

RESEARCH ARTICLE

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Towards net-zero buildings in developing countries – a simplified approach for assessment

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Abstract. Construction projects are associated with huge amount of embodied and operational energy. Therefore, the construction industry contributes significantly to the emission of energy related greenhouse gases (GHGs). Adopting sustainable green construction and the concept of net-zero energy buildings (NZEB) could reduce GHGs emissions from the construction sector and lower its contribution to global warming. However, implementing NZEB comes with different challenges, especially for developing countries. One of the main challenges is the lack of interest from landlords, property developers and investors. Motivating and empowering construction stakeholders to embrace the NZEB approach are crucial for developing countries aiming to lower their GHGs emissions. However, assessment and verification of NZEB face challenges in these countries due to the absence of viable assessment methods that consider local and national needs. Simplification of the process could encourage property developers to be engaged and adopt the concept of NZEB. This paper aims to propose a simplified approach for the assessment of sustainability of buildings. It provides property developers and stakeholders with a viable and affordable tool that produce timely results to demonstrate the sustainability of their new developments. The proposed approach eliminates several costly and time-consuming aspects and focuses on main factors within the three primary phases of construction projects; design, construction and operation. The implementation of the proposed simplified approach is illustrated, and it has been shown that the approach is viable, simple and easy to apply. It could lead to significant savings in energy and reduction in the associated GHGs.

Keywords: Climate change / sustainable construction / net-zero buildings / passive design / LCSA / renewable energy / sustainability certification

1 Introduction

The adverse impact of the construction sector on the environment and its contribution to global warming and climate change presents significant challenges to the construction industry. The global emission of greenhouse gases (GHGs) from the construction of buildings and associated activities contributes about 39% of the energy related GHGs emissions worldwide. Therefore, the construction industry is considered one of the main contributors to climate change and global warming. However, only 11% of these emissions is from embodied related energy and mainly comes from materials and construction processes [1]. The remaining 28% are emissions from activities related to the operation of buildings including lighting, cooling, heating, cooking, and day-to-day operation. Most emissions from these activities comes from residential buildings.

The direct and indirect emission from the operation of residential buildings account for 61% of the total emissions from operational energy in the construction industry, as can be seen in Figure 1 [2–4].

Reducing the emissions from the consumption of operational energy of buildings, therefore, could have a very significant impact on the reduction of the total energy-related emissions from buildings. Although every effort should be made to minimize the energy consumption in the construction and operation of buildings, more emphasis should be on the operational activities within residential buildings because they are responsible for most of the energy related emissions.

1.1 Net-zero concept

There are several expressions and definitions associated with the concept of zero energy in buildings and constructions. However, net-zero energy building (NEZB) and net-zero building (NZB) are the most

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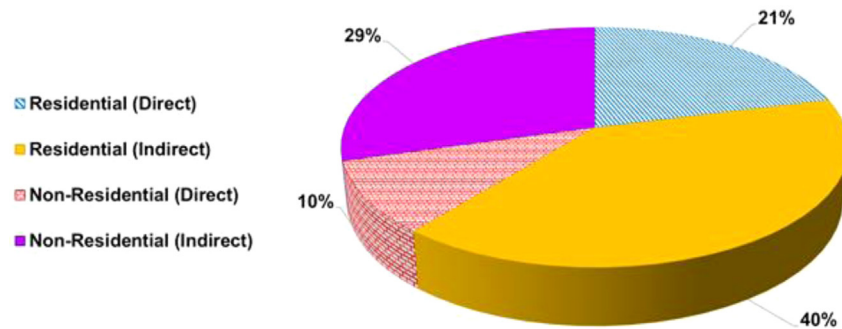


Fig. 1. Emission of CO₂ from the operational energy in buildings. Source: Produced by the author using data from IEA [5].

common. The latter could simply be defined as a building that has no net GHGs emissions from its construction and operation [6,7].

Buildings with reduced emission close to zero are often described as nearly-zero energy buildings (nZEB) [4]. For the sake of simplicity, these abbreviations (NZB, NZEB and nZEB) will be used, in this paper, for single and plural terms.

