CEFIA
Cleaner Energy Future Initiative for ASEAN
ASEAN+3

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Zero Energy Buildings (ZEB) in ASEAN

Exploring the Potential Benefits, Challenges, and Strategies for Implementation

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About ASEAN Centre for Energy

Established on 1 January 1999, the ASEAN Centre for Energy (ACE) is an intergovernmental organisation within the Association of Southeast Asian Nations' (ASEAN) structure that represents the 10 ASEAN Member States' (AMS) interests in the energy sector. ACE supports the implementation of the ASEAN Plan of Action for Energy Cooperation (APAEC), a blueprint for better collaboration towards upgrading energy. The Centre is guided by a Governing Council composed of Senior Officials on Energy from each AMS and a representative from the ASEAN Secretariat as an ex-officio member.

The three key roles of the ACE:

1. As a catalyst to unify and strengthen ASEAN energy cooperation and integration by implementing relevant capacity building programmes and projects to assist the AMS develop their energy sector.
2. As the ASEAN energy data centre and knowledge hub to provide a knowledge repository for the AMS.
3. As an ASEAN energy think tank to assist the AMS by identifying and surfacing innovative solutions for ASEAN's energy challenges on policies, legal & regulatory frameworks and technologies.

Keeping the region's energy security, affordability, and sustainability is a fundamental concern of the ASEAN energy sector. Hosted by the Ministry of Energy and Mineral Resources of Indonesia, ACE's office is located in Jakarta, Indonesia. For more information: https://aseanenergy.org/

About CEFIA

Cleaner Energy Future Initiative for ASEAN or CEFIA was proposed by Japan and welcomed by the ASEAN+3 Ministers on Energy at the 16th ASEAN+3 Meeting of Energy Ministers in Bangkok, Thailand on 5th September 2019. CEFIA serves as a platform to facilitate collaboration between public and private sectors in deployment of cleaner energy and decarbonisation technologies in the ASEAN region.

Under CEFIA, several Flagship Projects are undergoing. Flagship Projects are decarbonising projects implemented by private companies and organisations whose purpose is to showcase best practices of co-operation in technology deployment, in parallel with developing appropriate policy and institutional frameworks and mobilising public and private funding (governments, private sector and academia). For more information: https://www.cefia-dp.go.jp/

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Abbreviations

ACE	: ASEAN Centre for Energy
AEC	: ASEAN Economic Community
AEO	: ASEAN Energy Outlook
AJEEP	: ASEAN-Japan Energy Efficiency Partnership
AMS	: ASEAN Member States
APAEC	: ASEAN Plan of Action for Energy Cooperation
ASEAN	: Association of Southeast Asian Nations
BEC	: Building Energy Code
BCA	: Building and Construction Authority
BELS	: Building-Housing Energy Efficiency Labelling System
CEE	: Energy Efficiency and Conservation
CEFIA	: Cleaner Energy Future Initiative for ASEAN
DEDE	: Department of Alternative Energy Development and Efficiency
DOE	: Department of Energy
ECAP	: Energy Conservation Workshop under ASEAN-Japan Energy Efficiency Partnership
ECON	: Economic level
ECCJ	: Energy Conservation Centre Japan
EE&C-SSN	: Energy Efficiency and Conservation Sub-sector Network
ESCO	: Energy Service Companies
GBCI	: Green Building Council Indonesia
GDP	: Gross Domestic Product
GHG	: Greenhouse Gas
HEPS	: Higher Energy Performance Standard level
JASE-W	: Japanese Business Alliance for Smart Energy Worldwide
MEMR	: Ministry of Energy and Mineral Resources
METI	: Ministry of Economy, Trade and Industry
MTOE	: Million Tonnes of Oil Equivalent
NEA	: National Energy Awards (Malaysia)
nZEB	: Nearly ZEB
NZEB	: Net Zero Energy Building
PETRA	: Ministry of Energy Transition and Water Transformation (Malaysia)
RE	: Renewable Energy
SARE	: Supply Agreement on Renewable Energy
SLE	: Super Low Energy
SEDA	: Sustainable Energy Development Authority
ZEB	: Zero Energy Building

Chapter 1

Introduction

1.1. Background

Home to more than 670 million people, the Association of Southeast Asian Nations (ASEAN) has increasingly emerged on the global map as a fast-growing region in both economy (4% average annual GDP growth rate until 2050) and urbanisation (reaching 66% of the regional population by 2050) **[1]**, signalling a significant increase in energy demand. According to the 8th ASEAN Energy Outlook (AEO8) published by the ASEAN Centre for Energy (ACE), the region's energy consumption is projected to continue its upward trajectory until 2050, with energy demand standing at 2.6 times higher than in 2022. This projected surge in demand underscores the importance of reducing reliance on fossil fuels to ensure energy security, economic stability, and environmental sustainability.

Among the sectors, the residential and commercial building sector made up 22% of ASEAN's total energy consumption in 2022. The projection for the sector's energy consumption is expected to be a 56% increase from 95.52 MTOE in 2022 to 144.13 MTOE by 2050. This growth is particularly concerning as electricity is the dominant energy source, supplying 55% of building appliances and accounting for roughly 21% of the region's greenhouse gas emissions. The building sector in ASEAN is thus a major contributor to energy consumption and greenhouse gas emissions. In 2020, buildings accounted for 23% of the region's total final energy consumption and an equal share of energy-related CO_2 emissions, amounting to approximately 0.4 gigatonnes of CO_2 **[2]**. This highlights that the building sector's greenhouse gas (GHG) emissions are disproportionately high compared to its share of energy consumption, likely because of the reliance on carbon-intensive electricity sources. AEO8 data confirms that without significant policy interventions, the building sector's emissions will continue to rise, undermining ASEAN's climate goals.

Given that context, ASEAN has strived to work towards a pathway to low-emission and efficient buildings. This objective is captured in the ASEAN Plan of Action for Energy Cooperation (APAEC), a series of guiding policy documents that aims to promote multilateral energy cooperation and integration to attain the goals of the ASEAN Economic Community (AEC) **[3]**. Within the initiatives aligned with APAEC, specifically Programme Area No. 4 – Energy Efficiency and Conservation, and Outcome-Based Strategy (OBS) 3: Strengthen Sustainability of Energy Efficiency in Buildings, the adoption of Zero Energy Buildings (ZEB) promises a key solution for the region to reducing energy consumption and carbon emissions in the building sector.

ZEB is a highly energy-efficient building that generates as much energy as it consumes over a defined period, typically a year. This is achieved through a combination of energy efficiency measures, renewable energy generation, and advanced building design to minimise energy consumption. By reducing energy demand and leveraging clean energy, ZEB significantly lower the building sector's carbon footprint. This

directly contributes to the broader objectives of APAEC, particularly in enhancing energy efficiency, promoting renewable energy, and decarbonising the energy sector. Furthermore, the widespread adoption of ZEB positions ASEAN to play a pivotal role in achieving its long-term decarbonisation targets and demonstrating leadership in global climate action.

1.2. Objectives

This report aims to explore the potential benefits and challenges of ZEB Implementation, as a strategic solution for energy efficiency and decarbonisation in ASEAN.

Specifically, the objectives are to:

- Assess the current and future energy consumption and emissions profile of ASEAN's building sector, considering factors such as urbanisation, economic growth, and energy consumption patterns.
- Examine the potential benefits of ZEB in reducing energy consumption, mitigating greenhouse gas emissions, and enhancing energy security in the region.
- Identify the key barriers and challenges hindering ZEB implementation in ASEAN, including policy gaps, technical constraints, financial limitations, and awareness deficits.
- Propose actionable strategies and policy recommendations to accelerate the adoption of ZEB in ASEAN Member States, aligning with APAEC and contributing to the region's broader climate and sustainable development goals.

