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

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Foreword

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

Any feedback or questions on this document should be directed to the user’s national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

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.

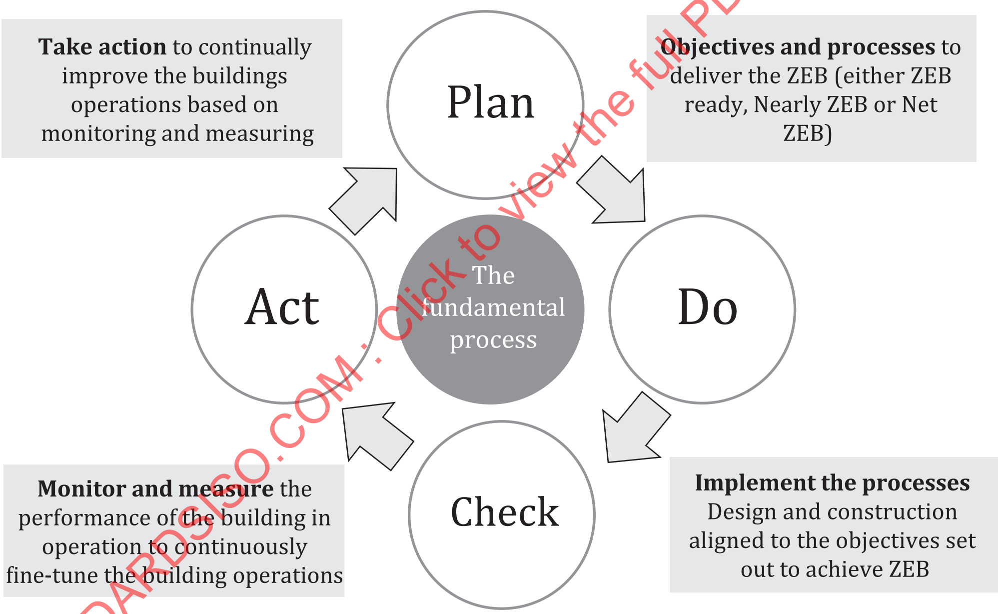


Figure 1 — Key process for achieving ZEB – PDCA (Plan, Do, Check, Act)

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);

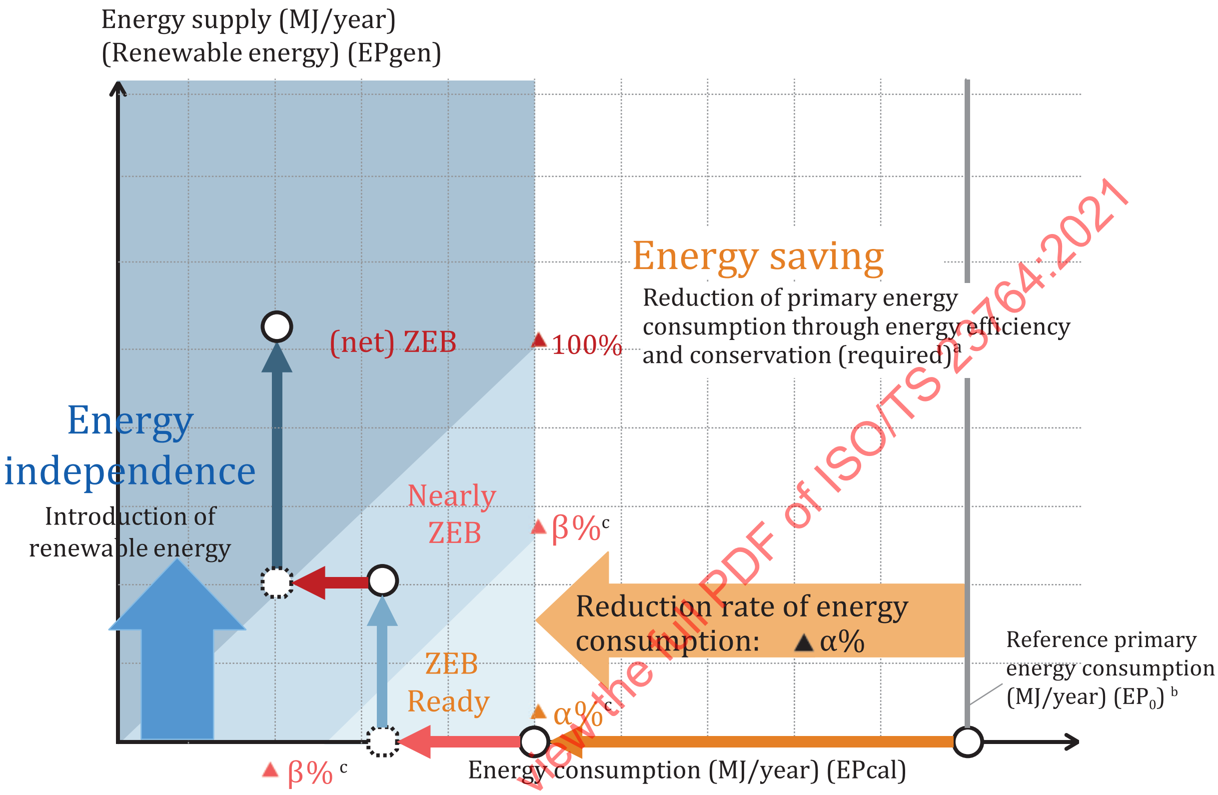
EP_{cal} is the primary energy consumption (MJ/year);

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.

  - Introduction of the items that properly control the solar radiation from windows (glazing with excellent shading performance, window shades, eaves and the equivalent).
- Use of natural energy
  - Utilization of natural ventilation.

    EXAMPLES automatic windows, opening of ceiling spaces by the stack effect.

  - Utilization of daytime sunlight.

    EXAMPLES construction of openings, neighbouring buildings, and topographic features on the sunlight side, light shelves, light duct systems.

4.3.5.3 Selection of equipment and systems

4.3.5.3.1 Air-conditioning equipment

- Selection of heat-source type:

  The heat-source system can be centralized or distributed.

- Selection of a model with high partial-load properties that adjusts the partial load efficiency in accordance with the load change (compressor inverter and other equipment).
- Consideration of following energy-conservation technologies for a central heat-source system:

  Control of the number of heat sources, free cooling systems, large temperature-differential water supply systems, variable flow control for cooling water pumps, pump capacity control (using an inverter) and boiler efficiency.

- Consideration of the following energy-conservation technologies for the load side equipment:

  Variable blow control for air conditioners, total heat exchangers, air-conditioning systems that separate the latent and sensible heat, fresh-air intake controls that respond to CO_2 concentration, and unused energy sources such as underground heat, underground water, and temperature differences in river water.