Theoretically, NZEB status of a building or a project could be achieved by eliminating or offsetting energy related GHGs emission during the construction stage and producing its own operational energy. The latter could be achieved by producing enough on-site renewable energy (RE) and lowering its energy consumption by using energy efficiency techniques [8].

1.2 The role of the construction industry in combating global warming

Since the early 1970s, the international community recognized the challenges of climate change and global warming. The universal effort resulted in several protocols, agreements, and treaties to address global warming and adapt to climate changes. The most recent, and arguably the most important, is the current Paris Agreement on climate change, which has a main goal of keeping the rise in global warming to well below 2°C above pre-industrial levels, by 2050 [9]. More than two hundred country and entity committed to the main goal of Paris Agreement and each of them is obliged to submit its own Nationally Determined Contribution (NDC). The submitted NDCs should state the targets of each country to reduce its national emissions and outline the actions planned to achieve the target. The treaty does not impose specific targets to be included in the NDCs. However, they are updated every 5 years and should demonstrate progress by including higher targets in each review.

The reduction of the emissions from the construction sector has been included in the NDCs of most countries [10]. The construction industry is facing significant challenges in the race against global warming, and it is under significant pressure to remove barriers and to accelerate the full implementation of net-zero concept in buildings [3,11,12].

The progress made during the current decade is critical to achieve the climate goals of the Paris Agreement on climate change by mid-century. Global decarbonization

trajectories indicate that the construction industry needs to diminish half of its greenhouse gases (GHGs) emissions by the end of this decade to reach a net zero status by 2050 [12]. Therefore, it is imperative that stakeholders, developers, designers, architects, and contractors within the building and construction sector to take serious actions to decarbonize the construction industry. Innovative and practical approaches are, therefore, required to overcome any barriers and to ensure wider engagement from all stakeholders.

2 Research aims and objectives

This paper aims to contribute to motivating and empowering construction stakeholders to embrace the net-zero energy buildings (NZEB) concept. It proposes a simplified approach for the assessment of sustainability that could be used by property developers to demonstrate the sustainability of their new developments. This could help developing countries to meet their international obligations by lowering their contribution to the emission of energy related greenhouse gases (GHGs).

In order to achieve the main aim of this research the following objectives are established:

- Review the practicability of performing a full life cycle analysis to assess the sustainability of buildings in developing countries.
- Propose a generic simplified approach for sustainability assessment, which eliminates costly and time-consuming complexity from current international methods.
- Illustrate the application of the proposed approach and demonstrate its simplicity and ease of use, to encourage property developers and investors to be engaged in the process and adopt net zero buildings.

3 Research methodology

This is an investigative study using an inductive research approach. Structured interviews and group discussions were conducted following a well-designed questionnaire aiming to investigate the barriers to sustainable construction in developing countries, particularly in south-hemisphere and middle east countries.

This paper primarily builds on a significant finding from the output of the questionnaire, because a noteworthy portion of the thirty-seven participants identified the

complication of assessing building sustainability as one of the main barriers for implementing the green buildings concept; hence the focus of this paper.

In addition to the questionnaire, fourteen interviews and two large group discussions were conducted to gain further understanding of the various views of the stakeholders.

The participants were different stakeholders, including property developers, contractors, consultants, and academics from several southern-hemisphere and middle east countries, including Nigeria, Oman, Egypt, India, Qatar and the Philippines.

Additional data was collected by documentary analysis, including reports from the United Nations (UN), International Energy Agency (IEA) and other available global data.

4 Discussion

Adopting green construction approach and moving towards NZEB or nZEB face challenges and barriers that prevent a wider implementation in almost every county. However, it is more difficult for developing countries. One of the main reasons, is the lack of national standards, codes, and guidance for landlords, developers, and investors. Those stakeholders need access to a practical national system of assessment and certification of green building.

