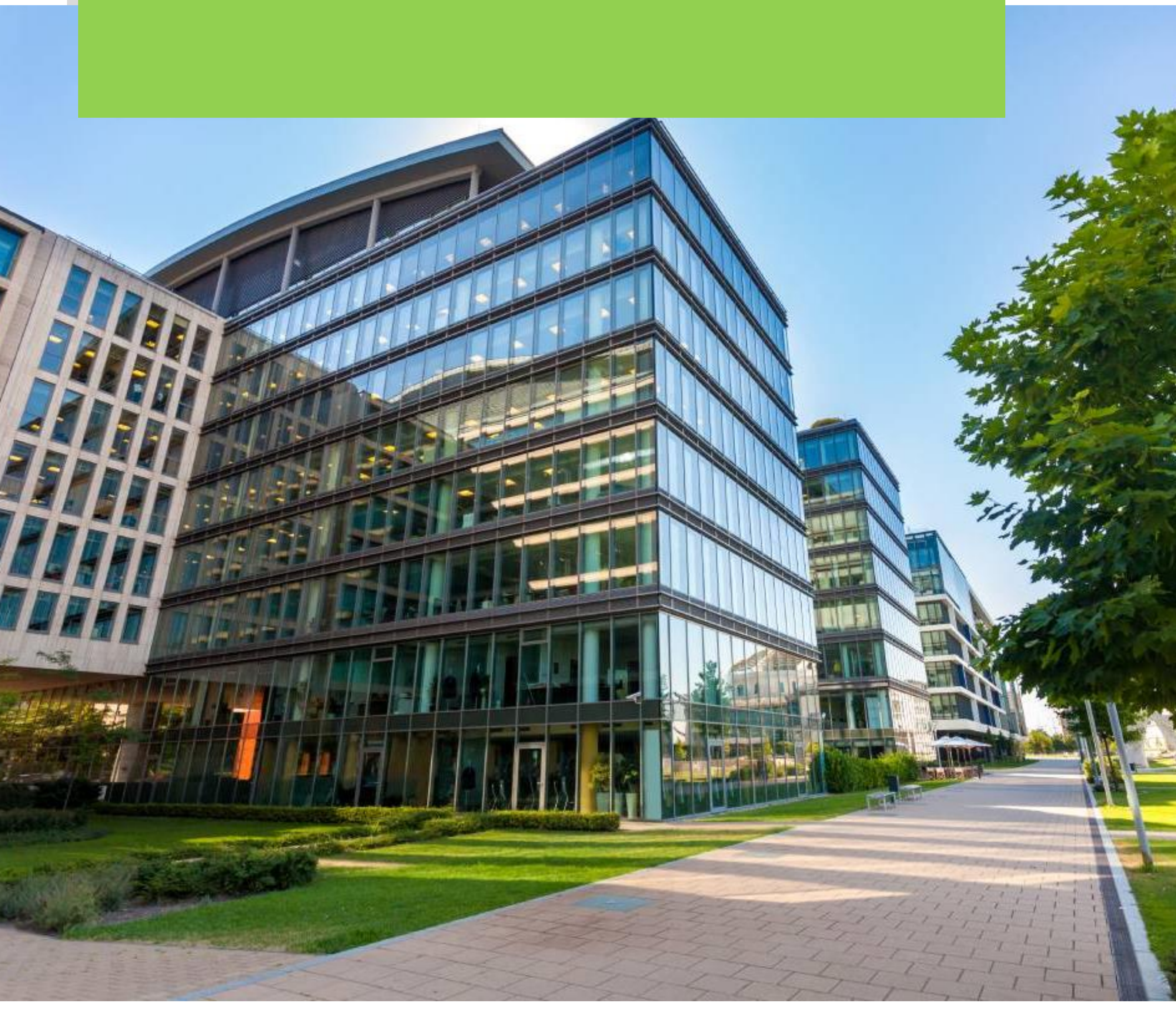
Handbook-2:

Guidelines on Thai BEC Standard Design and Compliance

For Practitioners



Preface

In Thailand, Energy consumption in the building sector has been increasing 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. 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 tonnes CO_2. BEC is considered to be one of these strategic measures according to Thailand's Nationally Determined Contribution (NDC) Roadmap on Mitigation 2021-2030.

Building Energy Code (BEC) is the standards setting minimum energy efficiency requirements for buildings that request permission for construction or modification with DEDE, according to the Ministerial Regulation B.E. 2552. BEC is the key tool assuring buildings will be designed to conserve maximum energy, increase energy efficiency in new or renovated buildings, and reduce energy consumption and greenhouse gas emissions. In addition, it will contribute to the reduction of overall operation costs of the building in the long run. The Cabinet approved the revised BEC 2020 on July 8, 2020, and the revised BEC has been promulgated in the Government Gazette since November 12, 2020.

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). This handbook aims to provide guidelines and principles on designing the buildings envelope according to the BEC Ministerial regulations requirements; by considering selecting high-performance technology and materials available in the commercial market. In addition, it aims to encourage inspiration for practitioners (Architect, Engineers, and Project developers) for designing a higher-energy performance buildings.

Bangkok

December 2021

Contents

Contents 3

Background-the New BEC Enforcement Regulation 7

The Regulation of the Ministerial Regulation 7

BEC Building Types and Groups 8

Update BEC Minimum Performance Standard 9

Component 1: Overall Thermal Transfer Value of Building's Envelope System 9

Component 2: Lighting System (LPD) 10

Component 3: Air Conditioning System 10

Option for designing building under the BEC standards 11

Reference of applicable documents on BEC 12

Statistics of BEC implementation 13

Overview of BEC implementation in Thailand 13

Benchmarking of the EUI Trend 13

Importance of BEC building envelope design 14

Factors related to heat transfer value 17

Correlation between OTTV and WWR 19

High-energy performance building envelope design 21

Characteristic of Baseline Building Models 22

Model Description 23

Symbolic description of building envelope materials used 24

Cont.: Symbolic description of building envelope materials used 25

Material Codes Used in Each Model 26

Description of the example of energy-saving potential analysis 27

Model 1 (Group 1) 28

Model 1 (Group 1) - Energy Saving Potential 29

Model 1 (Group 2) 30

Model 1 (Group 2) - Energy Saving Potential 31

Model 1 (Group 3) 32

Model 1 (Group 3) - Energy Saving Potential 33

Model 2 (Group 1) 34

Model 2 (Group 1) - Energy Saving Potential 35

Model 2 (Group 2) 36

Model 2 (Group 2) - Energy Saving Potential 37
Model 2 (Group 3) 38
Model 2 (Group 3) - Energy Saving Potential 39
Model 3 (Group 1) 40
Model 3 (Group 1) - Energy Saving Potential 41
Model 3 (Group 2) 42
Model 3 (Group 2) - Energy Saving Potential 43
Model 3 (Group 3) 44
Model 3 (Group 3) - Energy Saving Potential 45
Model 4 (Group 1) 46
Model 4 (Group 1) - Energy Saving Potential 47
Model 4 (Group 2) 48
Model 4 (Group 2) - Energy Saving Potential 49
Model 4 (Group 3) 50
Model 4 (Grouup 3) – Energy Saving Potential 51
Conclusions 52
Glossary 53

Introduction

In Thailand, BEC is the minimum performance requirement 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. Recently, the BEC was revised in order 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 promulgated in the Government Gazette on November 12, 2020, and it is scheduled to be enforced starting in 2022.

In accordance with the Ministerial Regulation B.E. 2563, new or retrofitted buildings being constructed which have the total area of all stories equal to 2000 square-meters or more must be designed 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. In 2022, the new code is scheduled to apply in full to a massive building of floor area over 10,000 square meters: however, a phase-step compliance strategy over three years.

A good building design is a highly efficient right from the start. Designing buildings to meet good energy efficiency standards, excellent functionality, and outstanding architectural design from the beginning will produce better energy efficiency and energy conservation results. This handbook aims to provide guidelines and principles on designing the buildings envelope according to the regulation's BEC minimum requirements, by considering selecting high-performance technology and materials available commercially. In addition, it aims to encourage inspiration for practitioners (Architect, Engineers, and Project developers) for designing a higher-energy efficiency performance building in the future.

Highlights:

- Designing buildings according to minimum energy efficiency requirement (BEC) is not difficult to achieve.
- Why should BEC developers/practitioners focus on designing buildings to meet good energy efficiency standards, excellent functionality, and outstanding architectural design from the beginning?
- Designing a high-efficiency energy building envelope that exceeds BEC minimum standards is feasible and cost-effective.
- Good building design with high energy efficiency performance from the beginning will benefits the building in reducing energy consumption and save operation costs in the long run over the lifetime; and it would be worth the investment.

This handbook is divided into three main sections as follows:

Background- the New BEC Enforcement Regulation

This section will provide a key summary of the BEC regulation requirements in accordance with the Ministerial Regulations of Building Energy Code (B.E. 2563) in Thailand, including assessment BEC certification procedures to be officially enforced in 2022. This section aims to provide an updated BEC regulations to support BEC developers and practitioners. For the newcomer, it also providing a reference document guide on regulations and publishable legal requirements so that interested persons can study further.

Statistics of BEC implementation

This section aims to provide an overview of 10-years historical BEC implementation in Thailand from 2009-to 2019, including the linkage of BEC criteria requirements and common practice building design fundamentals that affect building performance values. Historical statistics on passing OTTV and RTTV criteria and the importance of building envelope design to achieve the minimum energy performance for buildings.