4.3.5.3.2 Lighting equipment

- Utilizing high efficiency lighting systems
  - Designing and installing solid state lighting systems.
- Designing quality daylighting
  - Maximizing daylight availability,
  - Providing quality views for all occupants,
  - Limiting daylight excessiveness.
- Incorporating lighting controls that adjust to daylight availability, occupancy sensing, lumen depreciation, and personal dimming.
- Optimizing illuminance
  - Designing to ANSI/IES/CIE recommended illuminance levels and visual quality recommendations.

4.3.5.3.3 Hot water supply equipment:

— Reduction of energy consumption by employing the following hot-water saving systems:

High-efficiency heat pump units for the hot water supply, a hot-water heater with latent heat recovery, solar panels for hot water generation and automatic faucets for washbasins.

4.3.5.3.4 Elevators and escalators

— Consideration of the following energy-conservation technologies for elevators and escalators:

  — For elevators: Variable-voltage variable-frequency control, power regeneration control, group control.

  — For escalators: Automatic operation (sensor-based start and stop operations).

4.3.5.3.5 DC distribution system

— Reduction of energy conservation loss from DC to AC by introduction of DC distribution system along with the DC power resources, DC loads, and the AC loads driven by DC power.

4.3.6 Forecast of primary energy consumption and energy supply for attaining the targets

4.3.6.1 General

In a ZEB, the designed energy consumption must be compared with the actual energy consumption during operation on a system-by-system basis. This is important for re-monitoring the energy consumption and making improvements. Therefore, the methods of energy management and building operation shall be determined during the design phase.

4.3.6.2 Forecast of primary energy consumption

The primary energy consumption of the equipment, e.g. air conditioning, ventilation, lighting, hot water supply, and elevators and escalators, should be forecasted in the design phase. The forecasted energy consumption of the air-conditioning equipment should be based on the annual hourly loads plus the partial load characteristics under the thermal load, which depend on the climatic circumstances and the building characteristics. The primary energy consumption should be estimated using calculation software that considers the above-mentioned matters.

4.3.6.3 Forecast of renewable energy supply

Renewable energy facilities should be installed as electric-power supplies in the target building. The actual supply should account for fluctuations in solar radiation imposed by location, season, time, climate, installation conditions, and other circumstances, as well as DC/AC conversion loss (power conditioner) and other losses.

4.4 Construction phase

4.4.1 General

Construction should follow the prescribed use of the building materials and selected equipment.

4.4.2 Construction plan

Once the design phase is complete, the correct procurement strategy that ensures the fully implemented design and performance should be studied. A construction plan using the building materials and selected equipment should be created during the construction phase in accordance with the specifications and design drawings. The construction plan should include the following items:

— construction overview;

— project schedule;

— on-site organization chart;

— safety management;

— designated machinery;

— materials and equipment;

— construction methods;

— construction management plan.

4.4.3 Construction and inspection

Buildings should be constructed in accordance with the construction plans. During construction, intermediate inspections should be implemented so that the installed materials and equipment follow the specifications and the design drawings. If it is found that the contractor installs the wrong materials and equipment, the contractor should replace or rectify such materials and equipment following the construction plan.

4.4.4 Final check and verification (as built)

After completion, trial operation and adjustment, the building is transferred to its owner. The adjustment is designed to be implemented at peak load under the design conditions. Many buildings operate without change after completion and adjustment. The properties of buildings vary and will be understood only through post-completion operation.

Verification after practical operation for a predetermined amount of time will assess whether the building has been constructed as initially planned.

4.5 Operations and management

4.5.1 Fine tuning

Once its properties have been understood through verification and operation, the building shall be fine-tuned for energy conservation. This step involves adjusting the equipment and systems for better efficiency and continuous commissioning.

Constant monitoring will check whether the building's actual energy consumption meets the energy consumption planned in the design phase. If there are any shortfalls, the operation should be improved under the PDCA cycle.

Refer to ISO 50001:2018 for the requirements of energy management.

4.5.2 Understanding the primary energy consumption

Energy consumption of individual systems and equipment should be monitored continuously.

4.5.3 Comparison between planned primary energy consumption and actual measurements

The measured energy consumption of the individual systems and equipment shall be compared with the planned levels to evaluate the impact and prioritize the actions for improvement.

4.5.4 Optimizing the energy consumption

To optimize the energy consumption, energy managers shall accurately understand the system conditions and energy consumption and implement advanced control of the individual pieces of equipment. Optimization requires an energy management system (EMS), an organization for managing the energy consumption in the building, and a building automation system (BAS). For optimizing the building operation, the BAS manages the state of the equipment and monitors the appropriateness of the energy consumption and equipment operation.

The following are the major management items required for optimizing the energy consumption. Management should be mainly undertaken by the energy manager of the building.

— Monitoring the state of the equipment, alarm monitoring, operation management and automatic efficient control of equipment.

— Energy management and indoor environment management.

In conjunction with energy consumption optimization, the energy manager shall conduct a PDCA cycle, which involves creating an implementation plan and self-evaluation of the achievements. A method for processing the accumulated data, preparation of diagrams, and other aspects shall be determined, and an EMS shall be designed for high-quality analysis of the accumulated data. The control system in the EMS should optimize the interlinkage between the devices and the entire building, rather than control the individual devices. Whole-building control ensures that the energy conservation, comfort and productivity adapt to changes in the building thermal load. System control technologies include an inter-equipment integrated control system that combines air conditioners, lighting, and information technology equipment. This system maintains the indoor-environment quality by minimizing the energy consumption, providing an advanced load-following control, and applying prediction-based control and reduction of the building load. The operation efficiency of the equipment is boosted by exploiting natural energy sources.

4.5.5 Measurement and feedback

Post-completion measurement determines whether the performance of the building during the predetermined period meets the initial plan. The result is fed into the brief for future retrofitting or optimization of the building, and to the project team for their knowledge management and application in future projects.

5 Examples of evaluations on ZEB

Examples of evaluations on ZEB are given in the following annexes:

— Refer to Annex A for an evaluation of (net) ZEB.

— Refer to Annex B for an evaluation of nearly ZEB.

— Refer to Annex C for an evaluation of ZEB-ready.

