TECHNICAL SPECIFICATION

ISO/TS 23764

First edition
2021-09

Methodology for achieving non-residential zero-energy buildings (ZEBs)

Reference number
ISO/TS 23764:2021(E)

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Foreword

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This document was prepared by Technical Committee ISO/TC 205, *Building environment design*

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Introduction

This document aims to apply a methodology for achieving a zero-energy building (ZEB).

Since the Paris Agreement was adopted in the 21st Session of the Conference of the Parties to the United Nations Framework Convention on Climate Change, all member countries (including emerging countries) have been required to set a target for reducing their greenhouse gas emissions by 2020 and later. In all countries, reducing energy consumption is the most effective means of mitigating greenhouse gas emissions.

The building sector takes a 30 % share of the world's energy consumption, and this contribution appears to be increasing[8]. Therefore, reducing the greenhouse gas emissions from this sector is an important global issue. Ultimately, the energy consumption of the building must be reduced and balanced by renewable energy to create a (net) ZEB. Such advanced cases have already been constructed.

Although the ultimate goal of achieving ZEBs is clearly understood, its realization has been limited by practical barriers such as high initial investment. However, as the life cycle of buildings is long, the design and construction of more energy-efficient buildings is considered as a present attempt rather than a future one for greenhouse gas reduction. Hence, accelerating the movement toward ZEBs is an immediate urgency.

From this perspective, this document advocates a step-by-step realization approach for (net) ZEBs. Its aim is to accelerate the ZEB movement and describe the practical realization of ZEBs. Namely, this document proposes a practical ZEB approach and outlines the basic considerations during the complete process of ZEB realization, from design to the operation and maintenance stages.

To accelerate the reduction of greenhouse gases, this document aims to contribute policies and/or guidelines for disseminating ZEBs that suit the conditions of individual countries, especially those of emerging countries undergoing rapid urbanization.

To assist understanding of the contents of this document, the following four ZEB examples are included as annexes:

— (net) ZEB results of evaluating a ZEB renovation of an actual use office building (see Annex A);

— nearly ZEB results of evaluating a ZEB city hall encompassing regional history, climate, and resources[1)] [2)] (see Annex B);

— ZEB-ready model of an urban medium-sized office (see Annex C).

1) Net Zero Energy Buildings International Projects of Carbon Neutrality in Buildings (IEA SHC).

2) Three examples toward realizing ZEB were selected from the Net Zero Energy Building Advanced Case Collection published by The Society of Heating, Air-Conditioning and Sanitary Engineers of Japan (SHASE). The (net) ZEB example is the Takenaka Corporation Higashi Kanto Branch Office. The nearly ZEB is Unnan City Hall. The ZEB ready example is the KT Building. The nearly ZEB example in Singapore non-residential building. Reference URL: http://www.shasej.org/recommendation/ZEB%20in%20Japan_2017_SHASE100th.pdf

Methodology for achieving non-residential zero-energy buildings (ZEBs)

1 Scope

This document provides a basic step-by-step approach for achieving non-residential (net) zero-energy buildings (ZEBs). It also describes the basic concept of ZEBs and the items for consideration in this approach.

The following are within the scope of this document:

— application to non-residential buildings;

— annual energy consumption of a ZEB (this includes the operating consumption of the building and excludes the energy consumed by the manufacturing of materials and equipment, and the energy consumed during construction);

— renewable energy supply (this can be on-site or off-site, depending on the policy and conditions of the country in which the supply is installed);

— application to any climate zone.

The following are out of the scope of this document:

— recommendations or suggestions for the adoption of any specific technologies and/or equipment and materials that are expected to be continuously innovated (however it does stipulate the technologies for selection);

— specific methods or calculation formulae;

— commissioning methods.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 50001:2018, *Energy management systems — Requirements with guidance for use*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org

NOTE The terms defined in this clause are detailed in 4.1.