Potential to design a high-energy performance building envelope.

This section aims to provide an example of designing the building to achieve the BEC minimum requirements and up to the higher energy performance standards, by presenting through examples of 4 different building models and considering selecting high-performance technology and materials available commercially. In addition, it will provide an initial estimation of energy-saving potential and return on investment to encourage and inspire investing in high-efficiency performance buildings in the future.

Part 1 Background-the New BEC Enforcement Regulation

The Regulation of the Ministerial Regulation

Building Energy Code (BEC) is the minimum performance requirement on energy conservation for large commercial buildings under the Ministerial Regulation B.E. 2563. It is a mandatory prescriptive code to improve the energy performance for large new buildings in the commercial sector. New or retrofitted buildings being constructed with the total area of all stories equal to 2000 square meters or more must be designed 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.

Under the new revision of Ministerial regulations, in 2022, the new code is scheduled to apply in full to a massive building of floor area over 10,000 square meters: however, a phase-step compliance strategy over three years will be enforced as illustrated in figure below:

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

BEC Building Types and Groups

The BEC regulation distinguishes three different patterns based on the operating hour usages, which it is identified as follows:

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

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

In this regard, the essence of revised regulation in the new BEC ministerial code are: (1) Condition of the Minimum standard, criteria, and procedure for energy conservation design buildings. (2) Determination of a BEC auditor/inspector to evaluate the BEC-designed building; needs to be trained and certified by the accredited training agency registered with DEDE. (3) Determination of certification methods, procedures and document formatting, and the conditions for enforcement.

Update BEC Minimum Performance Standard

This sub-section will indicate the revised BEC's energy efficiency performance standard minimum value of components 1-3. Nothing changed under Components 4-6; for more information, references of the applicable documents on BEC building design are listed in this chapter.

Component 1: Overall Thermal Transfer Value of Building's Envelope System

The Overall Thermal Transfer Value (OTTV) and Roof Thermal Transfer Value (RTTV) are used to measure annual average heat gained pass through building envelope as a cooling load of the air conditioning system. To comply with the BEC standard requirement, the OTTV and RTTV of the building envelope shall comply with the following maximum standard value.

Group of BEC building type	Overall Thermal Transfer Value	
	OTTV (W/m²)	RTTV (W/m²)
Group 1: Office building, and School	≤ 50	≤ 10
Group 2: Exhibition building, Theater, Entertainment service, and Department store	≤ 40	≤ 8
Group 3: Hotel, Hospital, Condominium	≤ 30	≤ 6

Component 2: Lighting System (LPD)

Minimum value of the lighting power density (LPD) for each type of building shall calculate from its average value per total usage area of the building. For each building, LPD value shall comply with the following standard value given in table:

Group of BEC building type	Lighting Power Density (LPD), W/m²
Group 1: Office building, and School	≤ 10
Group 2: Exhibition building, Theater, Entertainment service, and Department store	≤ 11
Group 3: Hotel, Hospital, Condominium	≤ 12

Component 3: Air Conditioning System

The Coefficient of Performance (COP) of energy and the Seasonal Cooling Energy Efficiency Ratio (SEER) is the energy efficiency of the air conditioning system used in the building. For each type of air conditioning system installed in the building, COP and SEER shall comply with the BEC standards requirements.

This document will show the performance standard of the air conditioner system only for split type air conditioner and a large chiller system, where the standard value has been changed.

(1) COP and SEER standards for small air-conditioning system (split type)

For small air conditioning system– a split type in which the cooling capacity is not more than 12,000 Watt shall have a minimum seasonal energy efficiency ratio to comply with the current minimum energy efficiency criteria of the No.5 label standard.

Type of split type AC	Size of Cooling capacity (CC)	Minimum of Energy Efficiency Ratio	
		COP (W/W)	SEER (Btu/h/W)
Fixed speed	CC ≤ 8,000 Watt (27,296 Btu/hr)	≥ 3.76	≥ 12.85
	8,000 > CC ≤ 12,000 Watt (CC > 27,296 - 40,994 Btu/hr)	≥ 3.63	≥ 12.40
Inverter	CC ≤ 8,000 Watt (27,296 Btu/hr)	≥ 4.39	≥ 15.0
	8,000 > CC ≤ 12,000 Watt (CC > 27,296 - 40,994 Btu/hr)	≥ 4.10	≥ 14.0

(2) COP standards for large air-conditioning system (Vapor-Compression Chiller System)

For large air conditioning system (Chiller), the minimum requirement values for coefficient of performance are based on type of chiller installed as shown in table below. For the integrated system of a large air-conditioning system, maximum allowable value of rated power of the air-handling system, condenser water cooling system, and chilled water transport system taken together is 0.5 kW/TR.

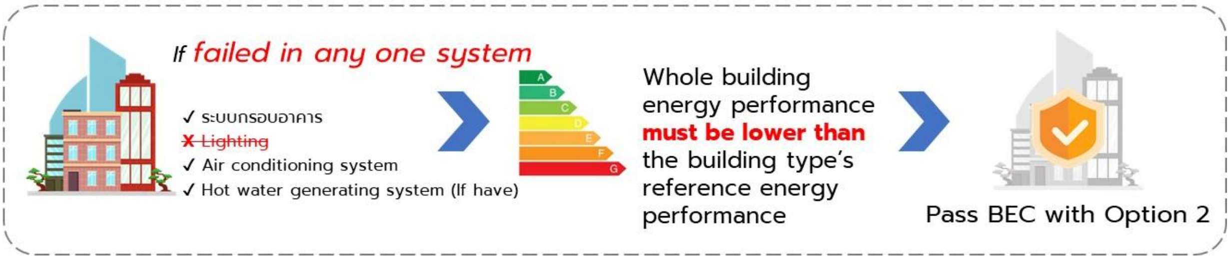
Type of Condenser	Type of Compressor	Cooling capacity at full cooling load (Ton refrigeration)	Coefficient of Performance (kW/TR)
Air-cooled chiller	All Type	≤ 300	≤ 1.12
Water-cooled chiller	Reciprocating	All Type	≤ 0.88
	Rotary, Screw	All Type	≤ 0.70
	Scroll	All Type	≤ 0.89
	Centrifugal	≤ 300 ≥ 300	≤ 0.67 ≤0.61

Option for designing building under the BEC standards

Following the BEC ministerial regulation, there are two options for building design to be qualified under BEC standard as shown in figure below:

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



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

Reference of applicable documents on BEC

The reference of applicable documents on BEC building design criteria following BEC legislation and handbook for energy conservation building design are listed as follows:

1) The Ministerial Regulation on Prescribing Types or Size of Building and Standard, Criteria and Procedure in Designing Building for Energy Conservation B.E. 2563
2) Ministry of Energy's Notification on prescribing standard values for designing building for energy conservation B.E. 2564
3) Ministry of Energy's Notification on Criteria, Calculation Methods and Assessment for designing building for energy conservation of various systems, overall energy consumption of buildings and use of renewable energy system B.E. 2564
4) Guidelines for building design and construction auditing for energy conservation buildings according to the Building Control Act- for local officer authorities

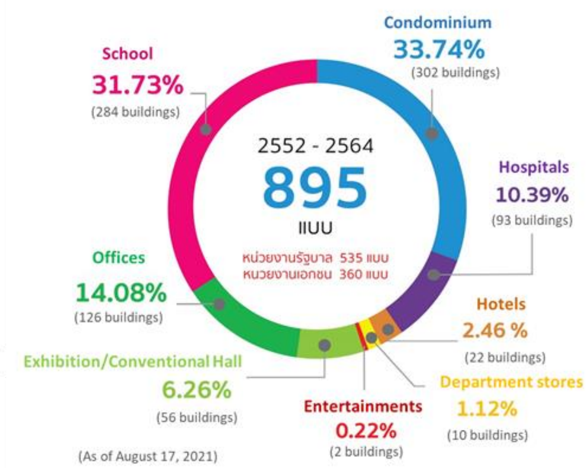
For more information, please find out in the publishable of the Ministerial regulation announcement documents. and available publishable papers of the Department of Alternative Energy Development and Efficiency, and other published documents of the Building Design Coordination Center for Energy Conservation.

(http://new.2e-building.com)

Part 2 Statistics of BEC implementation

Overview of BEC implementation in Thailand

From 2009 to 2021, a total of 895 buildings in 9 Building types has been designed and certified according to the BEC Ministerial Regulations. The Energy Conservation Building Design Coordination Center (2e-Building Center) has provided BEC building designed assessment services for 535 government and 360 private buildings.



Following the BEC ministerial regulation, there are two options for building design to be qualified under BEC standards. Most of the building fails to comply with the individual system performance requirements of option 1. With option 2 given on the BEC standard, most buildings can pass BEC criteria with the whole building energy performance criteria of Option 2; by using some high-efficiency equipment to reduce overall energy consumption, e.g., high-efficiency air conditioning, lighting system.

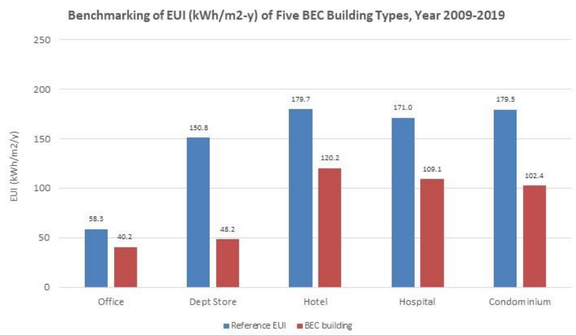
As a result, some types of BEC buildings may still have different energy efficiency and building's operating costs in the long run.