Annex A
(informative)

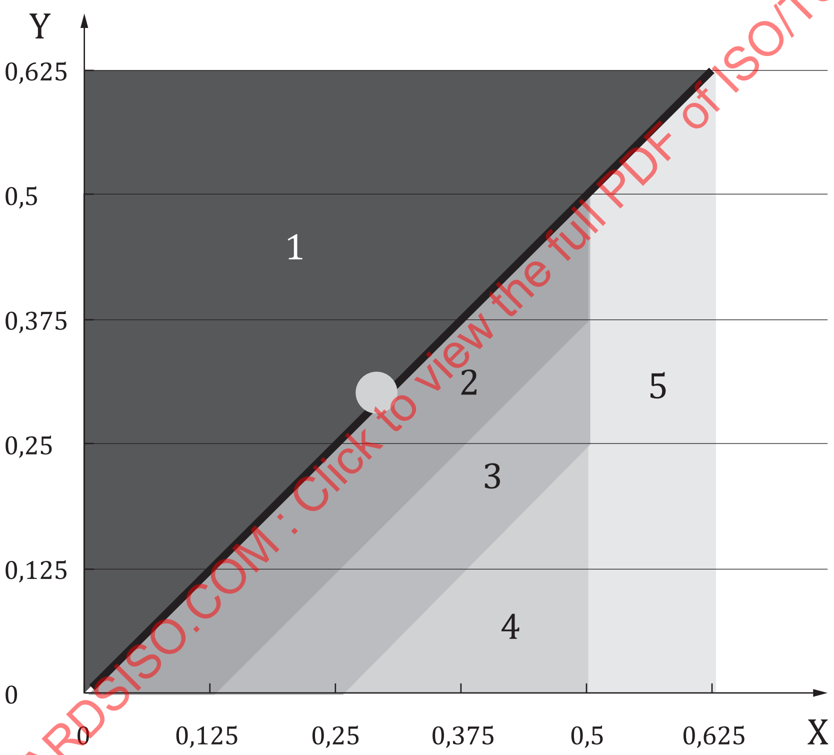
Example of (net) ZEB evaluation

A.1 Evaluation results of (net) ZEB

The (net) ZEB project renovated the operation of an existing building, converting its amenities and intellectual productivity to a ZEB.

The results are shown in Figure A.1.

Primary Energy Intensity (including outlet) =14 MJ/(m^2/year) (−3,9 kWh/(m^2/year))



Key

X normalized energy consumption

Y normalized energy generation

1 net plus energy building

2 nearly ZEB level I

3 nearly ZEB level II

4 ZEB-ready

5 ZEB-oriented

Figure A.1 — (net) ZEB evaluation result

A.2 Actions taken toward (net) ZEB

In this project, the operation of an existing building was renovated and converted into a (net) ZEB in terms of its amenities and intellectual productivity.

In the planning stage, a new work style was adopted that introduced passive energy-saving technologies, pursued added value such as amenity improvements, and prepared a business continuity plan for future disaster events.

Consequently, the existing occupied building was converted to a (net) ZEB. This project is the first conversion to a (net) ZEB in Japan.

For the building exterior, existing glass was replaced with highly insulated glass, and blinds and single glass panels were provided outside the existing windows to provide a simple double skin facade.

For the heat source and air-conditioning systems, it was planned to maximize the use of renewable energy.

In summer, radiant cooling is directly sourced from geothermal heat, and the desiccant is regenerated by solar heat. In winter, geothermal heat powers the geothermal heat pumps, and solar heat is used for heating.

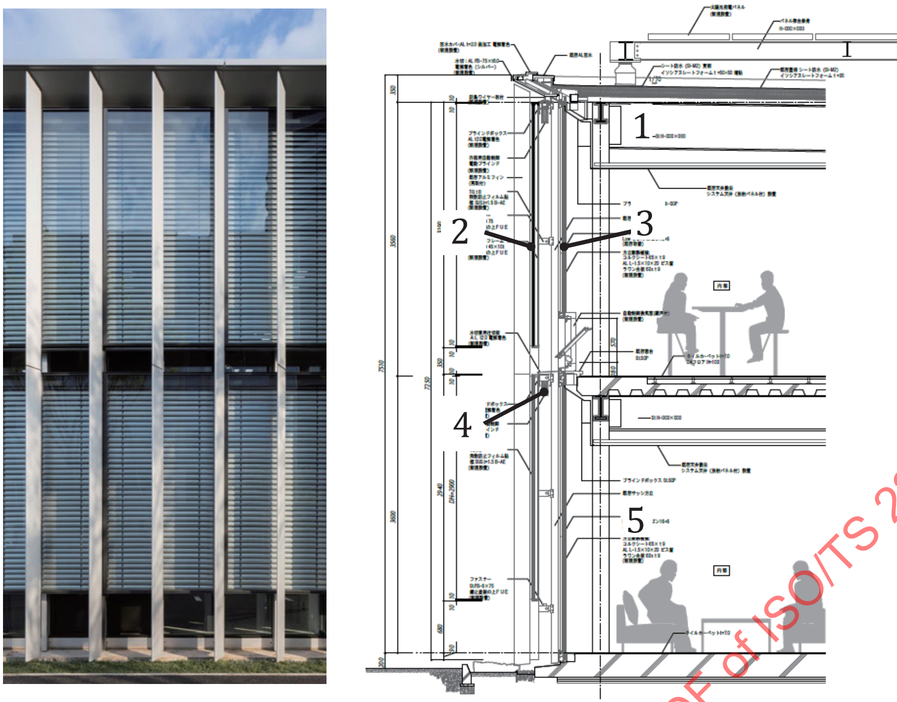
One year after commencing the building operation, the primary energy consumption was 403 MJ/m^2. This energy was provided to the, e.g. air-conditioning, lighting, electrical outlets, through the entire building. After the renovation, the energy consumption was 71 % lower than the original energy consumption.

The photovoltaic power generation system installed on the rooftop generated 417 MJ/m^2 per year.

As the energy created exceeded the energy actually consumed in the offices, a (net) ZEB was successfully created.

Figures A.2 to A.12 illustrate the descriptions above.

Figure A.2 — Building facade



Key

1 roof: addition of 100 mm thermal insulation
2 addition of outer skin glass
3 enhanced thermal insulation using low-E glass filled with argon gas
4 addition of automatic external blind control system
5 wall: addition of 50 mm thermal insulation

Figure A.3 — Renovation with double skin facade

Figure A.4 — 2nd floor office

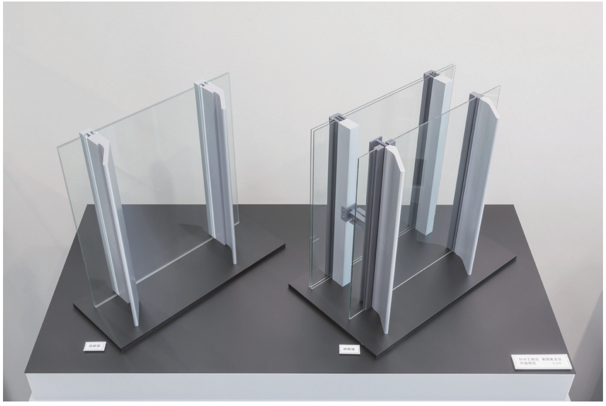
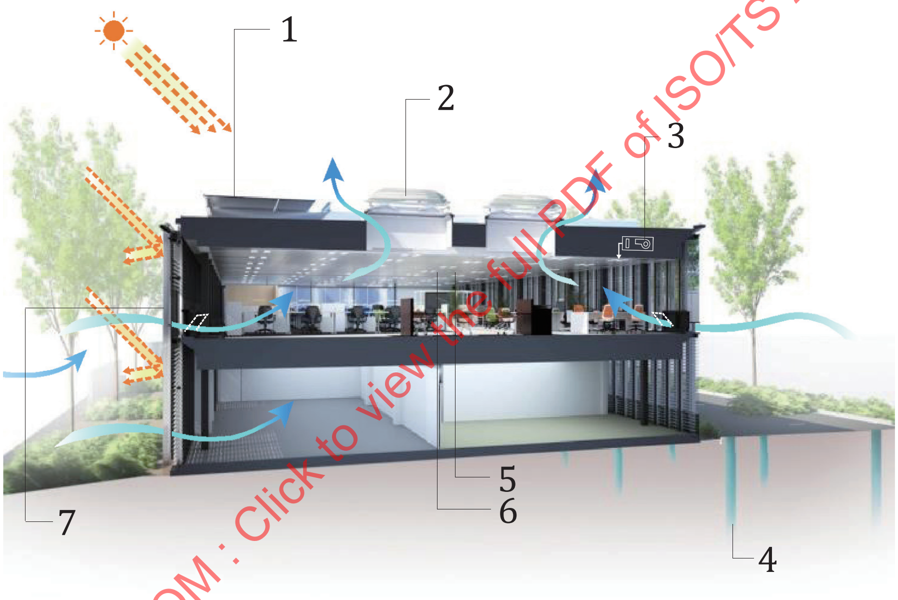