3.1
ZEB-ready
building that prospectively achieves *(net) ZEB* (3.3) through enhanced insulation suited to building use and climate, exterior surface and shading for suppressing the load, high-efficiency energy-conservation equipment and optimization of energy consumption by data integration and verification

3.2
nearly ZEB
building that almost achieves *(net) ZEB* (3.3), with an annual primary energy consumption of almost zero using renewable energy while meeting the criteria of *ZEB-ready* (3.1)

3.3
(net) ZEB
building with zero or negative net annual primary energy consumption while meeting the criteria of *ZEB-ready* (3.1)

4 Stepwise approach toward ZEB

4.1 General

The stepwise approach toward ZEB from ZEB-ready to (net) ZEB follows a plan⟶ do⟶ check⟶ act (PDCA) process that is consistent within many standards. This process is explained in Figure 1.

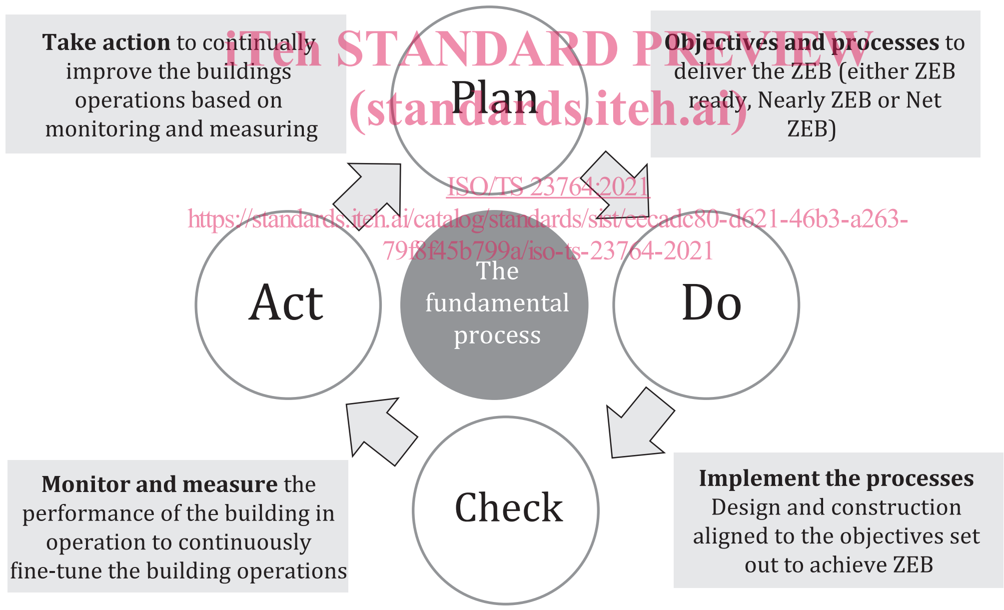


Figure 1 — Key process for achieving ZEB – PDCA (Plan, Do, Check, Act)

This clause describes this approach in detail in consideration of six core elements listed in Figure 2.

Six core elements of ISO/TS 23764

1	**At planning stage,** to have a clear policy to achieve ZEB by the three steps: ZEB Ready → Nearly ZEB → (net) ZEB, but not to achieve it by only one step to (Net) Zero Energy Building.
2	**At the design stage**, to identify appropriate passive and active design strategies and select proper materials and equipment, which are in accordance with a national or international standard, as far as possible.
3	**During construction,** to install the selected materials and equipment correctly according to the drawings and specifications.
4	**After completion of building,** to realize the energy consumption targeted at the design stage.
5	**After the start-up of the operation,** to inspect actual energy consumption continuously (suitable times per year) to monitor whether there is any difference of energy consumption between the targeted at design stage and the measurment during actual operation.
6	**After the start-up of the operation,** to calculate the primary energy consumption periodically by using simulation software, if possible.

