

Handbook-1

Enforcement Guidelines of BEC Standard Design and Compliance

The Ministerial Regulation and Building
Evaluation Procedures



Preface

In Thailand, Energy consumption in building sector has been increasingly rapidly over the years. In 2019, the Department of Energy Alternative Development and Efficiency (DEDE) reported that around 25% of total energy consumption was in the building sector. The consumption has increased at an average of 5.9% per year during 2010 – 2019. Therefore, the promotion on energy conservation in the building sector is an important factor in meeting the goals of the Energy Conservation Plan in Thailand.

Building Energy Code (BEC) is the standards setting minimum energy efficiency requirements for buildings that request permission for construction or modification with DEDE, according with the Ministerial Regulation B.E. 2552. BEC is the key tool assuring building will be designed to conserve maximum energy, increase energy efficiency in new or renovated buildings, and reduce energy consumption and greenhouse gas emission. In addition, increasing the implementation of energy efficiency measures in commercial buildings and government buildings can reduce greenhouse gas (GHG) emissions by about 1 million ton CO₂. BEC is considered to be one of these strategic measures according to Thailand's Nationally Determined Contribution (NDC) Roadmap on Mitigation 2021-2030.

This document is a part of the project on “Enabling Readiness for Up Scaling Investments in Building Energy Efficiency for Achieving NDC Goals in Thailand” jointly commissioned by the Climate Technology Centre and Network (CTCN), the Office of National Higher Education Science Research and Innovation Policy Council (NXPO), and DEDE and funded by Global Climate Fund (GCF). The document aims to (i) be one of tools to assist Thailand achieve NDC Goals, (ii) build capacity for key relevant stakeholders – government offices, state enterprises, project owner, etc. – to implement BEC according to new Ministerial Regulation which will be enforced in 2022, and (iii) build collaboration with academies for implementing the building's inspection which will lead to a building design for energy conservation. The document provides details for inspecting buildings for energy conservation prescribing in the Ministerial Regulation, the Ministerial Notifications, and the Departmental Notifications.

Bangkok

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1 New BEC Enforcement Regulations and Strategy

Introduction

In Thailand, the Energy Conservation Promotion Act (ECP Act) of Thailand was promulgated in 1992 (amended in 2007). Under the ECP Act, the BEC was established under the Ministerial Regulations of the Ministry of Energy (MoE), for large commercial buildings in 1995. The BEC set the minimum performance requirements on energy conservation for large commercial buildings, and it is a mandatory prescriptive code to improve the energy performance for large new buildings in commercial sector.

The Ministerial Regulation B.E. 2552 (2009) has been issued by the Department of Alternative Energy Development and Efficiency (DEDE), Ministry of Energy. The main article prescribes the types and sizes of buildings and standards, rules and procedures for designing energy conservation buildings. Any new or retrofitted buildings being constructed must be designed in accordance with the Ministerial Regulation B.E. 2552.

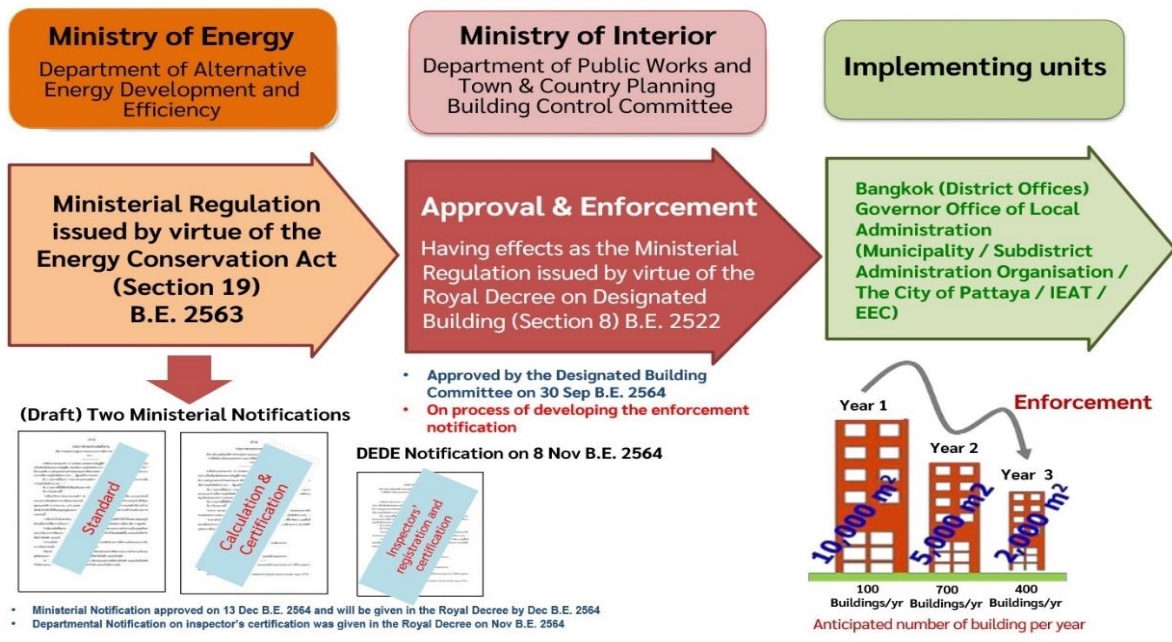
Under the Energy Conservation and Promotion Act (ENCON Act), 1992 (amended in 2007), DEDE is the leading agency responsible for developing and promoting the BEC. The BEC enforcement has been carried out through an inter-ministerial collaboration between DEDE and the Department of Public Works and Town and Country Planning (DPT) under the Ministry of Interior (MoI) and Local Administration Organizations (LAOs). The enforcement of the Code is designated under Section 8 of the Building Control Act (B.E. 2552); a new building that does not comply with the Code is not allowed for construction.

Over the past decade, the BEC was revised to strengthen the code requirements and it was designed to cover both new and retrofitted buildings with floor areas equivalent to or exceeding 2,000 square meters. The revised BEC 2020 was approved by the Cabinet on July 8, 2020, and the revised BEC has been promulgated in the Government Gazette since November 12, 2020.

Under the new revision of Ministerial regulations of BEC, the enforcement process of the revised BEC is shown in the figure below.



Process of enforcing the Ministerial Regulation



The Process Flow of BEC Mandatorily under Thai Law

The New BEC 2021 Phase-Step Enforcement Strategy on Government Building and Private Sector

Under the new revision of Ministerial regulations of Building Energy Code 2021 (B.E 2563), new or retrofitted buildings being constructed which have the total area of all stories equal to or exceeding 2,000 square meters must be designed to comply under the energy conservation requirements. There are nine types of targeted buildings for BEC; 1) Exhibition building, 2) Hotel, 3) Entertainment service, 4) Hospital, 5) School, 6) Office, 7) Department Store, 8) Condominium and 9) Theatre.



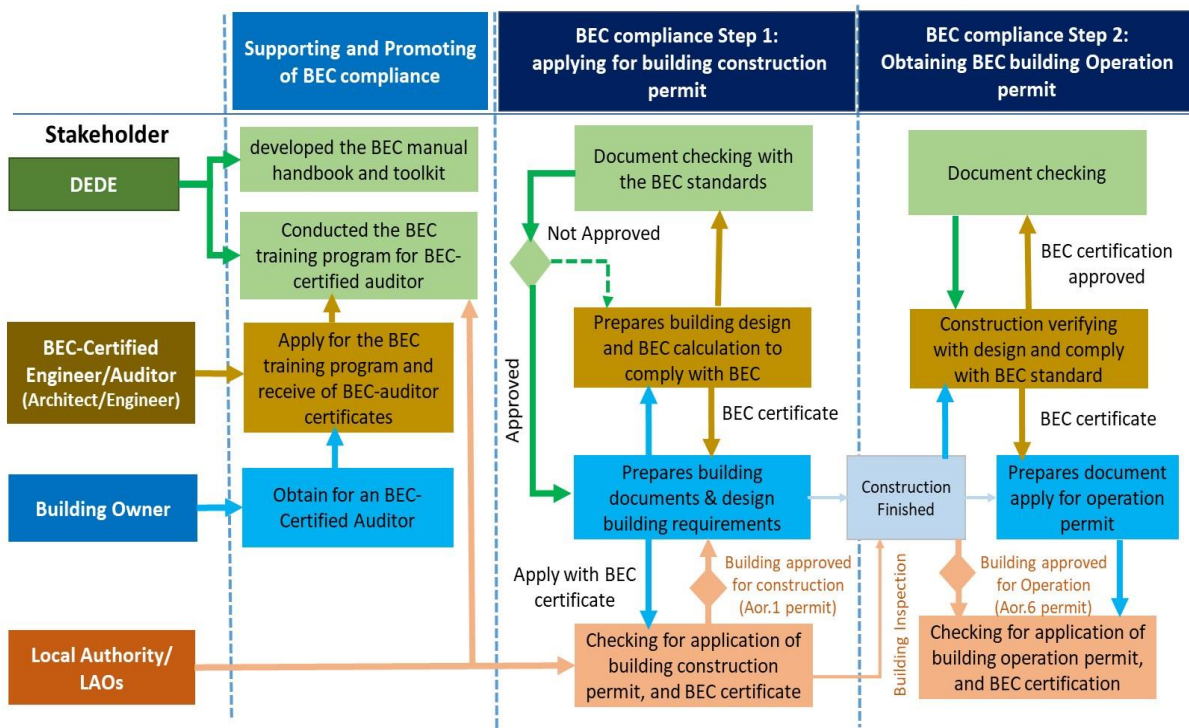
BEC Phase-Step Enforcement under the new BEC ministerial regulation 2020

In 2022, the new code is scheduled to apply in full for buildings of floor area over 10,000 square meters; with provision for a phase-step compliance strategy over three years. The BEC will be

reviewed and revised every six years to strengthen the code requirements for enhancing building performance progressively.

Procedure for construction permit under BEC compliance

Following the BEC compliance regulation, it is a requirement for the building owner to prepare an application document, and design the building complying to the BEC standard. Before applying to the local administration organization for building construction/modification permit, the building design must be approved by an authorized person holding BEC-certified professional license (for professional engineer/architect). The role of stakeholder and procedure of applying for the construction permit under BEC compliance is illustrated in diagram below.



Procedures for Applying for Construction Permit under BEC and Role of Stakeholder

Any project developer and/or concerned organization planning to construct or modify one of the nine types of buildings with the total areas of that building equal to or more than 2,000 square meters must ensure that the building is designed to meet the energy conservation requirements in accordance with the Ministerial Regulation B.E. 2563 (see the detail of Ministerial Regulation in Chapter 2 and 3).

2 Ministerial Regulation

On Prescribing Type or Size of Building and Standard, Criteria and Procedure in Designing Building for Energy Conservation B.E. 2563

The Regulation of the Ministerial Regulation

In accordance with the Ministerial Regulation on Prescribing Type or Size of Building and Standards, Criteria and Procedure in Designing Building for Energy Conservation B.E. 2563, any buildings belonging to government sectors or private sectors must have to submit the documents to determine whether it meets the minimum energy conservation requirements standard in accordance to the Ministry of Energy's Notification B.E. 2564 (see the detail of the BEC regulation in Chapter 2-4).

The evaluation certificate of energy conservation building design as required in accordance with the Ministry of Energy's Notification B.E. 2564 (BEC standard) must be complied with six components under BEC standard as follows:

- 1) Building Envelope (Wall and Roof)
- 2) Lighting system
- 3) Air conditioning system
- 4) Hot water generating system
- 5) Renewable energy performance
- 6) Whole building energy performance

Details of the BEC standard requirement and the calculation method is specified in the Ministry of Energy' Notification B.E. 2564 (see the detail of criteria, calculation methods, and assessment in designing the building for energy conservation in Chapter 3 and 4).



