A Review of Housing Certification Standards with a Focus on Energy Efficiency

Zaiyi Liao*, Claire Tam
Department of Architectural Science, Ryerson University, 325 Church Street, Toronto, ON, Canada
*Corresponding Author: zliao@ryerson.ca

Abstract. In addition to building codes and regulations, voluntary housing certification standards also play an important role in the energy efficiency of housing. Each of these standards was established in response to a set of specific demands for high performance housing. Consequently, the energy conservation technologies and design approach applicable could be very diverse and dynamic. This paper is aimed to provide a comprehensive review for the state-of-the-art housing standards with a focus on energy efficiency. It was observed that these standards normally evaluate energy efficiency based on percentage savings of the design with energy conservation measures compared to a reference case. The net-zero energy balance between energy consumption and on-site energy generation is considered the highest level of performance. This paper examines if this approach is adequate and prompts future research in order to improve the effectiveness of housing standards in defining sustainable housing.

1. Introduction

According to the United Nations Environment Programme [1], buildings account for 40% of energy consumption on a global scale. The building construction industry is a large contributor to global carbon emissions and is responsible for approximately one-third of the Greenhouse Gas (GHG) emissions. Reducing energy consumption has been one of the primary focus of climate change action plans across many countries in relation to the Paris Agreement [2]. Global efforts to reduce energy consumption includes the Three Percent Club from the International Energy Agency (IEA) with involvement from the United Kingdom and several developing countries, which targets to improve energy efficiency by 3% per year [3]. Although there are targets set in place by government initiatives to achieve this goal, actual strategies to implement energy conservation measures are only outlined by voluntary certification standards [4].

Energy efficiency of buildings is about minimizing the energy demand and consumption to obtain the same amount of service. Such service should be of desirable performance. For example, thermal comfort should not be compromised when increasing energy savings. As a measurable quantity, energy efficiency is the ratio between the input of processes and the output of converted energy for useful work. It is a clear goal to lower the energy consumption as much as possible until the building can offset its energy consumption with generated renewable energy. However, there is no universal definition of a zero-energy building. There are many existing definitions of energy efficient or Zero Energy buildings, which several recent studies have pointed out the lack of a universal definition [5]–[7]. Taherahmadi et al. [7] note that there are two steps in designing for zero-energy: energy conservation and offsetting demand with energy generation. Either mandatory code regulations or specific voluntary standards are followed to implement the two steps. Zero-energy buildings also vary in definition depending on the...
difference between source energy or secondary energy; embodied energy or operational energy; off-grid or on-grid energy supply; building types and age; energy end-use; and different renewable energy sources. These variations allow many possibilities when achieving energy efficiency. The boundaries of energy efficiency are also blurred due to different concerns and regional policies. Taherahmadi et al. [7] point out that the definition for Net-Zero can be split into four dimensions: energy, carbon emissions, exergy, and cost. European countries refer to energy efficiency with regards to carbon emissions while North America has traditionally focused on lowering energy consumption more than the environmental impact [7].

Energy codes and standards address the fact that energy efficiency can be achieved in multiple ways. There are three compliance paths to most energy codes: prescriptive, performance-based, and outcome-based [8]. Prescriptive codes and standards offer packages of options for builders and designers to adopt. The performance metrics, such as minimum insulation thermal resistance (R-value), guide the design to achieving energy efficiency without further energy modelling. However, choosing prescribed packages may lead builders to make decisions based on the least expensive and code minimum requirements. The operational performance of the design is not monitored in the long-term. The energy consumption of the building is usually not further assessed. In addition, prescriptive packages neglect site conditions and the passive methods that can increase energy efficiency prior to the implementation of systems such as the orientation of the building. Secondly, performance-based codes and standards focus on the broad energy efficiency goals [8]. The building can be designed in multiple ways suited to the builder but must demonstrate that the required performance is met through an energy model of the building and benchmarking with a baseline reference building. In such a context, energy efficiency is a relative measure and expressed as a percent better than the baseline energy consumption. Such “percent savings” metric may be ineffective since code minimums often change and unregulated plug loads during the operational phase of a building are not accounted for. The third path is outcome-based compliance, which considers that performance is based on not exceeding the maximum required operational energy of a consecutive 12-months period. This method involves both the designers, building owner, and occupants in achieving energy efficiency in collaboration but requires more effort in maintenance and continuous commissioning [8].