Figure A.5 — Exterior model: before (left) and after (right) renovation



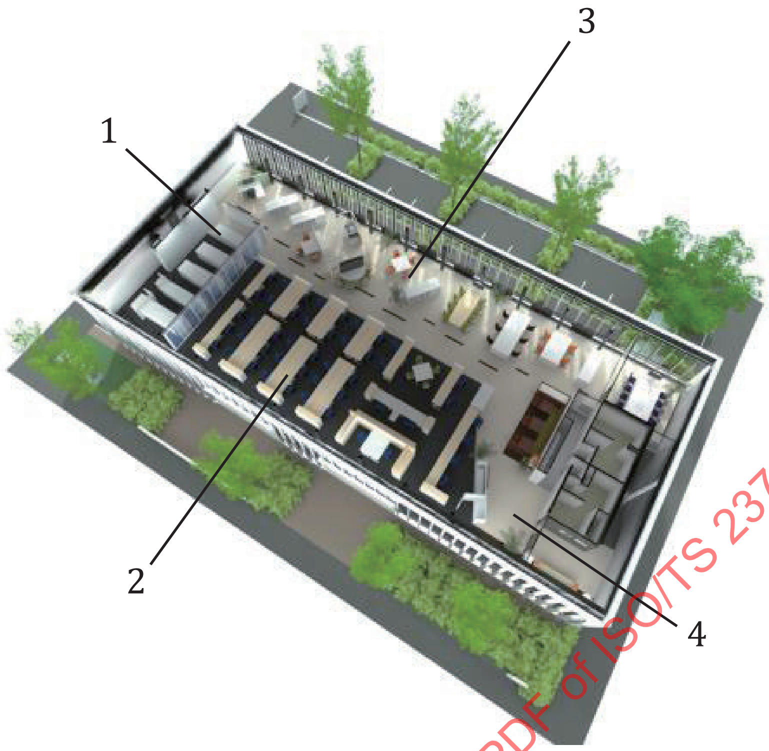
Key

1 solar photovoltaic power generation panel
solar heat collection panel
2 natural light and ventilation through skylight
3 desiccant air-conditioning for low humidity
4 geothermal heat utilization
5 ceiling LED lamps
6 radiation air-conditioning
7 adoption of double skin structure
enhanced thermal insulation using high-insulation glass
automatic external blind control
automatic natural ventilation opening control

Figure A.6 — Principal applied technologies in the ZEB

Concept#1	The value of comfort
	1. Optimal light environment using natural light for office spaces
	2. Automatic external blind control
	3. Automatic natural ventilation opening control
	4. Personal diffuser unit
	5. Desiccant air-conditioning for low humidity
	6. Natural light through skylight
Concept#2	Super energy saving
	1. Ceiling LED lamps
	2. Enhanced thermal insulation using high-insulation glass Enhanced thermal insulation performance of existing frames Adoption of double skin structure Automatic external blind control to adjust sunlight
	3. Radiation air-conditioning
	4. Geothermal heat utilization
	5. Solar heat utilization
Concept#3	Work smart
	1. Communication area
	2. Shared outlets for equipment
	3. Work place Wellness control using wearable devices
Concept#4	Disaster resistance
	1. Solar photovoltaic power generation panels
	2. Solar heat collection panels
	3. Lithium ion rechargeable batteries

Figure A.7 — Renovation concept of the ZEB



Key

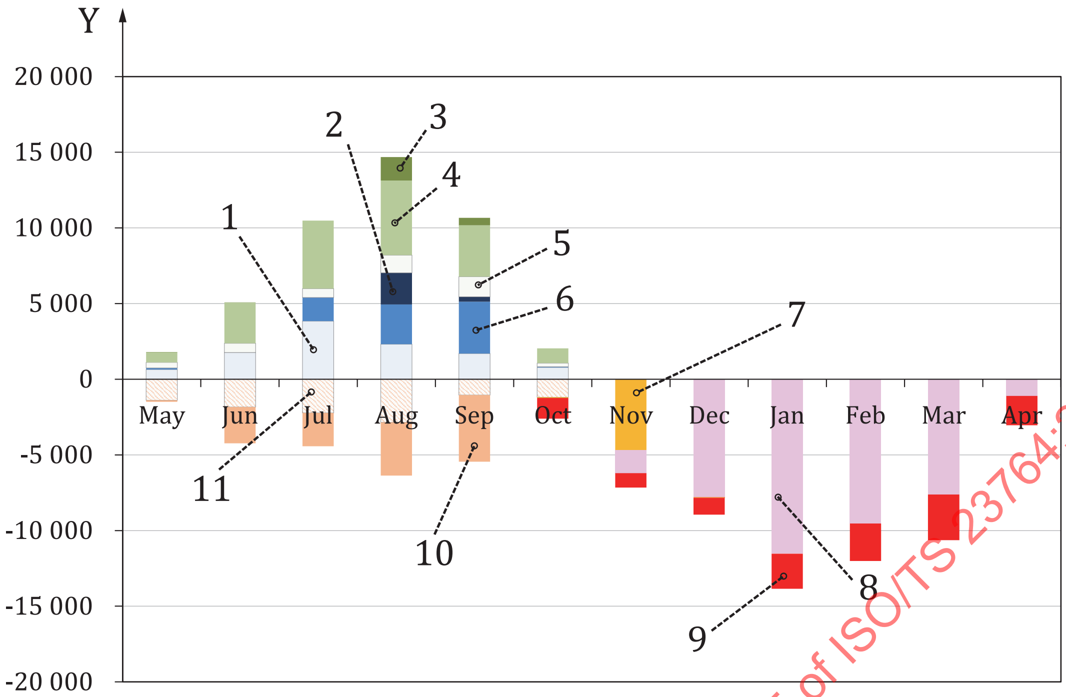
1 filling area

2 work place

3 communication area (these offer unique views, seating positions and angles to encourage interaction and communication)