In order to compare the calculated annual energy consumption of a building with the reference building, the BEC regulation distinguishes three different patterns based on the operating hour usages; which is identified as follows:

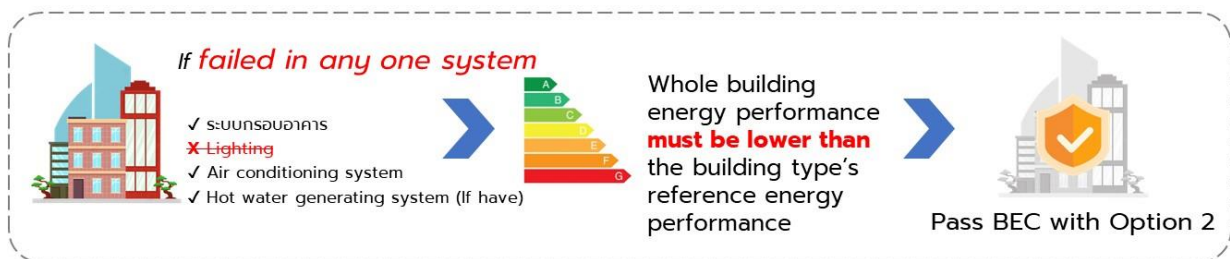
- **Group 1:** Operating hour usage 8 hr/day, will be complied with Office building, and School.
- **Group 2:** Operating hour usage 12 hr/day, will be complied with Department Store, Exhibition building/Conventional Hall, Entertainment service, and Theater.
- **Group 3:** Operating hour usage 24 hr/day, will be complied with Hotel, Hospital, and Condominium.

Following the BEC ministerial regulation, there are two options for building design to be qualified under the BEC standard, as shown in Options for designing building to be qualified under the BEC standard.

Option 1: Passing for all energy performance standard for all four systems



Option 2 Passing in whole building energy performance and hot water generating system



Options for designing building to be qualified under the BEC standard

Option 1: Qualified by passing energy performance standard for all four systems (building envelope, lighting system, air-conditioning system and hot water generating system).

Option 2: Qualified by passing whole building energy performance and hot water generating system. If the design for new building/retrofitted building does not meet the energy performance standard with option 1 for all four systems, option 2 calculating the whole building energy performance must be lower than that building type's reference energy performance.

In case the building consumes energy from its renewable power generation source (Solar PV system), it is allowed to consider the power generation from RE system to be deduct from the whole building energy performance value.

Government sectors, state enterprises, or project developers must provide the project detail, the building blueprint, and the assessment conclusion form of the energy conservation building plan determined by the certified BEC auditor to the Department of Alternative Energy Development and Efficiency (DEDE) – the BEC.001 and .002 form.

Bureau of Energy Regulation and Conservation, DEDE by Coordinating Center for Energy Conservation Building Design (2e-Building Centre) will evaluate the building plan. If the building satisfies the standard required by the Ministerial Regulation, the evaluation certificate of energy conservation building design will be issued and certified by the director-general of DEDE.

Ministerial Regulation on Prescribing Type or Size of Building and Standard, Criteria and Procedure in Designing Building for Energy Conservation B.E. 2563

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12 November B.E 2563



Ministerial Regulation

Prescribing Type or Size of Building and Standards, Criteria and Procedure in Designing Building for Energy Conservation B.E. 2563

By virtue of provision in Section 6 paragraph two and Section 19 of the Energy Conservation Promotion Act B.E. 2535 amended by the Energy Conservation Promotion Act (No. 2) B.E. 2550. The Minister of Energy, by advice of the National Energy Policy Committee, issues Ministerial Regulation as follow:

Clause 1: This Ministerial Regulation shall be enforced when one hundred twenty days have elapsed from the date of its publication in the Government Gazette onward.

Clause 2: The Ministerial Regulation on Prescribing Type or Size of Building and Standard, Criteria and Procedure in Designing Building for Energy Conservation B.E. 2563 shall be repealed

Clause 3: in this Ministerial Regulation

“Audit” means the energy audit for designing building for energy conservation

“Reference Building” means building plan for construction or modification which has the same space, usage, direction, and area of each envelope as the building designed and its envelope system, lighting system and air-conditioning system have to be calculated according to standard.

Section 1:

Type and Size of Building for Energy Conservation

Clause 4: Construction of following buildings, if a total area is from 2,000 square meters and more, must be designed for energy conservation according to standard, criteria and procedure mentioned in this Ministerial Regulation.



- (1) Theatrical building according to the law concerning building control
- (2) Hotel building according to the law concerning hotel
- (3) Entertainment service building according to the law concerning place for entertainment service
- (4) Hospital or clinic according to the law concerning Medical center or hospital
- (5) Educational place according to the law concerning national education
- (6) Office
- (7) Building of department store or trade center
- (8) Condominium according to the law concerning condominium
- (9) Building for congregation according to the law concerning building control

Clause 5: Modification of the building mentioned in Clause 4, if a total area is from 2,000 square meters and more, must be designed for energy conservation according to standard, criteria and procedure mentioned in this Ministerial Regulation.

Section 2

Standard, Criteria and Procedure for Designing Building for Energy Conservation

Clause 6: Following building envelope system must follow the standard prescribed in announcement by the Minister:

- (1) External wall and roof of building which has air conditioning in each type of building.
- (2) Other types of building envelope system.

For building, which has use of several manners, each part of area must use specification of building envelope system according to manner of use of each part of that area.

Clause 7: Lighting system must follow these standards

(1) Lighting performance of electrical equipment for lighting inside of the building must not exceed standard value for each specific building type which is prescribed in announcement by the Minister.

(2) Luminance of the use of lighting electricity inside of building, excluding car parking space, for each type of work must have sufficient level and must comply with the law concerning building control or specific law concerning such case.

For building which has use of several manners, maximum lighting performance of each area must not exceed standard value for each type of work.

Clause 8: Each type and size of air conditioning system installed in the building must have minimum performance, seasonal energy efficiency ratio or ratio of electrical power per ton of refrigeration complying with standard prescribed in announcement by the Minister.

Clause 9: Hot water producing equipment installed in the building must have minimum coefficient of performance and minimum efficiency according to standard prescribed in announcement by the Minister.

Clause 10: Calculation of designing building for energy conservation shall follow criteria and methodology prescribed in announcement by the Minister.

Clause 11: Designing building for energy conservation must audit the plan of construction or modification which the standard value of each system should not exceed the value prescribed in announcement (Clause 6, 7 or 8) by the Minister.

Inspection report shall present the calculation prescribed in announcement (Clause 10) by the Minister or the methodology according standard prescribed by the Engineering Institute of Thailand under H.M. the King's Patronage or by the Association of Siamese Architects under Royal Patronage or according standard certified by the Building Control Committee.

Clause 12: If results of the inspection are different from standard prescribed in Clause 6, 7, or 8, a total energy consumption of the building must be less than the Reference Building.

Clause 13: For the building which uses renewable energy, its energy consumption can be subtracted by a use of renewable energy. Criteria and methodology shall follow Clause 10 prescribed in announcement by the Minister.

Clause 14: Inspection shall be conducted by person who has engineering license for professional practice or architect license for professional practice and pass the training certified by the Department of Alternative Energy and Energy Efficiency.

Clause 15 Certification of inspection report: The building owner must develop inspection report for plan of construction or modification prescribed in announcement by the Minister, and arrange to have inspector who has qualification in according to Clause 14 for requesting the permission on instruction or modification according to the Building Control Act.

When construction or modification is completed, the building owner must submit a certification on energy conservation according to the Building Control Act.

Transitory Provision

Clause 16: In an initial phase this Ministerial Regulation shall not enforce the construction or modification of building which is prescribed in Clause 4 and has a total area not excess 10,000 square meters. The initial phase will be end by

- (1) One year for the building which has a total area from 5,000 square meters to 10,000 square meters.
- (2) Two years for the building which has a total area from 2,000 square meters to 5,000 square meters.

Clause 17: Plan of building, for which a request for permission for construction or modification according to the Building Control Act or the specific law concerning such case, or for approval of environmental impact analysis or environmental impact assessment according to the Enhancement and Conservation of National Environment Quality Act before the date of enforcement of this Ministerial Regulation, shall be exempted from complying with this Ministerial Regulation.

This is given on 30 October B.E. 2563

Supattanapong Punmeechow
Minister of Energy

Remark: Reasons for promulgation of this Ministerial Regulation is: whereas type or size of building and standard, criteria and procedure of designing building for energy conservation was prescribed in the Ministerial Regulation B.E. 2552, they do not suit current situation. Therefore it is necessary to revise the standard, criteria and procedure to suit a change of technology, and the energy audit for designing building for energy conservation suit a permission of construction or modification according to the Building Control Act. This Ministerial Regulation needs to be issued.

2 Ministry of Energy's Notification

On Prescribing standard values in designing building for energy conservation B.E. 2564

Ministry of Energy's Notification on prescribing standard values in designing building for energy conservation B.E. 2564

Unofficial Translation



Ministry of Energy's Notification

Prescribing Standard Values in Designing Building for Energy Conservation B.E. 2564

By the authority of the particulars in Clause 6, 7, 8 and 9 of the Ministerial Regulation prescribing type or size of buildings and standard, criteria and procedure in designing building for energy conservation B.E. 2563, issued according to the particulars of the Energy Conservation Promotion Act B.E. 2535 as amended by the Energy Conservation Promotion Act (Vol. 2) B.E. 2550, The Minister of Energy, therefore, does hereby issue the following announcement:

Clause 1: This Notification is called “Ministry of Energy’s Notification on prescribing standard values for designing building for energy conservation B.E. 2564”.

Clause 2: This Notification shall become effective since it is published in the Government Gazette.

Clause 3: Repeal the Ministry of Energy’s Notification on prescribing coefficient of minimum performance, coefficient of performance of refrigeration, and ratio of electrical power and cooling capacity of refrigeration installed in building in B.E. 2552.

Clause 4: In this Notification

“Maximum Lighting Power Density” means an average value of the installed lighting power density per building area (Watt per square meters). This excludes car parking area.

“Air-Conditioner” means split-type air-conditioner which heat is ventilated by air or water. It is designed for condensing unit and fan-coil unit to work together and uses alternate current with the frequency of 50 Hertz for reducing the temperature and humidity in the air that passes fan-coil unit as identified in this notification.

“Water Cooler for Air-conditioning System” means equipment that lowers the temperature of water in order to be used in the air-conditioning or cooling by using the cooling cycle (vapor compression or absorption).

“Energy Efficiency of Air-Conditioning System” is as coefficient of minimum performance, seasonal energy efficiency ratio and ratio of electrical power per cooling capacity.



“Coefficient of Performance” means ratio of net cooling capacity of air-conditioning system or net heating capacity of water heater (Heat Pump) and electrical power (Watt).

“Coefficient of Minimum Performance” means ratio of level of net cooling capacity of air-conditioning system or net heating capacity of water heater (heat pump) and level of electrical power. This identify as the minimum value for installing in the building.

“Seasonal Energy Efficiency Ratio” means ratio of net cooling capacity of air-conditioning system during season which is divided by electrical power (BTU per hour) and level of electrical capacity (Watt).

“Electrical Power per Ton Refrigeration” means ratio of electrical power (Kilowatt) and net cooling capacity of water cooler (Ton Refrigeration).

“Steam Boiler” means closed container loading 2 liter of water or more. When it is heated by fuel combustion or other thermal energy source, water will change to steam under pressure which is more than 1.5 times of atmospheric pressure at sea level.

“Hot Water Boiler” means closed container having surface area 8 square meter or more is loaded with water for producing hot water.

“Minimum Efficiency” mean ratio of thermal energy of steam and heating value of fuel.

Section 1:

Overall Thermal Transfer Value of Building's Envelope System

Clause 5: Overall thermal transfer value of external wall of the building entering into inside the building which install air-conditioning shall not exceed the following value.