Figure 2 — Six core elements for achieving non-residential ZEBs

4.2 Planning phase

4.2.1 Determining the ZEB stage target: ZEB-ready, nearly ZEB, or (net) ZEB

In general, achieving a (net) ZEB requires a sharp reduction in energy consumption, without the reduction in quality of the indoor and outdoor environments, with the inclusion of renewable energy to offset the remaining energy consumed through the building activities.

The planning and design of a ZEB requires the generation and use of renewable energy. However, this should be considered after reducing the energy consumption as far as possible by a passive design approach, an active design approach including selection of energy-efficient active systems, and deployment of energy management systems that facilitate optimized building energy performance.

Immediately achieving a (net) ZEB may be prevented by regional and climatic circumstances, building typology, and other circumstances beyond the project team's control. To accommodate these limitations, this document adopts a three-tiered nomenclature for ZEB:

a) A ZEB-ready building meets the following condition:

— The primary energy consumption is reduced by a predetermined amount (α%) or more from the reference primary energy consumption, excluding renewable energy.

b) A nearly ZEB building meets both of the following conditions:

— The primary energy consumption is reduced by a predetermined α% or more from the reference primary energy consumption, excluding renewable energy.

— The primary energy consumption is reduced by β% or more (less than 100 %) from the reference primary energy consumption, including renewable energy.

c) A (net) ZEB meets both of the following conditions:

— The primary energy consumption is reduced by a predetermined α% or more from the reference primary energy consumption, excluding renewable energy.

— The primary energy consumption is reduced by 100 % or more from the reference primary energy consumption, including renewable energy.

4.2.2 Reference primary energy consumption and reduction rate targets

The reference primary energy consumption (EP0) in Figure 3 should be calculated by adding the primary energy consumption of the air conditioners, ventilators, lighting equipment (including task lighting), hot water supply equipment, the elevators and escalators, and other energy consuming equipment in the building. This shall be calculated according to the energy efficiency standards of buildings, while considering the climatic impact on the construction site. The annual primary energy consumption per unit of floor area and the floor area in a standard model building may be used to calculate the reference primary energy consumption in different countries. When appropriate, the reference primary energy should be revised in accordance with technological advancements on building materials and energy-efficient equipment, and with the level of maturity of the energy-conservation scheme.

Reduction rate targets for primary energy consumption should be determined in the three stages: ZEB-ready, nearly ZEB, and (net) ZEB. The energy-efficiency improvement should first support equipment that consumes energy (toward ZEB-ready). Once that target has been met, the total primary energy consumption should be reduced by encouraging electric-power generation from renewable energy sources.

$$\text{Target of } \alpha\% \text{ for ZEB-ready} \leqq (1 - EP_{cal}/EP_0) \times 100$$

$$\text{Target of } \beta\% \text{ for nearly ZEB} \leqq (1 - (EP_{cal} - EP_{gen})/EP_0\,) \times 100$$

$$\text{Target for (net) ZEB, } 100\ \% \leqq (1 - (E_{cal} - EP_{gen})/EP_0\,) \times 100$$

where

EP_0 is the reference primary energy consumption (MJ/year);