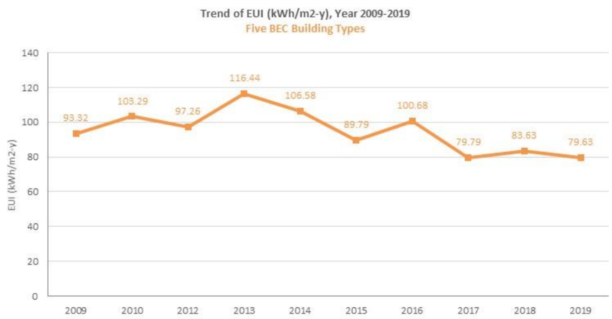
Benchmarking of the EUI Trend

Under this guidebook analysis, a breakdown of the five-building types under the Thai BEC compliance program, namely, offices, hotels, department stores, hospital or medical centers, and condominiums, were conducted.

From the BEC Assessment database over the BEC implementation period, from 2009 to 2019 the energy use index (EUI) in kWh/m^2/year is used as an indicator for benchmarking of energy efficiency. The breakdown of the EUI profile based on the percentile of the number of five building types benchmarking against the reference EUI is shown in the table below.

BEC Buildings Type	No. of Buildings	EUI ranges (kWh/m^2-y) based on percentiles					Reference EUI
		1%-25%	26%-50%	51%-75%	76%-100%	Average EUI	
Group 1 - Office	114	4.48-31.31	31.66-39.15	39.25-52.56	52.81-102.65	40.19	58.26
Group 2 – Department store	10	34.35-39.76	40.54-54.42	67.82-90.63	94.58-112.64	48.17	150.81
Group 3 - Hotel	21	53.28-79.48	79.96-117.40	117.43-134.66	137.15-188.36	121.93	179.67
Hospital	87	11.67-80.86	82.12-116.84	117.43-132.31	134.89-256.98	111.18	171.03
Condominium	273	17.48-90.54	90.62-108.75	108.77-126.16	126.46-390.42	102.40	179.48





Statistics show that the minimum energy consumption benchmark BEC can play an essential role in improving energy efficiency in the building sector if adopted at the design stage.

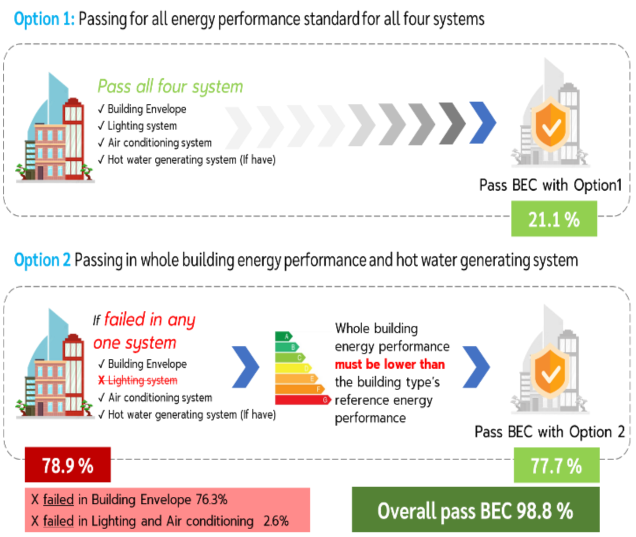
The graph shows the average energy use intensity (EUs) of all five building typs over 10 years from 2009 to 2019. Based on the historical data, the results indicate the decreasing trend of the average EUI with a 15% reduction over ten years from 93.3 kWh/m^2-y to 79.6 kWh/m^2-y.

Importance of BEC building envelope design

BEC specifies the maximum overall thermal transfer value (OTTV) for walls and windows and the roof thermal transfer value (RTTV) for roof to limit external heat transfer through the building envelope. The thermal transfer properties of the building envelope will directly impact the cooling loads and energy consumption of the air conditioning system. The BEC criterion aims to reduce the external cooling load of the building, which is indirect will help reduce the energy consumption of the air conditioning system in the long run.

Based on Thailand's 10-year BEC database (2009-2019) in 5 types of buildings with high energy consumption, it was found that most BEC buildings can comply with the BEC-option 2 of the whole building energy performance standard accounting for 97.2% of the buildings. Only 21.1% of the BEC buildings could meet all energy performance system criteria in all systems, and there are more than 79% of buildings failed in the OTTV and RTTV criteria.

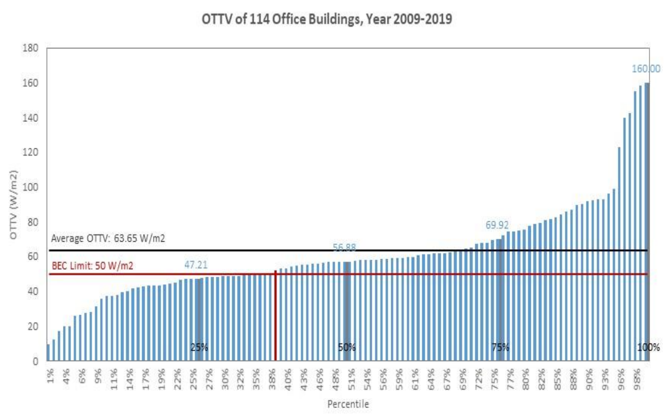
Building developers/designers often focus on investing in high-efficiency types of equipment to reduce power consumption, e.g., use of high-efficiency air conditioner or lighting system. But may not pay much attention to designing the building envelope for efficient performance to reduce the amount of heat transferred into the building, which determines the cooling load of the building. As a result, the cooling load in the facilities remain high.



Passing OTTV and RTTV standard is therefore a major challenge for project developers, and engineer-architect. However, a good building design is highly efficient right from the start. Planning to construct a building with a good energy efficiency performance since the beginning design stage would save energy costs over the lifetime of the building operations.

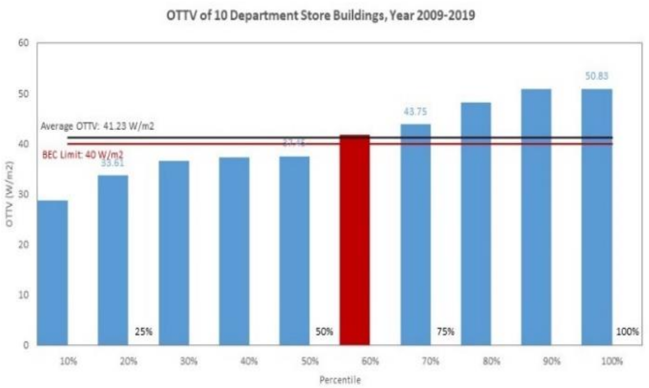
Overall Thermal Transfer Value (OTTV) of external wall of the building

- Group 1: Office buildings



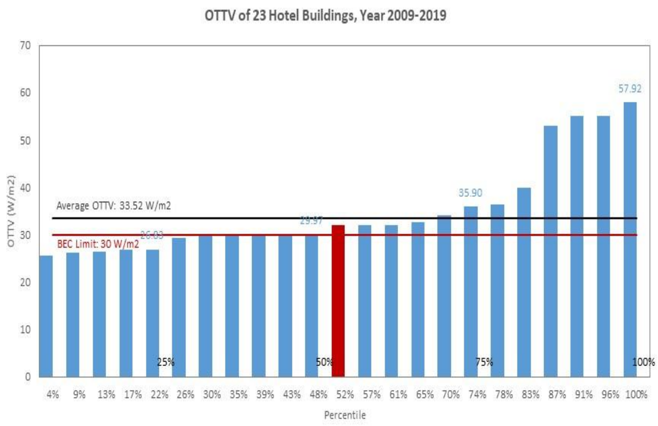
Based on historical BEC assessment data, office buildings have an average OTTV from the BEC building assessment of 63.65 W/m2. Still, 38 out of 114 BEC office buildings can pass the OTTV minimum criteria of ≤ 50 W/m2, representing 38% of office buildings that can achieve these BEC standards.

- Group 2: Department stores



Department stores buildings have an average OTTV from the BEC building assessment of 41.23 W/m². More than 50% of BEC buildings can pass the criteria of the OTTV minimum standard of ≤ 40 W/m².

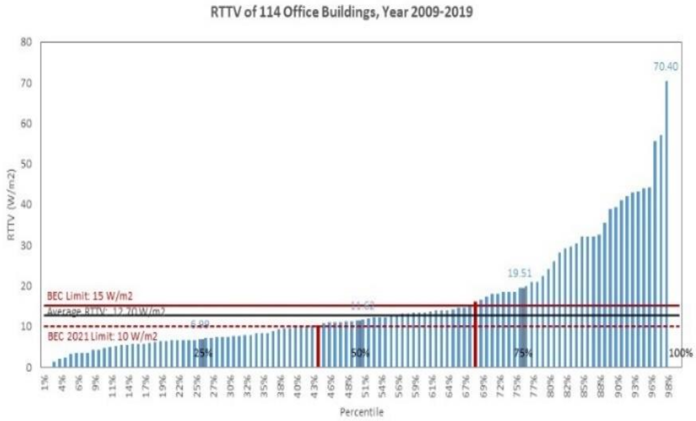
- Group 3: Hotels



Hotel buildings have an average OTTV from the BEC building assessment of 33.52 W/m². More than 52% of BEC buildings can pass the criteria of the OTTV minimum standard of ≤ 30 W/m².