Stakeholders declaring a building as NZEB or nZEB need to provide evidence that carbon emission has been reduced to the target level. For example, eliminated in the case of NZEB or reduced to a specific target close to zero, in the case of nZEB. Therefore, it is necessary to check and verify such claims and, then issue building energy certification or classification.

Policy makers in developing countries attempt to enforce the green buildings concept by developing policies, codes and standards. However, the absence of national data and the complexity of processing such data, if existed, impair the assessment process [13], and compromise the trust in the verification and certification processes. It is crucial, therefore, to employ a viable assessment that uses national data to gain the trust of stakeholders in the process and encourage them to be actively involved.

To address these challenges and barriers in developing countries, the discussion in this section is focusing on the practicability of performing a full life cycle analysis. Then, will review the suitability of international building certification forms for adaptation in developing countries.

4.1 Life cycle sustainability assessment (LCSA)

There are several methods for sustainability assessment including LEED, BREEAM, Living Building Challenge, and whole Life Cycle Assessment (LCA). The latter is, arguably, the most common method in assessing the sustainability of buildings. LCA of new buildings could provide valuable information about the impact of the project on the environment. It is a widely recognized method in assessing environmental performance of buildings and their adverse impact on the environment. Compared to LEED, BREEAM and other methods LCA

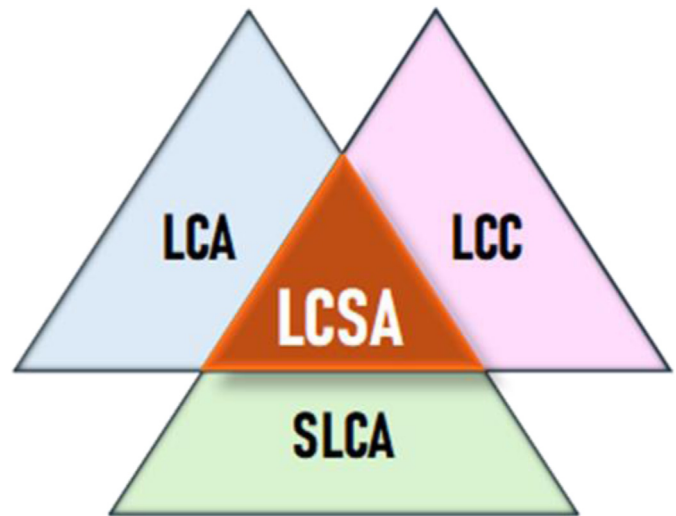


Fig. 2. Life cycle sustainable assessment (LCSA). Source: work by the author.

is increasingly being acknowledged by professionals in the construction industry [14–17]. However, in response to environmental, social and economic challenges, environmentalists, professionals recommended a more holistic approach to address sustainability in a more comprehensive assessment. Thus, the concept of Life Cycle Sustainability Assessment (LCSA) has emerged. The LCSA integrates LCA with life cycle costing (LCC), life cycle assessment and social life cycle assessment (SLCA) [18]. The LCSA concept is illustrated by a schematic presentation in Figure 2. Combining these three concepts makes LCSA so comprehensive that it could provide valuable information and evaluation on the impact of processes on the economy, the society and the environment. Informed decisions could then be taken to help in reducing the adverse impact exerted on the environment.

Reliable assessment of buildings sustainability requires addressing real challenges at various stages including design stage, selection of materials, and construction. LCSA performance evaluation considers design efficiency, material selection, construction systems, energy consumption, resources, ease of maintenance, prospect of reusing or recycling of components, dismantling, and demolition waste, to name a few. Therefore, a full application of LCSA requires processing of complex sets of interconnected – and often missing – data. Consequently, imposing systematic application of LCSA for comprehensive assessment of buildings performance could present property developers and stakeholders with prohibitive challenges, particularly in developing countries. This is perceived as one of the most significant barriers to the utilisation of LCSA and adoption of the concept of NZEB. Researchers and stakeholders, therefore, highlighted the need for simplifications of the process and considered proposals that do not lead to significant change in the outcome [19–23].