Type of Building	Overall Thermal Transfer Value of external wall of the building (Watt/m ²)
(1) Theatrical Building	40
(2) Hotel	30
(3) Entertainment Service	40
(4) Medical center or hospital	30
(5) Educational Place	50
(6) Office	50
(7) Department Store or Tread Center	40
(8) Condominium	30
(9) Building for congregation	40

Clause 6: Roof thermal transfer value passing into an inside of building which install air-conditioning shall not exceed the following value

Type of Building	Overall Roof Thermal Transfer Value (Watt/m ²)
(1) Theatrical Building	8
(2) Hotel	6
(3) Entertainment Service	8
(4) Medical center or hospital	6
(5) Educational Place	10
(6) Office	10
(7) Department Store or Tread Center	8
(8) Condominium	6
(9) Building for congregation	8



Clause 7: Overall Thermal Transfer Value of external wall of the building entering into an inside of each type of building according to Clause 5, and Roof thermal transfer value passing into an inside of building which install air-conditioning according to Clause 6 are summation of the weighted average value of each side according to Ministry of Energy’s Notification on criteria, calculation method and certification of inspecting a design for each energy conservation system, an overall energy consumption of the building, and a use of renewable energy B.E. 2564.

**Section 2:
Maximum Lighting Power Density**

Clause 8: Maximum value of lighting power density of each type of building shall not exceed the following value.

Type of Building	Maximum Lighting Power Density (Watt/m ²)
(1) Theatrical Building	11
(2) Hotel	12
(3) Entertainment Service	11
(4) Medical center or hospital	12
(5) Educational Place	10
(6) Office	10
(7) Department Store or Tread Center	11
(8) Condominium	12
(9) Building for congregation	11

Maximum value of lighting power density for each type of building shall calculate from its average value per area according to Ministry of Energy’s Notification on Criteria, Calculation Methods and Certification in designing building for energy conservation of various system, an overall energy consumption of the buildings, and a use of renewable energy systems B.E. 2564.



Section 3:
Energy Efficiency of Air-Conditioning System

Clause 9: Type and size of each air-conditioning system which is installed in building shall have energy efficiency as follow.

(1) Air-conditioning which is not more than 12,000 Watt shall have seasonal energy efficiency ratio according to current energy efficiency criteria for air-conditioning No. 5 (minimum) developed by the Electricity Generation of Thailand.

(2) Refer to a standard testing which temperature of outlet cooling water is 7.2°C and temperature of water outlet from condenser system is 32.2°C, water cooler for the vapor-compression air-conditioning system shall has an electric power per ton refrigeration no more than the following value.

Type of water cooler for the vapor-compression air-conditioning system		Size of cooling capacity at the full cooling load (ton refrigeration)	Electrical power per ton refrigeration (kilo Watt / tone refrigeration)
Type of Condenser	Type of compressor		
Air-cooled chiller	All types	All sizes	1.12
Water-cooled chiller	Reciprocating	All sizes	0.88
	Rotary or Screw	All sizes	0.70
	Scroll	All sizes	0.89
	Centrifugal pump	Less than or equal 300 More than 300	0.67 0.61

Other parts of air-conditioning system driven by electricity consisting of heat evaporation and condenser system, water cooling system, and cooling fan system shall have electrical power per ton refrigeration of no more than 0.5 Kilowatt per ton refrigeration.

b

(3) Absorption Chiller shall have coefficient of minimum performance which shall not exceed the following value.

(A) Identification of rated condition by mentioning temperature and rate of water flow into condenser. It shall not exceed the following value.

Type of Absorption Chiller	Rated condition				Coefficient of minimum performance
	Chilled- Water		Condenser-Cooling Tower		
	Temp. of chilled-water (Inlet)	Temp. of chilled-water (Outlet)	Temp of water flow into condenser	Flow rate of water flow into condenser (liter / second / kilo Watt)	
	(Degree Celsius)				
A. Single stage	12.0	7.0	32.0	0.105	0.65
B. Double stage	12.0	7.0	32.0	0.079	1.10

(B) Identification of rated condition by mentioning temperate of hot water into and from condenser. It shall not exceed the following value.

Type of Absorption Chiller	Rated condition				Coefficient of minimum performance
	Chilled- Water		Condenser-Cooling Tower		
	Temp. of chilled-water (Inlet)	Temp. of chilled-water (Outlet)	Temp of water flow into condenser	Flow rate of water flow into condenser	
	(Degree Celsius)				
A. Single stage	12.0	7.0	32.0	37.5	0.65
B. Double stage	12.0	7.0	32.0	37.5	1.10

Calculation of the coefficient of performance shall focus only on heating value (excluding electrical power in system). Calculation of seasonal energy efficiency ratio, coefficient of performance, and coefficient of minimum performance of the air-conditioning system installed in the building shall follow the Ministry of Energy’s Notification on Criteria, Calculation Methods and Certification in designing building for energy conservation of various system, an overall energy consumption of the buildings, and a use of renewable energy systems B.E. 2564

Clause 10: Energy Efficiency of air-conditioning system mentioned in Clause 9 shall not be applied to solar thermal air conditioning).

**Section 4:
Minimum Efficiency and Coefficient of minimum performance for water heater**

Clause 11: Minimum efficiency and coefficient of minimum performance for water heater installing in the building shall have value as follows:

(1) Steam boiler and hot water boiler shall have efficiency not less than the following minimum efficiency.

Type of Boiler	Minimum efficiency (%)
A. Oil fired steam boiler	85
B. Oil fired hot water boiler	80
C. Gas fired steam boiler	80
D. Gas fired hot water boiler	80

(2) Air-source heat pump water heater shall have the coefficient of performance not less than the following coefficient of minimum performance

Standard Condition of Performance				Minimum Coefficient of Performance (COP)
Type of design	Temp. of water inflow (°C)	Temp. of water outflow (°C)	Temp of ambient (°C)	
	(Degree Celsius)			
a). Type 1	30.0	50.0	30.0	3.5
b). Type 2	30.0	60.0	30.0	3.0

Minimum efficiency and coefficient of minimum performance of water heater shall calculate according to the Ministry of Energy’s Notification on Criteria, Calculation Methods and Certification in designing building for energy conservation of various system, an overall energy consumption of the buildings, and a use of renewable energy systems B.E. 2564

Given on

Supattanapong Punmeechow
Minister of Energy

3 Ministry of Energy's Notification

On Criteria, Calculation Methods and Certification in Designing Building for Energy Conservation of Various Systems, an Overall Energy Consumption of Buildings and a Use of Renewable Energy Systems
B.E. 2564

Ministry of Energy's Notification on Criteria, Calculation Methods and Certification in Designing Building for Energy Conservation of Various Systems, an Overall Energy Consumption of Buildings and a Use of Renewable Energy Systems B.E. 2564



Unofficial Translation

(Draft) Ministry of Energy's Notification

On Criteria, Calculation Methods and Certification in Designing Building for Energy Conservation of Various Systems, an Overall Energy Consumption of Buildings and a Use of Renewable Energy Systems B.E. 2564

By the authority of the particulars in Clause 10 and 15 of the Ministerial Regulation on prescribing type or size of buildings and standard, criteria and Procedure in designing building for energy conservation B.E. 2563, issued according to the particulars of the Energy Conservation Promotion Act B.E. 2535 as amended by the Energy Conservation Promotion Act (Vol. 2) B.E. 2550. The Minister of Energy, therefore, does hereby issue the following announcement:

Clause 1: This announcement is called "The Notification of the Ministry of Energy on Criteria, Calculation Methods and Certification in Designing Building for Energy Conservation of Various Systems, an Overall Energy Consumption of the Buildings and a Use of Renewable Energy Systems B.E. 2564.

Clause 2: This Notification shall become effective since it is published in the Government Gazette.

Clause 3: Repeal the Ministry of Energy's Notification on Criteria, Calculation Methods and Certification in Designing Building for Energy Conservation of Various Systems, an Overall Energy Consumption of Buildings and a Use of Renewable Energy Systems B.E. 2552.

Clause 4: of this announcement

"Building" refers to a structure according to Clause 4 and 5 of the Ministerial Regulation prescribing type or size of buildings and standard, criteria and procedure in designing building for energy conservation B.E. 2563, which has been issued according to the Energy Conservation Promotion Act B.E.2535.

"Certification Method" means an assessment of energy conservation of building's design by using the software developed by the Department of Alternative Energy and Energy Efficiency or standard method certified by the Engineering Institute of Thailand under H.M. the King's Patronage or by the Association of Siamese Architects under Royal Patronage or by the Building Control Committee.



Section 1

Calculation of the Overall Heat Transfer Value of Building Envelope

Part 1

Calculation of the Building's Overall Thermal Transfer Value

Clause 5: The calculation of the building's overall thermal transfer value shall be carried out according to the following specified criteria and methods:

(1) A building's Overall Thermal Transfer value, OTTV)

(1.1) A building's Overall Thermal Transfer value, OTTV) shall be calculated using the following equation:

$$OTTV_i = (U_w)(1-WWR)(TD_{eq}) + (U_f)(WWR)(\Delta T) + (WWR)(SHGC)(SC)(ESR)$$

When	OTTV _i	is the overall thermal transfer value of the outer wall being considered, the unit is Watt per square meters, (W/m ²).
	U _w	is the coefficient of the overall thermal transfer value of a solid wall, the unit is Watt per square meters, (W/m ² .°C).
	WWR	is the ratio of the transparent windows or walls to the total wall area of the building envelope being considered.
	TD _{eq}	is the equivalent temperature difference between the outside and inside of the building, including the results of the solar ray absorption of the solid wall, the unit is in Celsius degrees (°C).
	U _f	is the coefficient of the overall thermal heat transfer of a transparent wall or glasses wall; its unit is Watts per square meter-degrees Celsius (W/(m ² .°C).
	ΔT	is the temperature difference between outside and inside of the building, (°C)
	SHGC	is the coefficient of the thermal heat transfer value from solar rays which is penetrated through a transparent or glass wall.
	SC	is the shading coefficient of the shading devices.
	ESR	is the solar radiation which has an effect on the thermal transfer through transparent and/or solid walls; its unit is in (W/m ²)

(1.2) A building's overall thermal transfer value (OTTV) is the weighted average value of the total thermal transfer value (OTTV) on each outer wall, and it is to be calculated by the following equation:

$$OTTV = \frac{(A_{w1})(OTTV_1) + (A_{w2})(OTTV_2) + \dots + (A_{wi})(OTTV_i)}{A_{w1} + A_{w2} + \dots + A_{wi}}$$

When A_{wi} is the area of the wall being considered, including the area of solid wall and the area of window or transparent wall; its unit is in square meters (m^2).
 $OTTV_i$ is the overall thermal transfer value of the outer wall being considered, the unit is Watt per square meters, (W/m^2)

(2) The coefficient of the overall thermal heat transfer of a solid wall (U_w).

The coefficient of the overall thermal heat transfer of each side of outer solid wall (U_w) shall be calculated by the following equation:

(2.1) The Overall Thermal Transfer Coefficient (U)

The coefficient of the overall thermal heat transfer of each side of outer solid wall (U_w) shall be calculated by the following equation:

$$U = \frac{1}{R_T}$$

When R_T is the total thermal resistance; its unit is in $((m^2 \cdot ^\circ C)/W)$.

(2.2) Thermal Resistance (R)

The thermal resistance of any material shall be calculated as follows:

$$R = \frac{\Delta X}{k}$$

When R is the thermal resistance; its unit is square meter-degree Celsius per Watt $((m^2 \cdot ^\circ C)/W)$.

Δx is the material's thickness; its unit is in meters (m).

k is the coefficient of the material's thermal conductivity; its unit is Watt per square meter-degrees Celsius ($W/(m^2 \cdot ^\circ C)$).