1.3. Literature Review: ZEB Definitions and Standards

This report acknowledges the various definitions and approaches to ZEB globally and within ASEAN. While a universal standard remains elusive, the core principle focuses on achieving a balance between energy consumption and on-site renewable energy production. Various countries and organisations, both globally and within ASEAN, have established their frameworks and guidelines for ZEB implementation. Similarly, the ASEAN Energy Awards recognise ZEB as structures utilising advanced design, passive technologies, and high-efficiency systems to achieve significant energy savings. This review highlights the importance of energy efficiency as the primary step toward achieving ZEB status, followed by integrating renewable energy technologies to offset remaining consumption. The existing ISO Technical Specification TS23764 offers a three-step methodology for achieving ZEB, further guiding implementation efforts. This report builds upon these existing definitions and standards, providing a regional context for ZEB adoption in ASEAN.

1.4. Scope and Limitations

Scope

This report focuses on evaluating the potential benefits, challenges, and strategies for implementing ZEB across the ten AMS. The analysis primarily considers non-residential and commercial buildings, encompassing both new constructions and retrofitting existing structures. The temporal scope covers the period from 2022 to 2050, aligning with APAEC targets and long-term decarbonisation goals.

Limitations

- Data Availability: The availability and consistency of energy consumption and building data vary across ASEAN Member States. This may introduce uncertainties in the analysis and projections.
- ZEB Definition Variability: The lack of a universally accepted ZEB definition poses a challenge in comparing and benchmarking ZEB performance across the region. The report acknowledges the existing definitions with different boundaries based on the country's needs, as a core principle of ZEB is to prioritise energy efficiency
- Expert Input: While efforts were made to consult with experts from ASEAN Member States, Japanese Business Alliance for Smart Energy Worldwide (JASE-W), and Energy Conservation Centre Japan (ECCJ), the insights gathered may not fully represent the diverse perspectives and experiences within the region.
- Methodological Constraints: The report employs a combination of literature review, data analysis, and qualitative assessments. The findings and recommendations are subjected to the limitations inherent in these methodologies.
- Implementation Barriers: The report analysis focused on technical feasibility but did not address in detail some implementation barriers such as high initial investment and technical complexities. A more detailed analysis of financial mechanisms to overcome investment barriers is suggested for further research.

Chapter 2

ZEB Definition and Implementation Methodologies

2.1. ZEB Definitions: Global and ASEAN Perspectives

The concept of ZEB has gained significant global prominence in recent years, offering potential solutions to improve efficiency and reduce energy consumption in buildings. However, a universally accepted definition of ZEB remains elusive, hindering consistent implementation. Due to the complexity of global standardisation, ZEB can be defined in various ways, depending on the boundary and metric chosen, and the specific definition should align with the country's needs **[4][5]**. Regardless of the classification, a core principle of ZEB is to prioritise energy efficiency. This is achieved by first minimising energy demand through energy efficiency measures and then integrating renewable energy technologies to offset remaining consumption **[6].** The following definitions illustrate the differences in ZEB definitions and classifications from global and ASEAN perspectives.

2.1.1. United States

The U.S. Department of Energy (DOE) defines ZEB as an energy-efficient building where the total annual energy consumption is equal to or less than the renewable energy produced on-site **[7]**. This is achieved by maximising energy efficiency and integrating renewable energy systems to cover remaining energy demand. In defining net ZEB (NZEB) types, the DOE considers the source of renewable energy generation, distinguishing between on-site renewable generation and off-site renewable procurement **[8]**, as detailed in **Table 1**.

Table 1. *ZEB in the United States*

Category	Energy Efficiency	Renewable Energy
NZEB: A	Mandatory compliance, though not specifically defined	Footprint Renewables - All RE is available within the building footprint
NZEB: B		Site Renewables - All RE is generated within the boundary of the building site
NZEB: C		Imported Renewables - Off-site RE (e.g. biomass, biodiesel) is used to generate energy
NZEB: D		Off-site Purchased Renewable - Purchase RE which is generated off site

2.1.2. Japan

The realisation of ZEB is considered an important measure included in the Strategic Energy Plan in Japan in 2018, which aimed to achieve ZEB on average for all newly constructed public buildings by 2020 for non-residential buildings and by 2030 for all newly constructed public and private buildings nationwide **[9]**. Japan’s METI announced the ZEB design Guideline, based on the 2017 energy performance

standard. The Building-Housing Energy Efficiency Labelling System (BELS) was incorporated with this ZEB family concept **[10]**. Japan has supported the development of ZEB promotion in ASEAN and the dissemination of the ZEB family Concept, as a step towards achieving net ZEB, as detailed in **Table 2**.

***Table 2**. ZEB in Japan*

Category	Energy Efficiency	Renewable Energy
ZEB Ready	Energy saving ≥ 50%	Exclude RE
Nearly ZEB (nZEB)	Net energy saving ≥ 75%	Include RE
Net Zero Building (NZEB)	Net energy saving ≥ 100%	Include RE

2.1.3. Singapore

The Building and Construction Authority (BCA) in Singapore has been at the forefront of promoting sustainable building practices through its comprehensive BCA Green Mark scheme. The BCA Green Mark categorises high-performance buildings into progressive levels, including Positive Energy Building, Zero Energy Building, and Super Low Energy (SLE) Building **[11]**, which are 60-80% more energy-efficient than 2005 levels, as detailed in **Table 3**. ZEB in Singapore is defined as the best-in-class energy-performing Green Mark building, with all its energy consumption, including plug load, supplied from renewable sources (both on-site and off-site) **[12]**.

***Table 3**. ZEB in Singapore*

Category	Energy Efficiency*	Renewable Energy
Super Low Energy Building	60% energy savings based on 2005 levels	-
Zero Energy Building		RE ≥ 100% Energy Consumption
Positive Energy Building		RE ≥ 110% Energy Consumption

**Beyond BCA Green Mark Platinum*

2.1.4. Malaysia

The Zero Energy Building voluntary program started in 2018 right after receiving assistance from the Japanese Business Alliance for Smart Energy Worldwide (JASE-W) and the formation of ZEB focus group. The Sustainable Energy Development Authority (SEDA) Malaysia has developed a voluntary guideline for Zero Energy Buildings in Malaysia. It aims to support current government policies, including a 40% renewable energy target by 2035 and a 45% reduction in Greenhouse Gas (GHG) intensity by 2030, all contributing to the nation's goal of achieving carbon neutrality by 2050 **[13]**. Currently, there is no specific policy on ZEB, but there are current policies on energy efficiency and renewable energy. Therefore, since the components of ZEB are mainly the integration of both energy efficiency and renewable energy, the

implementation and promotion of ZEB is timely to support energy security and GHG reduction policies and targets. The ZEB program, as part of SEDA Malaysia's low carbon building facilitation program, classifies the definition of ZEB into three categories, as described in **Table 4**.

The categories are adopted from the Japanese definition of ZEB and ISO/TS 23764, with minor changes to suitthe local scenario and the current Sustainable Energy Low Carbon Building Assessment GreenPASS rating for ZEB voluntary certification for new design and existing buildings. The ZEB development program has also been considered as an alternative option to the existing green buildings program, for the building sector to achieve the net zero GHG emissions target by 2050. This is because the implementation of ZEB buildings is straightforward and cost-effective in achieving energy and carbon reduction. Malaysia has added ZEB as a category to its National Energy Awards (NEA), managed by the Ministry of Energy Transition and Water Transformation (PETRA) **[14]**. This aims to highlight successful ZEB practices and projects.

