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:

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

When

OTTVi	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, ($W/m^2.^oC$).
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 (^oC).
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 ($W/(m^2.^oC)$.
ΔT	is the temperature difference between outside and inside of the building, (^oC)
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:

$$\mathrm{OTTV} = \frac{(\mathrm{A}_{w1})(\mathrm{OTTV}_1) + (A_{w2})(OTTV_2) + \cdots + (A_{wi})(OTTV_i)}{A_{w1} + A_{w2} + \cdots + A_{wi}}$$

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:

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

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

(2.2) Thermal Resistance (R)

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

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

When R is the thermal resistance; its unit is square meter-degree Celsius per Watt ((m^2.°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.°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:

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

When R_T is the building's wall total thermal resistance; its unit is square meter-degrees Celsius per Watt (W/(m^2.°C)).

R_o is the thermal resistance of outer air; its unit is square meter-degree Celsius per Watt (W/(m^2.°C)).

R_i is the thermal resistance of inner air; its unit is square meter-degree Celsius per Watt (W/(m^2.°C)).

$\Delta X_1, \Delta X_2, \ldots, \Delta X_n$ is the thickness of each type of composited material of the building wall; its unit is meters (m).

$k_1, k_2, \ldots, k_n$ is the coefficient of thermal conductivity of each composited material used in the building wall.

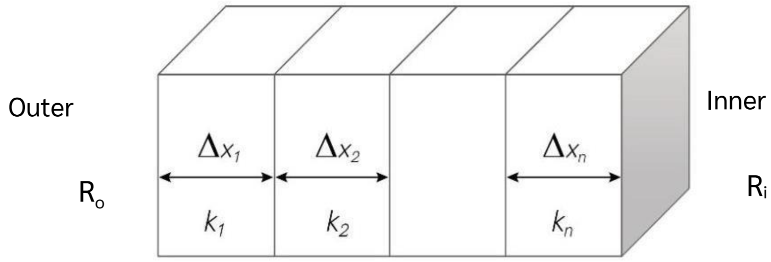

Figure 1 Thermal transfer through the building wall with the structure consisting of n types of different materials.

(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:

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

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.°C) /W).

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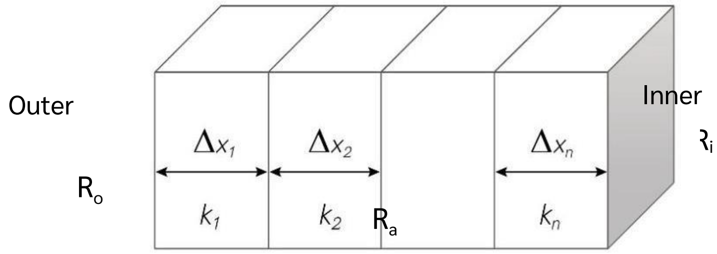

Figure 2 Thermal resistance through a building wall with structure consisting of N Types of different materials and air space inside.

(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.^{o}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.^{o}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

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/ (m^2.°C)). The material's density (ρ), which has a unit of kilograms per cubic meter (kg/m^3) 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 (Cp) 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/m³)	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 Cp_i and a thickness of Δxi, the density-specific heat product is to be calculated by using the following equation:

$$\mathrm{DSH_i} = (\rho_i)(Cp_i)(\Delta x_i)$$

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:

$$\mathrm{DSH} = \mathrm{DSH_1} + \mathrm{DSH_2} + \cdots + \mathrm{DSH}_n$$

When DSH_i is the product of density and specific heat of material i; its unit is kilojoules per square meter-degrees Celsius (kJ/(m^2.°C)).

ρ_i is the density of material i; its unit is kilograms per square meter (kg/m3) according to the value specified in Table 1.3.

Cp_i is the volume of specific heat of material i; its unit is kilojoules per kilogram-degree Celsius (kJ/(kg. °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:

$$\mathrm{U} = \frac{1}{R_T} \quad , and$$

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

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.^{o}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 ΔT(°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 (αs), which is the angle where the vertical ray of the sun acts upon the earth's surface and the sun's azimuth (γs), which is the angle where the sun's horizontal position acts upon the earth's south.