(2.3) The Building’s Overall Thermal Resistance

The calculation of the building’s overall thermal resistance depends upon the type of wall material as follows:

(2.3.1) The wall consists of various types of materials:

The overall thermal resistance (R_T) of any part of a building wall which consists of n types of materials and shall be calculated as follows:

$$R_T = R_o + \frac{\Delta X_1}{k_1} + \frac{\Delta X_2}{k_2} + \dots + \frac{\Delta X_n}{k_n} + R_i$$

- When R_T is the building’s wall total thermal resistance; its unit is square meter-degrees Celsius per Watt ($W/(m^2 \cdot ^\circ C)$).
- R_o is the thermal resistance of outer air; its unit is square meter-degree Celsius per Watt ($W/(m^2 \cdot ^\circ C)$).
- R_i is the thermal resistance of inner air; its unit is square meter-degree Celsius per Watt ($W/(m^2 \cdot ^\circ C)$).
- $\Delta X_1, \Delta X_2, \dots, \Delta X_n$ is the thickness of each type of composited material of the building wall; its unit is meters (m).
- k_1, k_2, \dots, k_n is the coefficient of thermal conductivity of each composited material used in the building wall.

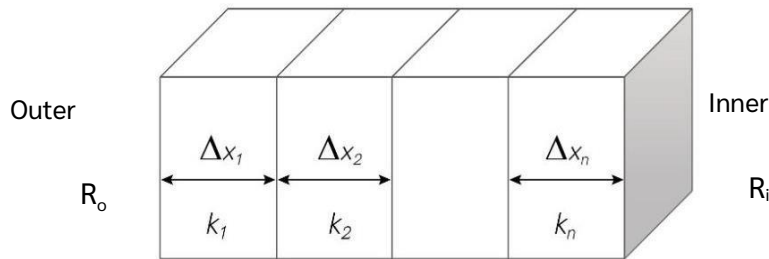


Figure 1 Thermal transfer through the building wall with the structure consisting of n types of different materials.

(2.3.2) A wall with air space inside

The overall thermal resistance (R_T) of any part of a building wall consisting of n types of different materials and with air space inside shall be calculated as follows:

$$R_T = R_o + \frac{\Delta X_1}{k_1} + \frac{\Delta X_2}{k_2} + \dots + R_a + \frac{\Delta X_n}{k_n} + R_i$$

- When R_o is the thermal resistance of the air space within the building wall; its unit is square meter-degrees Celsius per Watt ($(m^2 \cdot ^\circ C) / W$).

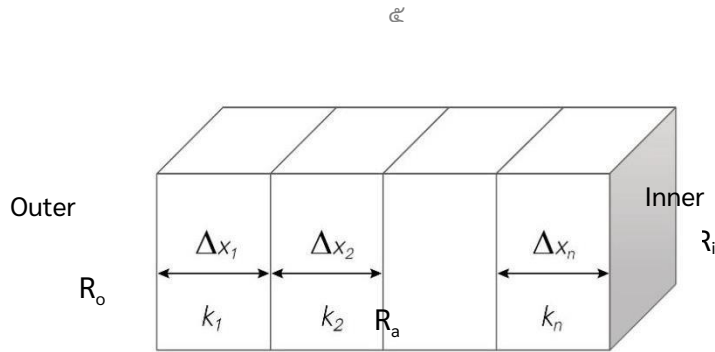


Figure 2 Thermal resistance through a building wall with structure consisting of N Types of different materials and air space inside.

(2.4) Thermal resistance of air film and air gap

The thermal resistance of air film on a building wall depends upon the air movement around building wall surface and the building wall’s coefficient of thermal emittance with the values specified in Table 1.1 as follows:

Table 1.1 thermal resistance of air film for building walls

Type of materials used for building wall	Thermal resistance of air film ((m ² .°C)/W)	
	At wall inner surface (R _i)	At wall inner surface (R _o)
Wall surface with high thermal emittance coefficient	0.120	0.044
Wall surface with low thermal emittance coefficient	0.299	0.044

In cases where the wall surface has a high thermal emittance coefficient, using the general wall surface will be deemed to have a high thermal emittance coefficient. In cases where the wall surface has a low thermal emittance coefficient, the surface will be used only for building walls with ray reflecting surfaces, e.g., walls with a reflecting foil, etc.

The thermal resistance of air space within a building wall depends upon the coefficient for thermal emittance of the wall surface adjoining the air space according to the values specified in Table 1.2 as follows:

Table 1.2 Thermal resistance of air space within a building walls

Type of materials used as inner wall of air Space	Thermal resistance of air space according to Thickness of air space ((m ² .°C)/W)		
	5 millimeters	20 millimeters	100 millimeters
Wall surface with high thermal emittance	0.110	0.148	0.160
Wall surface with low thermal emittance	0.250	0.578	0.606

b

The coefficient for low thermal emittance shall be used when any or both surfaces in the air space are light reflective e.g., in cases where aluminum sheet is installed in the air space, etc.

For general cases, the surface in the air space shall be deemed as having a high thermal emittance coefficient. For air spaces between 5 millimeters and 20 millimeters thick or between 20 millimeters and 100 millimeters thick, the linear interpolation method shall be used to calculate the desired air space thermal resistance. For air spaces thicker than 100 millimeters, use the thermal resistance value for air spaces thicker than 100 millimeters.

(2.5) Coefficient of Thermal Conductivity (k) and Other Properties of the Materials

For normal construction materials, use the thermal conductivity coefficient with units in square meter-degrees Celsius per Watt (W/ (m².°C)). The material’s density (ρ), which has a unit of kilograms per cubic meter (kg/m³) and specific heat (C_p), which has a unit in kilojoules per kilogram degrees Celsius (kJ/(kg.°C)) as specified in Table 1.3 as follows:

Table 1.3 Heat conductivity coefficient (k), density (ρ), specific heat (C_p) of various types of materials.

Item	Material	k (W/(m. °C))	ρ (kg/m ³)	C_p (kJ/(kg. °C))
1	Roof materials			
	(a) Concrete Roof Tiles	0.993	2,400	0.79
	(b) Small Corrugated Asbestos Tiles	0.384	1,700	1.00
	(c) Large Corrugated Asbestos Tiles	0.441	2,000	1.00
	(d) Double-Corrugated Asbestos Tiles	0.395	2,000	1.00
	(e) Asphalt Roofing Materials	0.421	1,500	1.51
	(f) Light-weight Rooftop Tiles	0.341	930	0.88
	(g) Smooth Translucent Fiberglass Tiles	0.213	1,340	1.88
	(h) Large Corrugated Translucent Fiberglass Tiles	0.181	1,700	1.88
	(i) Translucent Ribbed Tiles	0.160	1,340	1.88
	(j) Opaque White Fiberglass Tile Pairs	0.208	1,500	1.88
2	Floor/wall materials			
	(a) Linoleum (petroleum carpet)	0.227	1,200	1.26
	(b) Rubber Tiles	0.573	1,900	1.26
	(c) Ceramic Tiles	0.338	2,100	0.80
	(d) Marble	1.250	2,700	0.80
	(e) Granite	1.276	2,600	0.79
	(f) Stone Slabs	0.290	2,640	0.96

Item	Material	k (W/(m. °C))	ρ (kg/m ³)	C _p (kJ/(kg. °C))
	(g) Sandstone	0.721	2,440	0.96
	(h) Parquet Wood	0.167	600	0.96
3	Brick/concrete wall			
	(a) Non-plastered bricks	0.473	1,600	0.79
	(b) Double-plastered bricks.	1.102	1,700	0.79
	(c) Plastered bricks or bricks closed with mosaic or tiles on one side	0.807	1,760	0.84
	(d) 80 mm wide Non-Plastered Concrete Blocks	0.546	2,210	0.92
	(e) Concrete Slab	1.442	2,400	0.92
	(f) Plastered Concrete (Cement Mixed with Sand)	0.72	1,860	0.84
4	Lightweight Concrete; Varied Density			
	(a) 620 kilograms/cubic meters	0.180	620	0.84
	(b) 700 kilograms/cubic meters	0.210	700	0.84
	(c) 960 kilograms/cubic meters	0.303	960	0.84
	(d) 1,120 kilograms/cubic meters	0.346	1,120	0.84
	(e) 1,280 kilograms/cubic meters	0.476	1,280	0.84
	(f) Light Density Concrete Plaster	0.326	1,200	0.84
5	Ceiling/wall materials			
	(a) Gypsum sheets	0.282	800	1.09
	(b) Smooth asbestos tiles	0.397	1,700	1.00
	(c) Plywood	0.213	900	1.21
	(d) Fiber boards	0.052	264	1.30
	(e) Regular cellocrete	0.106	500	1.30
	(f) Foam cellocrete	0.068	300	1.30
	(g) Sugarcane pulp fiber boards	0.052	250	1.26
	(h) Cork	0.042	144	2.01
	(i) Gypsum plaster	0.230	720	1.09
6	Fiberglass (blanket, rigid board, and rigid pipe section)			
	(a) 10 kg density/cubic meter	0.046	10	0.96
	(b) 12 kg density/cubic meter	0.042	12	0.96
	(c) 16 kg density/cubic meter	0.038	16	0.96
	(d) 24 kg density/cubic meter	0.035	24	0.96
	(e) 32-48 kg density/cubic meter	0.033	32-48	0.96
	(f) 56-69 kg density/cubic meter	0.031	56-69	0.96

Item	Material	k (W/(m. °C))	ρ (kg/m ³)	C _p (kJ/(kg. °C))
7	Asbestos (blanket and rigid board)			
	6.4-32 kg/cubic meter density	0.039	6.4-32	0.8
8	Polystyrene foam insulation			
	(a) 9 kg/cubic meter density	0.047	9	1.21
	(b) 16 kg/cubic meter density	0.037	16	1.21
	(c) 20 kg/cubic meter density	0.036	20	1.21
	(d) 24-32 kg/cubic meter density	0.035	24-32	1.21
9	Polyethylene foam	0.029	45	1.21
10	Polyurethane foam	0.023-0.026	24-40	1.59
11	Wood			
	(a) Hard Wood	0.217	800	1.30
	(b) Moderately Hard Wood	0.176	600	1.30
	(c) Soft Wood	0.131	500	1.30
	(d) Plywood	0.144	800	1.30
12	Compressed Paper	0.086	400	1.38
13	Glass			
	(a) Clear Glass	0.960	2,500	0.88
	(b) Tinted Glass	0.913	2,500	0.88
	(c) Reflective Glass	0.131	2,500	0.88
	(d) Mirror	0.853	2,500	0.88
14	Metal			
	(a) Normal Aluminum Alloy	211	2,672	0.896
	(b) Copper	388	8,784	0.390
	(c) Steel	48.6	7,840	0.500

In cases where the wall material is different from the materials specified in Table 1.3, use the test results or values obtained from an accredited agency.

(3) Equivalent Temperature Difference (TD_{eq})

The equivalent temperature difference is the difference between the temperature outside and inside the building, including the results of thermal absorption of solid wall, depending upon the wall's duration for the thermal absorption, coefficient for thermal absorption, wall mass, direction and slope. The following equation is to be used for the calculation:

(3.1) Thermal Absorption Coefficient

The thermal absorption coefficient of the outer surface of the solid wall used to calculate the equivalent temperature difference is to be used as specified in Table 1.4.

Table 1.4 Thermal absorption coefficient of wall material and external paint of various types of walls used to calculate the equivalent temperature difference.