As such, simplification of the process of sustainability assessment should be considered. A simple assessment approach focusing on the factors that contribute most to the sustainability of buildings could provide a more

attractive alternative to stakeholders and developers. The latter could demonstrate the sustainability of their buildings using a flexible assessment method focusing on features and strategies of passive building design, integration of renewable energy technologies, and embracing recycling opportunities. The simpler the approach for the assessment of the sustainability of buildings the more the commitment expected from property developers and stakeholders [3].

Key stakeholders in the construction industry, such as property developers not only have doubts about the financial benefits of green construction, but also consider adopting sustainability features and strategies, including assessment methods, as a costly and time-consuming process [3,24]. The capital cost of sustainable construction is greater than that of normal construction. Research based on hundreds of case studies in several countries found that a 7% cost surcharge associated with sustainable construction [25]. In a survey conducted by DDA [26], most developers, and stakeholders listed the additional cost incurred due to adopting green construction practices as the number one barrier to the wider adaptation of green construction.

Indeed, the cost associated with the assessment method is even more prohibitive to developers and stakeholders in developing countries, particularly in the southern and middle east countries. These countries have some common socio-economic characteristics and have not realized their potentials, yet. Most of them, have high levels of poverty, limited access to education and more vulnerable to climate change and environmental degradation, compared to the well-developed countries in the northern hemisphere. Therefore, a simple affordable assessment method could help these developing countries in their effort to lower their GHGs emissions, contribute to combating global warming and meet their international obligations.

4.2 Building energy certification

There Energy rating, energy labelling schemes, and building energy certification are often introduced together with building energy codes to increase energy-efficient buildings. Building energy certification focuses on classifying energy performance of buildings and recognizing high performance building, whereas energy codes focus on setting minimum energy requirements.

Building energy certification could take different forms and could have different meanings and interpretation. Certification programmes vary in their objectives and what they could offer in terms of certification documents. They can take the form of classification labels that categorize buildings into classes such as energy performance labels. They could also offer endorsement labels or approval certificates.

It is more than three decades since the emergence of the idea of building energy certification programmes. Systems including LEED, BREEAM and others have been around for years [27]. However, voluntary certification programmes are more widespread compared to mandatory certification programmes. The latter are almost entirely limited to a small number of developed countries, as can be seen in Figure 3. Moreover, careful examination of this

figure reveals that most of the developing countries are still without any certification programme or information about such systems.

Approving energy rating, energy labelling schemes, or building energy certification requires a reliable sustainability database on building energy performance. Unfortunately, in developing countries, such sustainability data remains insufficient, due to the lack of actual data captured from the sustainability performance of national and local buildings. Even when some sustainability data is available – from international database for instance – it does not provide reliable information about the actual performance of local or national buildings. In addition, the need for reliable and systematic verification raises another challenge. The uncertainty about the available data leads to indecisive verification, whether it is authorized by a state department or endorsed by an independent approved third party. Most developing countries, therefore, are unable to enforce mandatory or voluntary building energy certification or labels.

An improved assessment process with reliable, trusted tools to assess building sustainability is needed [2]. As a first step, a simplified system could provide qualitative assessment and capture actual national data from actual performances of buildings.

5 A simplified approach for sustainable buildings (SASB)

This paper introduces a simplified assessment method of buildings sustainability. It is intended to empower stakeholders and help them to demonstrate the sustainability of their buildings. The proposed simplified approach could help in capturing relevant quality data about actual energy performances of national buildings. Eventually, each developing country could build its own national sustainability database and make it available to stakeholders. The availability of such data could increase the reliability and confidence among stakeholders in the energy verification method and certification process.

The proposed simplified approach focuses on three criteria, including:

- Low-energy building design (Mainly in design stage).
- Integration of renewable energy technologies.
- Embracing waste management opportunities.