This paper reviews the energy efficiency targets of voluntary certification standards. Although net-zero energy is the ultimate goal of energy efficient building designs, there are implications of only focusing on achieving a numerical energy consumption target. The thermal comfort and safety of occupants, and durability of buildings may be compromised despite a low energy consumption. Housing is chosen as the building type of interest in this paper since energy efficiency affects the affordability of securing a shelter (one of the basic needs of humans). The International Energy Agency (IEA) reports that residential buildings consume more energy globally than commercial buildings [9]. Increasing energy efficiency reduces the financial burden of low-income families and create healthier, higher quality living environments [10].

2. Methodology

This review analyzes how state-of-the-art housing standards address energy efficiency. An investigation has been conducted to create a concise and thorough understanding on the absolute energy targets that are required and encouraged by the certification standards, including Net-zero energy housing, Passive House, Active House, R-2000 House, Energy Star House. This insight allows for a thorough understanding on the reasons why absolute energy targets may not be sufficient for ensuring high-performance of buildings through a review of relevant case studies. The objective of this paper is to investigate whether existing housing standards are sufficient in addressing sustainability and to highlight a direction for improving existing standards. The paper questions if meeting absolute energy targets is a proper way to design a sustainable home. The literature search focused on the Thermal Resilience and Indoor Air Quality of low-energy homes. These two topics were the search terms used on major scientific databases such as Scopus, Science Direct, and Google Scholar to conduct this research. As illustrated in Figure 1, this paper is aimed to present the current definitions of energy efficiency from
existing energy targets-based housing standards and the emerging definitions which the housing standards should consider addressing in future development.

3. Housing Standards for Energy Efficiency

Housing standards benchmark energy performance to a reference level (see Figure 2). The reference can be the modelled energy performance before the implementation of energy conservation measures or the code-compliant baseline design. The U.K. Building Research Establishment Environmental Assessment Method (BREEAM) and its Home Quality Mark standard measure energy efficiency based on comparing the predicted energy consumption of the building with an equivalent “Notional Building” which meets mandatory energy performance requirements [11]. The Leadership in Energy and Environmental Design Green Building Rating System (LEED) for Homes, developed by the U.S. Green Building Council (USGBC), is a sustainability rating system commonly used in North America [12]. Within the Energy and Atmosphere category, the minimum required energy performance is meeting an EnerGuide Rating of 76 or a Home Energy Rating System (HERS) Index of 80. The EnerGuide Rating System (ERS) was developed by the Natural Resources Canada (NRCan) to rank energy performance based on benchmark targets [13]. On the scale, a minimum code-compliant house has a rating of 80. The ENERGY STAR for New Homes Standard [14], which requires a 25% increased energy efficiency compared to the local building code, has a rating of 83. R2000 [15], another energy efficiency housing standard developed by the NRCan, targets 50% better energy efficiency than the code minimum and has a rating of 86. After 86, renewable energy systems are needed to achieve further energy efficiency until the house is considered Net-Zero, which has a rating of 100 [13]. The rating is based on the constructed building. An energy advisor verifies the energy upgrades and conducts a blower door test to evaluate the home. Similarly, the Residential Energy Services Network (RESNET) HERS [16] measures the energy efficiency of a home based on the 2006 International Energy Conservation Code which is at a rating of 100. A HERS index score higher than 100 is less energy efficient than the standard new home.

![Energy Efficiency in Housing Standards](image)

### Energy Efficiency in Housing Standards

#### Current Definitions

**Energy Efficiency Rating System (Percentage Better Than Reference)**
- BREEAM Home Quality Mark
- LEED for Homes
- EnerGuide Rating System (ERS)
- Home Energy Rating System (HERS)

**Absolute Energy Target**
- Passive House
- Active House

**Net-Zero Energy**
- U.S. DOE Zero Energy Ready Home
- Canadian Home Builders’ Association Net Zero Home Labelling Program
- Living Future Institute Zero Energy Certification

### Additional Definitions

| Year | Reference | Case Studies |
|------|-----------|--------------|
| 2011 | Figueiredo et al. [27] | Passive House |
| 2016 | Mlakar and Štrancar [28] | Passive House |
| 2016 | Baniassadi et al. [30] | Archetype Buildings |
| 2020 | Sun, Specian, Hong [31] | Nursing Home |
| 2020 | Moreno-Rangel et al. [35] | Passive Houses |
| 2016 | Alviti [39] | LEED Platinum Zero Energy Building |
| 2018 | Brom, Meijer, Visscher [36] | Social Housing |