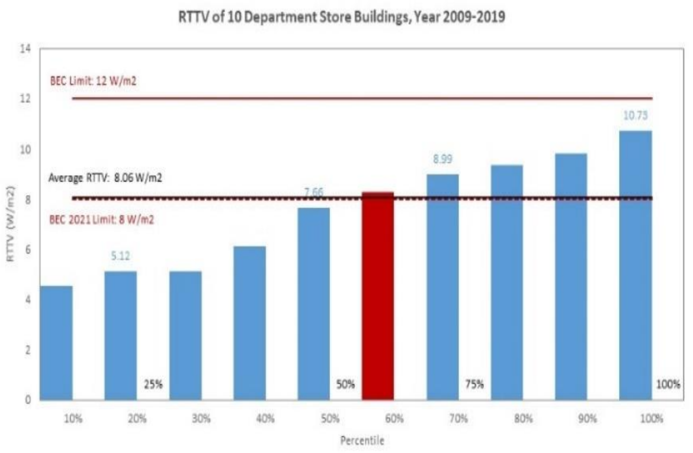
Roof Thermal Transfer Value (RTTV)

- Group 1: Offices



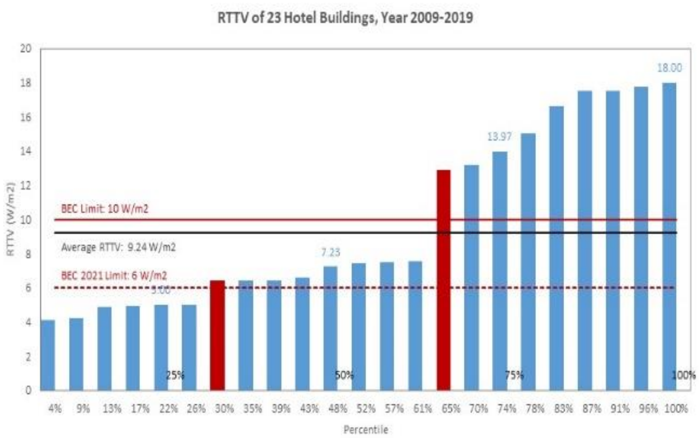
Based on historical BEC assessment data, the office buildings have an average RTTV from the BEC building assessment of 12.70 W/m². Still, 48 out of 114 BEC office buildings can pass the RTTV minimum criteria of ≤ 10 W/m², representing 43% of office buildings that can achieve these BEC standards.

- Group 2: Department stores



Department stores buildings have an average RTTV from the BEC building assessment of 8.06 W/m^2. More than 60% of BEC buildings can pass the criteria of the RTTV minimum standard of ≤ 8 W/m^2 (new BEC 2022 criteria).

- Group 3: Hotels



Hotel buildings have an average RTTV from the BEC building assessment of 9.24 W/m^2. More than 30% of BEC buildings can pass the criteria of the RTTV minimum standard of ≤ 6 W/m^2 (new BEC 2022 criteria).

Based on the historical data, it is not impossible to design a building to meet the OTTV and RTTV criteria according to the minimum energy efficiency BEC standards. Choosing to create a building envelope with a high-efficiency performance from the beginning will produce better results. It is possible by selecting highly efficient technology, and building materials developed and commercially available nowadays.

Factors related to heat transfer value

Factors related to building design that affect the amount of heat transmitted through the building (OTTV and RTTV) consist of both internal factors. and external factors are as follows:

1. **Internal factors:**
    - Thermal properties of solid and translucent wall materials, e.g., thermal conductivity (U), material's density (p), specific heat capacity (Cp), Solar heat gain coefficient (SHGC), Visible transmittance (VT) of light through a transparent wall, etc.

- Material thickness, and color of wall and roof related to coefficient for thermal absorption.
- Window to wall ratio (WWR)
- Direction of the building, inclination angles of the wall and roof surface, shading instrument installation, etc.

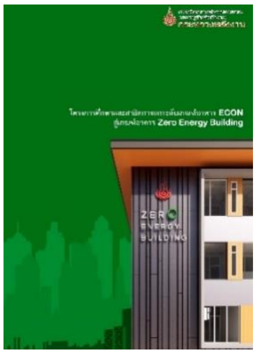
2. **External factors:** such as direction of sunlight, building landscape, natural plants cultivation, and ground plants cultivation.

For more information about the techniques and fundamental design guidelines for designing highly efficient architectural or energy-efficient energy conservation buildings, please find out in the available publishable papers of the Department of Alternative Energy Development and Efficiency and other published documents of the Building Design Coordination Center for Energy Conservation, such as:

Reference: http://new.2e-building.com

1. Handbook of building design guidelines for energy efficiency conservation buildings, DEDE

2. Handbook of Architectural High-Performance Building Design



Correlation between OTTV and WWR

A building designed with highly OTTV value is always has a high Window to Wall Ratio (WWR), which results in a large amount of heat being transmitted through the translucent building wall into the building. This in turn leads to an increase in the cooling load of the air conditioning system.

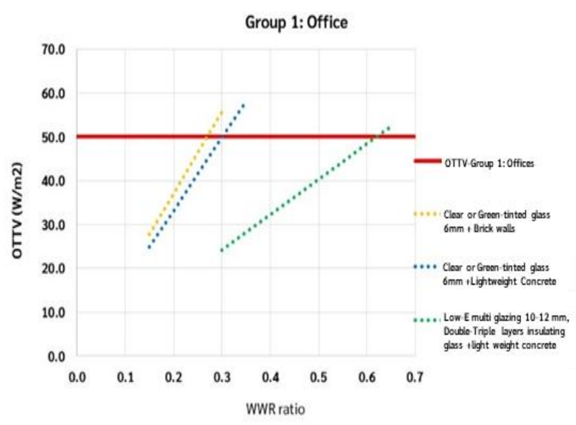
When the building has been designed with a high WWR ratio, improving the building envelope will require additional investment, such as installing heat-reflective film on the glass inside the building or opting for more efficient glass. Some may choose to renovate the building with double insulating glass or a Low E glass or even add a double wall layer internal behind the glass, which these methods will need a high renovation cost.

One of the most viable approaches is to design a building with a proper WWR ratio, including investing in appropriate high-performance materials and equipment. This approach may help avoid or reduce additional costs after construction.

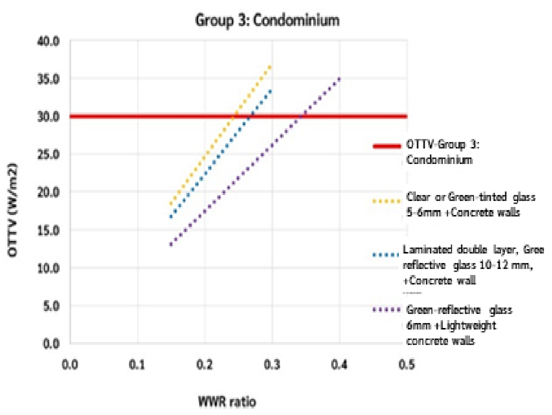
Using the 10-year BEC historical data, this section shows the standard practice model of a building designed with WWR ratio and various commons construction materials used by BEC buildings in Thailand. It shows the effectiveness of a correlation of building designed WWR ratio and the calculated OTTV value of the certified BEC building. The analysis data will be a guide to select and design the structure with a proper WWR ratio per the preferred materials used. It also shows what type of material should be used and how it fits with the WWR ratio, if it is necessary to design a building with a large proportion of glass space in the building envelope.

Correlation between OTTV and WWR

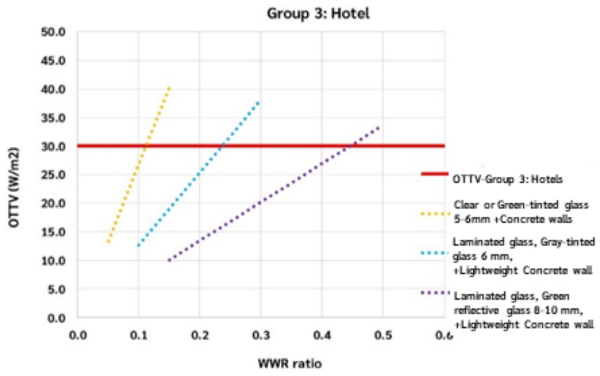
- Offices



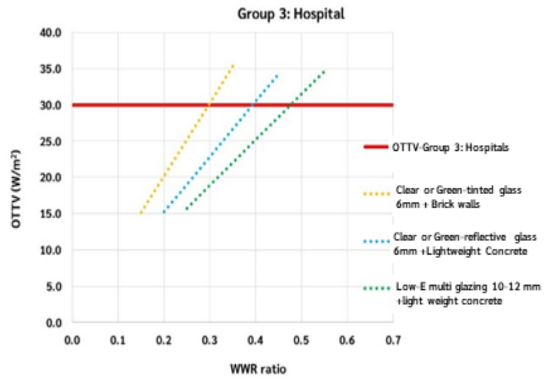
- Condominiums



- Hotels



- Hospitals



The correlation graph shows the requirements to pass the OTTV criteria:

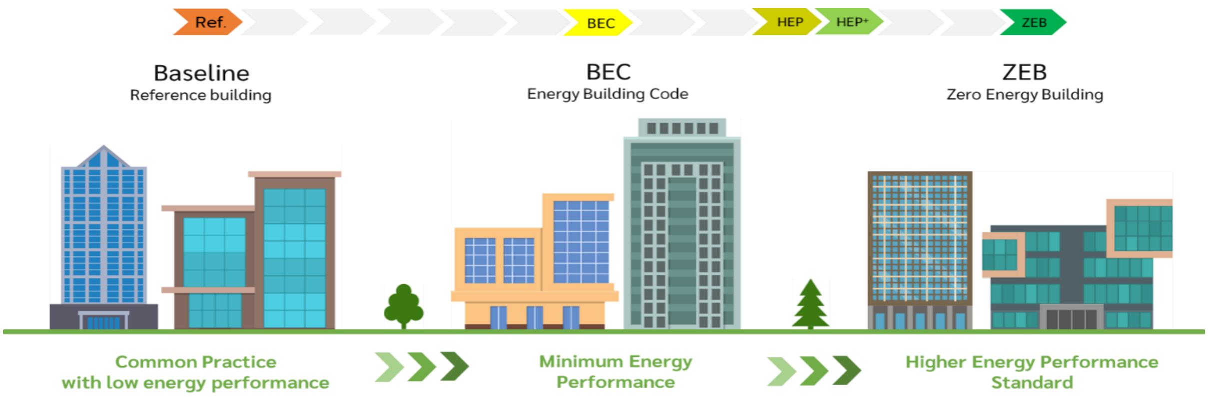
- If using a clear glass or green-tinted glass 5-6 mm thickness with common concrete walls or brick walls, the building should be designed to have a WWR of less than 15% for all types of buildings.
- Using a green laminated or green-tinted glass of 6 mm up to 8 mm thickness with light weight concrete blocks, the building should be designed to have a WWR of less than 15-25%.
- Using a green laminated or reflective glass of 8 mm to 10 mm thick with light weight concrete blocks, the WWR ratio should be between 15 and 40%.
- Using a highly efficient insulating glass, Low-E multi glazing 10-12 mm thickness or double-triple insulating glass 2-3 layers with light weight concrete blocks, WWR ratio should be between 30-50%.

Note: Despite choosing the appropriate WWR ratio, the building design must consider other relevant external factors as well, e.g., building's orientation and shading instrument design and installation

Part 3 High-energy performance building envelope design

This section provides an example of designing the building to achieve the BEC minimum requirements and up to the higher energy performance standards of building design; by presenting examples of 4 different building models. To demonstrate the energy-saving potential of high energy efficient building design, selecting high-performance technology and materials available in the commercial market were used. In addition, the analysis will provide an initial estimation of energy-saving potential and return on investment to encourage and inspire investing in high-efficiency performance buildings in the future.

The analysis illustrated in this section is simulated based on a 10,000 m^2 building. The examples presented in model simulations aim to achieve OTTV and RTTV levels based on the BEC minimum requirements and up to the higher energy performance standards of building design. The simulation deploys a web based BEC program for setting material properties and calculating thermal transfer value (OTTV and RTTV) per unit area (W/m^2) of each type of building group.



The four simulation models are commonly used for design of buildings in Thailandand, it is a typical characteristic of high-rise and low-rise buildings. The model used a simple building pattern; rectangular shape with identical opaque and transparent wall type materials, and vertical stand (90°), the roof is horizontal (0°) and does not have any translucent roof material. The window to wall ratio (WWR) is set at fixed ratio in each building module.

The assumption of Baseline buildings four models are as follows:

Characteristic of Baseline Building Models

Model 1: Typical High-Rise Building with WWR 50%

This model is a traditional 10-story high-rise rectangular building, 25 x 40 m. It is a typical design for conventional high-rise office buildings, hotels, hospitals, and condominiums. The building envelope materials are assumed to be opaque walls with a standard plastered concrete wall, transparent green-float glass with a 50% WWR ratio, and the roof is a concrete roof and gypsum board ceiling without insulation.

Model 2: Curtain Wall High-Rise Building (WWR 100%)

This model is assumed a 10-story building, rectangular shape with curtain wall, 25 x 40 m. A curtain wall is typically used in current modern high-rise office buildings in city areas. The wall structure is all glass, Green float glass with a 100% WWR ratio, and the roof is concrete and gypsum board ceiling without insulation.

Model 3: Traditional Low-Rise Building with WWR 50%

This model is a traditional 2-story low-rise rectangular building, 50 x 100 m. It is a typical design of the traditional small and medium modern trade departments store and shopping center building types. It is assumed the building envelope materials includes an opaque wall with a regular plastered concrete wall, transparent green-float glass with 50% WWR ratio, and the roof is concrete and gypsum board ceiling without insulation.

Model 4: Modern Low-Rise Building with WWR 50%

This model is a 2-story low-rise rectangular building, 50 x 100 m. It is a typical design of the small and medium modern trade department store buildings and shopping center building types. It is assumed the building envelope materials used include opaque wall with a lightweight concrete wall, transparent, green float glass with 50% WWR ratio, and the roof is a metal sheet without insulation.

Model Description

Simulation of each energy efficiency building model for analyzing the energy-saving potential is conducted based on OTTV and RTTV level, according to the BEC minimum requirements and up to the higher energy performance standards of building design. Each model is analyzed based on the BEC group categories, classified into three groups of operating hours. Building envelope thermal transfer value is based on materials properties:

1. Transparent wall or glasses materials
2. Composit of Opaque wall materials
3. Composit of Roof materials
4. Color and thermall absorption
5. Window to Wall Ratio (WWR)

OTTV&RTTV analysis is classified by a group of operating hours

Group 1 –8 hr/day

Group 2 –12 hr/day

Group 3 –24 hr/day

Baseline Model 1

- High-Rise building 10-story FL., 25 x 40 m
- plastered concrete, pale color 0.5
- Green-float glass 6 mm.
- WWR 50%
- Concrete roof, pale color
- Gypsum board ceiling

Group 1 Group 2 Group 3

Baseline Model 2

- High-Rise building 10 FL., 25 x 40 m
- Curtain wall
- Green float glass 6 mm.
- WWR 100%
- Concrete roof, pale color Gypsum board ceiling

Group 1 Group 2 Group 3

Baseline Model 3

- Low-Rise building 2-story FL., 50 x 100 m
- plastered concrete, pale color 0.5
- Green-float glass 6 mm.
- WWR 50%
- Concrete roof, pale color
- Gypsum board ceiling

Group 1 Group 2 Group 3

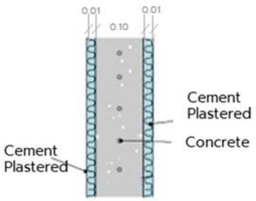
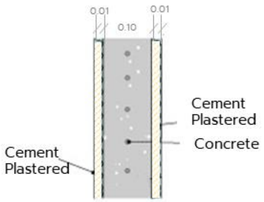
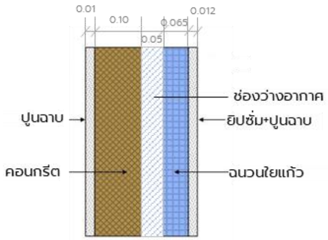
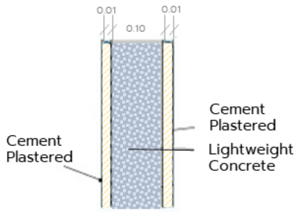
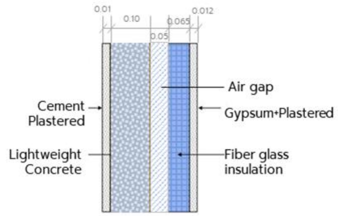
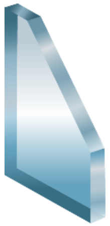
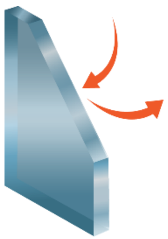
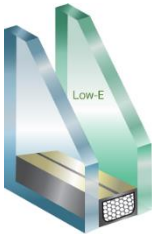
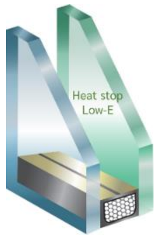
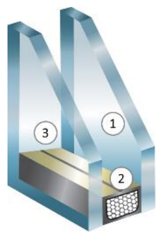
Baseline Model 4

- Low-Rise building 2-story FL., 50 x 100 m
- Lightweight concrete wall, light color 0.3
- Green-float glass 6 mm.
- WWR 50%
- Metal sheet roof
- Light Dark colorr 0.7

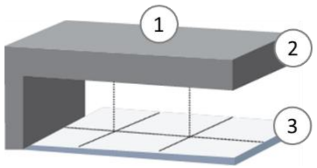
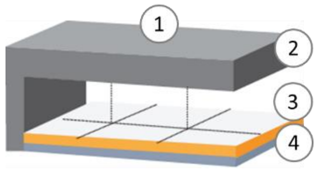
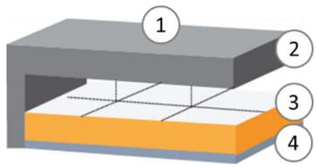
Group 1 Group 2 Group 3

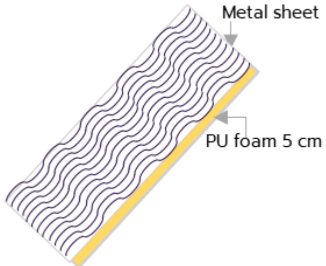
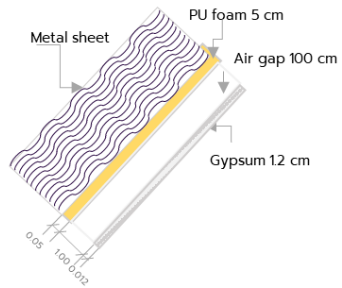
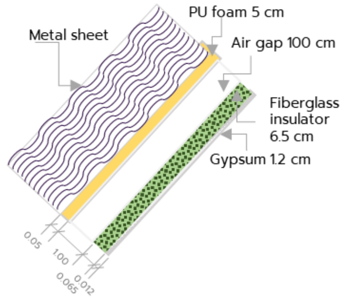
Symbolic description of building envelope materials used

The example models used a combination of opaque wall, window glass, roof materials, and window-to-wall ratio (WWR), which are set for each building model and described with symbolism. Improving building design will be determined by the thermal properties of materials and factors related to heat transfer value to reduce heat gain and energy consumption of the air conditioning system. Examples of simulation models present in this handbook only illustrate the possibility of a high-efficiency building envelope to achieve a better OTTV and RTTV level; by selecting some high-performance technology and materials available in the commercial market.