4 entrance area (desk lighting and air-conditioning are personalized for individual comfort and productivity)

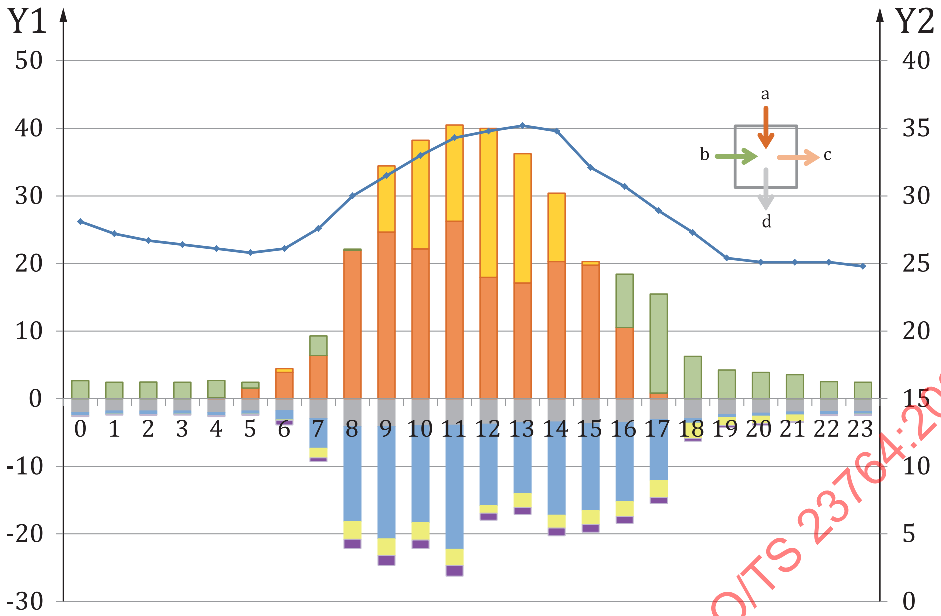
Figure A.8 — Office layout after renovation



Key

Y MJ/month
1 direct use of underground heat source (for radiant cooling)
2 WHP (for radiant cooling)
3 WHP (for desiccant unit)
4 AHP (for desiccant unit)
5 direct use of underground heat source (for desiccant unit)
6 AHP (for radiant cooling)
7 AHP (for radiant heating and dessicant unit)
8 WHP (for radiant heating and dessicant unit)
9 solar heat collector (for radiant heating and dessicant unit)
10 AHP (for regeneration of desiccant unit)
11 solar heat collector (for regeneration of desiccant unit)

Figure A.9 — Breakdown of air-conditioning heat consumption in the 2nd floor office



Key

Y1 amount of electric power [kWh]

Y2 outdoor temperature [°C]

appliance

others

exported

air-conditioning

generation-exported

outdoor temperature

lighting

delivered

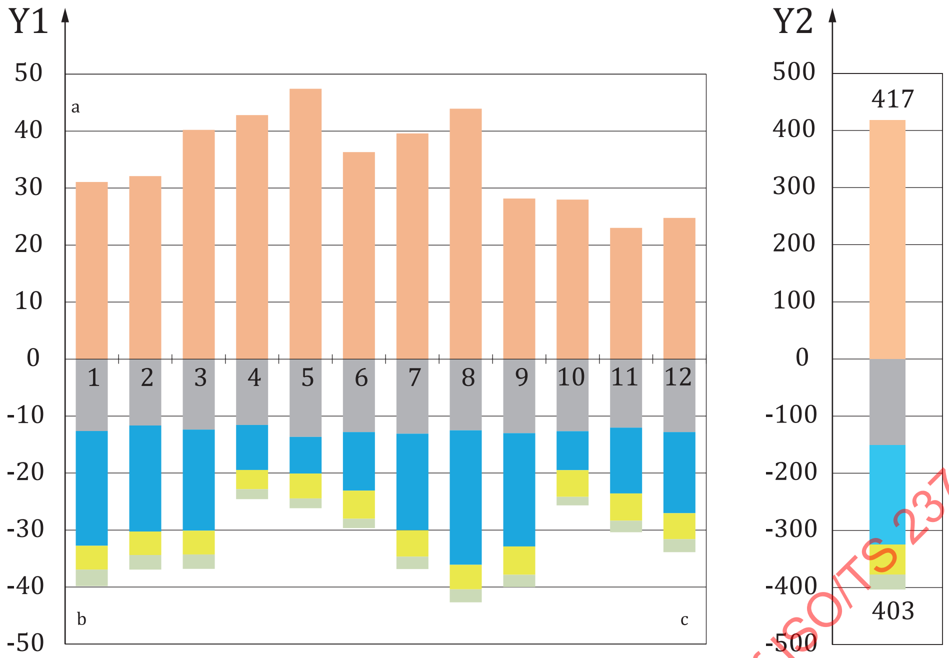
a Generation.

b Delivered.

c Exported.

d Consumption.

Figure A.10 — Electricity change on a typical summer day



Key

Y1 monthly primary energy MJ/(m^2·month)

Y2 annual primary energy MJ/(m^2·year)

appliance

lighting

air-conditioning and ventilation

others

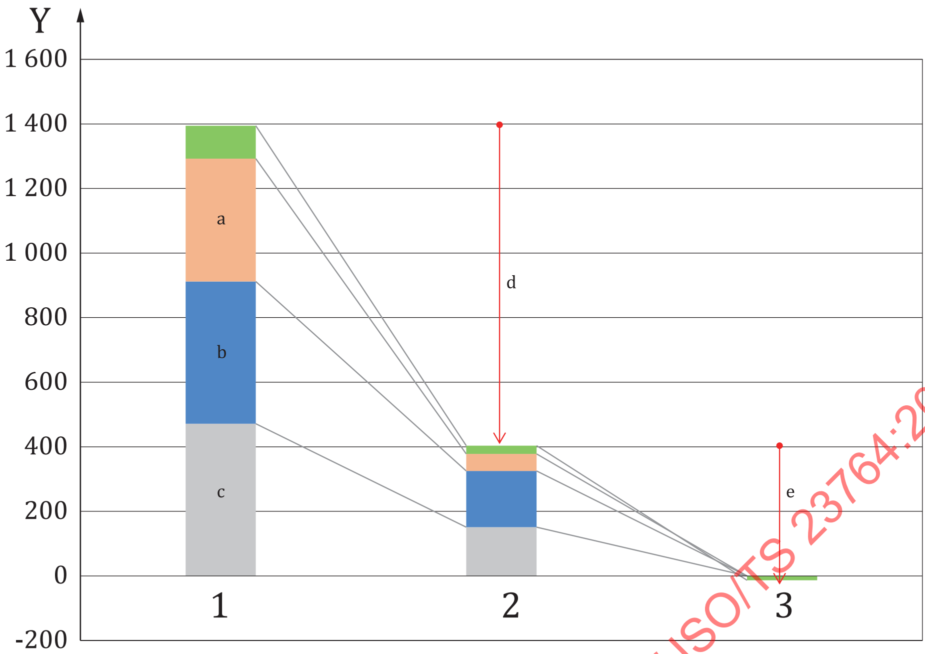
photovoltaics

[a] Energy generation.