![Figure 1 Definition of Energy Efficiency in Housing Standards](image)
whereas a score lower than 100 is more energy efficient by increments of 10% until an index of 0 indicates a Net-Zero Energy home which produces as much energy through renewable sources as it consumes. The ERS also altered its rating system in 2019 to a target of 0 GJ/year [17]. The energy balance between consumption and production is considered the best practice by these rating systems. Several organizations certify net-zero energy buildings including the U.S. Department of Energy’s Zero Energy Ready Home certification [18], Canadian Home Builders’ Association Net Zero Home Labelling Program [19], and Living Future Institute’s Zero Energy Certification [20].

In addition to rating systems, housing standards such as Passive House [21] and Active House [22] set a target energy demand. Passive House is a recognized standard with stringent targets to lower energy demand by five key principles: super-insulated building envelope with continuous control layers, airtightness, high-performance windows, balanced ventilation with minimal mechanical systems, and compact building form [21]. The energy demand target for Passive House is 10W/m² of peak heat load or 15kWh/m²/yr. of annual heat demand. Airtightness is a critical component for increasing energy efficiency, of which the standard requires 0.6 ACH₅₀ or less. Passive House Institute of United States (PHIUS) promotes a climate-specific energy demand standard [23]. Active House evaluates energy demand from 100kWh/m² as minimum to 40 kWh/m² as the best performance. The annual non-renewable primary energy performance, which is the energy balance between consumption and production, should be between 0kWh/m² (best performance) and 130kWh/m² (minimum requirement) [22].

Minimizing energy demand is prioritized when increasing a home’s energy efficiency. This is achieved by increasing the insulation level and airtightness of the building envelope. A higher performance building envelope lowers the load on the mechanical system. A lower load prevents oversizing and reduces the energy consumption needed for maintaining thermal comfort. Hamada et al. [24] observed the trends and strategies of energy efficiency using a database of 66 low-energy housing projects from 17 countries. The study concluded that the combination of appropriate solar collector sizing, passive solar design, and ground source heat pump in addition to high-performance envelope can be used to achieve net-zero energy targets. The International Energy Agency Solar Heating and Cooling (SHC) Programme Task 28 [25] explores the renewable energy technologies which assist buildings in achieving net-zero energy such as photovoltaic panels, solar collectors, and thermal storage.
4. Discussion
State-of-the-art housing standards measure energy efficiency based on a target performance level. The highest performance is achieving net-zero energy in terms of the balance between energy consumption and production through renewable sources. However, is achieving low energy consumption or net-zero energy an indicator of a high-performance and comfortable home? The discussion below highlights three cases which show evidence that an absolute energy target or net-zero energy should not be the only indicator of energy efficiency for housing standards.

4.1. Passive Survivability
Passive Survivability is particularly important for homes than other building types such as offices because occupants may reside in the space for a prolonged period of time during an emergency or extreme weather event. Passive Survivability is the ability of a building to remain in comfortable conditions during a power or water outage [26]. The building envelope, according to housing standards, is designed to be well-insulated and airtight to minimize energy consumption. However, several studies [27]–[29] demonstrated that overheating in various climates may occur for Passive Houses with superinsulated and airtight envelopes when subjected to atypical weather conditions. A warm summer projected for 2050 in London, UK would result in indoor temperatures above 25°C for 5-10% of the year for Passive Houses [30]. Sun, Specian, and Hong [31] demonstrated with a case study of a nursing home that energy conservation measures contribute in improving thermal resilience in the event of a power outage caused by a hurricane. It was observed that providing shading and natural ventilation are effective measures to increase thermal resilience. On the other hand, increasing airtightness of the building envelope reduces energy consumption under normal conditions but increases the risks of dangerous thermal conditions during extreme heat events. In addition, active measures such as providing an eight-hour thermal storage would allow the space to maintain a normal cooling setpoint for one and a half day after the power outage. The indoor thermal condition would be safe for 70% of the time. The study also showed that the effectiveness of passive and active measures for ensuring safe conditions vary between climates (the study analysed the Florida, San Francisco, and Chicago climates). Therefore, both energy savings and thermal resilience need to be considered when deciding which energy conservation measure to implement in a home during new construction or retrofits according to the specific climate region [31]. Existing housing standards only focus on energy savings and lack the evaluation of a home’s thermal resilience. A home’s thermal resilience can be evaluated by accounting the number of hours annually that the indoor air temperature exceeds 20°C in the heating season and 25°C in the cooling season [32]. According to ASHRAE Standard 55 Thermal Environmental Conditions for Human Occupancy [33], the indoor air temperature should not exceed the threshold more than 10% of the time.