Opaque Wall	Opaque Wall-01R  Plastered Concrete Pale color paint	Opaque Wall-02  Plastered Concrete Light color or Reflective color	Opaque Wall-02R  Concrete & Insulation Light color or Reflective color	Opaque Wall-03R  Lightweight Concrete Light color or Reflective color น	Opaque Wall-04R  Lightweight Concrete & Insulation Light color or Reflective color
Transparent Wall	Glass Win-01R  Ocean Green Float Glass 6 mm	Glass Win-02R  Reflective Glass 8 mm	Glass Win-03R  Double glazing Low-E 6-12-6 mm *1 - Float glass with Low-E coating* *2 - Air gap* *3 - Clear float glass*	Glass Win-04R  Double glazing Heat stop Low-E 6-12-6 mm *1. Float glass with heat stop Low-E coating* *2. Air gap* *3. Clear float glass*	Glass Win-05R  Double Insulating glass 6-12-6 mm *1 - Tinted Float glass* *2 - Air gap* *3 - Clear float glass*

Cont.: Symbolic description of building envelope materials used

Concrete Roof	Concrete Roof-01R	Concrete Roof-02R	Concrete Roof-03R
	 *1 - Concrete 20 cm Pale color* *2 - Air gap 100 cm* *3 - Gypsum 1.2 cm*	 *1 - Concrete 20 cm, light color* *2 - Air gap 100 cm* *3 - Fiberglass Insulator 7.5 cm* *4 - Gypsum 1.2 cm*	 *1 - Concrete 20 cm, light color* *2 - Air gap 100 cm* *3 - Fiberglass Insulator 15 cm* *4 - Gypsum 1.2 cm*

Metal sheet Roof	Metal Roof-04R	Metal Roof-05R	Metal Roof-06R	Metal Roof-07R
	 Metal sheet roof Light dark color	 Metal sheet roof with PU foam insulation Light or reflective color 0.3	 Metal sheet roof with PU foam insulation, air gap and gypsum Light or reflective color 0.3	 Metal sheet roof with PU foam insulation, air gap and gypsum Light or reflective color 0.3

Note: Thermal properties of building materials used refer to the manual of building design guidelines for energy efficiency conservation buildings, DEDE. The selection of translucent or window glass materials should consider both Solar Heat Gain Coefficient (SHGC) and a relatively Visible Light Transmittance (VLT) to gain an advantage of natural light. If choosing a reflective mirror, a reflectance value should not be more than 15% to avoid problems with neighboring buildings.

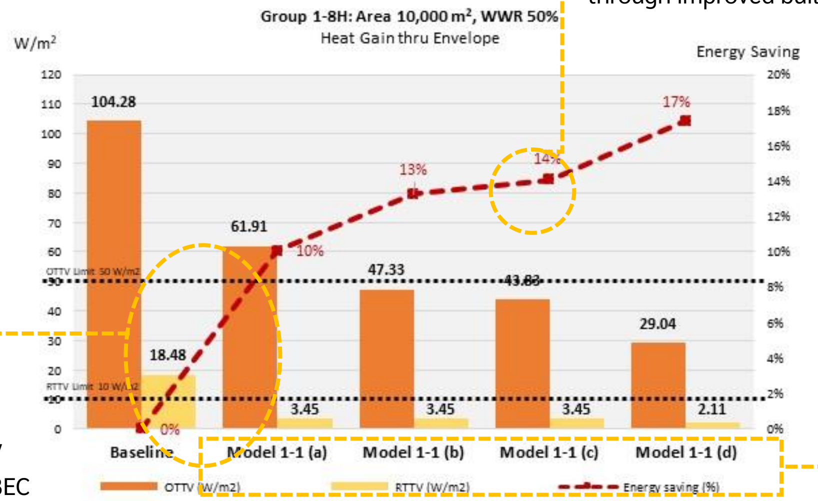
Material Codes Used in Each Model

	Efficiency Level	Baseline	Model- (a)	Model - (b)	Model - (c)	Model - (d)
Model-1	Opaque Wall	Opaque Wall-01R	Opaque Wall-02	Opaque Wall-02R	Opaque Wall-02R	Opaque Wall-02R
	Transplent Window	Glass Win-01R	Glass Win-02R	Glass Win-02R	Glass Win-03R	Glass Win-04R
	Roof	Opaque Roof-01R	Opaque Roof-02R	Opaque Roof-02R	Opaque Roof-02R	Opaque Roof-03R
	WWR ratio	50%	50%	50%	50%	50%
Model- 2	Opaque Wall	-	-	-	-	-
	Transplent Window	Curtain wall Glass Win-01R	Curtain wall Glass Win-02R	Curtain wall กระจก Win-05R	Curtain wall กรจก Win-03R	Curtain wall Glass Win-04R
	Roof	Opaque Roof-01R	Opaque Roof-02R	Opaque Roof-02R	Opaque Roof-02R	Opaque Roof-03R
	WWR ratio	100%	100%	100%	100%	100%
Model -3	Opaque Wall	Opaque Wall-01R	Opaque Wall-02	Opaque Wall-02R	Opaque Wall-02	Opaque Wall-02R
	Transplent Window	Glass Win-01R	Glass Win-02R	Glass Win-02R	Glass Win-03R	Glass Win-04R
	Roof	Opaque Roof-01R	Opaque Roof-02R	Opaque Roof-02R	Opaque Roof-02R	Opaque Roof-03R
	WWR ratio	50%	50%	50%	50%	50%
Model-4	Opaque Wall	Opaque Wall-03R	Opaque Wall-03R	Opaque Wall-04R	Opaque Wall-04R	Opaque Wall-04R
	Transplent Window	Glass Win-01R	Glass Win-02R	Glass Win-02R	Glass Win-03R	Glass Win-04R
	Roof	Metal Roof-04R	Metal Roof-05R	Metal Roof-05R	Metal Roof-06R	Metal Roof-07R
	WWR ratio	50%	50%	50%	50%	50%

Description of the example of energy-saving potential analysis

Energy saving potential

Energy saving potential from reduced heat gain through improved building

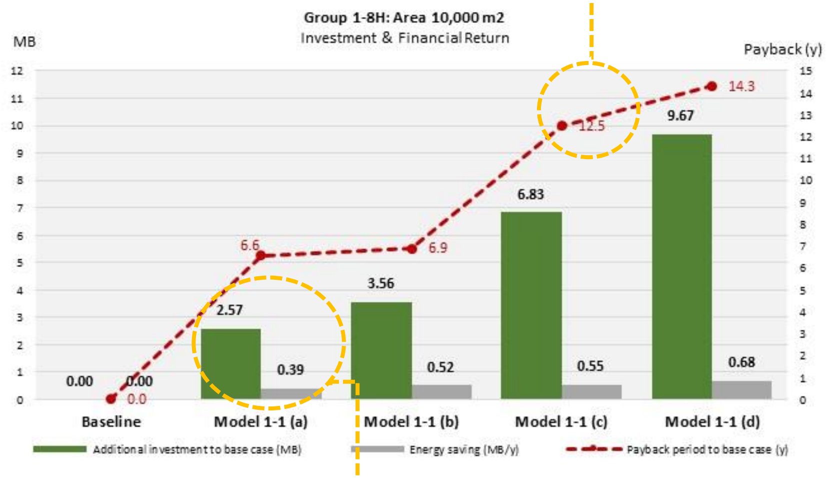


Calculated OTTV and RTTV from BEC simulation model Baseline

Representative building models for building envelope simulation

Financial return on investment

Estimated return on investment



Estimated scale of additional investment, net saving and payback of each model compared to baseline scenario.

The highlights of potential energy savings of a highly energy efficient building design is summarized here. The simulation results indicate the energy-saving potential of air conditioning from reduced heat gain through the improved building envelope. The estimated scale of additional investment, net saving, and payback from enhanced building envelope efficiency of each model are noted; compared to the baseline scenario.

Model 1 (Group 1)

Group 1 – 8 Hr/day

Baseline

Opaque

Wall-01R

Window Glass

Win-01R,

WWR 50%

Roof

Roof-01R

Group 1 OTTV 104.48 W/m^2

RTTV 18.48 W/m^2

Baseline Model 1 is assumed to be a 10-story high-rise rectangular building, 25 x 40 m. It is a typical design of the conventional high-rise office buildings, hotels, hospitals, and condominiums. The building envelope materials are assumed to be opaque walls with a standard plastered concrete wall, transparent green-float glass with a 50% WWR ratio, and the roof is concrete without insulation.