This simplified approach focusses on crediting current and visible measures or processes that can be checked and verified anytime. The demolition and disposal are not included, as there is no confidence that claimed actions will be still available for verification. Verification could be approved by design documents, building permissions or physical existence of facilities during the operation of the building. To this end, buildings could claim some credit towards achieving NZEB/nZEB status if they adopt significant visible and measurable means in each of above criteria. Credits could be scored for specific measures that could reduce the carbon footprint by implementing one or more of the following aspects:

- Saving energy.
- Reducing the use of raw materials.

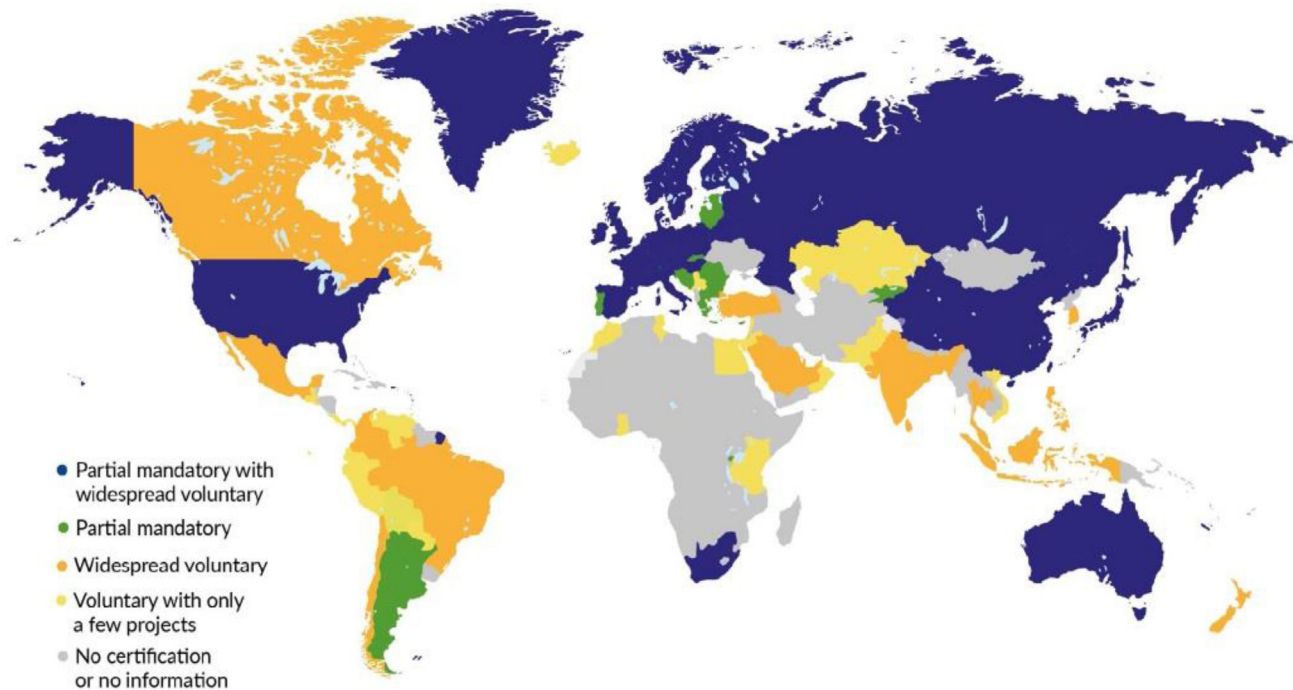


Fig. 3. Mapping of Building Energy Certification. Source: Adapted from IEA [28].

- Recycling/reusing materials and resources.
- Offsetting carbon emissions.

To clarify the crediting process, the following examples are considered. A good building design focusing on energy efficiency and reducing the amount of steel could be credited against the first *criterion* “low-energy building design” because they contribute to “saving energy”, “reducing of raw materials” and “offsetting carbon emissions” *aspects*. Similarly, utilisation of solar panels in a building to produce its own electricity or part of it, is a *measure* that should be credited against “integration of renewable energy (RE)” *criterion* in two *aspects*, including “saving energy” and “offsetting carbon emissions”.