***Table 4**. ZEB* in Malaysia*

Category	Energy Efficiency	Renewable Energy
ZEB Ready	Energy saving ≥ 50%	Exclude RE
Nearly ZEB (nZEB)	Net energy saving ≥ 70%	Include RE (on site)
Net Zero Building (NZEB)	Net energy saving ≥ 100%	Include RE (on site)

** The ZEB Building is currently different from the conventional green building program since it has different performance metrics*

2.1.5. Thailand

The Department of Alternative Energy Development and Efficiency (DEDE) in Thailand actively promotes energy reduction through the Energy Conservation Promotion Act and the Building Energy Code (BEC), which was implemented in Thailand in January 2023 and applied to buildings with an area of less than 2,000 m^2 in March 2023 **[15]**. While the BEC primarily focuses on energy conservation, it serves as a key tool with a long-term goal of integrating ZEB criteria. ZEB is included in Thailand Energy Efficiency Plan 2018 (EEP2018) (2015 – 2036), which outlines three higher energy efficiency standards for buildings **[16]**, as described in **Table 5.**

***Table 5.** ZEB in the Building Energy Code (BEC) Thailand*

Category	Energy Efficiency	Renewable Energy
Higher Energy Performance Standard level (HEPS)	Not specifically defined	Not specifically defined
Economic level (ECON)		
Zero Energy Buildings level (ZB)		

2.1.6. Indonesia

The Ministries of Energy and Mineral Resources (MEMR) and Public Works and Housing play pivotal governmental roles in Indonesia's push for low-carbon buildings, aligning with the national aspiration for net-zero emissions by 2060 and a vision for 100% Net Zero Carbon Buildings by 2050. While a singular governmental regulation specifically defining ZEB is not yet in place, the Green Building Council Indonesia (GBCI) is crucial for its practical implementation through its “Greenship Net Zero” certification. Launched in 2023, this certification applies to both new and existing buildings, with a two-level certification **[17]**, as described in **Table 6**.

***Table 6**. ZEB in the Greenship Net Zero certification in Indonesia*

Category	Energy Efficiency	Renewable Energy
Net Zero Ready	Not specifically defined	Min. 8% RE or 20% RE
Net Zero Certified		Min. 100% RE

2.1.7. ASEAN Energy Awards

Following its success as Southeast Asia's highest recognition since 2000, the ASEAN Energy Efficiency and Conservation Best Practices Award continues to promote the best practices in energy efficiency in the region. In 2019, ZEB was added as a new subcategory under the Energy Efficient Building category of the ASEAN Energy Awards. This addition aimed to accelerate the implementation of ZEB in AMS to further reduce energy intensity in the building sector in the region **[18]**. The new award category defined ZEBs as structures utilising advanced design, passive technologies, and high-efficiency systems to achieve significant energy savings while using renewable energy to balance annual primary energy use to zero. The "ZEB Ready" designation recognised buildings achieving at least a 40% energy reduction compared to conventional standards.

***Table 7.** ZEB category in the ASEAN Energy Awards*

Category	Energy Efficiency	Renewable Energy
ZEB Oriented	Energy saving ≥ 30%	Exclude Renewable Energy
ZEB Ready	Energy saving ≥ 40%	Exclude Renewable Energy
Nearly ZEB (nZEB)	Net energy saving ≥ 60%	Include Renewable Energy
Net Zero Building (NZEB)	Net energy saving ≥ 100%	Include Renewable Energy

The development of this category was part of Energy Conservation Workshop under ASEAN-Japan Energy Efficiency Partnership (ECAP) 17, jointly organised by ECCJ and ACE, with representatives nominated by the ASEAN EE&C-SSN participated in this workshop. Adopting the definition from the Japanese ZEB family concept, the

ASEAN Energy Awards established its own criteria to suit the regional context **[19]**. The specific criteria for this category are defined in **Table 7**.

2.2. ZEB Implementation Methodology

Achieving carbon neutrality necessitates reducing building sector energy consumption, with ZEB as an aspirational goal. However, realising net-zero energy status in a single step presents challenges, including initial investment and technical complexities. To facilitate a progressive approach toward ZEB implementation, ISO has published Technical Specification TS23764: Methodology for achieving non-residential ZEB **[20]**. TS23764 outlines the following three steps depicted in **Figure 1**.

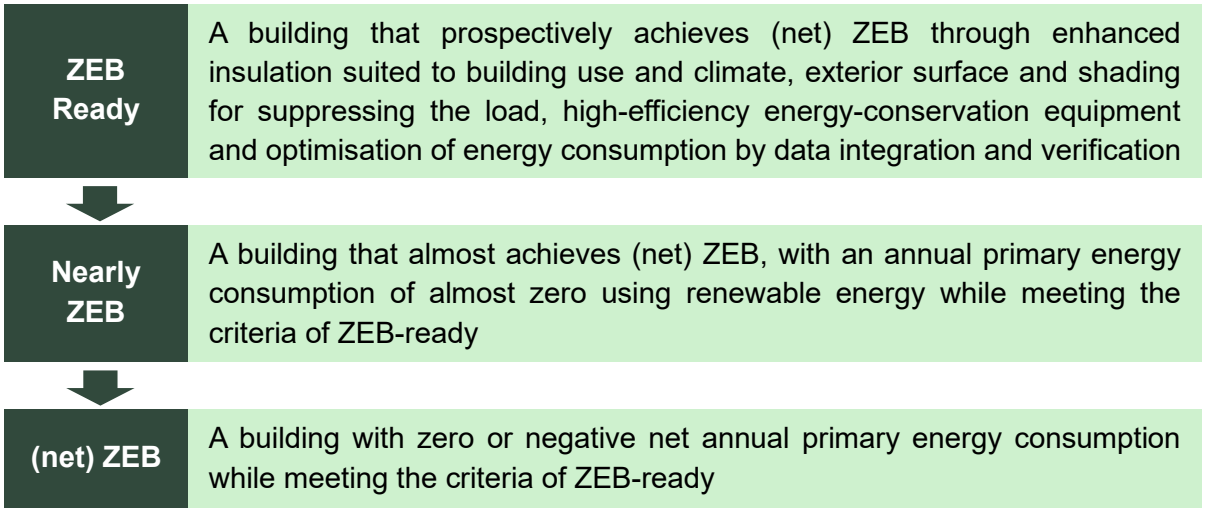
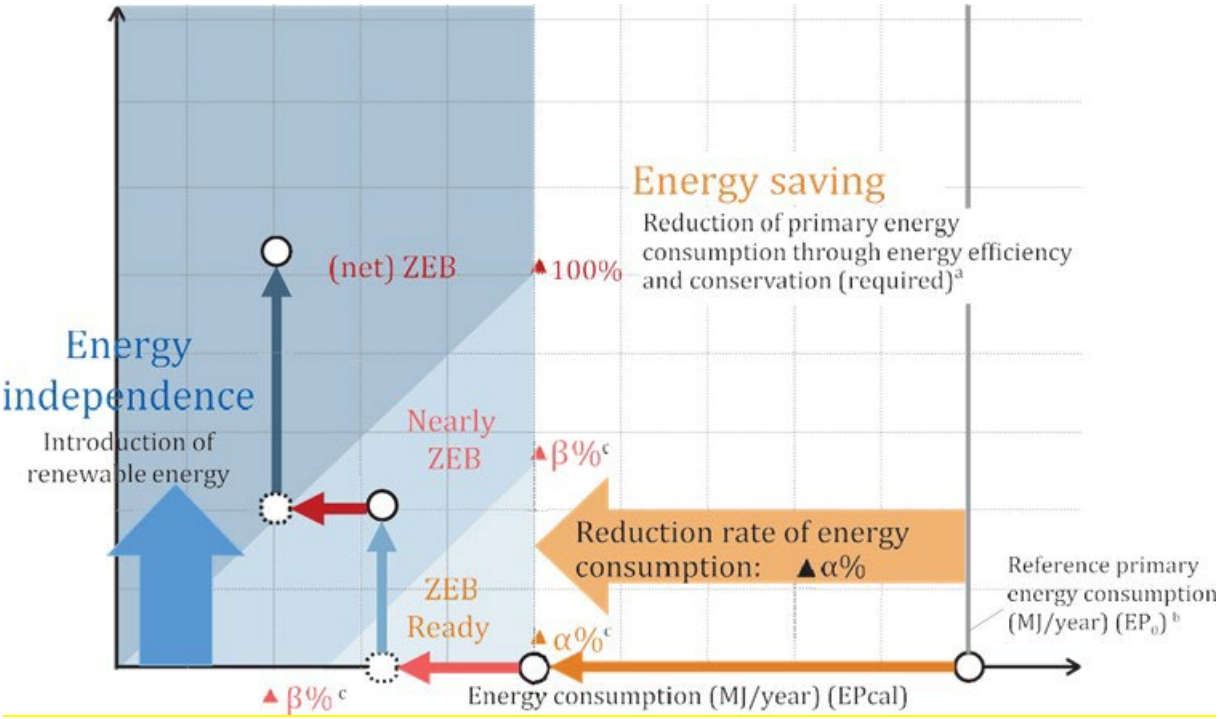


Figure 1. *Three steps in achieving ZEB based on ISO TS23764*

2.3. ZEB Evaluation Parameters

Figure 2 presents a stepwise methodology for achieving ZEB status. The reference primary energy consumption (EP_0), as shown in the figure, is calculated by summing the primary energy consumption of all relevant building systems, including but not limited to air conditioning, ventilation, lighting (including task lighting), hot water supply, elevators, and escalators. This calculation must comply with established building energy efficiency standards and incorporate climatic conditions specific to the construction site.