[b] Energy consumption.

[c] May 2016 – April 2017.

Figure A.11 — Primary energy consumption and generation in the ZEB during operation



Key

Y actual primary energy consumption (MJ/m²·year)
1 before renovation
2 after renovation
3 after renovation (including PV)
others
lighting
air-conditioning and ventilation
power outlet

a Maximum utilization and control of day lighting.
Task and ambient lighting.
Multiple lighting control.

b Downsizing building service capacity by thermal load reduction.
Direct utilization of geo-thermal and solar heat.
Maximum utilization of natural ventilation and control.
Environmental setting for each area and control.

c Downsizing PC devices.
Sharing of eco-saving copy machines and others.

d 71 % reduction.

e 32 % reduction
30 % reduction

Figure A.12 — Comparison of energy consumption before and after renovation

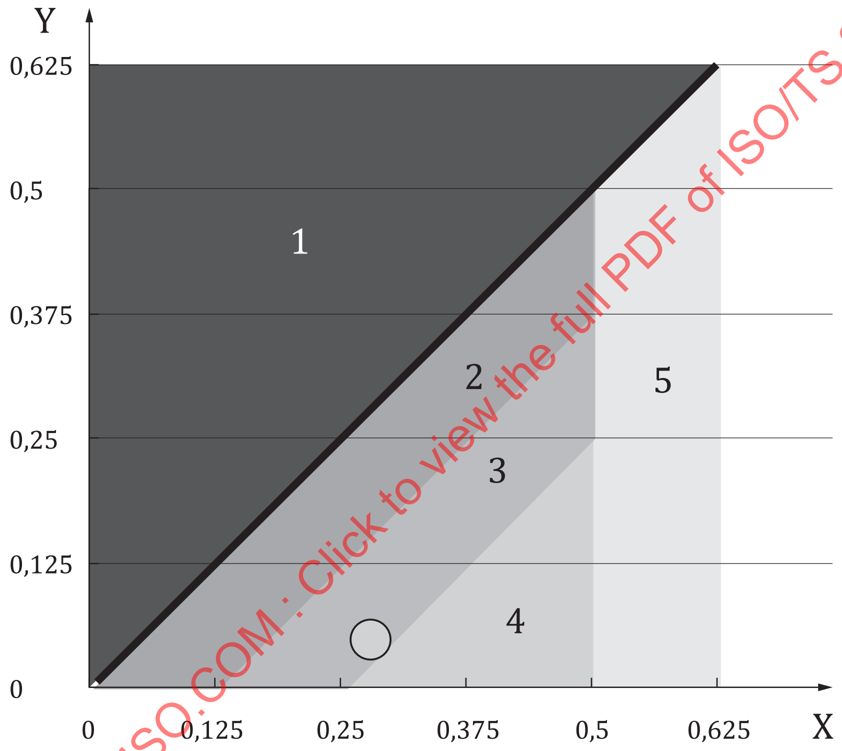
Annex B
(informative)

Example of a nearly ZEB evaluation

B.1 Evaluation results of nearly ZEB

The evaluation results of a nearly ZEB are shown in Figure B.1.

Primary Energy Intensity (excluding the outlet): 274 MJ/(m^2/year) (76 kWh/(m^2/year))



Key

X normalized energy consumption
Y normalized energy generation
1 net plus energy building
2 nearly ZEB level I
3 nearly ZEB level II
4 ZEB-ready
5 ZEB oriented

Figure B.1 — Example of nearly ZEB evaluation result

B.2 Actions taken toward nearly ZEB

This building showcases a city style environmental architecture and the following three design principles:

— reduction of heat load by steel louvers;

— passive use of natural energy by, e.g. natural ventilation, night purge ventilation;

— active use of renewable energy sources, e.g. wood chips and groundwater.

The heat-source/air-conditioning system uses hot water heated by wood chips, and medium-temperature and cold water collected from groundwater for the desiccant and radiation air-conditioning systems.

The renewable energy sources cover 53,5 % of the annual heat load (34,7 % by wood chips and 18,7 % by groundwater).

One year after opening, 26,6 % [150 MJ/ (m^2/year)] of the annual primary energy consumption was covered by renewable energy. The primary energy consumption per unit floor area was 414 MJ / (m^2/year) [(274 MJ/ (m^2/year)] excluding the power outlets.

This building achieved the "nearly ZEB level II" criteria of the 2016 Building Energy Efficiency Act (Japan), with 72 % energy saving and 5 % renewable-energy generation (a combined energy reduction of 77 %).

Figures B.2 to B.11 illustrate the descriptions above.