Of course, there are measures that could contribute to all aspects of a specific criterion. For example, reusing condensate water from A/C units. This measure satisfies all the aspects of the third criterion “embracing waste management opportunities”. It saves the energy that would have been needed to produce a similar amount of water, it reduces the amount of wastewater going to the drainage system and wastewater treatment plants, it reuses a valuable resource, it recycles this amount of what would have considered waste, and finally it contributes to offsetting carbon emission.

An example of the expected outcome of the process is given in Table 1, which includes credits detailed in the above examples. More details are given in the following sections.

5.1 Low-energy building design

Sustainable performance of buildings starts at the conceptual and full design stages. They could have great potential for improving the sustainability credentials of buildings.

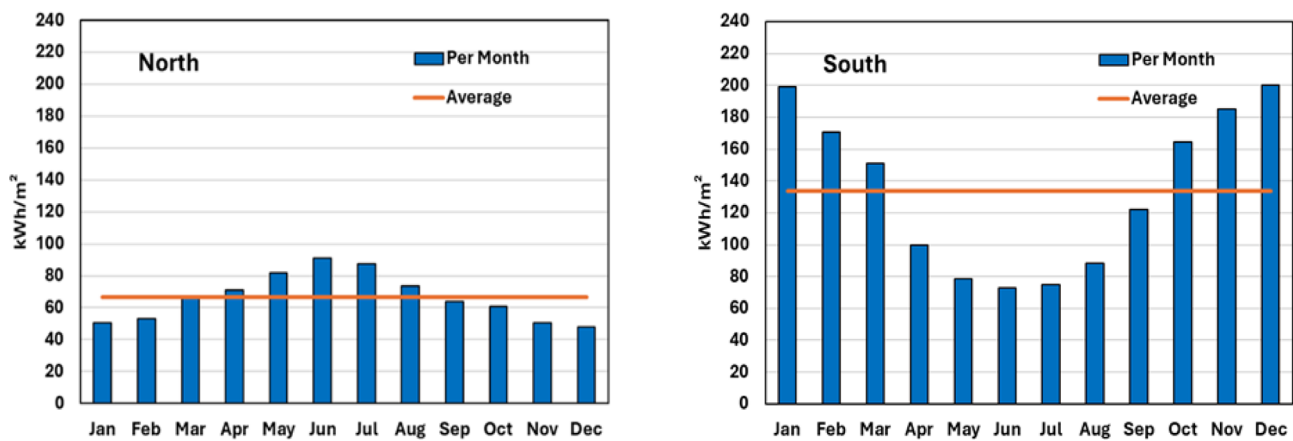
The importance of considering the early design stage during sustainability assessment is increasingly acknowledged by designers. Several studies identified a strong link between the specifications decided during the design phase and improving the environmental performance of buildings and construction projects, as evidenced by reductions in energy consumption and adverse impact on the environmental [29–31].

Low-energy building design focuses mainly on optimizing the building’s system, shape, orientation, and envelope to reduce its energy consumption without impairing the comfort of end-users. Usually, passive or low-energy design could involve many aspects including strategies integrated into the building. This could include passive solar features, efficient electric lighting, utilization of natural daylighting, exterior shading, natural ventilation, energy-saving sensors, energy management system and controls, low-energy mechanical systems, and many more. However, these aspects vary in importance and their contribution to the reduction of operational energy. In the proposed simplified approach, the focus will be on optimizing the building shape and orientation [2,32,33].

Careful consideration of the building shape, orientation, and insulation of the building skin during the early design stage play crucial role in the energy performance of the building. This is achieved by eliminating unwanted solar radiation, maximizing beneficial solar gain, and proper insulation. Therefore, the proposed simplified approach focusses on optimizing the building shape and orientation as well as considering the importance of insulation during the design stage, with aim of reduction in energy consumption.

Table 1. Illustration of crediting sustainable measures, in the proposed simplified approach. Source: work of the author.

