildings	**[14], [20]**

3. Result

In this section, for each paper that you listed in Google Sheet, you will write a paragraph report (summary) including the following points:

- What are the goals of the paper?
- Which methods did they use?
- The achieved results? (may combine with the first question)
- What limitations do you think they had?

1. One of the important steps to design a Zero Energy Building consists of predicting the energy production and consumption. In [1] Kneifel and Webb suggest a model of predicting the performance of ZEB based not on physics

imitation but on a statistically derived regression that considers the data after settlement of residents and common known weather factors. The authors used data from Net-Zero Energy Residential Test Facility of the National Institute of Standards and Technology. After computing the results they were compared to the ones produced by a physics-based imitation model. It turned out that the regression model requires less data, and does not include underlying assumptions.

2. The authors of [2] make a literature review of different energy solutions for ZEB and its performance. This article compares energy consumption and production of existing buildings with different purposes such as educational, residential, and industrial within Southern Europe (moderate climate with hot summer). This article also discusses passive and active solutions for space cooling, heating and lightning such as design factor, thermal insulation, thermal energy storage, appliance, and heating ventilation and air-conditioning, existing solutions for power supply and generation (solar and wind energy, heat pump, district heating and cooling and bioenergy) comparing them according to following parameters: performance, technique, result, cost, preferable mode and limitations.

3. To minimize expenses of the construction of ZEB it must have an economically efficient design that should consider the influence of the local climate, the endogenous energy resources and the local economic conditions. [3] suggests the methodology and the calculation platform that might help to achieve it for residential NZEB. The authors use a special set of design variables for every engineering system. For example, such variables as levels of thermal insulation and inertia, type of glazing and shading, glazed area, orientation characterize space cooling. After that they calculated useful heating and cooling needs, peak heating needs, useful needs for hot water, final needs of energy, and energy generated by different sources using calculating and optimizational software and checked its work on a low rise building.

4. Unlike standard buildings ZEB have one primal disadvantage that consists in the high price of construction and equipment. In [4] Hu conducts research that investigates the difference between actual cost of ZEB and planned costs of conventional (CB) and green buildings(GB). To achieve his goal the author takes the following steps. Firstly, he conducts literature review to identify patterns. The second step is detailed analysis focused on quantitative studies and comparing results. The last step is a quantitative

comparative analysis of twelve constructed zero-energy buildings. Based on this, the following conclusions were made: there is no significant difference between the cost of ZEB and CB, however the costs of ZEB and GB vary considerably.

5. [5] focuses on artificial intelligence application in order to improve energy efficiency of Zero Energy Building. The first way to apply AI within advancement of energy efficiency is usage of remote sensors. The authors compare existing studies about remote sensors using the following parameters: building type, objective, algorithm, advantages and disadvantages, possibility for its use for energy efficiency, thermal control and building security. AI control methods can be used in order to ensure the functioning of multi-energy systems for ZEB. Artificial Neural Networks might be applied to improve the predictive accuracy of energy, load, subsystem performance forecasting.

6. Unlike the majority of decision supporting tools, a tool introduced in [6] focuses on the comfort conditions of the hot climate of Egypt and allows to evaluate the design before decision making. Developed tool (ZEBO) is based on an embedded benchmark model and contains the database of residential buildings in Egypt that allows a variety of different variants in the short time. The authors suppose that the main auditory of this tool would be architects and architecture students that do not have experience with computing the energy efficiency.

7. [7] proposes new methodology that might help reach buildings that use renewable energy (particularly solar and wind energy) Nearly Zero Energy Building status. This methodology follows three steps: defining the input data (geometric and envelope characteristics, energy potential), decreasing the energy demand, by reducing the heat losses and by ensuring an efficient electricity use, and increasing the energy from RES. After formulating the methodology the authors test it on Solar House (case study) that reaches Nearly Zero Energy Building status.

8. [8] introduces several improvements for solar energy use and cost in a residential net-zero energy building. First of them is simultaneous application of heat insulation solar glass and solar energy systems which will minimize heat loss and generate power. By comparing flat-plate and compound parabolic concentrator (CPC) solar collectors, it was revealed that CPC solar collectors were more successful because of higher efficiency

of transformation from solar to thermal energy. The scenario of using a PV-and-HISG hybrid system turned out to be very promising. Based on these improvements was developed a decision making framework.