Reference primary energy consumption in different countries may be determined using the annual primary energy consumption per unit of floor area and the floor area of a standard model building. These reference values should be updated to reflect technological advancements in building materials and energy-efficient equipment, as well as the maturation of energy-conservation measures



Notes

a The target of the energy consumption reduction from the reference primary energy consumption is set in accordance with regional circumstances and adopted as a standard.

b A reference building may be determined in accordance with regional circumstances and its energy consumption is defined as the reference energy consumption.

c Reduction rate targets, α% and β% to be set by individual countries.

***Figure 2**. Energy supply versus energy consumption (Source: ISO TS23764)*

The stepwise approach toward ZEB, from ZEB-ready to (net) ZEB, aligns with a Plan-Do-Check-Act (PDCA) cycle, a process consistent across numerous standards. This process is illustrated in **Figure 3**.

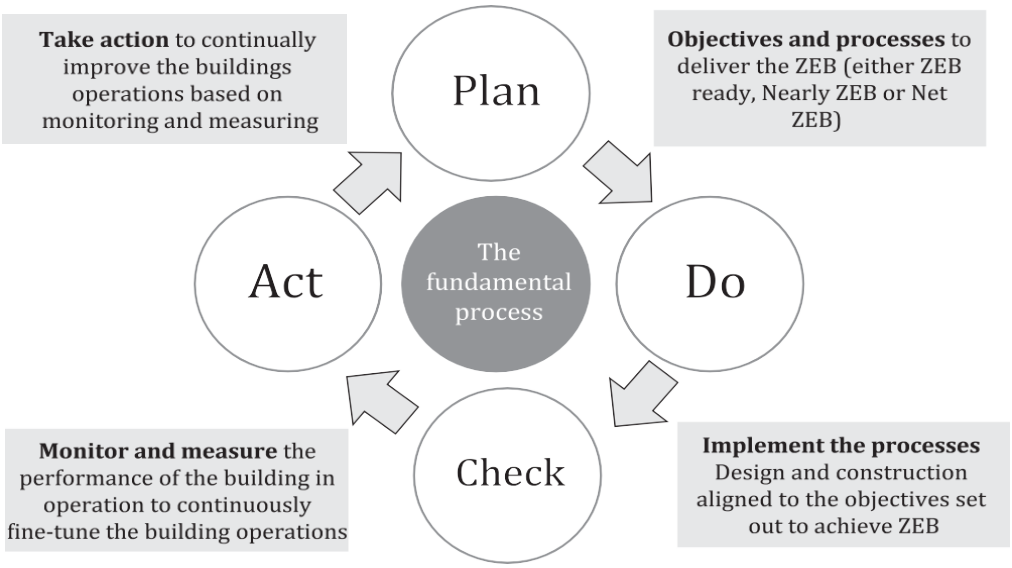


***Figure 3**. Stepwise ZEB evaluation approach (Source: ISO TS23764)*

Figure 4 illustrates the six core elements outlined in ISO/TS 23764, an approach for non-residential ZEB, providing a structured pathway to achieving ZEB status. This framework emphasises a phased approach during the planning stage, moving from ZEB Ready to Nearly ZEB and ultimately to net ZEB, rather than pursuing a single-step transition. It highlights the importance of selecting certified materials and equipment during the design stage, ensuring accurate installation during construction, and verifying targeted energy consumption post-completion. Continuous monitoring of actual energy consumption during operation, coupled with periodic primary energy consumption simulations, ensures ongoing performance evaluation and optimisation.

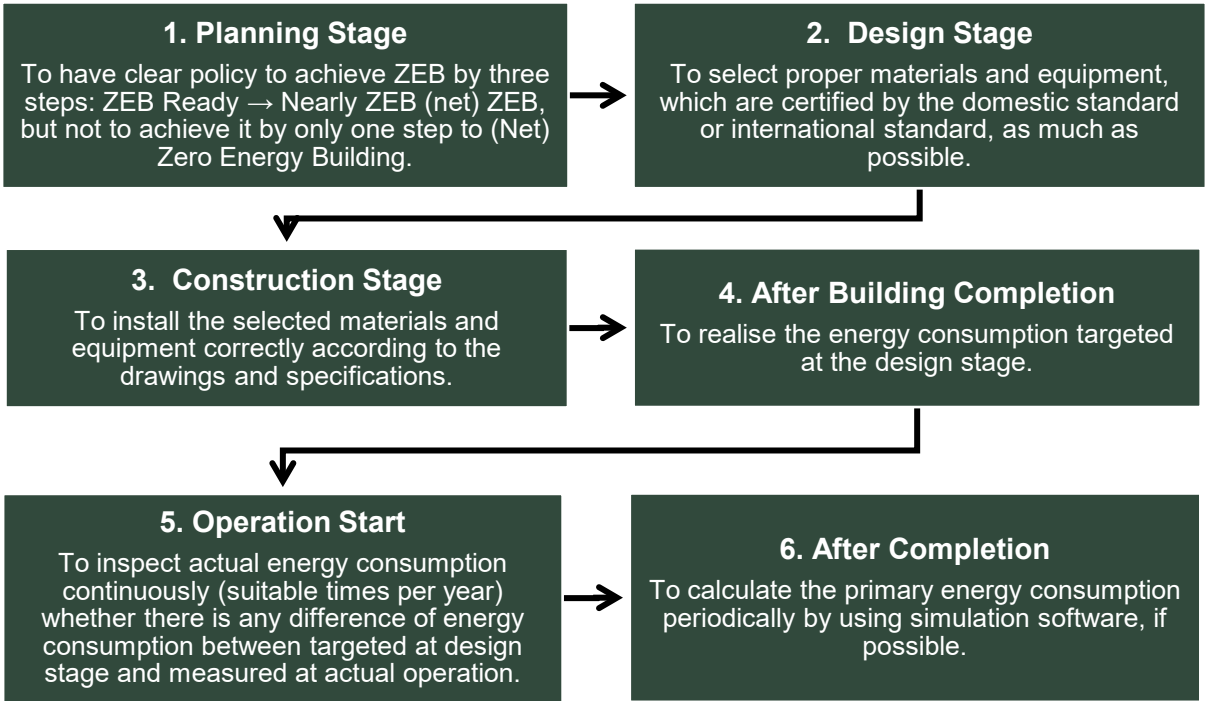


***Figure 4**. Six core elements for achieving non-residential ZEB*

Chapter 3

Expected Roles and Benefits of ZEB in ASEAN

A literature review has been conducted on the design and implementation of net-zero energy buildings (NZEBs), revealing numerous benefits and practical applications. This section provides a summary of the existing literature, highlighting key studies and their findings highlighted that ZEB offer significant benefits for the ASEAN region, addressing critical environmental, economic, and social imperatives, as detailed in the subsequent sections. Environmentally, ZEB contribute to net-zero energy consumption in the building sector and enhance regional energy access and security through decentralised renewable energy generation. Economically, they drive industry innovation, market transformation, and create significant job opportunities across the building value chain. Socially, ZEB improve productivity and indoor comfort for occupants in ASEAN's rapidly urbanising environments.