4.2. Balancing Low Energy with Indoor Air Quality
Another issue that absolute energy targets cannot fully address is the Indoor Air Quality (IAQ) of low-energy homes. An absolute energy target does not quantify the effectiveness of ventilation for reducing indoor air pollutants in the building. Airtightness and Mechanical Ventilation Heat Recovery (MVHR) systems are critical elements to ensure desirable indoor air quality. Mechanical ventilation, often used in combination with natural ventilation, would increase energy consumption but lower the concentration levels of harmful pollutants such as Volatile Organic Compounds (VOCs), Particulate Matters (PM2.5 and PM10) and bio-effluents such as Carbon Dioxide (CO2). Less et al. [34] reported from measurements of 24 high-performance homes that airtight homes had better IAQ upon reliance on ventilation strategies to maintain satisfactory IAQ when the building envelope limits air exchange. Besides regulating that the minimum supply flow should be between 8.33 L/s and 8.9 L/s for the entire building [23], there are a lack of ventilation guidelines in the Passive House standard which could lead to the inability to reduce concentration of VOCs and PM. Moreno-Rangel et al.’s review [35] highlighted that there are contradictory evidence of CO2 levels above or below the 1000ppm threshold in Passive Houses. The CO2 levels were most often exceeded when occupant numbers were high. Therefore, MVHR systems
have a critical role in maintaining a healthy indoor environment. Where applicable, natural ventilation would be the ideal solution to both reduce energy consumption and improve IAQ. Otherwise, evaluation solely based on maximizing energy savings risks compromising IAQ.

4.3. Long-term Energy Performance

Lastly, existing housing standards rely on reference energy models using Building Energy Simulation to compare the design with a baseline case. A “percentage better than reference” approach is taken to quantify the energy savings and predict the home’s ability to achieve a target level of annual energy consumption. Brom, Meijer, and Visscher [36] show that occupant behaviour and building characteristics may differ between the modelled building and the constructed condition which causes a performance gap between predicted and actual energy consumption. BES is susceptible to the inaccuracies of weather data, where future weather files are needed to predict the energy consumption as impacted by climate change rather than from past conditions [37]. The capability of the building to achieve consistent energy performance over its life cycle and adapt to climate change is a primary challenge in the implementation of Net-Zero Energy buildings [38]. Furthermore, Attia [39] expressed that targeting energy efficiency to Net-Zero only encourages energy savings and the balance of energy demand with energy generated on site. The approach limits further exploration of regenerative resources which could create fossil-fuel independent buildings, hence eliminate the root cause of climate change.

5. Conclusion

This paper has provided an overview of how existing housing standards address energy efficiency. All of the standards measure energy efficiency on a rating system by comparing the energy consumption to a reference baseline case or based on an absolute energy target. Net-Zero Energy is considered the target performance of maximum energy efficiency which can be achieved by using on-site energy generation from renewable sources. The global target to achieve Net-Zero Energy buildings by 2030 is fast approaching. When implementing energy conservation measures, building designers should consider more than achieving a target energy consumption level in accordance with existing housing standards. This review paper prompts further investigations of low-energy homes regarding the thermal resilience, the contribution to improving indoor air quality, and the long-term independency from fossil-fuel energy supply. Future research should investigate performance indicators which are suitable for use in housing standards to better define energy efficiency.

Acknowledgement

This research is partially supported by the Natural Sciences and Engineering Research Council of Canada, Discovery Grant (NSERC DG (RGPIN-2016-04176)).

References

[1] “UN Environment Programme,” United Nations, 2021. https://www.unep.org.

[2] “Paris Agreement,” United Nations, 2015. https://unfccc.int/sites/default/files/english_paris_agreement.pdf.

[3] “New global effort on climate change targets 3% increase in energy efficiency per year,” UNEP DTU Partnership, 2019. https://unepdtu.org/new-global-effort-on-climate-change-targets-3-increase-in-energy-efficiency-per-year/.