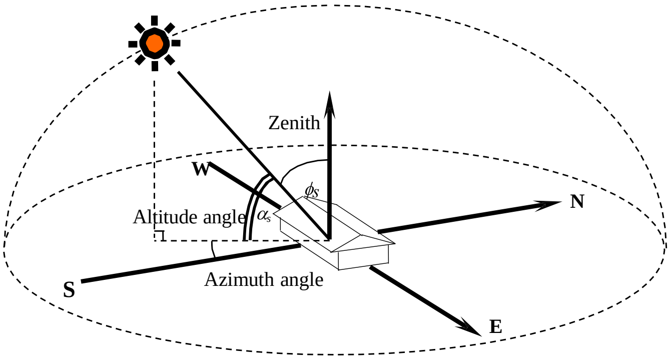

Figure 3 The sun's position and direction related to the building site on the earth's surface:

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:

$$E_{qt} = 9.87(sin2B) - 7.53(cosB) - 1.5(sinB)$$

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

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:

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

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

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:

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

(7.2) Calculation of the Shading Coefficient

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

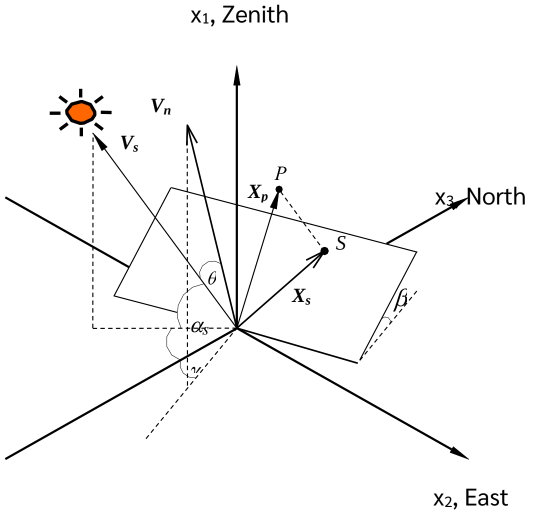

Figure 4 Position and direction of various planes and points on planes related to the sun's position

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:

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

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

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

$$\cos\theta = (V_s^x, V_n^x)$$

$$= (sin\alpha_s)(cos\beta) + (cos\alpha_s)(sin\gamma_s)(sin\beta)(sin\gamma_p) + (cos\alpha_s)(cos\gamma_s)(sin\beta)(cos\gamma_p)$$

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_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:

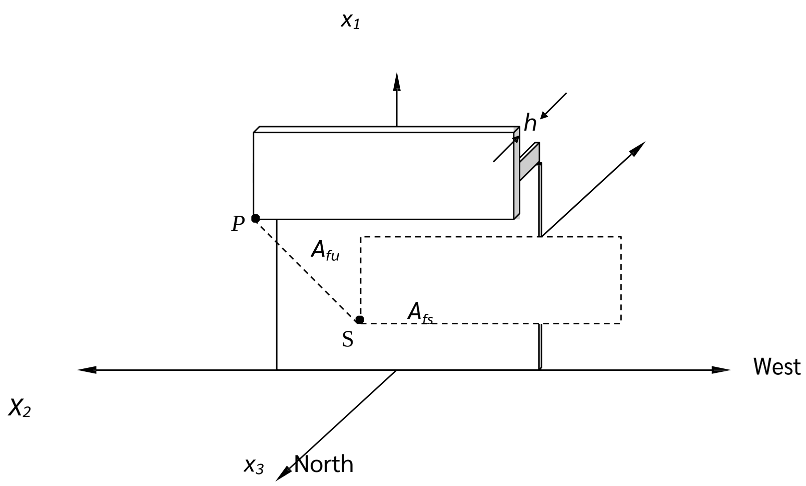

Figure 5 - The Horizontal Shading Instrument Installed at the Front of the Window

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 Afu 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

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

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 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/m²)							
	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/m²)							
	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/m²)							
	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:

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

When $RTTV_i$ is the overall thermal transfer value of the roof being considered, the unit is Watt per square meters, (W/m^2)

Uf is the coefficient of the overall thermal transfer value of a opaque roof, the unit is Watt per square meters, ($W/m^2.^oC$)

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 (^oC).

U_s is the coefficient of the overall thermal transfer value of a transparent roof; its unit is Watts per square meter-degrees Celsius ($W/(m^2.^oC)$.

ΔT is the temperature difference between outside and inside of the building, (^oC)

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:

$$\mathrm{RTTV} = \frac{(\mathrm{A}_{r1})(\mathrm{RTTV}_1) + (A_{r2})(RTTV_2) + \cdots + (A_{ri})(RTTV_i)}{A_{r1} + A_{r2} + \cdots + A_{ri}}$$

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_f).

The solid roof thermal transfer (U_f) 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:

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

When	LPD_i	is the average lighting power density installed per i area. Its unit is Watts per square meter (W/m^2).
	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 (m^2)

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:

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

When	LPD	is the average lighting power density installed per i area. Its unit is Watt per square meter (W/m^2)

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:

$$\mathrm{SEER} = \mathrm{CSPR} \times 3.412$$

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 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

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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:

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

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

Clause12: 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:

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

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:

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

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).

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