9. In [9] were suggested several architectural techniques to improve the energy efficiency such as the optimal building orientation, the presence of the vestibule at the entrance, pent roof on a low-light side, and maximum glazing northwestern facades and blank walls on the low-light scenes sides, and improvements of control solutions following engineering systems: heating (remote transmission of data and remote control of the system, quick and detailed notifications about current state of the systems), ventilation (regulated air supply, exhaust mechanical ventilation equipped with heat recovery of the ground), air conditioning (high quality and low energy cost).

10. Zeiler and Boxem, the authors of [10], focused their research on comparing measurements of indoor thermal comfort, air quality and CO2 emissions of 2 ZEB schools and 9 schools with traditional design in the Netherlands during 1 week. The ZEB showed lowering the carbon emissions indicators by 23% compared to other schools. In the end the authors made a conclusion that consists of advantages and disadvantages of ZEB. The benefits of using ZEB technology are protection from future energy price increases, possible carbon emission taxes, improved energy efficiency that leads to decreasing of total ownership cost, longer service life of the equipment and the faults are climat dependency and possibility of higher price of construction.

11. [11] investigates the impact of net zero energy building on the environment and grid interaction. To analyze environmental impact the authors calculate global warming potential, that is expressed in kg of CO2 emissions/year. To evaluate grid interaction the thermal loads model in TRNSYS was developed. This model divides buildings into several thermal zones. Using this model on case study proved that it is suitable for use by designers to balance optimal grid interaction and minimal environmental impact.

12. [12] develops a framework focused on ZEB performance and based.on energy trilemma (energy security, energy equity and environmental sustainability). This framework includes 5 main indicators: contribution, dependence, energy loss, electricity cost and CO2 emissions. Contribution means generation energy using renewable energy sources. Dependence assumes reducing dependence from external grid electricity. Energy loss,

carbon emissions responsible for lowering these parameters. Electricity cost means reduced import and increase in export to the grid.

13. According to [13], the designers currently do not consider embodied energy while calculating energy consumption. Using IREEA (Initial and Recurring Embodied Energy Assessment) worksheet tool that allowed to measure initial EE of building system and services, of glazing systems and window frames, recurring EE and the total EE. The authors analyze Skyslide (case study) to prove that EE and operational energy should also be calculated during the process of ZEB design. In the best case scenario initial and recurring EE give primary energy demand in about 24 kWh/m2yr and in the worst case it will be 45 kWh/m2yr.

14. Based on the author's experience with the design of Solar XXI, office building in Portugal, [14] introduces a framework for using their NetZEB methodology. Developed methodology has 2 major steps: solar building design that helps to improve energy efficiency, and generation of energy. The first step contains several technique solutions such as use of solar gains, Building Integrated Photovoltaic - Thermal system, natural lightning and ventilation, and ground cooling system. By using this methodology Solar XXI was able to reach NZEB status and energy performance that is 10 times greater than energy performance of a standard portuguese office building.

15. Existing methods for energy balance assessment for ZEB have two major faults: it considers only the energy needed for operations and associated emissions, and does not guarantee that the energy consumption will be optimized before integration of renewable energy systems. In [15] was developed a method for assessment of the renewable energy balance of ZEB. Renewable emergy balance maximize use of renewable sources using renewable energy sources substitution and minimization of nonrenewable resources usage. Renewable emergy balance assessment consists of three main components: the manufacturing and maintenance emergy analysis, the building operation emergy and the maximum renewable emergy potential.

4. Discussions

In this section, we will write about the limitations/pros, and cons of each article that we mentioned in the previous section (sec. 4) and how you will suggest/propose to improve the article (solve issues).
Some articles may have the same/similar solutions, therefore we categorize them and will write a paragraph about them.

5. Search questions

The research questions that may your report answer are:

1) How to predict energy performance of ZEB?
2) What models for predicting energy performance exist?
3) What are the pros and cons of current technical solutions for the main systems of ZEB?
4) What tools can be used to design a ZEB in different stages?
5) What parameters can affect the difference between planned and actual cost of ZEB?
6) How can we use AI in order to improve ZEB energy performance?
7) How can we transform buildings with renewable resources into ZEB?
8) How does ZEB impact the environment?
9) What frameworks for ZEB design exist?

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