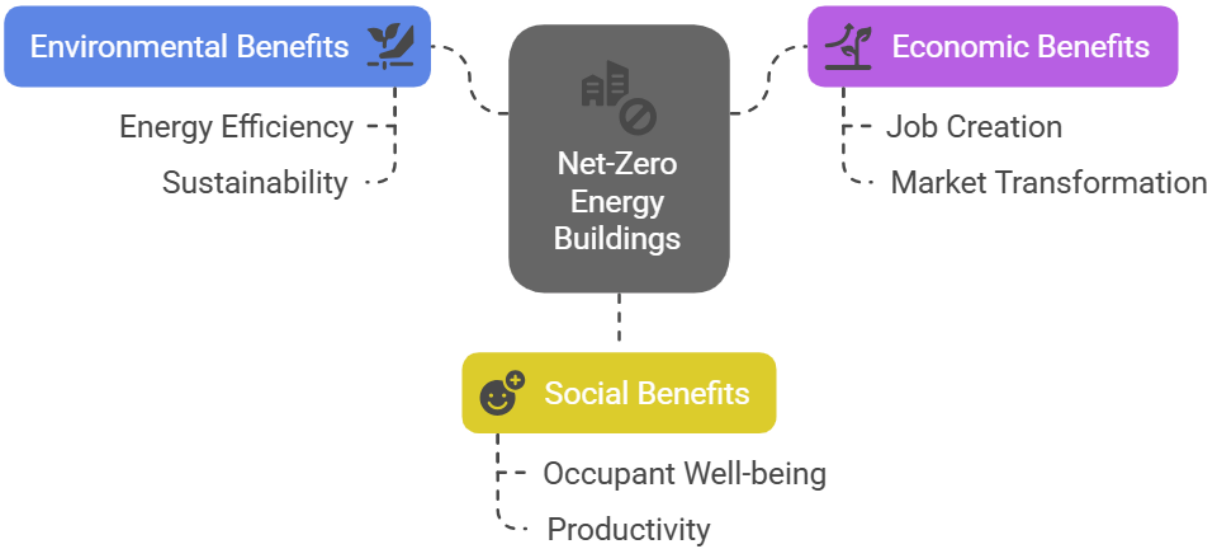


Figure 5. *Benefits of net zero energy buildings in ASEAN*

3.1. Environmental Benefits

Contributing to Net-Zero Energy Consumption in the Building Sector

ZEB in a building with significantly reduced energy consumption is achieved through efficient design, high-performance energy-efficient systems, and renewable energy integration. It aims to achieve a balance between energy consumption and renewable energy production over a defined period, resulting in net-zero energy consumption. Furthermore, ZEB is expected to be a key measure to address decarbonisation in the building sector that significantly contributes to national and regional decarbonisation targets, as buildings account for a substantial portion of ASEAN's total energy consumption and CO_2 emissions.

Contributing to the Improvement of Regional Energy Access and Security

The generation of renewable energy at individual buildings enhances regional energy access and security through local production for local consumption model. This

approach is especially valuable in developing countries where rapidly increasing energy demand outpaces electricity infrastructure development, creating economic bottlenecks. Distributed energy systems offer an effective solution by enabling power generation at the point of use, reducing reliance on centralised grids. Building integrated renewable energy, from rooftop solar to small-scale wind, represents a pioneering approach in this transition, providing reliable power while contributing excess generation to surrounding areas. By reducing transmission losses and decreasing dependence on imported fuels, building-level renewable energy strengthens overall energy security across the ASEAN region.

3.2. Economic Benefits

Driving Industry Innovation, Market Transformation, and Job Opportunities

Promoting ZEB in ASEAN will significantly boost the construction industry across ASEAN by creating substantial new business opportunities throughout the entire building value chain, from materials to finished buildings. The introduction of new technologies, such as advanced insulation materials and renewable energy systems, will expand markets and increase building value for both new constructions and renovations of existing buildings, thereby doubling the economic impact. These initiatives will also support local manufacturing and service industries. Across ASEAN, ZEB will open up new markets spanning multiple disciplines, including new construction techniques, building retrofits, supply chains for high-performance materials and hardware, specialised maintenance and operations services, and sophisticated energy management systems. This transition will not only benefit the environment but also create jobs, drive innovation, and foster industrial development throughout the region.

3.3. Social Benefits

Increasing Productivity and Indoor Comfort

A well-designed ZEB not only optimises energy performance but also enhances indoor environmental quality, leading to higher productivity and well-being for occupants. Features such as advanced ventilation systems, optimised natural lighting, and superior insulation contribute to stable indoor temperatures and improved air quality. In ASEAN’s fast-growing urban areas, where high temperatures and humidity can affect indoor comfort, ZEB presents a sustainable solution that improves the quality of life while reducing energy demand.

Chapter 4

Challenges to ZEB Implementation in ASEAN

Despite the compelling long-term benefits of ZEB in reducing energy consumption and carbon emissions, their widespread adoption across ASEAN remains limited, with Malaysia and Singapore currently demonstrating more significant progress in this area. The following challenges, which will be explored in detail in this chapter, hinder the broader uptake of ZEB principles throughout the region, spanning issues from a fundamental lack of awareness and financial hurdles to inconsistent regulatory frameworks and technical capacity gaps.

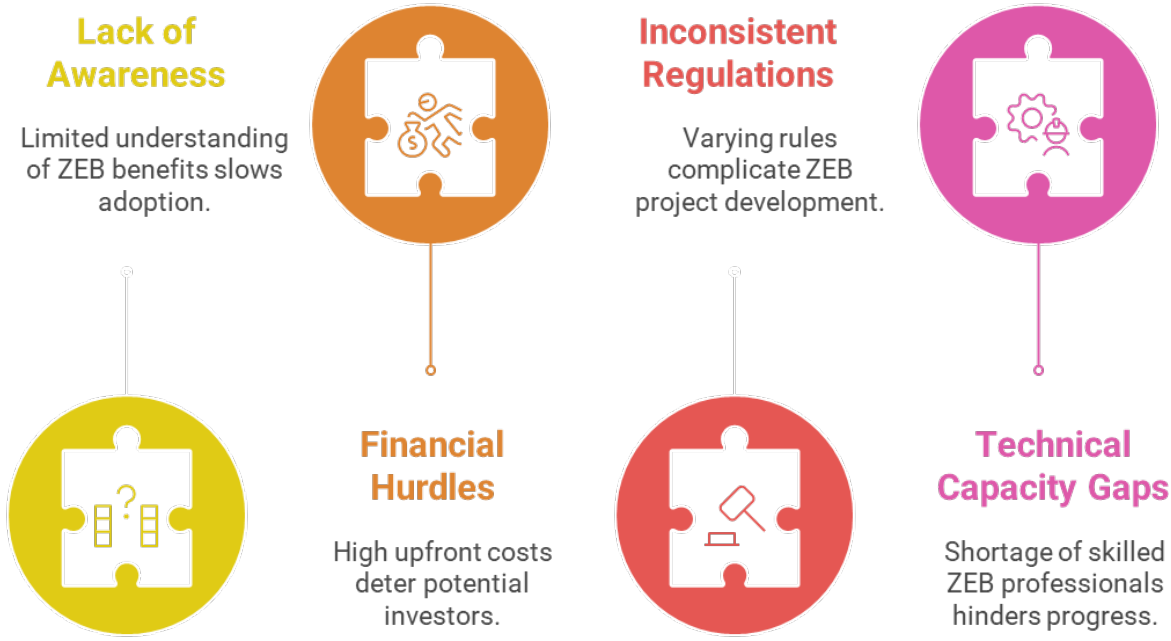


Figure 6. *ZEB adoption challenges*

Lack of Awareness and Knowledge Gaps

A significant barrier to the widespread adoption of ZEB in ASEAN is the lack of awareness and understanding of the ZEB concept among various stakeholders, including policymakers, construction specialists, designers, developers, building owners, and end users. This knowledge gap regarding ZEB definitions, performance levels (ZEB Ready, Nearly ZEB, and Net Zero), and necessary technologies hinders making appropriate technical proposals during the planning stages, limits the motivation for investment in energy-efficient technologies, and hampers collaboration between government agencies and the private sector.