Model 1-Group 1 (a)

Opaque

Wall-02

Glass

Win-02R,

WWR 50%

Roof: Roof-02R

Group 1 OTTV 61.91 W/m^2

RTTV 3.45 W/m^2

If the wall is concrete and the glass is 8 mm reflective glass at 50% WWR and the building wall color will be light color or heat-reflective color. Although it cannot pass the OTTV threshold of ≤ 50 W/m^2, it could reduce the heat load into the building by 10%.

Model 1-Group 1 (b)

Opaque

Wall-02R

Glass

Win-02R,

WWR 50%

Roof: oof-02R

Group 1 OTTV 47.33 W/m^2

RTTV 3.45 W/m^2

Changing to a reflective glass 8 mm with 50% WWR, adding insulation on concrete wall and top ceiling roof, light color. It will result in OTTV passing the threshold of ≤ 50 W/m^2, thereby reducing the heat load entering the building by 13%.

Model 1-Group 1 (c)

Opaque

Wall-02R

Glass

Win-03R,

WWR 50%

Roof: Roof-02R

Group 1 OTTV 43.83 W/m^2

RTTV 3.45 W/m^2

Changing to a double glazing Low-E 6-12-6 mm and add insulation on concrete wall and top ceiling roof. It will result in OTTV passing the threshold of ≤ 50 W/m^2, thereby reducing the heat load entering the building by 14%.

Model 1-Group 1 (d)

Opaque

Wall-02R

Glass

Win-04R,

WWR 50%

Roof: oof-03R

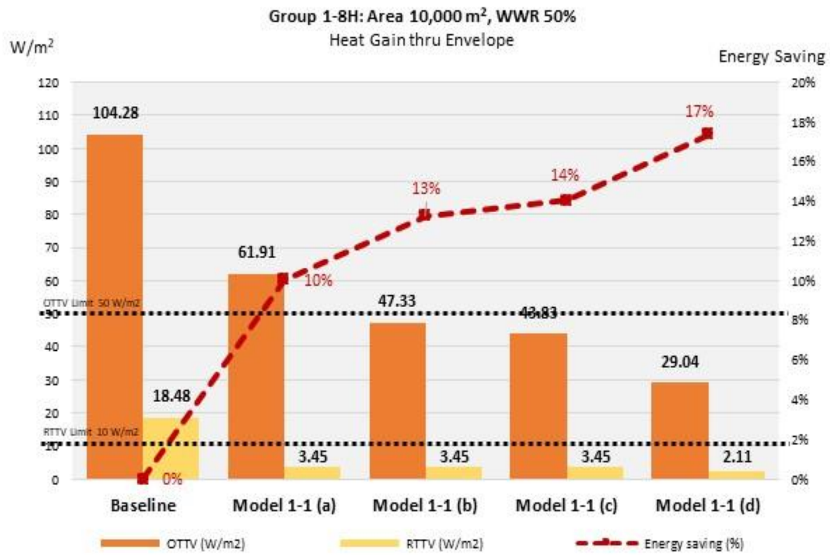
Group 1 OTTV 29.04 W/m^2

RTTV 2.11 W/m^2

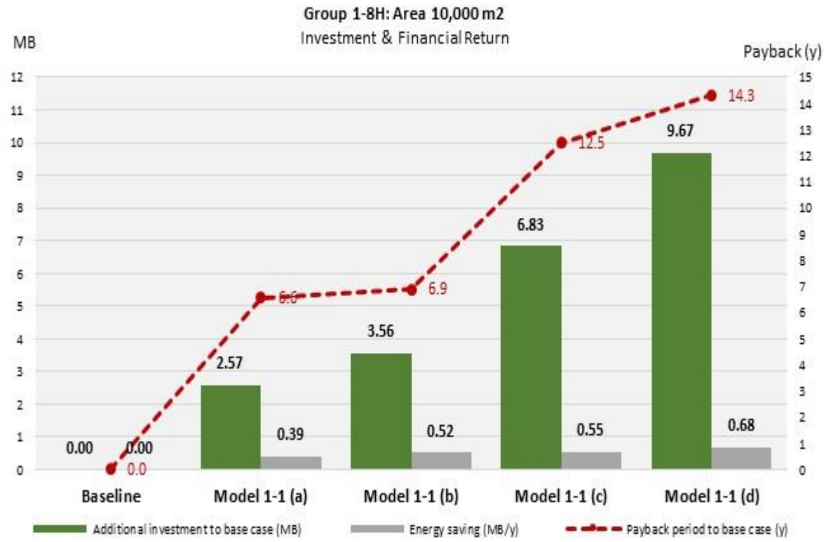
If changing to a more high-efficiency glass of Double Glass Heat Stop Low-E 24 mm, even with 50% WWR, it will pass the HEB standard at OTTV ≤ 30 W/m^2. Thereby, it will reduce the heat load entering the building by 17% compared to the baseline scenario.

Model 1 (Group 1) - Energy Saving Potential

Energy saving potential



Financial return on investment



For high-rise buildings designed where a large glass area is required (WWR50%), it should consider using an insulated concrete or lightweight concrete wall with a reflective glass of at least 8 mm thickness; to meet the BEC minimum requirements of Group 1 of OTTV ≤ 50 W/m^2. Higher efficiency glass with low SHGC that allows less heat to pass through should also be selected or consider switching to Low-E double-glazed windows. By an estimate, improving the efficiency of OTTV and RTTV to reduce the amount of heat transfer through the building envelop and passing the BEC minimum standards will result in air conditioners cooling load reduction by 10-13%, equal to approximately potential energy saving of 0.39-0.52 million baht/year. The difference of additional incremental cost is about 257-356 baht/sqm. The payback period does not exceed seven years. But high investment may be required if designed to meet a higher HEP+ level at OTTV ≤ 30 W/m^2; additional cost will be up to 967 baht/sqm.

For buildings that do not require high investment costs and intend to design with a standard concrete opaque wall with 6 mm clear window glass, the WWR ratio used should be less than 15%.

Model 1 (Group 2)

Group 2 – 12 Hr/day

Baseline

Opaque
Wall-01R
Window Glass
Win-01R,
WWR 50%
Roof
Roof-01R

Group 2 OTTV 84.30 W/m²
RTTV 19.28 W/m²

Baseline building material is assumed to be the same as Model 1 -Group 1, the materials used are combination of opaque wall, window glass, roof materials, and WWR ratio is set at 50%.

Compared with its model baseline, the envelope with better insulation significantly reduced heat gain and would have resulted in reducing the energy consumption of the air conditioning system.

Model 1-Group 2 (a)

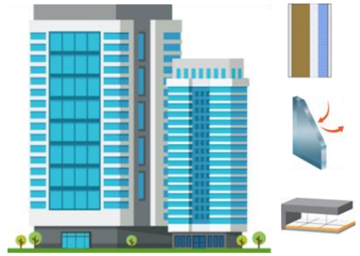
Opaque
Wall-02
Glass
Win-02R,
WWR 50%
Roof: Roof-02R

Group 2 OTTV 52.43 W/m²
RTTV 3.72 W/m²

If the wall is concrete and the glass is 8 mm reflective glass at 50% WWR and the building wall color will be light color or heat-reflective color. Although it cannot pass the OTTV threshold of ≤ 40 W/m², it could reduce the heat load into the building by 15%

Model 1-Group 2 (b)

Opaque
Wall-02R
Glass
Win-02R,
WWR 50%
Roof
Roof-02R



Group 2 OTTV 37.58 W/m²
RTTV 3.72 W/m²

Changing to a reflective glass 8 mm with 50% WWR, adding insulation on concrete wall and top ceiling roof, light color. It will result in OTTV passing the threshold of ≤ 40 W/m², thereby reducing the heat load entering the building by 17%.

Model 1-Group 2 (c)

Opaque
Wall-02R
Glass
Win-03R,
WWR 50%
Roof: Roof-02R

Group 2 OTTV 32.74 W/m²
RTTV 3.72 W/m²

Changing to a double glazing Low-E 6-12-6 mm and add insulation on concrete wall and top ceiling roof. It will result in OTTV passing the threshold of ≤ 40 W/m2, thereby reducing the heat load entering the building by 18%

Model 1-Group 2 (d)

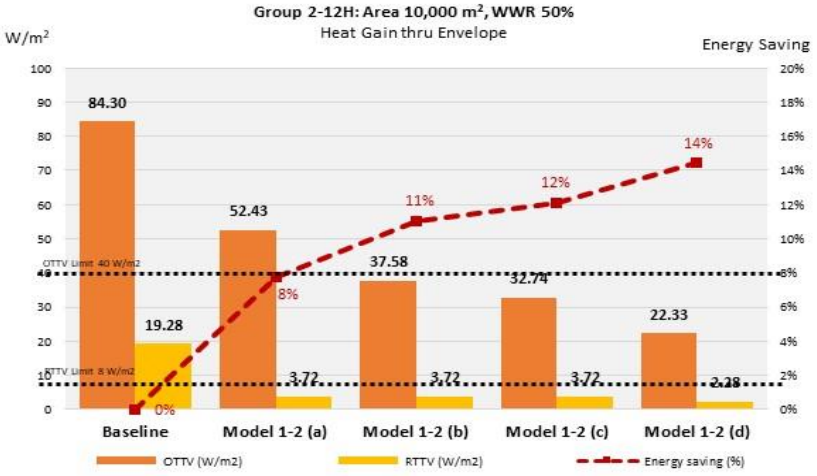
Opaque
Wall-02R
Glass
Win-04R,
WWR 50%
Roof: Roof-03R