 Criteria Aspects 	Saving energy	Reducing raw materials	Reusing multiple times	Recycling for new purpose	Offsetting carbon emissions
Low-energy building design	✓	✓			✓
Integration of RE	✓				✓
Embracing waste management opportunities	✓	✓	✓	✓	✓

**Fig. 4.** Solar radiation on buildings facing North or South, in the Northern Hemisphere. Source: Adapted from Badr (2024).

5.1.1 Building orientation

Solar radiation absorbed by building surfaces results in significant heat gain in the building. This could be considered as a blessing in cold countries but a disadvantage in hot countries. Badr [33] showed that solar radiation depends on the longitude and latitude of the location of the building, particularly with respect to the Equator. Equally, it also depends on the season and the number of sunshine hours per day. For example, Figure 4 shows the radiation on a building in Egypt, which is a developing country located in the northern hemisphere with hot climate. The figure shows radiation over a full year for the buildings facing North or South.

In order to illustrate the importance of optimizing the building orientation, a rectangular shape will be considered, assuming it is exposed to the radiation shown in Figure 4. It can be seen that the North radiation is less than that from the South. The building is in a hot country and, therefore, aligning the long side facing the North direction could reduce the heat gain and reducing the energy needed for cooling the indoor environment using air-conditioning units.

On the contrary, if this building was in a cold country, in eastern Europe for instance, orienting the long side facing the South would work to the advantage of the building. In this case, the heat gained from radiation will help in reducing the energy needed for heating the indoor, particularly in the colder months from September to March.

5.1.2 Building shape

The optimization of the building shape depends on its location, site layout, and the surrounding climate. Again, solar radiation will play a significant role in deciding the shape of a building with a specific decided orientation. Solar radiation absorbed by the surface area of the building results in significant heat gain in buildings, which could be considered a blessing in cold countries but a disadvantage in hot countries. The aim of the optimization of the building shape is maximizing the surface area of the exposed surface in cold locations and minimizing it in hot countries.

In hot countries, most buildings are fitted with air-conditioners for the comfort of the occupants. In this case, the main aim is reducing the cooling load. Therefore, the

optimum shape of a building should minimize the solar heat absorbed by the building surfaces, which ultimately will transfer into the interior of the building. Clearly, this could be achieved by the most compact shape. That is a square shape, if the site layout permits, or a rectangle shape with a minimum length to width ratio.

The best shape in a cold country would be a shape of maximum perimeter exposed to solar radiation, particularly in winter. A rectangle shape with a maximum possible length/width ratio and fit within the site layout. The solar heat gained from the large surface area will be transmitted into the interior and help in reducing the consumption of heating energy.

5.1.3 Building envelope and insulation

Proper insulation of the outer skin of buildings by a material with low embodied energy could reduce the rate of energy flow from outdoor into indoor and vice versa. The actual energy consumption could be reduced with good insulation. In addition, using a material with low embodied energy will contribute to the reduction in the building embodied energy.

The efficiency of the envelope not only has a direct influence on the energy consumption but also it could help in reducing the mechanical heating/cooling load. Thus, minimizing the size of the air-conditioning units or central heating systems operating inside the buildings.

5.2 Integration of renewable energy technologies

Construction and infrastructure projects demand energy at various stages of projects from start to completion, and then during operation and maintenance to keep them fit for purpose. The source of this energy defines the carbon footprint of these projects. The production of the energy needed from sustainable and renewable sources could reduce the negative impact on the environment and help in adapting to climate change [34]. Renewable energy produced onsite presents the best solution. Most sources of renewable energy including solar, wind, biomass and geothermal could be used directly in some application or could be converted to electricity before being used in many other applications [35]. The most effective and economical method is integrating them directly in the project during the construction stage. Integrating renewable energy within any process reduces its impact on the environment and improve its sustainability. For example, Badr [18] showed that the sustainability credentials of desalination plants are enhanced by integrating renewable energy in the process, such as photovoltaic (PV) powered desalination.