Outer Surface of Building Wall	Thermal Absorption Coefficient	Remarks
Materials used to cover the surface Reflectors made of aluminum White marble White-washed gravels External paint White Silver Sparkled Silver or bronze	0.3	Reflective surface and White materials
Materials used to cover the surface Cream color or light color marble Cream color or light color granite Cream color or light color washed gravel Light color materials External paint Cream Light blue Light green Light yellow Light orange	0.5	Light colored
Materials used to cover the surface Unpainted concrete Unpainted brick Unpainted fiber sheet Gray washed gravel Unpainted cemented asbestos External paint Red Blue Green Orange Rustic	0.7	Light Dark colored materials Light Dark colored materials

Outer Surface of Building Wall	Thermal Absorption Coefficient	Remarks
Materials used to cover the surface Red brick Asphalt Dark gray and black concrete Dark green and dark red roofing materials External paint Dark Blue or Dark green Dark gray Dark Brown Black	0.9	Dark colored materials

(3.2) Wall Material’s Density-Specific Heat Product (DSH)

In cases where the solid wall consists of one i materials with density equal to ρ_i , specific heat equal to C_{p_i} and a thickness of Δx_i , the density-specific heat product is to be calculated by using the following equation:

$$DSH_i = (\rho_i)(C_{p_i})(\Delta x_i)$$

For cases where the walls are opaque and made from various “ n ” materials, the product of the density and specific heat is to be calculated by the following equation:

$$DSH = DSH_1 + DSH_2 + \dots + DSH_n$$

- When
- DSH_i is the product of density and specific heat of material i ; its unit is kilojoules per square meter-degrees Celsius ($\text{kJ}/(\text{m}^2 \cdot ^\circ\text{C})$).
 - ρ_i is the density of material i ; its unit is kilograms per square meter (kg/m^3) according to the value specified in Table 1.3.
 - C_{p_i} is the volume of specific heat of material i ; its unit is kilojoules per kilogram-degree Celsius ($\text{kJ}/(\text{kg} \cdot ^\circ\text{C})$) according to the value specified in Table 1.3.
 - Δx_i is the thickness of material i ; its unit is meters (m).

In cases where the wall has air space inside, aforementioned air space will be deemed as not having changed the wall’s density-specific heat product.

(3.3) The wall’s slope is the angle where the wall sits on the earth’s surface or the ground. The vertical wall’s slope is set to be 90 degrees.



(3.4) Solid wall's equivalent temperature difference (TD_{eq})

A solid wall's equivalent temperature difference for each type of building depends upon the thermal absorption coefficient of the wall's outer surface. The product of the density specific heat of the wall materials, direction and slope will be according to the value specified in TD_{eq} table in the appendix of this announcement.

(4) Overall thermal transfer coefficient of glass or transparent walls (U_f)

The overall thermal transfer coefficient of glass or transparent wall shall be calculated using the same method as the calculation of the overall thermal transfer coefficient of solid walls according to Clause 5(2) using the equations in Clause 5 (2),(2.3),(2.3.1) or (2.3.2) depending upon the case and the type of glass or transparent wall.

The overall thermal transfer coefficient will use the values from the manufacturer wherein the aforementioned coefficient must have test results and calculation methods obtained from an accredited agency. In cases where there are no such values from the manufacturers, the calculation will be according to the following equation:

(4.1) Single layer glass

The overall thermal transfer coefficient of single layer glass or transparent walls will be calculated by the following equation:

$$U = \frac{1}{R_T} , \text{ and}$$

$$R_f = R_i + \frac{\Delta X}{k_g} + R_o$$

When	R _f	is the overall thermal resistance of glass or transparent walls; its unit is square meter-degrees Celsius per Watt ((m ² .°C) /W).
	R _i and R _o	is thermal resistance of the air film inside and outside the building; its unit is square meter-degrees Celsius per Watt ((m ² .°C) /W) and will be according to the value specified in Table 1.1.
	ΔX	is the thickness of the glass or transparent wall; its unit is in meters (m).
	k _g	is the thermal conduction coefficient of glass or transparent wall; its unit is Watt per square meter-degree Celsius (W/(m ² .°C)).



(4.2) Laminated glass

The overall thermal transfer coefficient of laminated glass is to be calculated using the equations in 5 (2), (2.3), (2.3.1).

(4.3) The window system consisting of multiple layers of glass or transparent wall and with air space inside.

The thermal resistance coefficient of the window system consisting of multiple layers of glass or transparent wall is to be calculated using the equations in Clause 5 (2), 2(2.3), and (2.3.2), and the thermal resistance of the air space is to be used as specified in Table 1.5 as follows:

Table 1.5 Thermal Resistance of Air Space In Between Glass or Transparent Wall

Air Space Thickness (mm)	Thermal Resistance of Air Space ((m ² .°C) /W)	
	Wall Surface with High Thermal Emittance Coefficient	Wall Surface with Low Thermal Emittance Coefficient
13	0.119	0.345
10	0.110	0.278
7	0.097	0.208
6	0.091	0.196
5	0.084	0.167

For general air space between window glass and transparent walls, the value of thermal resistance for wall surfaces with high thermal emittance coefficients is to be used. In case of the interconnected surface of window glass or transparent wall to air gap is coated with the low emittance coefficient material, the value of thermal resistance for wall surfaces with low thermal emittance coefficients is to be used.

For air space with values between the values specified in Table 1.5, the linear interpolation method shall be used to calculate the desired air space thermal resistance. For air spaces thicker than 13 millimeters, use the thermal resistance value of the air space thicker than 13 millimeters.

(5) The difference between the temperatures inside and outside the building (ΔT):

The Difference between the temperature inside and outside the building is the difference between the air temperature in the air conditioned areas of the building and the temperature outside the building which is used to calculate thermal conductivity through glass or transparent walls. In calculating OTTV_i in Clause 5 (1) (1.1), the difference between the temperature inside and outside of the building is to use the values specified in Table 1.6 as follows:

Table 1.6 Temperature differences inside and outside the building for each type of building

Type of Building	Temperature Difference Inside and Outside the Building $\Delta T(^{\circ}C)$
(1) Theatrical Building	5
(2) Hotel	3
(3) Entertainment Service	5
(4) Medical center or hospital	3
(5) Educational Place	5
(6) Office	5
(7) Department Store or Tread Center	5
(8) Condominium	3
(9) Building for congregation	5

(6) Solar Heat Gain Coefficient (SHGC)

The solar heat gain coefficient is the proportion of solar heat sent through the transparent or clear part of the wall material and roof and allowing the thermal transfer to enter the building. The aforementioned value includes the combination of solar heat directly sent through the glass or clear material and thermal transfer as a result of thermal absorption in the glass or clear material.

To calculate the solar heat gain coefficient, use the value obtained from the manufacturer of the glass or clear material with test results and calculation methods from an accredited agency. In cases where the aforementioned data is available, the values specified in Table 1.7 are to be used.

Table 1.7 - Solar Heat Gain Coefficient and Visible Transmittance, τ_{vis} of Various Types of Glass

Glass Thickness (mm)	Glass Type	Visible Transmittance (τ_{vis})	Solar Heat Gain Coefficient (SHGC)
Single Layer Non-Laminated Glass			
6	Clear glass	0.88	0.73
6	Bronze color glass	0.54	0.54
6	Green glass	0.76	0.54
6	Gray glass	0.46	0.52
6	Greenish blue glass	0.75	0.55



Glass Thickness (mm)	Glass Type	Visible Transmittance (τ_{vis})	Solar Heat Gain Coefficient (SHGC)
Single Layer Reflective Glass			
6	20%-Stainless Metal Plated Clear Glass	0.20	0.24
6	20%-Titanium Plated Clear Glass	0.20	0.27
6	30%-Titanium Plated Clear Glass	0.30	0.35
Double Layer Non-Plated Glass			
6	Clear glass-clear glass	0.78	0.60
6	Bronze –clear glass	0.47	0.41
6	Green – clear glass	0.68	0.41
6	Gray – clear glass	0.41	0.39
6	Greenish blue – clear glass	0.67	0.43
6	High quality green –clear glass	0.59	0.33
Double Layer Reflective Glass			
6	30% Titanium plated and clear glass	0.27	0.25
Double layer glass with plated material with low thermal emittance coefficient (Thermal emittance coefficient = 0.2)			
6	Glass plated with low thermal emittance coefficient and clear glass	0.73	0.53
Double layer glass with plated material with low thermal emittance coefficient (Thermal emittance coefficient = 0.1)			
6	Glass plated with low thermal emittance coefficient and clear glass	0.72	0.44
6	High quality green glass–glass plated with low thermal emittance coefficient	0.57	0.27

(7) Shading coefficient (SC)

The shading coefficient is the proportion of the solar thermal that passes through the shading instrument to the transparent or glass part of the window and shall be calculated using the following equation:

(7.1) Sun Position and Direction

The sun’s position and direction acting upon any point on the earth can be identified by using the sun’s altitude (α_s), which is the angle where the vertical ray of the sun acts upon the earth’s surface and the sun’s azimuth (γ_s), which is the angle where the sun’s horizontal position acts upon the earth’s south.

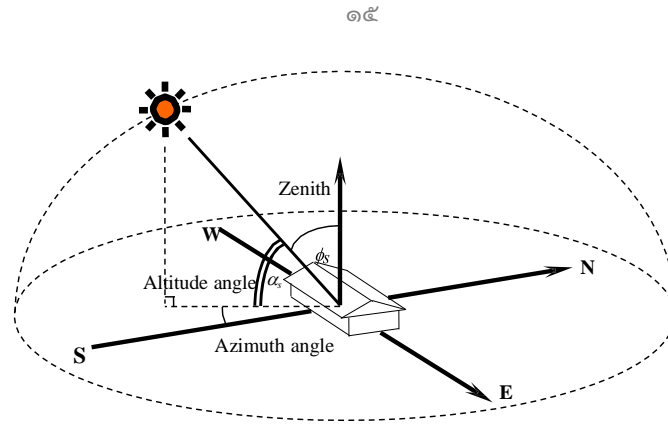


Figure 3 The sun’s position and direction related to the building site on the earth’s surface:

The sun’s position and direction are to be calculated by the following equation:

(7.1.1) Solar Time

Solar time is the time that corresponds to the sun’s position. The time when the sun’s altitude is at the highest point is solar noon. Solar time is to be calculated using the following equation:

$$t_s = t_i - 4(L_{gs} - L_{gi}) + E_{qt}$$

- When t_s is solar time.
- t_i is local standard time.
- L_{gs} is the standard longitude for Thailand, which is 105 degrees east.
- L_{gi} is the longitude of the position under consideration for Thailand. The value of 100.5 degree east will be used.
- E_{qt} is the equation of time or the difference between solar time and normal time. Its unit is in minutes.

The equation for time can be calculated by:

$$E_{qt} = 9.87(\sin 2B) - 7.53(\cos B) - 1.5(\sin B)$$

$$B = \frac{(360^\circ)(j_d - 81)}{364}$$

- When j_d is the Julian date, i.e., the order of the days in one year.
For example, 1 = 1 January or 152 = 1 June, etc.