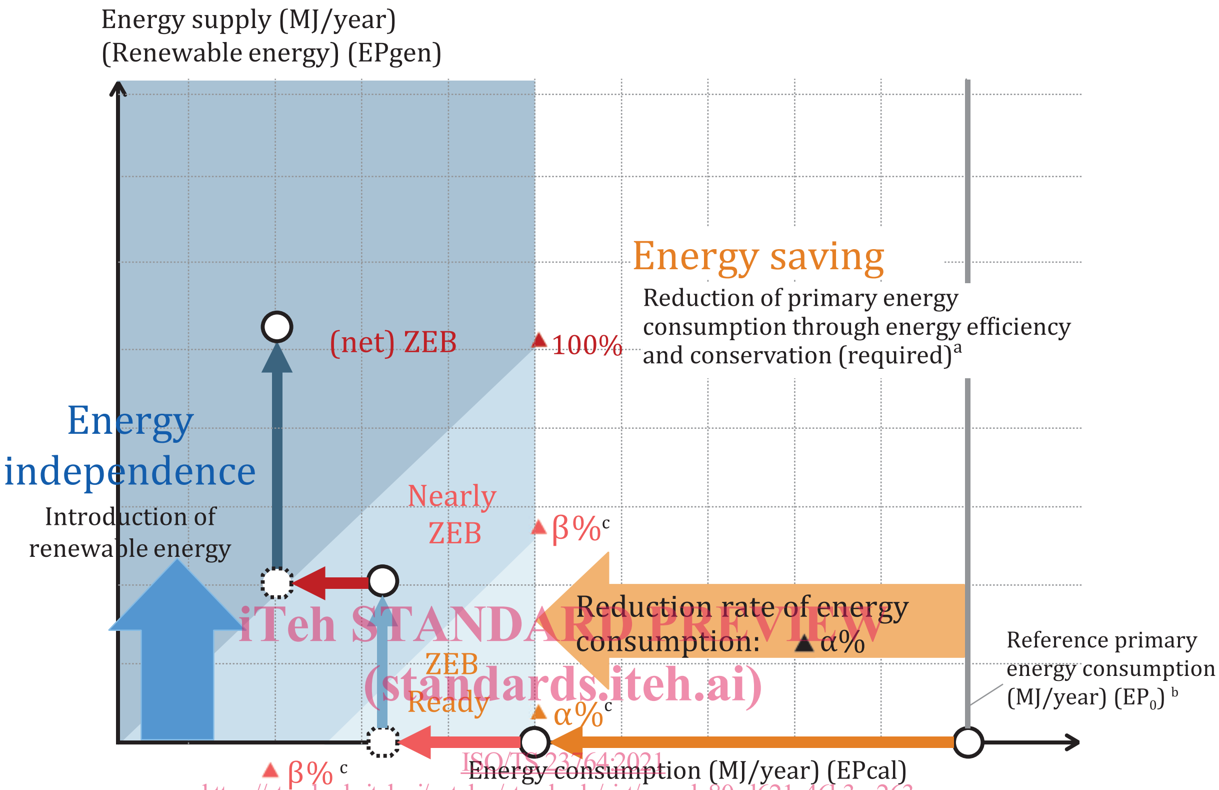
EP_{cal} is the primary energy consumption (MJ/year);

EP_{gen} is the energy supply (renewable energy) volume (MJ/year).

Primary energy consumption is annual consumption and is not defined in detail in this document.

The reduction-rate targets α% and β% should be set by individual countries, although β should be larger than α. Multiple α and β values may be set at different levels.

The reference primary energy consumption EP_0, the target values of α and β, and other parameters may be revised in accordance with technological advancements.



Key

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 3 — Energy supply versus energy consumption

4.3 Design phase

4.3.1 General

An evaluation method for energy performance equivalent to ISO 52000-1 can be used. The matters stated below should be considered for specific design methods.

4.3.2 Setting the outcome

Defining the project's performance at the briefing stage is important. If the constraints on and opportunities for setting design goals for environmental sustainability are considered at the onset of a building project, a holistic total building performance is ensured. Thus, feasibility studies and assessments of the available options and benchmarking of similar projects provide the project team with a realistic grounding of the achievable ZEB level.

The project brief formalizes the sustainability targets and estimates the building lifespan and operational cycles. Early consultations and studies ensure that the targets are achievable and that the post completion goals (against which the building will be judged) are clearly stated.

An integrative design process encourages a collaborative framework for setting the building-performance benchmarks and targets. Through this process, the project team is obliged to regularly review the design goals across disciplines and can address and negotiate among the various needs of all stakeholders to achieve the ZEB target.