5.2.1 Solar power systems

Integrating solar energy generated from photovoltaic (PV) systems within new building structures is known as Building Integrated Photovoltaics (BIPV). It requires installing a PV system during the construction of the building. Compared to non-integrated systems, BIPV offers advantages such as reducing utilized land [36]. The process is well-established and is gaining popularity among

developers and stakeholders, but not in developing countries. Li et al. [37], investigated the economic and environmental performance of new types of BIPV in three countries in Europe and proved that they are economically feasible systems. They concluded that the outcome of their study can serve as valuable guidelines for the design of BIPV projects. If the electricity generated by the system is enough for the consumption of occupants of the building, then it could be claimed that the building is producing its own operational energy.

5.3 Embracing opportunities for recycling and reusing of resources

Sustainable design should prioritize reducing the quantities of materials used in the building without impairing the ability of the building to perform its purpose. Additionally, sustainable materials should be prescribed in the specifications. Furthermore, the embodied energy and the carbon footprint of any building could be reduced significantly by embracing opportunities for recycling and reusing by-products and construction waste [38,39]. Not only will this reduce the use of raw resources but also could deduct from the building's carbon emissions and reduce its embodied energy.

The proposed approach focuses on recycling and reusing resources during the operation of the building because they could be verified at any time of the building's entire life. Therefore, reusing by-products and waste that is produced during the operation of the building could contribute to a strong claim of sustainability of the building. One example could be by recycling water condensate from air-conditioning units, in hot countries [40].

On the other hand, developing countries with cold weather and long rainy seasons could collect on-site rainwater and reuse it as a green source of freshwater. Furthermore, some countries with tropical climate, such as Malaysia, experience hot humid climate and long rain season, almost all year round. In this case, both on-site rainwater and condensate water from air-conditioning units could be collected in one collection system.

Collecting and reusing on-site rainwater and condensate water from air-conditioning units offer a green source of water that could help in reducing the demand for freshwater from municipality [41,42]. Furthermore, it saves the energy that would have been used to produce similar amount of freshwater and deliver it to the site.

6 Conclusion

This research contributes to the global knowledge of adapting to climate change. The practicability of performing a LCSA of buildings in developing countries was reviewed. Then, a simplified approach was proposed for conducting an easy and simple assessment, with focus in crediting low-energy design, integration of renewable energy technologies, and embracing opportunities for recycling and reusing of resources. The following conclusions are made:

- The assessment of the sustainability of buildings faces real challenges in developing countries due to the absence of national assessment methods. Adopting international methods of sustainability assessment in developing countries is not practical due to the lack of reliable national social and economic data. A viable generic tool that could produce timely results with minimum effort could help these countries move quicker towards NZEB or at least towards nZEB.
- A simplified approach for the assessment of sustainability of buildings was proposed to enable property developers to demonstrate the sustainability of their new developments and their contribution to control GHG emission and embracing the concept of net zero buildings.
- The proposed approach eliminates several costly and time-consuming aspects and focuses on the three main phases of construction projects including design, construction stage and operation of the building.

The implementation of the proposed approach could help developing countries in motivating an empowering construction stakeholder in adopting the concept of NZEB and contribute to combating global warming.

7 Limitations and further research

- The focus of this research was on proposing a simplified method for the assessment of the sustainability of buildings and providing developing countries with a practical tool to encourage stakeholders to adopt the NZEB approach. Therefore, the examples used in different sections were general so that they can be used by any country.
- Further research, therefore, could include the application of the proposed method on projects in a specific country to develop a strong database including reliable national data and vital information on social and economic aspects related to the construction of buildings in that country.
- Optimizing the proposed simplified approach without readmitting complication into the assessment and certification process, could be an important area for further research. This could include developing a structured set of indicators and weights to make the identified aspects and criteria more operative and improve the assessment method.

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Conflicts of interest

The author has nothing to disclose.

Data availability statement

Some data used in this study was collected by documentary analysis, including reports from the United Nations (UN) [9], International Energy Agency (IEA) [5,28], and other available global data. All are cited and acknowledged in the relevant sections.

Author contribution statement

The author has nothing to disclose.

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