(7.1.2) The mathematical relationship between the sun’s altitude and azimuth can be calculated by the following equation:

$$\sin \alpha = (\sin L_t)(\sin \delta) + (\cos L_t)(\cos \delta)(\cos \omega)$$

$$\sin \gamma_s = \frac{(\cos \delta)(\sin \omega)}{(\cos \alpha_s)}$$

- When
- L_t is the latitude of the site being considered, e.g., Bangkok’s latitude is 13.7 degrees north.
 - δ is the sun’s declination angle. Its unit is in radians (rad).
 - ω is the solar hour angle. Its unit is in radians (rad)

$$\omega = \pi (t_s - 12)/12$$

The sun’s declination angle is the angle where the sun’s beam to the middle of the earth acts upon the equatorial plane. The sun’s declination angle for any Julian day (j_d) can be calculated by using the following equation:

$$\delta = 23.45 \sin \left(\frac{(360^\circ)(284 + j_d)}{365} \right)$$

(7.2) Calculation of the Shading Coefficient

The sun’s position and direction are to be calculated from the following equation

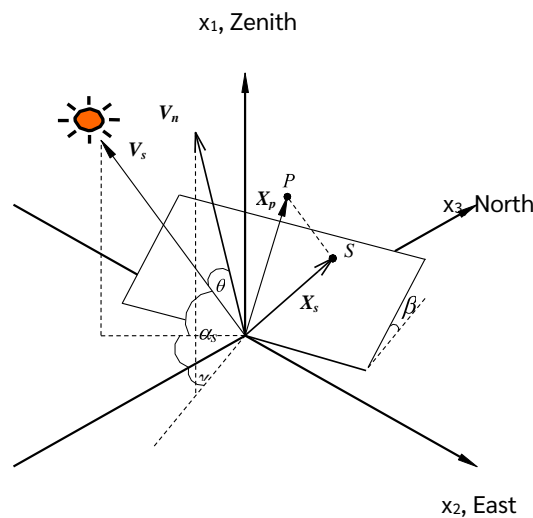


Figure 4 Position and direction of various planes and points on planes related to the sun’s position

Consider the coordinate (x_1, x_2, x_3) , which is specified by the zenith line, the east and the north, the vector (V_s^x) showing the sun's direction solar vector (V_n^x) and the vector of tilted plane, which is perpendicular to the tilted plane, can be calculated from the following equation:

$$V_s^x = \begin{bmatrix} \sin\alpha_s \\ -\cos\alpha_s \sin\gamma_s \\ -\cos\alpha_s \cos\gamma_s \end{bmatrix}, \quad \text{solar vector}$$

$$V_n^x = \begin{bmatrix} \cos\beta \\ -\sin\beta \sin\gamma_p \\ -\cos\beta \cos\gamma_p \end{bmatrix}, \quad \text{Tiled surface vector}$$

When θ is the latitude of the site being considered, e.g., Bangkok's latitude is 13.7 degrees north.

$$\begin{aligned} \cos\theta &= (V_s^x, V_n^x) \\ &= (\sin\alpha_s)(\cos\beta) + (\cos\alpha_s)(\sin\gamma_s)(\sin\beta)(\sin\gamma_p) + (\cos\alpha_s)(\cos\gamma_s)(\sin\beta)(\cos\gamma_p) \end{aligned}$$

When β is the inclination angle of the surface

γ_p is the azimuth of the surface

$\cos\theta$ is the cosine of the angle between the surface being considered and the sun's direction (solar vector)

(7.2.1) Solar thermal on the surface without shading

In the event that the wall's light opening, or any surface has no shading, the total thermal falls on the aforementioned surface can be calculated from the following equation:

$$E_{et\theta} = E_{es}(\cos\theta) + E_{ed} \frac{(1 + \cos\beta)}{2}$$

When E_{es} is the sun's direct ray, its unit is Watt per square meter (W/m^2)

E_{ed} is the sun's diffusions ray on the horizontal surface. Its unit is Watt per square meter (W/m^2)



(7.2.2) Position of shadow over the surface being considered

From figure 5, if X_p is the vector for the coordinate of point P, which is above the surface being considered and the distance from the tilted surface to point P is h.

Let S be the shadow of point P that falls on the surface under consideration when receive sunlight, vector X_s being the coordinate of point S, vector X_p , and vector V_s^x

$$X_s = X_p - \frac{hV_s^x}{\cos\theta}$$

The shadow will appear on the surface being considered only when the point that causes shadow is above or in front of the surface and when the sun faces the surface being considered.

(7.2.3) Shadow causes by shading instrument

Consider the horizontal shading instrument installed at the front of the window in the picture as follows:

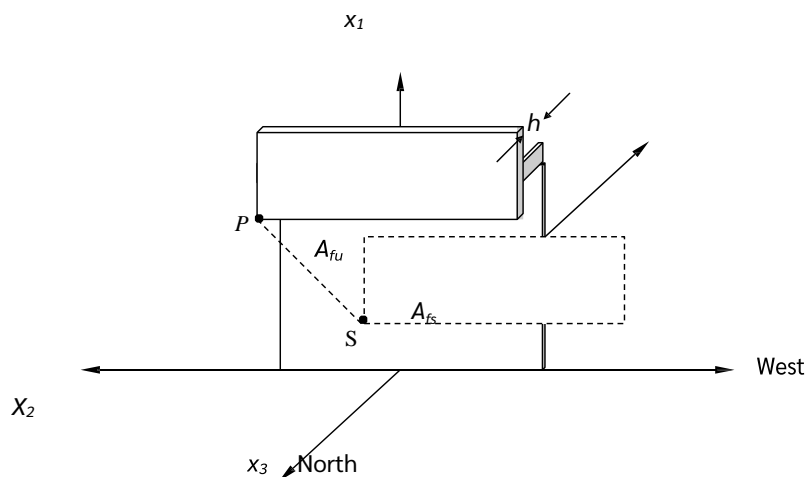


Figure 5 - The Horizontal Shading Instrument Installed at the Front of the Window

When the window faces north, point P is at the corner of the shading instrument. If the coordinate of point P can be replaced by X_p , the coordination of point S or the shadow point occurs on the window surface due to point P being replaced by X_s , vector X_s can be calculated using the equation in Clause 5 (7) (7.2) (7.2.2). In this case, h is the distance between shading instrument and window, the area of shade that occurs is the area caused by the connection of point of shadow caused by each corner of the shading instrument. Area A_{fs} is area that the shade occurs on the window, which is the area not receiving direct radiation from the sun. A_{fu} is the area the shade not occurred on the window. Both the direct radiation and partial solar radiation thus falls on this area A_{fu} while there is only partial solar radiation that falls on the area A_{fs} .

(7.2.4) Solar radiation that falls on window with shading instrument

If the area of window not under the shade is A_{fu} and total window area is A_f , Solar radiation that falls on window with shading instrument (E_{ew}) for window with tilt angle β can be calculated using the following equation:

$$E_{ew} = (A_{fu}/A_f)(E_{es})(\cos\theta) + E_{ed} \frac{(1 + \cos\beta)}{2}$$

(7.2.5) Shading coefficient (SC)

Shading coefficient (SC) is to be calculated using the following equation

$$SC = \frac{E_{ew}}{E_{et\theta}}$$

When E_{ew} is solar radiation that passes through shading instrument and falls onto the window being considered. Its unit is Watt per square meter (W/m^2)

$E_{et\theta}$ is total solar radiation that falls onto the window being considered. Its unit is Watt per square meter (W/m^2).

The annual average shading coefficient can be calculated from the ratio of the sum of solar radiation that falls on the window being considered throughout building usage on each of the 4 reference days and the sum of total solar radiation that falls on the window being considered virtually there are no shading instrument during the same period of time wherein the 4 reference days are 21 March, 22 June, 23 September and 22 December.

Annual average shading coefficient can be calculated using the following equation:

$$(SC)_y = \left[\frac{(\sum_{h=i}^n E_{ew})_{21March} + (\sum_{h=i}^n E_{ew})_{22June} + (\sum_{h=i}^n E_{ew})_{23September} + (\sum_{h=i}^n E_{ew})_{22December}}{(\sum_{h=i}^n E_{et\theta})_{21March} + (\sum_{h=i}^n E_{et\theta})_{22June} + (\sum_{h=i}^n E_{et\theta})_{23September} + (\sum_{h=i}^n E_{et\theta})_{22December}} \right]$$

When $(SC)_y$ is annual average of shading coefficient of the instrument outside the building

i and n are the hour that the sun rises and falls

For direct radiation (E_{es}) and fragmented radiation (E_{ed}) of the sun on a horizontal surface for 4 reference days, use the values specified in Table 1.8 as follows:

Table 1.8 – Sun Beams (E_{es}) and Diffusions, (E_{ed}) for 4 Reference Days

Time	Solar Radiation Energy (W/m ²)							
	21 March		22 June		23 September		22 December	
	Beam	Diffuse	Beam	Diffuse	Beam	Diffuse	Beam	Diffuse
1.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6.00	0.0	0.0	7.5	5.6	0.0	0.0	0.0	0.0
7.00	68.5	44.9	105.0	77.8	94.4	77.1	64.4	19.9
8.00	185.7	121.6	196.2	145.4	202.3	165.1	270.0	83.5
9.00	290.1	190.0	275.6	204.3	296.2	241.8	454.4	140.5
10.00	374.8	245.5	338.6	250.9	369.9	302.0	603.3	186.5
11.00	433.8	284.1	381.2	282.6	418.3	341.4	704.9	217.9
12.00	463.2	303.4	401.1	297.3	437.9	357.5	751.3	232.2
13.00	461.0	301.9	397.0	294.2	427.6	349.0	738.9	228.4
14.00	427.3	279.8	369.1	273.6	388.0	316.7	668.7	206.7
15.00	364.5	238.7	319.1	236.5	321.7	262.6	546.1	168.8
16.00	276.7	181.2	250.0	185.3	233.5	190.6	380.8	117.7
17.00	170.0	111.3	165.9	123.0	129.2	105.5	185.6	57.4
18.00	51.7	33.9	72.0	53.3	16.1	13.1	0.0	0.0
19.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

(8) Effective solar radiation (ESR)

Effective solar radiation is solar radiation that falls on walls with different tilted angles. The wall's tilt angle is to be measured from the corner of the wall that acts upon the earth's surface (or the ground) wherein the vertical wall has a tilt angle of 90 degree and the horizontal wall (or flat roof) has a tilt angle of 0 degree.

For effective solar radiation for various angles and wall directions of various types of building, the values specified in table 1.9, 1.10 and 1.11 are to be used (for tilt angles and directions not shown in the table, an estimated value is to be used) as follows:

Table 1.9 – Effective Solar Radiation (ESR) For Education Buildings or Offices

Angle (Degrees)	Effective Solar Radiation According to Wall Direction (W/m ²)							
	North	North-East	East	South-East	South	South-West	West	North-West
0	326.55	326.55	326.55	326.55	326.55	326.55	326.55	326.55
15	303.15	307.90	315.66	323.63	330.14	333.80	331.91	321.31
30	268.08	278.60	293.82	308.44	319.42	324.35	319.10	299.32
45	227.46	243.07	264.27	283.71	297.18	301.59	292.50	266.04
60	187.41	205.70	230.29	252.20	266.21	268.90	256.53	226.97
75	154.06	170.92	195.12	216.63	229.31	229.66	215.55	187.56
90	133.52	143.11	162.04	179.75	189.27	187.26	173.98	153.31

Table 1.10 Effective solar radiation for theaters, business center, service facility, department store, or community building

Angle (Degrees)	Effective Solar Radiation According to Wall Direction (W/m ²)							
	North	North-East	East	South-East	South	South-West	West	North-West
0	191.44	191.44	191.44	191.44	191.44	191.44	191.44	191.44
15	177.49	185.24	190.45	193.01	193.33	191.76	188.38	183.39
30	157.51	171.84	181.79	186.87	187.63	184.64	178.12	168.59
45	134.67	153.68	167.29	174.48	175.71	171.59	162.54	149.52
60	112.13	133.17	148.76	157.33	158.93	154.12	143.54	128.65
75	93.08	112.74	128.05	136.87	138.66	133.74	123.01	108.45
90	80.68	94.81	106.98	114.57	116.26	111.96	102.86	91.40

Table 1.11 - The Effective Solar Radiation (ESR) For Hotels, Hospitals or Condominiums

Angle (Degrees)	Effective Solar Radiation According to Wall Direction (W/m ²)							
	North	North-East	East	South-East	South	South-West	West	North-West
0	437.38	437.38	437.38	437.38	437.38	437.38	437.38	437.38
15	405.00	421.74	433.61	440.00	441.62	438.90	431.51	419.53
30	358.99	390.20	412.96	425.48	428.59	422.98	408.39	385.65
45	306.68	348.31	379.58	397.17	401.47	393.20	372.57	341.61
60	255.37	301.60	337.61	358.44	363.45	353.18	328.62	293.33
75	212.39	255.60	291.21	312.65	317.70	306.52	281.11	246.70
90	185.06	215.84	244.53	263.14	267.41	256.82	234.58	207.62