[4] W. L. Lee and F. W. H. Yik, “Regulatory and voluntary approaches for enhancing building energy efficiency,” Prog. Energy Combust. Sci., vol. 30, no. 5, pp. 477–499, 2004. doi:10.1016/j.pecs.2004.03.002.

[5] D. D’Agostino and L. Mazzarella, “What is a Nearly zero energy building? Overview, implementation and comparison of definitions,” J. Build. Eng., vol. 21, no. September 2018, pp. 200–212, 2019. doi:10.1016/j.jobe.2018.10.019.

[6] J. Williams et al., “Less is more: A review of low energy standards and the urgent need for an international universal zero energy standard,” J. Build. Eng., vol. 6, pp. 65–74, 2016.
[7] J. Taherahmadi, Y. Noorollahi, and M. Panahi, “Toward comprehensive zero energy building definitions: a literature review and recommendations,” *Int. J. Sustain. Energy*, 2020. doi:10.1080/14786451.2020.1796664.

[8] K. Spataro, M. Bjork, and M. Masteller, “Comparative Analysis of Prescriptive, Performance-Based, and Outcome-Based Energy Code Systems,” 2011. doi:10.3182/20090603-3-RU-2001.2095.

[9] “Transition to Sustainable Buildings,” *International Energy Agency (IEA)*, 2013. https://www.iea.org/topics/energy-technology-perspectives.

[10] “Energy Efficiency in Affordable Housing: a Guide to Developing and Implementing Greenhouse Gas Reduction Programs,” *United States Environmental Protection Agency*, 2011. https://www.epa.gov/sites/production/files/2015-08/documents/affordable_housing.pdf.

[11] “BREEAM Energy Efficiency Technical Guide,” *Building Research Establishment Ltd.*, 2021. https://www.breeam.com/BREEAMInt2013SchemeDocument/content/06_energy/ene_01_reduction_of_co2_emissions.htm.

[12] “LEED Canada for Homes Rating System,” *Canada Green Building Council LEED Canada*, 2009. https://www.cagbc.org/CAGBC/Programs/LEED/LEED_Canada_Rating_System/Homes/Leed_Canada_for_Homes.aspx (accessed Feb. 10, 2021).

[13] “Development of Energy Efficiency Requirements for the Toronto Green Standard: Final Report,” *Sustainable Buildings Canada*, 2012. https://taf.ca/wp-content/uploads/2018/02/Sustainable_Buildings_Canada_Report_TGS_Energy_Efficiency_Requirements_2012-05-09.pdf (accessed Feb. 04, 2021).

[14] “ENERGY STAR for New Homes Standard Version 12.8 and 17.0 Ontario,” *Natural Resources Canada*, 2017. https://www.enerquality.ca/wp-content/uploads/2017/03/ESNH-Standard-Ver-12.8-and-Ver-17.0-Ontario_Effective-Feb-21-2017.pdf (accessed Feb. 04, 2021).

[15] T. Mayo and R. Sinha, “R-2000 and advanced houses: The Canadian experience,” *J. Therm. Envel. Build. Sci.*, vol. 21, no. 7, pp. 91–111, 1997. doi:10.1177/109719639702100108.

[16] “RESNET HERS Index,” *Residential Energy Services Network*, 2021. https://www.hersindex.com.

[17] “EnerGuide Energy Efficiency Home Evaluations,” *National Resources Canada*, 2020. https://www.nrcan.gc.ca/energy-efficiency/energuide-canada/energuide-energy-efficiency-home/after-your-energuide-home-evaluation/20572 (accessed Feb. 05, 2021).

[18] “Zero Energy Ready Homes,” *U.S. Department of Energy Energy Efficiency and Renewable Energy*, 2021. https://www.energy.gov/eere/buildings/zero-energy-ready-homes.

[19] “The CHBA Net Zero Home Labelling Program- v1,” *Canadian Home Builders’ Association (CHBA)*, 2017. https://buildingknowledge.ca/wp-content/uploads/2017/05/BKC-SpringCamp-2017-SonjaWinkelmann.pdf (accessed Feb. 08, 2021).

[20] “Zero Energy Certification,” *Living Future Institute*, 2021. https://living-future.org/zero-energy/.

[21] Passive House Institute, “Passive House Requirements,” 2015. https://passiv.de/en/02_informations/02_passive-house-requirements/02_passive-house-requirements.htm (accessed Jul. 10, 2020).