High Initial Costs and Financing Barriers

High upfront costs for energy-efficient technologies present a major financial obstacle to ZEB development. Without an adequate understanding of ZEB principles, stakeholders are unable to recognise the long-term benefits that offset initial costs, leading to reluctance to adopt what are perceived as expensive or unproven approaches. Furthermore, limited access to green financing, incentives, and credit guarantee schemes further restricts investment in ZEB projects. Additionally, the lack

of established Energy Service Companies (ESCOs) adds to the implementation challenges.

Lack of Regulatory and Policy Frameworks

There is no regional roadmap or guidelines for implementing ZEB. Although several countries have established strong policies regarding energy management systems, building energy codes, building standards, and labels and certification programs, others are still in the developmental phase, which creates challenges for achieving regional standardisation. Furthermore, existing EE&C laws, not specifically tailored to ZEB, inadequately address energy efficiency and renewable energy integration.

Inconsistent Definitions and Measurement Standards

The lack of mutually agreed definitions and standardised measurement, exemplified by Malaysia's diverse terminology (Energy Efficient Building and ZEB) compared to Singapore's (Positive Energy Building, ZEB, and SLE Building), presents significant challenges. Establishing consistent baseline energy intensity values is challenging within individual countries for diverse building types and becomes even more complex when attempting regional harmonisation. These challenges are compounded by the absence of standardised monitoring, benchmarking, and verification for building energy performance.

Limited Technical Expertise and Technology Challenges

A lack of skilled professionals in ZEB design, construction, and maintenance can hinder implementation. Furthermore, there is insufficient knowledge of core ZEB strategies, including passive design strategies, energy modelling, and renewable energy integration. The lack of attractive benefits and career development for energy managers in buildings, the scarcity of standardised ZEB simulation tools for ASEAN, and insufficient promotion of research and development for ZEB innovation also impede progress.

Chapter 5

Strategies for Promoting ZEB in ASEAN

To accelerate the widespread adoption of ZEB in ASEAN, a comprehensive and integrated approach is essential, encompassing strategic policy development, robust financial mechanisms, dedicated capacity-building initiatives, and the cultivation of market demand through collaborative efforts. The following sections outline suggested tangible actions and regional initiatives designed to establish a supportive ecosystem for ZEB implementation, addressing key barriers and leveraging opportunities for a sustainable built environment.

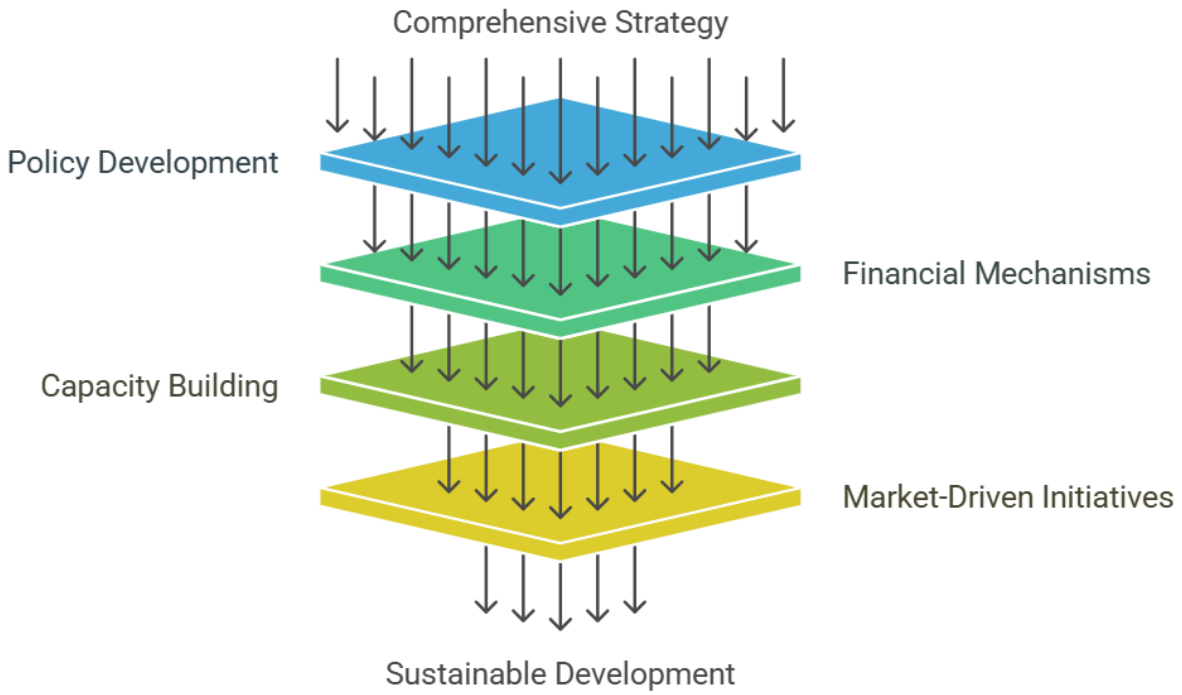


Figure 7. *Accelerating ZEB adoption in ASEAN*

5.1. Foundational Strategies: Knowledge Sharing and Enabling Frameworks

Raising Awareness and Sharing Knowledge

Awareness raising and knowledge-sharing represent critical first steps in establishing an ecosystem for ZEB across ASEAN countries. These foundational activities involve assessing ZEB benefits specifically tailored to tropical climates, evaluating existing policy and regulatory frameworks, and identifying business opportunities for various stakeholders within targeted countries. Through strategic information dissemination, educational workshops, demonstration projects, and technical exchanges, this approach bridges the knowledge gap among key players including government officials, developers, financial institutions, and building professionals. The process creates a common understanding of ZEB concepts, technologies, and implementation pathways while building the necessary momentum for policy adoption and market transformation. By fostering cross-sector dialogue and highlighting successful case studies, awareness raising establishes the groundwork for informed decision-making

and cultivates the supportive environment required for ZEB to move from concept to mainstream practice across the region's diverse building sectors.

Benchmarking Study and Developing ASEAN ZEB Roadmap

Benchmarking for ZEB establishes the technical and financial foundations for successful implementation across ASEAN countries. The benchmarking process involves collecting detailed data from targeted countries and conducting model case analyses of energy performance in tropical climates. This approach identifies the specific parameters and technologies required to achieve ZEB standards in local contexts, and it includes investment risk assessment, creating a holistic understanding of both the energy and financial dimensions of ZEB projects. This evidence-based framework culminates in the development of prototype in-house evaluation tools that enable financial institutions to accurately assess ZEB finance applications, thereby reducing perceived risks and facilitating greater investment in energy-efficient buildings tailored to tropical environments. Furthermore, the benchmarking results will serve as critical input for the development of a regional ZEB roadmap, which will provide a unified direction for AMS, ensuring consistent and effective progress towards achieving ZEB goals.

Figure 8. *Benchmarking process for Zero Energy Buildings in ASEAN*

5.2. Catalysing Implementation: Financial and Technical Empowerment

Enhancing Financial Mechanisms and Incentives

Establishing dedicated ZEB financing options, such as concessional loans, credit guarantees, and green bonds, alongside government incentive schemes like tax credits and rebates, is essential to make ZEB financially viable and attractive to developers. Promoting ESCO-based and third-party financing models, complemented by the development of a regional ZEB investment fund to showcase demonstrative projects within ASEAN Member States, will further support ZEB implementation. For example, in Malaysia, there are already ESCO-based programs for energy efficiency (under energy efficiency performance contracts) and renewable energy (under supply agreements for renewable energy – SARE). If these two programs are combined in a building, it can provide a cost-free or affordable ZEB retrofit program. Moreover, the creation of an ASEAN Green Finance Hub, serving as a centralised regional platform,

will be crucial in streamlining green financing and fostering investment specifically for ZEB projects throughout the region.