Part 2

Calculation of the Building's Roof Thermal Transfer Value

Clause 6: The roof thermal transfer value is to be calculated according to specified criteria and methods as follows:

(1) Roof Thermal Transfer value, RTTV)

(1.1) The roof thermal Transfer of each section (RTTV_i) shall be calculated using the following equation:

$$RTTV_i = (U_f)(1-SRR)(TD_{eq}) + (U_s)(SRR)(\Delta T) + (SRR)(SHGC)(SC)(ESR)$$

When	RTTV _i	is the overall thermal transfer value of the roof being considered, the unit is Watt per square meters, (W/m ²)
	U _f	is the coefficient of the overall thermal transfer value of a opaque roof, the unit is Watt per square meters, (W/m ² .°C)
	SRRR	is the ratio of the transparent roof area to the roof's total area being considered
	TD _{eq}	is the equivalent temperature difference between the outside and inside of the building, including the results of the solar ray absorption of the solid roof, the unit is in Celsius degrees (°C).
	U _s	is the coefficient of the overall thermal transfer value of a transparent roof; its unit is Watts per square meter-degrees Celsius (W/(m ² .°C).
	ΔT	is the temperature difference between outside and inside of the building, (°C)
	SHGC	is the coefficient of the thermal transfer value from solar rays which is sent through a transparent roof.
	SC	is the shading coefficient of the shading instrument.
	ESR	ESR is the solar ray value which has an effect on the thermal transfer through transparent and/or solid roofs; its unit is in (W/m ²)

(1.2) The roof thermal transfer value is the weighted average value of each part of the roof (RTTV_i). shall be calculated by the following equation:

$$RTTV = \frac{(A_{r1})(RTTV_1) + (A_{r2})(RTTV_2) + \dots + (A_{ri})(RTTV_i)}{A_{r1} + A_{r2} + \dots + A_{ri}}$$

When	A _{ri}	is the area of the roof being considered, including the area of solid and transparent roof; its unit is in square meters (m ²).
	RTTV _i	is the thermal transfer value of each section of the roof, the unit is Watt per square meters, (W/m ²)

(2) The coefficient of overall thermal heat transfer of the solid roof (U_r).

The solid roof thermal transfer (U_r) for each section shall be calculated by the following equation:

(2.1) The Thermal Transfer Coefficient (U)

Calculate by the same method as in 5 (2) (2.1)

(2.2) Roof Thermal Resistance Coefficient (R)

Calculate by the same method as in 5 (2) (2.2)

(2.3) The roof total thermal resistance (R) is to be calculated using the following method:

(2.3.1) For roofs consisting of various types of materials, the calculation will employ the same method as in 5 (2) (2.3) (2.3.1)

(2.3.2) For roofs with air space inside, the calculation will employ the same method as 5 (2) (2.3) (2.3.2)

(2.4) Roof Tilt Angle

The roof tilt angle is the angle where the roof acts upon the earth's surface or the ground. The horizontal roof is specified to have a tilt angle of 0 degrees.

(2.5) Thermal resistance of air film and air space

The thermal resistance of air film and air space are to be calculated according to the following method:

(2.5.1) For roof air film thermal resistance, values specified in the following table 1.12 are to be used:

Table 1.12 Roof Air Film Thermal Resistance Values

Types of material used to build walls	Thermal Resistance of air film ((m ² .°C)/W)				
	At Roof's Inner Surface (R_i)				At the Roof's Outer Surface (R_o) at any Tilt Angle
	0 degrees	22.5 degrees	45 degrees	60 degrees	
Roof with High radiation coefficient	0.162	0.148	0.133	0.126	0.55
Roof with Low radiation coefficient	0.801	0.595	0.391	0.249	



(2.5.2) For roof air space thermal resistance, use the values specified in Table 1.13:

Table 1.13 Roof Air Space Thermal Resistance Values

Types of Material Used as Outer Surface of the Roof		Thermal Resistance of Air Space according to the Thickness of air space ((m ² .°C)/W)		
		5 millimeters	20 millimeters	100 millimeters
Wall Surface With High Thermal Emittance Coefficient				
Angle from Horizontal Surface	0 degrees	0.11	0.148	0.174
	22.5 degrees	0.11	0.148	0.165
	45 degrees	0.11	0.148	0.158
	60 degrees	0.11	0.148	0.150
Wall Surface With Low Thermal Emittance Coefficient				
Angle from Horizontal Surface	0 degrees	0.25	0.572	1.423
	22.5 degrees	0.25	0.571	1.095
	45 degrees	0.25	0.570	0.768
	60 degrees	0.25	0.570	0.547

For cases in general, the roof surface shall be deemed as having a high thermal emittance coefficient. The coefficient for low thermal emittance is to be used when the roof surface on the side adjoining the air space is thermal reflective, e.g. a roof with an installation of reflective foil, etc.

For air spaces in the roof between 5 millimeters and 20 millimeters or 20 millimeters and 100 millimeters thick, the linear interpolation method is to be used to calculate the desired air space thermal resistance for each section. For air spaces thicker than 100 millimeters, use a thermal resistance value of air space with 100 millimeters thickness.

(2.5.3) In case of the ceiling exceeds 200 millimeters from the roof and there is no insulation insert between them, Air Space Thermal Resistance Values between them should be used for the calculation as followings:

Table 1.14: Air Space Thermal Resistance Values between roof and ceiling.

Types of Materials Used to Make the Ceiling	Air Space Thermal Resistance ((m ² .°C)/W)
Roof Surface with High Thermal Emittance Coefficient	0.458
Roof Surface with Low Thermal Emittance Coefficient	1.356

(2.6) For the thermal conductivity coefficient (k) and other properties of the materials, use the values in Table 1.3:



(3) Equivalent Temperature Difference (TD_{eq})

The equivalent temperature difference is the difference between the temperatures inside and outside the building roof, including the results of the roof thermal absorption, depending upon the roof's duration for the thermal absorption, thermal absorption coefficient, roof mass and direction and tilt angle.

The following equation is to be used for the calculation:

(3.1) Thermal Absorption Coefficient

For the thermal absorption coefficient of the outer surface of the roof used to calculate the equivalent temperature difference, values specified in Table 1.4 are to be used.

(3.2) Solid roof Density-Specific Heat Product (DSH)

A solid roof's density-specific heat product is to be calculated using the same method as Clause 5 (3) (3.2).

(3.3) Solid roof Equivalent Temperature Difference (TD_{eq})

For a solid roof's equivalent temperature difference (TD_{eq}) for various types of buildings, the values specified in the appendix added here to this announcement are to be used.

(4) Overall Thermal Transfer Coefficient of Glass or Transparent Roofs (U_f)

The overall thermal transfer coefficient of a transparent roof will use the values from the manufacturer wherein the aforementioned coefficient must have test results and calculation methods obtained from an accredited agency. In cases where there are no such values from the manufacturers, the calculation method is to be the same as the thermal transfer of glass or transparent walls (U_f) according to Clause 5(4). For the thermal resistance of air film and air space within transparent roofs, use the values in Table 1.12, 1.13 and 1.14:

(5) Temperature Difference between the Inside and Outside the Building (ΔT)

The temperature difference between the inside and outside of the building is the difference between the air temperature in the air conditioned area within the roof and the temperature outside the building which is used to calculate thermal conductivity through glass or transparent walls. In calculating the RTTVi in Clause 6(1) (1.1). Use the values specified in Table 1.6 for the temperature difference between inside and outside the building for each type of building just as in the case of building walls.

(6) Solar Heat Gain Coefficient (SHGC)

The solar heat gain coefficient is the proportion of solar heat sent through the transparent or clear part of the roof material and allowing heat to occur within the building. The aforementioned value includes the combined value of solar heat directly sent through the transparent roof and the thermal emittance absorbed in the roof transparent material and transferred into the building. For the calculation of the solar heat gain coefficient, use the value obtained from the manufacturer with test results and calculation methods from an accredited agency. In cases where the aforementioned is not available, use the values specified in Table 1.7.

(7) Shading Coefficient (SC)

For the roof shading coefficient, the calculation method will be the same as Item 5(7)

(8) Effective Solar Radiation (ESR)

For the effective solar radiation of various types of roofs, use the values specified in Table 1.9, 1.10 and 1.11 as in the case of building walls.

Section 2

Calculation of Maximum Lighting Power Density

Clause 7: The calculation of maximum lighting power density must comply with the following criteria and methods:

The maximum lighting power density in area i, i.e. the average lighting power per total usage area of area, is to be calculated by the following equation:

$$LPD_i = \frac{LW_i + BW_i - NW_i}{A_i}$$

- When LPD_i is the average lighting power density installed per i area. Its unit is Watts per square meter (W/m²).
- LW_i is the sum of the rating of all light bulbs installed in area i. Its unit is Watts (W)
- BW_i is the sum of power loss of all ballasts installed in area i. Its unit is Watt (W).
- NW_i the sum of power rating of the lighting system in area i replaced by natural light under the conditions of the use of renewable power in the building. Its unit is Watts (W) in Section 6.
- A_i is the total usage space of area i. Its unit is square meter (m²)

Maximum lighting power density installed in the building, which is the average maximum power installed per building area excluding parking space, is to be calculated using the following equation:

$$LPD = \frac{\sum_{i=1}^n (A_i)(LPD_i)}{\sum_{i=1}^n A_i}$$

- When LPD is the average lighting power density installed per i area. Its unit is Watt per square meter (W/m²)

Section 3

The Calculation of the Minimum Coefficient of Performance, Seasonal Energy Efficiency Ratio, and Power per Ton Refrigeration for the Air Condition System

Clause 8: The minimum coefficient of performance, seasonal energy efficiency ratio, and power per Ton refrigeration for the air conditioning system are to be calculated according to the following criteria and method:

(1) The minimum coefficient of performance (COP)

The coefficient of performance (COP) is the ratio between the total net cooling capacity of the air conditioning system (Watts) and rated power consumption (Watts), is to be calculated by the following equation:

$$COP = \frac{Q}{W}$$

When Q is the total net cooling capacity of the air conditioning system; its unit is Watts (W).

W is the rated power consumption of the air conditioner. Its unit is Watts (W).

(2) The seasonal energy efficiency ratio (SEER)

The seasonal energy efficiency (SEER) is the ratio between the total seasonal cooling capacities of the air conditioning system that the equipment can remove from the indoor air when operated for cooling in active mode (Btu/hr) to the total annual amount of energy consumed during the same period (Watts), is to be calculated by the following equation:

$$SEER = CSPR \times 3.412$$

When SEER is the seasonal energy efficiency ratio of the air conditioning system; its unit is Btu per hour per Watts (Btu/hr/W).

CSPF is cooling seasonal performance factor; is the ratio of the total annual amount of heat that the equipment can remove from the indoor air when operated for cooling in active mode to the total annual amount of energy consumed by the equipment during the same period. Its unit is Wh/Wh according to the testing standard TISI 2714.

$$CSPF = \frac{CSTL}{CSEC}$$

When CSTL Cooling Seasonal Total Load is total annual amount of heat that is removed from the indoor air when the equipment is operated for cooling in active mode, it unit is kilowatt-hour

CSEC Cooling seasonal energy consumption is total annual amount of energy consumed by the equipment when it operated for cooling in active mode, it unit is kilowatt-hour

(3) Power per TON of refrigeration

Power per TON of refrigeration is the ratio between the rated power (kW) and the total net cooling capacity performance of the chilled-water air conditioning system, is to be calculated by the following equation:

$$CHP = \frac{kW}{TON}$$

When	CHP	is power per TON refrigeration; its unit is kilowatt per ton
	kW	is the rated power of the large air conditioning system (chilled water -cooling system) at maximum load. Its unit is kilowatts. The value from the test results or the certified value by the manufacturer or by an accredited institute is to be used.
	TON	is the net cooling capacity of the refrigeration performance at maximum load. Its unit is TON of refrigeration (TR). The value from the test results or the certified value by the manufacturer or by an accredited institute is to be used.