Figure B.2 — Building facade

Figure B.3 — Center void

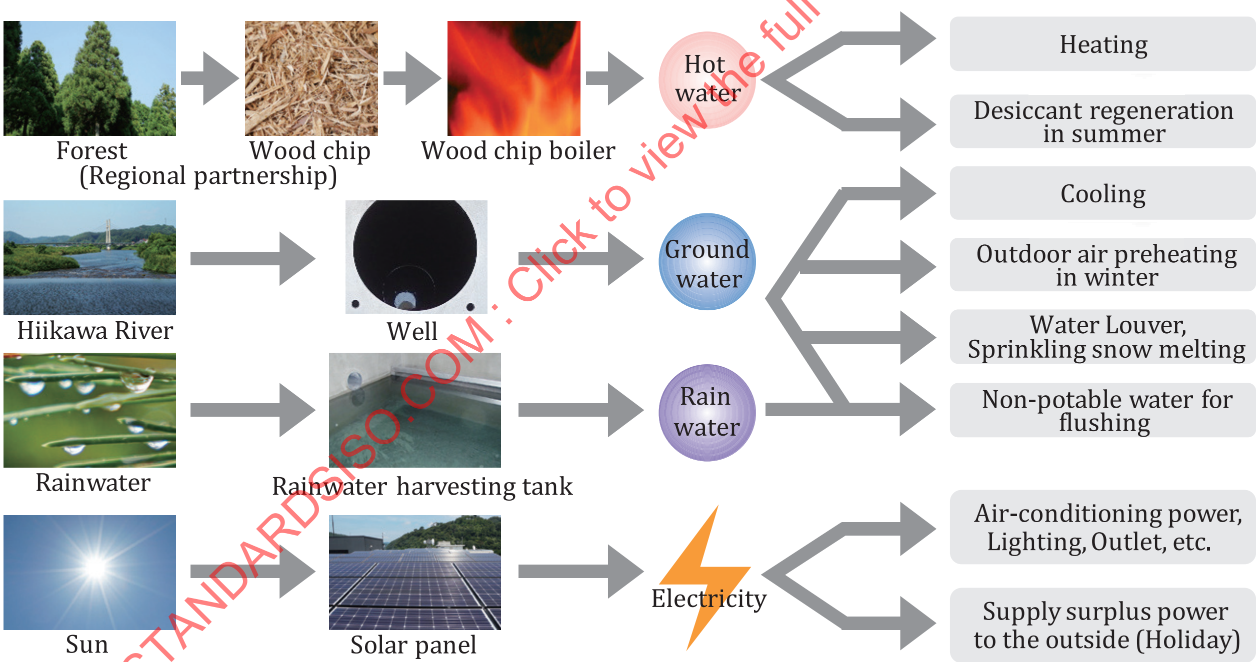


Figure B.4 — Renewable energy harvesting system in the building

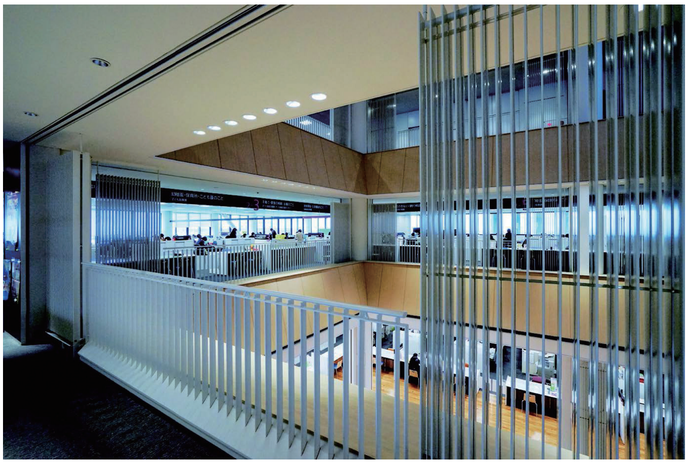


Figure B.5 — Office and centre void

Figure B.6 — Water louver

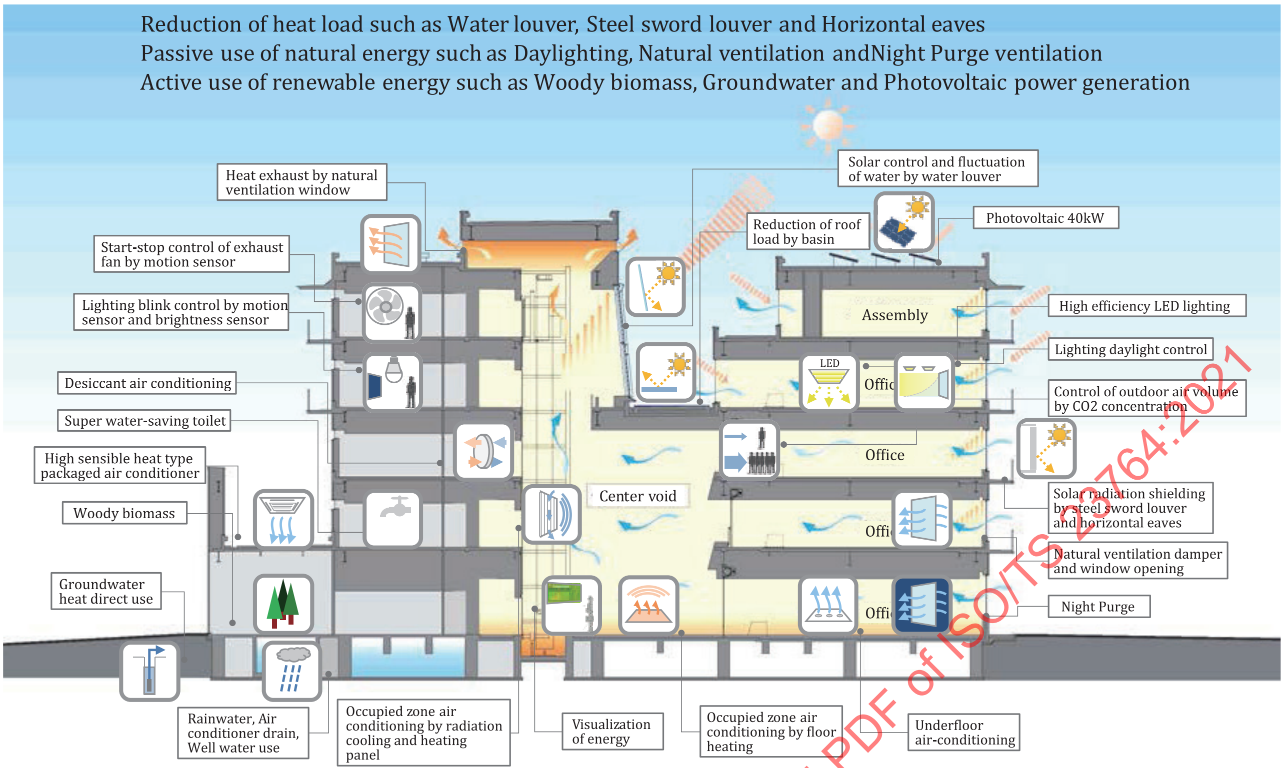


Figure B.7 — Overall picture of environmental architecture in Unnan City

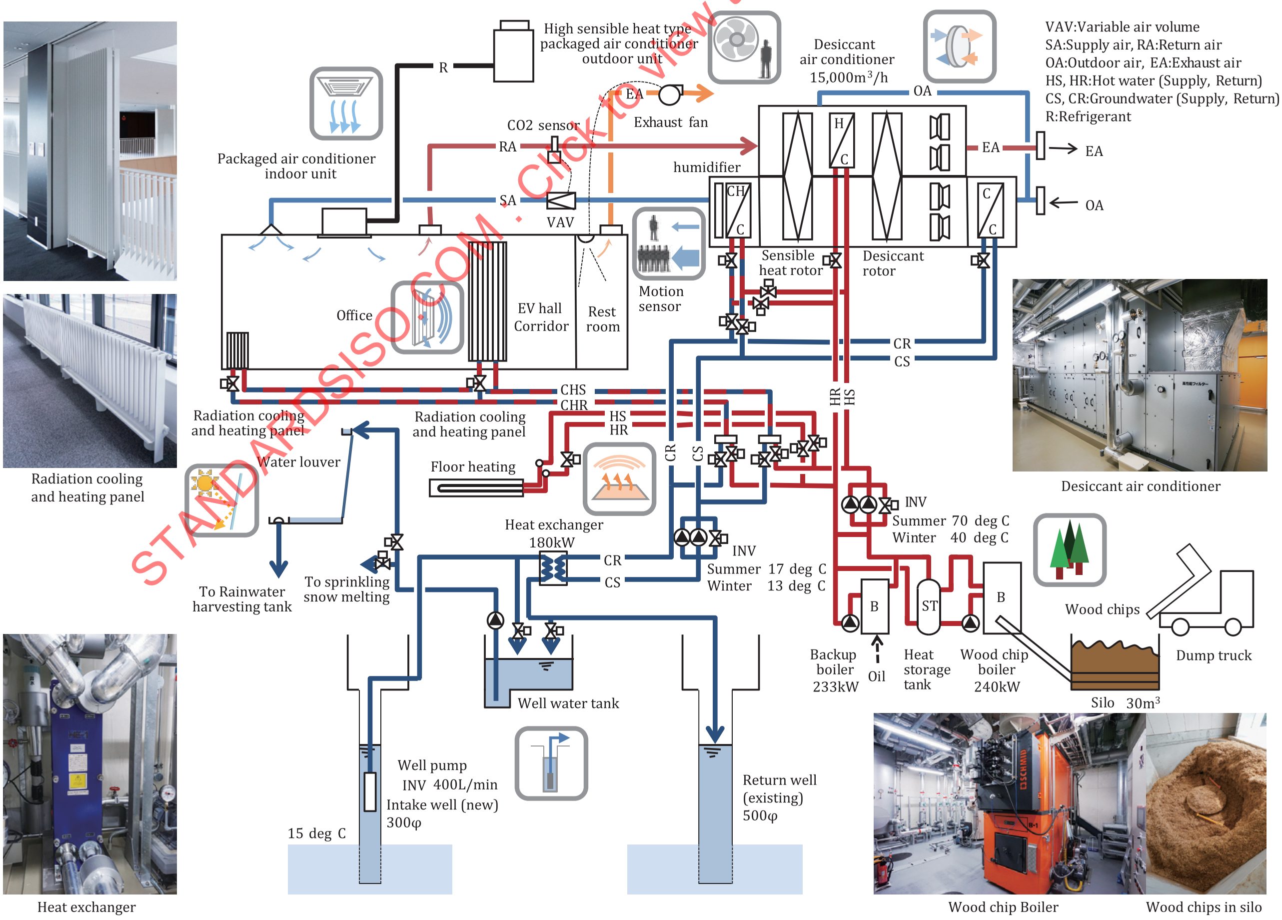
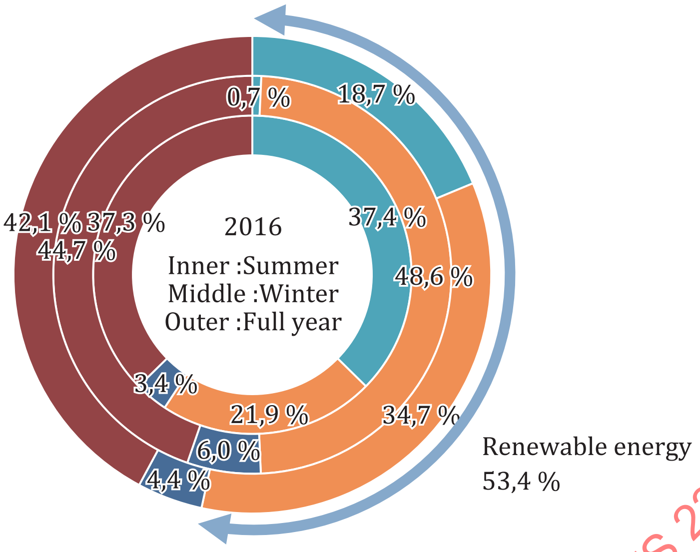


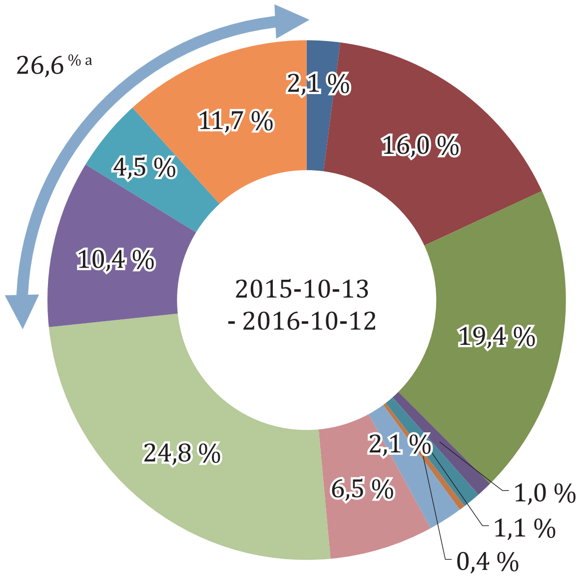
Figure B.8 — Heat-source/air-conditioning system harvesting wood chips and groundwater



Key

- groundwater
- wood chip
- heavy oil
- electricity

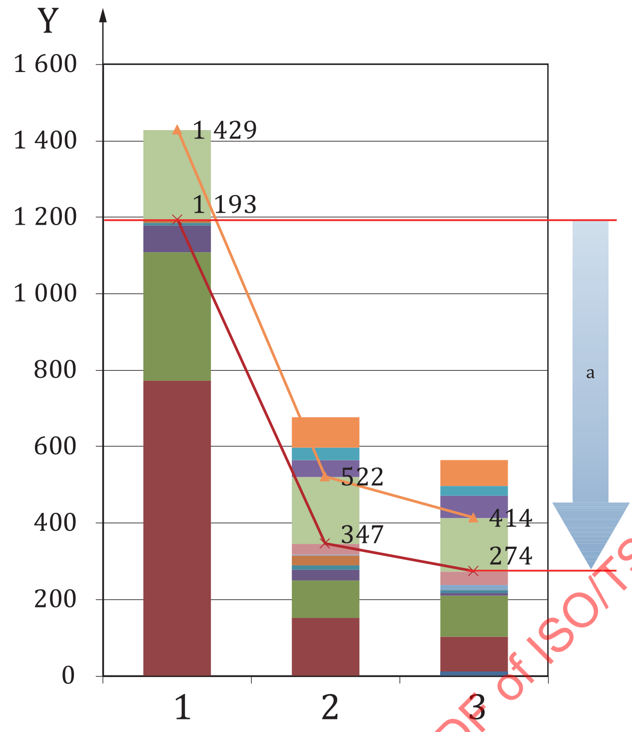
Figure B.9 — Annual heat load ratios of different energy sources



Key

- heavy oil
- air conditioning
- lighting
- ventilation
- hot water supply
- elevator
- plumbing
- others
- outlet
- PV
- groundwater
- wood chip

Figure B.10 — Annual primary energy ratios of different energy usages



Key

Y primary energy consumption per total floor area [MJ/(m²·year)]

1 2016 energy saving standard

2 design value

3 actual value

wood chip

groundwater

PV

outlet

others

plumbing

elevator

hot water supply

ventilation

lighting

air conditioning

heavy oil

primary energy

primary energy (expect for outlet)

a Reduce by 77 % nearly ZEB.

Figure B.11 — Comparison of primary energy consumption units