Enhancing Technical Expertise and Technology Innovation

Measures such as developing comprehensive ZEB training and certification programs for building professionals, promoting the use of open-source simulation tools for design and modelling, and fostering research and development collaborations between ASEAN universities and industry are recommended. Concurrently, regional initiatives such as the ASEAN ZEB capacity building program, offering specialised training in ZEB design and operation, and the ASEAN ZEB technology innovation hub, aimed at fostering research and development in advanced energy efficiency and renewable building solutions, are crucial for driving widespread knowledge dissemination and technological advancement.

5.3. Driving Regional Adoption: Collaborative Initiatives and Market Stimulation

Strengthening Regional Initiatives and Public-Private Partnerships

ACE is actively engaged in numerous regional cooperation initiatives on ZEB within ASEAN. Through the CEFIA, implemented by ACE and Japan, and with support from JASE-W under its flagship ZEB project, ZEB adoption is promoted through awareness-raising private-government forums, including the CEFIA Forum. JASE-W also conducts bilateral initiatives, such as training programs, workshops, and demonstration projects in Malaysia and Vietnam, with plans for expansion.

Additionally, the ASEAN-Japan Energy Efficiency Partnership (AJEEP) Program, implemented by ACE and ECCJ, focuses on carbon neutrality diagnoses in the building sector and developing net-ZEB building plans, having completed assessments in Thailand and the Philippines. The ECAPs capacity building program, co-organised by ACE and ECCJ, further facilitates policy discussions, provides training on WEBPRO simulation tools, and organises site visits to Japanese ZEB buildings.

Promoting ZEB Through Pilot Projects and ASEAN Energy Awards

Crucial strategies for advancing ZEB in ASEAN include developing demonstration projects in key cities to showcase feasibility, establishing procurement mandates for government buildings to lead by example, and encouraging corporate sustainability commitments that prioritise ZEB adoption. Complementing these efforts are regional initiatives such as the ASEAN ZEB pilot cities program and the ASEAN ZEB market transformation initiative, which are vital for fostering collaboration, creating market demand, and driving widespread replication and market transformation across the region.

To further advance the adoption of ZEB across ASEAN, ACE will collaborate with the EE&C-SSN to strengthen ZEB promotion within the ASEAN Energy Awards framework, representing a significant step towards a net-zero carbon building ecosystem. While recognising the 16 exemplary ZEB projects awarded between 2020 and 2024, as listed in **Table 8**, for inspiration, expanding participation, particularly from the private sector and building owners, is essential to maximise the awards' potential as a catalyst for broader ZEB implementation and best practice dissemination throughout the ASEAN region.

Table 8. *List of ASEAN Energy Awards winners: Energy Efficient Building Category Special Submission - Zero Energy Building (2020-2024)*

No	Winner Year	Company/Building Name	Country	ZEB Category
1	2020	Green Energy Office (GEO)	Malaysia	Nearly ZEB
2	2020	School of Design & Environment, SDE4, National University of Singapore	Singapore	Net ZEB
3	2021	Nanyang Technology University Campus	Singapore	Net ZEB
4	2021	Ulu Pandan Bus Depot	Singapore	Net ZEB
5	2021	Khonkean International Convention and Exhibition Center	Thailand	Net ZEB
6	2021	Dhanaphiphat Building	Thailand	Nearly ZEB
7	2022	Astaka Sports Complex	Malaysia	ZEB Ready
8	2022	Frontier National University of Singapore	Singapore	Net ZEB
9	2022	SMU Connexion	Singapore	Net ZEB
10	2022	Shell HO 1 Building	Thailand	Nearly ZEB
11	2023	QBIG Sinarmas Land	Indonesia	Nearly ZEB
12	2023	Dengkil RSA Northbound	Malaysia	Nearly ZEB
13	2023	Spritzer Asrs Warehouse	Malaysia	Net ZEB
14	2023	Samwoh Smart Hub	Singapore	Net ZEB
15	2023	PEA High Voltage Operations Training Center	Thailand	Net ZEB
16	2024	Singapore Discovery Centre	Singapore	Net ZEB

Chapter 6

Conclusion and Recommendations

6.1. Conclusion and Key Findings

The widespread adoption of ZEB in ASEAN presents a significant opportunity to enhance energy efficiency, reduce carbon emissions, and contribute to the region's long-term sustainability goals. With urbanisation and energy demand rising, integrating energy-efficient building designs and renewable energy technologies can play a crucial role in decarbonising the building sector. Despite its benefits, several challenges hinder ZEB implementation in ASEAN. Key obstacles include a lack of awareness among stakeholders, high upfront costs, inconsistent regulations, and limited technical expertise. Additionally, the absence of standardised definitions and performance benchmarks across ASEAN Member States complicates implementation. To overcome these barriers, a combination of policy and financial support, capacity-building initiatives, and public-private partnerships is needed. Strategies such as dedicated green financing mechanisms, ZEB roadmaps, benchmarking studies, and regional training programs can facilitate market transformation. Pilot projects, regulatory mandates for government buildings, and corporate sustainability commitments can further accelerate ZEB adoption, helping ASEAN transition toward a net-zero carbon building ecosystem

The report highlights several important insights regarding ZEB implementation in ASEAN:

1. **Varied implementation stages**: ASEAN Member States are at different stages of ZEB adoption, with Singapore and Malaysia leading as front-runners, while others are in earlier development phases.
2. **Common challenges**: Despite contextual differences, ASEAN countries face similar barriers including awareness gaps, financial constraints, technical expertise limitations, and inconsistent regulatory frameworks.
3. **Step-by-step approach is effective**: Progressive implementation through ZEB Ready, Nearly ZEB, and Net Zero stages offers a practical pathway suited to the region's diverse economic and technical capacities.
4. **Multi-stakeholder collaboration is essential**: Successful ZEB promotion requires coordination between policymakers, construction specialists, financial institutions, and end-users to establish supportive ecosystems.

6.2. Recommendations

Building on the key findings of promotion of ZEB series concept in ASEAN region, the study proposes the following action plan to accelerate ZEB adoption across ASEAN:

Figure 9. *Pathways to accelerate ZEB adoption in ASEAN*

Enhance Awareness and Knowledge Sharing

- **Establish an ASEAN ZEB Knowledge Hub**: Create a centralised platform for information sharing, accumulation of relevant data, and documentation of best practices in ASEAN region.
- **Strengthen the ASEAN Energy Awards ZEB Category**:
  - **Establish ZEB as a Standalone Award Category**: Elevate ZEB from a sub-category under "Special Submission" to a full category with equal prominence to other building categories, reflecting its importance in regional climate goals.
  - **Tiered Recognition System:** Formalise the existing four-level classification (ZEB Oriented, ZEB Ready, Nearly ZEB, Net ZEB) with distinct award recognition for each tier, encouraging progressive improvement.

- **Enhance the evaluation criteria to include:**
  - ✓ More rigorous energy performance metrics with clear benchmarking against regional reference buildings
  - ✓ Documented operational performance verification over at least one year post-occupancy
  - ✓ Comprehensive whole-building approach with detailed assessment of passive design strategies
  - ✓ Implementation of advanced monitoring and energy management systems
  - ✓ Integration of climate resilience and adaptive capacity measures
  - ✓ Innovative financing mechanisms and cost-effectiveness metrics
- **Cross-Cutting Requirements:**
  - ✓ Mandatory post-occupancy evaluation with user comfort surveys
  - ✓ Documentation of challenges and solutions during implementation
  - ✓ Transferability assessment for replication in other ASEAN contexts

- **Conduct Country-Specific ZEB Potential Assessments:** Develop detailed analyses of ZEB opportunities tailored to each ASEAN Member State's climate conditions, building stock, and energy profiles.