For power per TON of refrigeration for other parts of the air conditioning system which powered by electricity consisting of a heat radiation system (condenser or cooling tower), chilled water supply system, and cooled air distribution system (AHU, FCU) are to be calculated using the following equation:

$$MP = \frac{CW + PW + FW}{TON}$$

When	MP	is the power per TON of refrigeration for other parts of the air conditioning system powered by electricity; its unit is kilowatts per TON of refrigeration.
	CW	is the rated power of the heat radiation system (condenser or cooling tower). Its unit is kilowatts (kW). Use the values from the test results or the values certified by the manufacturer of the instrument or an accredited institute.
	PW	is the rated power of the chilled water distribution system. Its unit is kilowatts (kW). Use the values from the test results or the values certified by the manufacturer of the instrument or an accredited institute.
	FW	is the power rating of the cool air distribution system. Its unit is kilowatts (kW). Use the values from the test results or the values certified by the manufacturer of the instrument or an accredited institute.

Section 4

The Calculation of Minimum Efficiency and Coefficient of Performance of Hot Water Generation System

Clause 9: For the minimum efficiency and coefficient of the performance of hot water generation or hot water heating devices installed in the building, calculate according to the following criteria and methods:

- (1) The calculation of efficiency for steamers and boilers

Steamer and boiler efficiency are to be calculated using the following equation:

$$Eff = \left(\frac{h_s - h_w}{(F)(HHV)} \right) S \times 100$$

When	Eff	is the steamer and boiler efficiency (%).
	h_s	is the enthalpy value of the hot steam or hot water produced at the steamer and boiler, its unit is mega Joule/ton (MJ/ton). Use value from the steam table for steam, and from the enthalpy table for hot water.
	h_w	is the enthalpy value of water at 27 degrees Celsius and the pressure one atmosphere. Use the value of 113 mega Joule/ton here.
	S	is the amount of steam or hot water produced. Its unit is tons/day (ton/d) and can be obtained from the steam or boiler measuring instrument.
	F	is the amount of oil or gas consumed. Its unit is tons/day (ton/d)
	HHV	is the higher heating value of the oil or gas consumed; its unit is mega Joules/ton (MJ/ton).

- (2) The calculation of the coefficient of the performance of air-source heat pump water heaters.

The minimum coefficient of the performance (COP) of the air-source heat pump water heaters, i.e. the ratio between the water heating performance and power consumption, is to be calculated by the following equation:

$$COP = \frac{Q}{W}$$

When	COP	is the coefficient of the performance of the air-source heat pump water heater
	Q	is the heat used to produce hot water; its unit is in Watts (W)
	W	is the rated power consumption used. Its unit is Watts (W).

Section 5

The Calculation of Overall Building Energy Consumption for the Building

Clause 10: The Calculation of Overall Building Energy Consumption for the Building

In cases where the efficiency of the installed equipment of the building, one or more systems, is failed under consideration of the minimum efficiency requirements in according to the criteria for energy efficiency specified in Section 1, 2 or 3. The aforementioned building may be evaluated according to overall building energy consumption criteria; by calculating the building's overall annual energy consumption and comparing to the overall energy consumption of the reference building. The building will pass overall building energy consumption criteria only when the building's overall energy consumption value is lower than that of the reference building. To evaluate this criteria, the reference building must have the same usage area, direction for the building perimeter system on each side as the evaluated new building or renovate building. In addition, the reference building must have the minimum requirements for the building envelop system, lighting system and air conditioning systems according to the requirements for each system.

The building overall annual energy consumption for both cases is to be calculated by using the following equation:

$$E_{pa} = \sum_{i=1}^n \left[\frac{A_{wi}(OTTV_i)}{COP_i} + \frac{A_{ri}(RTTV_i)}{COP_i} + A_i \left\{ \frac{C_i(LPD_i) + C_e(EQD_i) + 130C_o(OCCU_i) + 24C_v(VENT_i)}{COP_i} \right\} \right] + \sum_{i=1}^n A_i(LPD_i + EQD_i)n_h - (PVE + HEE + ORE)$$

When	E_{pa}	is overall annual energy consumption; Its units is kilowatt hour per year (kWh/y)
	A_{wi}	is area of the wall being considered, including solid and transparent areas of the walls; its unit is square meters (m ²)
	A_{ri}	is area of the roof being considered, including the solid and transparent areas of the roof. Its unit is square meters (m ²)
	$OTTV_i$	is the overall thermal transfer of the outer wall under consideration, its unit is Watts/ square meter (W/m ²)
	$RTTV_i$	is the overall thermal transfer of roof for the building under consideration. Its unit is Watts/ square meter) (W/m ²)
	LPD_i	is average lighting power installed per area I; its unit is Watts/square meter (W/m ²).

- EQD_i is the power used for equipment and instrument per area i . Its unit is Watts/square meter (W/m^2).
- $OCCU_i$ is the building user density in area i ; its unit is person per square meter ($person/m^2$).
- $VENT_i$ is the air ventilation rate per area i ; its unit is liter per second (l/s)
- COP_i is the minimum coefficient of performance for small air conditioning systems or large air conditioning systems used for area i .
- A_i is air-conditioned area i (area i); its unit is square meters (m^2).
- PVE is the annual electricity generation by the solar power system. Its unit is kilowatt hours per year (kWh/y)
- HEE is the renewable heat equivalent to electricity in kilowatt hours per year (kWh/y) which refer in Section 6) for the overall building energy consumption. It is no HEE calculated in the equation of the reference building
- ORE is the other source of renewable heat in units of kilowatt hours per year (kWh/y) which refer in Section 6) for the overall building energy consumption. It is no ORE calculated in the equation of the reference building
- C_l, C_e, C_o and C_v is the coefficient of thermal power contribution to the load of air conditioning systems by lighting, equipment and appliances, occupants, and ventilations, respectively. The value of coefficient is shown in Table 1.15.
- n_h is the number of usage hours for each type of building

Table 1.15 The value of coefficient of thermal power contribution to the load of air conditioning system, and number of usage hours for each type of building

Building Type	C_l	C_e	C_o	C_v	n_h
(1) Theatrical Building	0.84	0.85	0.90	0.90	4,380
(2) Hotel	1.0	1.0	1.0	1.0	8,760
(3) Entertainment Service	0.84	0.85	0.90	0.90	4,380
(4) Medical center or hospital	1.0	1.0	1.0	1.0	8,760
(5) Educational Place	0.84	0.85	0.90	0.90	2,340
(6) Office	0.84	0.85	0.90	0.90	2,340
(7) Department Store or Tread Center	0.84	0.85	0.90	0.90	4,380
(8) Condominium	1.0	1.0	1.0	1.0	8,760
(9) Building for congregation	0.84	0.85	0.90	0.90	4,380

Section 6

The calculation of Renewable Energy Utilizations in the Building for Various Systems

Clause 11: Exclusion of partial power use in building with renewable energy utilization. In case the lighting electrical system of the building is designed to use natural light for indoor illumination, in areas along the shell of the building, it shall be calculated as if there are no lighting electrical equipment installed in that particular areas. By such design, must meet the following conditions:

(1) It must be clearly shown that there is an on-off power switch design for electrical lighting equipment applies to areas along the building line. Where the position of the installed lighting equipment must be not more than 1.5 times of the window height in the area; from the floor to the upper edge of the window frame, and

(2) Window glass along the building shell according to (1) must have an effective shading coefficient of not less than 0.3, and a light to solar gain ratio greater than 1.0. The width of window glass along the building shell according to (1) must not be less than the width of the opaque wall next to the side of the window. The calculation method is to be calculated by using the following equation:

(2.1) The effectiveness of the shading coefficient is to be calculated using the following equation

$$SC_{eff} = (SC)(\tau_{vis})$$

When SC_{eff} is the effectiveness of shading coefficient
 SC is the shading coefficient of shading device
 τ_{vis} is visible transmittance

(2.2) The Light to Solar Gain ratio of the glass is to be calculated using the following equation:

$$LSG = \frac{\tau_{vis}}{SHGC}$$

When LSG is the ratio of Light to Solar Gain
 $SHGC$ is solar heat gain coefficient

Clause 12: In case there is a renewable power generation in the building, it is possible to deduct the amount of renewable electricity power generated from the overall building energy consumption of the building, prior to comparing to the reference building energy consumption value. The renewable energy of solar power generation is to be calculated from the average annual electricity produced by the solar PV system; it is to be calculated using the following equation:

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$$PVE = \frac{(9)(365)(A_{mod})(\eta_{sys})(ESR_{PV})}{1000}$$

When	PVE	is the annual electricity generation by the solar power system. Its unit is kilowatt hours per year (kWh/y)
	(9)(365)	is the average number of hours the solar cell can produce power in one year wherein (9) is the average number of hours that sunlight is available in 1 day and (365) is the number of days in 1 year.
	A_{mod}	is the total area in which the solar cell panel is installed. Its unit is square meters (m ²)
	η_{sys}	is the system's overall efficiency
	ESR_{PV}	is the effective of solar radiation at tilt angle and direction corresponding to the installation of the solar cell, its unit is Watts per square meter (W/m ²). Use the values specified in Tables 1.11 for all types of buildings. (For tilt angles and directions not shown in the table, an estimated value is to be used).

Clause 13: The use of renewable energy heat for buildings can be calculated equivalent to the heat to electrical energy (HEE), in kWh/y. Buildings can take the amount of equivalent electrical energy to deduct from the overall energy consumption of the buildings.

The value of heat to electrical energy is to be calculated by using the following equation:

$$HEE = \frac{(h_s - h_w) \times S \times e_{ff}}{3.6}$$

When	HEE	is the renewable heat equivalent to electricity in kilowatt hours per year (kWh/y)
	h_s	is the enthalpy value of the hot water, its unit is mega Joule per ton (MJ/ton).
	h_w	is the enthalpy value of water at 27 degrees Celsius and the pressure one atmosphere. Use the value of 113 mega Joule per ton here.
	S	is the amount of hot water used. Its unit is tons per year (ton/y).
	e_{ff}	is the conversion efficiency of heat to electricity, minimum value to be used is 0.45

Clause 14: Other renewable energy (ORE) other than those renewable set forth in this Ministry's Notification in accordance with Clause 12 and 13, the list of renewable energy calculations according to engineering principles of the annual electricity consumption shall be listed, its units is kilowatt hours per year (kWh/y).

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Section 7

Certification Method in Designing Building for Energy Conservation

Clause 15: Calculation according to Section 1, 2, 3, 4, 5 and 6 shall present the result through software for assessing energy conservation developed by the Department of Alternative Energy and Energy Efficiency. For other calculation method according to Clause 11 (paragraph 2) in Ministerial Regulation prescribing type or size of building and standard, criteria and procedure in designing building for energy conservation B.E. 2563. Which all parameters shall be used according to table 1.15 in this Ministerial Regulation: Thermal resistance of air film, Thermal resistance of air gap, Thermal absorption coefficient, Temperature difference inside and outside the building, Effective solar radiation, Coefficient of thermal power contribution to the load of air conditioning system, and number of usages hours for each type of building.

Clause 16: For certifying results of assessing plan for construction or modification of building for energy conservation, the building owner must develop assessment report and certificate which their details are attached to this Ministry of Energy's Notification, and arrange to have an auditor who has qualification in according to Ministerial Regulation prescribing type or size of building and standard, criteria and procedure in designing building for energy conservation B.E. 2563 for requesting the permission on instruction or modification according to the Building Control Act.

Given on B.E. 2564

Supattanapong Punmeechow
Minister of Energy