[22] “The Active House Specifications 3rd Edition,” *Active House Alliance*, 2020. https://www.activehouse.info/wp-content/uploads/2020/01/Guidelines_ActiveHouse_III_2020_Spreads.pdf (accessed Feb. 10, 2021).

[23] PHIUS, “PHIUS+ 2018 Passive Building Standard Certification Guidebook,” Chicago, IL, 2019.

[24] Y. Hamada, M. Nakamura, K. Ochifuji, S. Yokoyama, and K. Nagano, “Development of a database of low energy homes around the world and analyses of their trends,” *Renew. Energy*, vol. 28, pp. 321–328, 2003. doi:10.1016/S0960-1481(02)00031-9.

[25] R. Charron, “A review of low and net-zero energy solar home initiatives,” *Energy Technology Centre-Varennes, NRCan*, 2005.

[26] E. Hotchkiss, A. Wilson, and P. Majidi, “Resiliency in the Face of Disaster: Energy Efficiency’s
[27] A. Figueiredo, J. Figueira, R. Vicente, and R. Maio, “Thermal comfort and energy performance: Sensitivity analysis to apply the Passive House concept to the Portuguese climate,” Build. Environ., vol. 103, pp. 276–288, 2016. doi:10.1016/j.buildenv.2016.03.031.

[28] J. Mlakar and J. Štrancar, “Overheating in residential passive house: Solution strategies revealed and confirmed through data analysis and simulations,” Energy Build., vol. 43, no. 6, pp. 1443–1451, 2011. doi:10.1016/j.enbuild.2011.02.008.

[29] M. J. Nahlik, M. V. Chester, S. S. Pincetl, D. Eisenman, D. Sivaraman, and P. English, “Building Thermal Performance, Extreme Heat, and Climate Change,” J. Infrastruct. Syst., vol. 23, no. 3, p. 04016043, 2017. doi:10.1061/(asce)is.1943-555x.0000349.

[30] A. Baniassadi and D. J. Sailor, “Synergies and trade-offs between energy efficiency and resiliency to extreme heat – A case study,” Build. Environ., vol. 132, no. August 2017, pp. 263–272, 2018. doi:10.1016/j.buildenv.2018.01.037.

[31] K. Sun, M. Specian, and T. Hong, “Nexus of thermal resilience and energy efficiency in buildings: A case study of a nursing home,” Build. Environ., vol. 177, no. February, p. 106842, 2020. doi:10.1016/j.buildenv.2020.106842.

[32] M. Santamouris, K. Pavlou, A. Synnefa, K. Niachou, and D. Kolokotsa, “Recent progress on passive cooling techniques. Advanced technological developments to improve survivability levels in low-income households,” Energy Build., vol. 39, no. 7, pp. 859–866, 2007. doi:10.1016/j.enbuild.2007.02.008.

[33] ASHRAE, “ASHRAE 55 Thermal Environmental Conditions for Human Occupancy.” The American Society of Heating, Refrigerating and Air-Conditioning Engineers, Atlanta, Georgia.

[34] B. Less, N. Mullen, B. Singer, and I. Walker, “Indoor air quality in 24 California residences designed as high-performance homes,” Sci. Technol. Built Environ., vol. 21, no. 1, pp. 14–24, 2015. doi:10.1080/10789669.2014.961850.

[35] A. Moreno-rangel and T. Sharpe, “Indoor Air Quality in Passivhaus Dwellings: A Literature Review,” Int. J. Environ. Res. Public Health, 2020.

[36] P. van den Brom, A. Meijer, and H. Visscher, “Performance gaps in energy consumption: household groups and building characteristics,” Build. Res. Inf., vol. 46, no. 1, pp. 54–70, 2018. doi:10.1080/09613218.2017.1312897.

[37] A. Robert and M. Kummert, “Designing net-zero energy buildings for the future climate, not for the past,” Build. Environ., vol. 55, pp. 150–158, 2012. doi:10.1016/j.buildenv.2011.12.014.

[38] L. Belussi et al., “A review of performance of zero energy buildings and energy efficiency solutions,” J. Build. Eng., vol. 25, p. 100772, 2019. doi:10.1016/j.jobe.2019.100772.

[39] S. Attia, “Towards regenerative and positive impact architecture: A comparison of two net zero energy buildings,” Sustain. Cities Soc., vol. 26, pp. 393–406, 2016. doi:10.1016/j.scs.2016.04.017.