Strengthen Policy and Regulatory Frameworks

- **Develop a Regional ZEB Benchmarking Framework to Support National Roadmaps**: Establish a comprehensive ASEAN-wide benchmarking system for building energy performance that aligns with the "Roadmap for Energy-Efficient Buildings and Construction in ASEAN." This framework will create standardised methodologies across climate zones and building types while allowing flexibility for country-specific adaptation. Through collaborative technology assessment and market analysis, Member States can develop tailored national implementation pathways that contribute to shared regional energy efficiency target and goals. This approach creates a coordinated regional trajectory toward net-zero carbon buildings by enabling countries to identify priority sectors, establish progressive energy reduction targets, and implement context-appropriate policies that collectively advance ASEAN's climate commitments while building local capacity and stimulating market transformation.
- **Harmonise ZEB Definitions and Standards**: Work toward regionally consistent ZEB classifications while allowing flexibility for country-specific conditions. The promotion and use of ZEB definitions and performance metrics referring to ISO/TS23764 is recommended since ISO is a globally based standard.
- **Implement Progressive Building Energy Codes**: Introduce increasingly stringent energy efficiency requirements in building codes with clear timelines for advancement of ZEB adoption.

Create Enabling Financial Mechanisms

- **Establish an ASEAN ZEB Financing Facility**: Create a dedicated funding mechanism to support demonstration projects, technical assistance, and capacity building across the region.
- **Develop Green Bonds for ZEB Projects**: Promote innovative financing instruments specifically targeting ZEB development and retrofitting.
- **Implement Targeted Incentive Programs**: Design fiscal incentives (tax credits, rebates, grants) and non-fiscal incentives (expedited permitting, density bonuses) to offset initial investment costs.

Build Technical Capacity

- **Create an ASEAN ZEB Planner Certification Program**: Develop standardised training and certification for professionals specialising in ZEB design, construction, and operation.
- **Establish Regional Centres of Excellence**: Partner with universities and research institutions to create specialised ZEB innovation and training centres.
- **Develop Tropical Climate ZEB Design Guidelines**: Create technical resources specifically addressing ZEB implementation challenges in Southeast Asia's unique climate conditions.

Demonstrate and Scale Up

- **Launch an ASEAN ZEB Pilot Cities Program**: Select cities across member states to pioneer comprehensive ZEB policies and showcase implementation at scale.
- **Support ZEB Demonstration in Public Buildings**: Leverage government procurement to lead by example through ZEB implementation in public facilities.
- **Create an ASEAN-Japan ZEB Initiative**: Build on existing collaboration to establish a formal platform (flagship programme) for technology transfer, capacity building, and demonstration projects with technical support from experienced partners. This initiative is recommended to co-exist with the current CEFIA program.

References

[1] ASEAN Secretariat. (2023) *ASEAN Statistical Yearbook 2023*. Jakarta: ASEAN Secretariat. Available at: ASEAN Statistical Yearbook 2023

[2] ASEAN Centre for Energy (ACE). (2024) *8th ASEAN Energy Outlook (AEO8)*. Jakarta: ASEAN Centre for Energy (ACE). Available at: 8th ASEAN Energy Outlook (AEO8)

[3] ASEAN Centre for Energy (ACE). (2020) *ASEAN Plan of Action for Energy Cooperation (APAEC) 2016-2025 Phase II: 2021-2025*. Jakarta: ASEAN Centre for Energy (ACE). Available at: ASEAN PLAN OF ACTION FOR ENERGY COOPERATION (APAEC) 2016-2025 PHASE II: 2021-2025

[4] Shirinbakhsh, M. and Harvey, L.D. (2021) *Net-zero energy buildings: The influence of definition on greenhouse gas emissions*, *Energy and Buildings*, 247, 111118. doi: https://doi.org/10.1016/j.enbuild.2021.111118

[5] Feng, W., Zhang, Q., Ji, H., Wang, R., Zhou, N., Ye, Q., Hao, B., Li, Y., Luo, D. and Lau, S.S.Y. (2019) *A review of net zero energy buildings in hot and humid climates: Experience learned from 34 case study buildings*. Renewable and Sustainable Energy Reviews, 114, p.109303. doi: https://doi.org/10.1016/j.rser.2019.109303

[6] Jaysawal, R.K., Chakraborty, S., Elangovan, D. and Padmanaban, S. (2022) *Concept of net zero energy buildings (NZEB) - A literature review*, Cleaner Engineering and Technology, 11, 100582. doi: https://doi.org/10.1016/j.clet.2022.100582

[7] Torcellini, P., Pless, S., Deru, M. & Crawley, D. (2006) *Zero Energy Buildings: A Critical Look at the Definition*. Conference Paper NREL/CP-550-39833. [Online] Available at: http://www.osti.gov/bridge

[8] European Commission. (n.d.) *nZEB definition* [Presentation]. Available at: https://ec.europa.eu/programmes/erasmus-plus/project-result-content/48ff898e-a503-414a-b112-fba01dd2976e/HI-MART_1.2_nZEB_definition_presentation.pdf

[9] Ministry of Economy, Trade and Industry (METI). (2018) *Strategic Energy Plan*. Available at: https://www.enecho.meti.go.jp/en/category/others/basic_plan/5th/pdf/strategic_energy_plan.pdf

[10] Japanese Business Alliance for Smart Energy – Worldwide (JASE-W). (2017) *A proposal for additional screening criteria of ASEAN Energy Award - ZEB Family Concept*. ECAP14 presentation. Tokyo. Japan. Available at: https://seforallateccj.org/wpdata/wp-content/uploads/ecap14-jasew-moroo.pdf

[11] Building and Construction Authority (BCA) Singapore. (n.d.). *Super Low Energy Programme*. Available at: https://www1.bca.gov.sg/buildsg/sustainability/super-low-energy-programme

[12] Building and Construction Authority (BCA). (2018) *Super Low Energy Building Technology Roadmap.* Available at: https://www1.bca.gov.sg/docs/default-

source/docs-corp-buildsg/sustainability/sle-tech-roadmap-report--published-ver1-1.pdf?sfvrsn=f2df22ed_0

[13] Sustainable Energy Development Authority (SEDA). (n.d.) *SEDA Zero Energy Building Facilitation Program Information*. Available at: https://www.seda.gov.my/energy-demand-management-edm/zeb-renovation-for-existing-buildings/

[14] Malaysian Green Technology and Climate Change Corporation (MGTC). (n.d.) *NEA Award Categories*. Available at: https://www.nationalenergyawards.com.my/the-award/nea-award-categories/

[15] Lazudi. (2023) *Thailand's New Building Energy Code (BEC) Law Effective from 13 Mar '23, 1 June*. Available at: https://lazudi.com/th-en/blog/thailands-new-building-energy-code-bec-law-effective-from-13-mar-23

[16] Energy Policy and Planning Office (EPPO). (2011) *Thailand 20-Year Energy Efficiency Development Plan (2011–2030)*. Available at: https://www.eppo.go.th/images/POLICY/ENG/EEDP_Eng.pdf

[17] Green Building Council Indonesia (GBCI). (2023) *GREENSHIP NET ZERO presentation for NZH Masterclass*. Available at: https://gbcindonesia.org/files/resource/ca41425f-7b30-40d0-8639-9d1080c90496/Greenship%20Introduction%20on%20NZ.pdf

[18] ASEAN Centre for Energy (ACE). (2018) *Zero Energy Building Added to ASEAN Energy Awards 2019*. Available at: https://aseanenergy.org/post/zero-energy-building-added-to-asean-energy-awards-2019/

[19] ASEAN Centre for Energy (ACE) (2025) *ASEAN Energy Awards 2025 Guideline Manual of the Board of Judges ASEAN EE&C Best Practices Competition for Energy Efficient Buildings*

[20] ISO. (2021) ISO/TS 23764:2021. *Methodology for Achieving Nonresidential Zero-Energy Buildings (ZEBs)*. Geneva: International Organization for Standardization.

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