4.3.3 Passive design

Passive strategies are fundamental in the design of energy-efficient buildings, as they maximize the climatic response to the site context, reduce the load on "active systems," and provide a comfortable indoor environment. The typical passive-design principles are as follows (the list is non-exhaustive):

— building orientation, massing and form;

— building envelope and material selection;

— use of natural ventilation;

— maximum use of free heating or cooling;

— design of daylighting (while minimizing visual discomfort).

4.3.4 Active design

4.3.4.1 Energy users

Typical active systems or building services are mechanical systems, e.g. air conditioning, heating, mechanical ventilation, lighting, vertical transportation, pumping, and other unregulated energy source equipment, which provide the bulk of the energy consumption in a building. The focal strategies for achieving a low energy building are as follows (the list is non-exhaustive):

— Correct sizing of equipment such as air-conditioning systems and heating systems:

This strategy ensures the proper allocation of the building loads, avoiding over- or under-provision that would reduce the operational efficiency.

— Selection of high efficiency systems and technologies:

Adoption of high-efficiency equipment, e.g. lighting, heating, and cooling systems, mechanical ventilation systems, vertical transportation systems, hot water systems. Equipment should be energy-labelled and provided with certified (tested) performance data. The control systems using sensors are also applied for those types of equipment.

— Selection of systems with high efficiency over the operational range:

For example, air-conditioning systems should operate with high efficiency over a range of loads under capacity control, e.g. inverter technology for the compressors. Fans and pumps should operate under variable flows and speeds.

— Use of energy recovery systems:

Converting waste energy to useful energy reduces the load on other systems. An example is heat recovery for air conditioning or heating systems.

4.3.4.2 Energy management system

A building or energy management system (BMS) can monitor and manage all mechanical and electrical services in a building. These systems improve the energy efficiency by tailoring the appliances to real needs and saving operation and maintenance costs while improving the occupancy comfort. Among the fastest-growing and dynamic ZEB-focused technologies are smart building technologies. By tapping into the Internet of Things, advanced sensors, and big data analytics, smart technologies have shown potential for significant savings through demand control, optimization, and predictive maintenance.

Strategies for energy management systems include the following (the list is non-exhaustive):

— Energy monitoring and visualization:

  This strategy provides occupants with an easy, accessible visualization of the energy consumption indices by area and the use/load, trend, cost, and target/benchmark. Related to this ideal of openly sharing the building data, open standards are required to future-proof the building's management system and to facilitate data exchange between subsystems. Furthermore, if the end users can access the monitored information, they are more likely to partake in engagement programs and make behavioural changes.

— Demand control systems:

  Occupancy-based controls can match the building services to the building use, facilitating energy savings and optimization of systems while maintaining high indoor environmental quality. For example, demand control ventilation strategies such as carbon dioxide sensors will help regulate the quantity of fresh air and ventilation in accordance with the space requirements.

— Integration and analytical systems:

  These systems integrate the sensor data for optimizing the workflow or maintaining high performance and energy efficiency in a building, providing an informed and effective operation in the building. By using automation data and behavioural science, building professionals can optimize the equipment and their related processes to maintain the equipment efficiency and building comfort requirements.

4.3.4.3 Renewable energy

Renewable energy sources are required to generate or offset the energy used by building systems. Renewable energy sources include (but are not limited to) solar (photovoltaics) and wind power.

4.3.5 Selection of building materials, equipment and systems

4.3.5.1 General

The building materials, equipment, and systems should be selected in the design phase. The selected items should have obtained performance certification, e.g. energy efficiency certification, appropriate to the regional circumstances, or which conform to the standards in the country of construction. To meet ZEB targets, high-efficiency equipment and systems are required.

To achieve an overall balance, the selected materials, equipment, and systems should also optimize the costs.

4.3.5.2 Selection of building materials

— Load reduction

  — Enhancement of the thermal insulation for the exterior surface of the building and control for solar radiation.

  — Selection of the materials with high thermal insulation performance for the exterior walls, roofs, floors, windows, and other openings.