Group 2 OTTV 22.33 W/m²
RTTV 2.28 W/m²

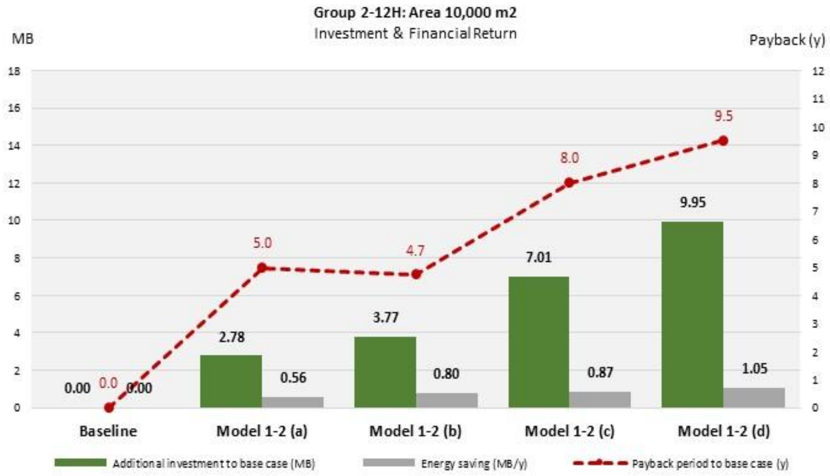
If changing to a more high-efficiency glass of Double Glass Heat Stop Low-E 24 mm, even with 50% WWR, it will pass the HEB standard at OTTV ≤ 25 W/m2. Thereby, it will reduce the heat load entering the building by 25% compared to the baseline scenario.

Model 1 (Group 2) - Energy Saving Potential

Energy saving potential



Financial return on investment



For high rise buildings Group 2, if designed where a large glass area is required (WWR50%), it should consider using an insulated concrete or lightweight concrete wall with a reflective glass of at least 8 mm thickness; to meet the BEC minimum requirements of OTTV ≤ 40 W/m2. Higher efficiency glass with low SHGC that allows less heat to pass through should also be selected or consider switching to Low-E double-glazed windows. By an estimate, improving the efficiency of OTTV and RTTV to reduce the amount of heat transfer through the building envelop and passing the BEC minimum standards will result in air conditioners cooling load reduction by 8-12%, equal to approximately potential energy saving of 0.56-0.87 million baht/year. The difference of additional incremental cost is about 278-7000 baht/sqm. The payback period does not exceed eight years. But high investment may be required if designed to meet a higher HEP level at OTTV ≤ 30 W/m^2; additional cost will be up to 995 baht/sqm.

For buildings that do not require high investment costs and intend to design with a standard concrete opaque wall with 6 mm clear window glass, the WWR ratio used should be less than 15-20%

Model 1 (Group 3)

Group 3 –24 Hr/day

Baseline

Opaque
Wall-01R
Glass
Win-01R,
WWR 50%
Roof
Roof-01R

Group 3 OTTV 51.89 W/m²
RTTV 13.12 W/m²

The baseline is assumed to be the same Model 1-Group 1 and Group 2.

Despite working 24 hours a day, the air conditioning system's workload from the heat transferred through the building envelope will be more effective during the day than at night.

Model 1-Group 3 (a)

Opaque Wall-02
Glass
Win-02R,
WWR 50%
Roof: Roof-02R

Group OTTV 32.19 W/m²
RTTV 2.60 W/m²

If the wall is concrete and the glass is 8 mm reflective glass at 50% WWR and the building wall color will be light color or heat-reflective color. Although it cannot pass the OTTV threshold of ≤ 30 W/m², it could reduce the heat load into the building by 7%

Model 1-Group 3 (b)

Opaque
Wall-02R
Glass
Win-02R,
WWR 50%
Roof: Roof-02R

Group 3 OTTV 22.96 W/m²
RTTV 2.60 W/m²

Changing to a reflective glass 8 mm with 50% WWR, adding insulation on concrete wall and top ceiling roof, light color. It will result in OTTV passing the threshold of ≤ 30 W/m2, thereby reducing the heat load entering the building by 8%.

Model 1-Group 3 (c)

Opaque
Wall-02R
Glass
Win-03R,
WWR 50%
Roof: Roof-02R

Group 3 OTTV 20.11 W/m²
RTTV 2.60 W/m²

Changing to a double glazing Low-E 6-12-6 mm and add insulation on concrete wall and top ceiling roof. It will result in OTTV passing the threshold of ≤ 30 W/m2, thereby reducing the heat load entering the building by 9%

Model 1-Group 3 (d)

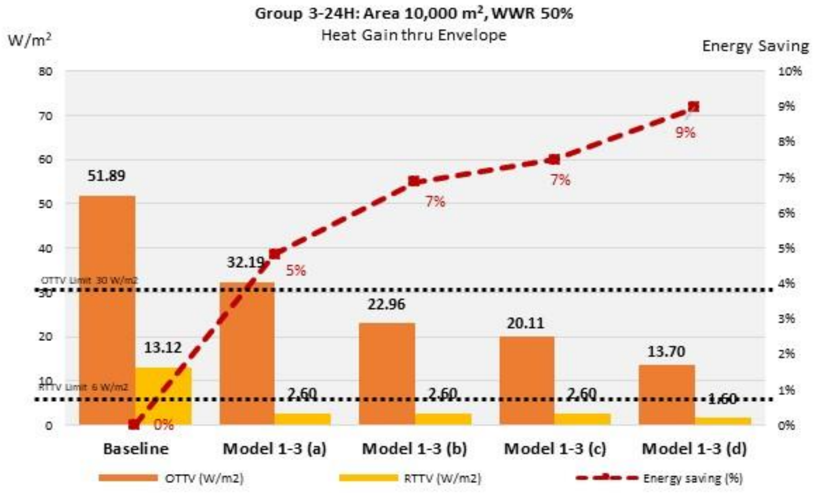
Opaque
Wall-02R
Glass
Win-04R,
WWR 50%
Roof: roof-03R

Group 3 OTTV 13.70 W/m²
RTTV 1.60 W/m²

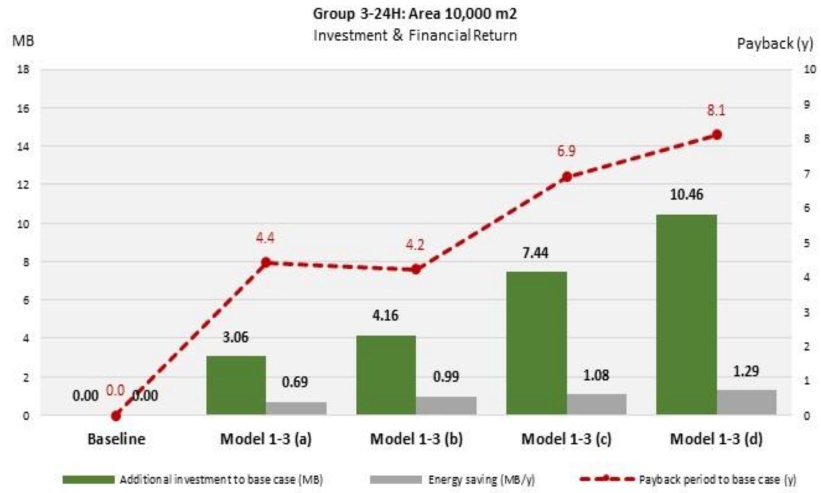
If changing to a more high-efficiency glass of Double Glass Heat Stop Low-E 24 mm, even with 50% WWR, it will pass the HEB standard at OTTV ≤ 15 W/m2. Thereby, it will reduce the heat load entering the building by 12% compared to the baseline scenario.

Model 1 (Group 3) - Energy Saving Potential

Energy saving potential



Financial return on investment



For buildings Group 3, if designed where a large glass area is required (WWR50%), it should consider using an insulated concrete or lightweight concrete wall with a reflective glass of at least 8 mm thickness; to meet the BEC minimum requirements of OTTV ≤ 30 W/m². Higher efficiency glass with low SHGC that allows less heat to pass through should also be selected or consider switching to Low-E double-glazed windows.

By an estimate, improving the efficiency of OTTV and RTTV to reduce the amount of heat transfer through the building envelop and passing the BEC minimum standards will result in air conditioners cooling load reduction by 5-7%, equal to approximately potential energy saving of 0.69-1.08 million baht/year. The difference of additional incremental cost is approximately 306-744 baht/sqm. The payback period does not exceed seven years. But the high investment may be required if designed to meet a higher efficency ZEB level at OTTV ≤ 15 W/m²; additional cost will be up to 1,046 baht/sqm.

For buildings that do not require high investment costs and intend to design with a standard concrete opaque wall with 6 mm clear window glass, the WWR ratio used should be less than 5%

Model 2 (Group 1)

Group 1 – 8 Hr/day

Baseline

Curtain Wall Glass

Win-01R,

WWR 100%

Roof

Roof-01R

Group 1 OTTV 162.59 W/m²

RTTV 18.48 W/m²

Building Model 2 l has assumed a 10-story building, rectangular shape with curtain wall, 25 x 40 m. A curtain wall is typically used in modern high-rise office buildings in various city areas. The wall structure is all glass, green float glass with a 100% WWR ratio, and the roof is concrete and gypsum board ceiling without insulation.

Model 2-Group 1 (a)

Curtain Wall Glass

Win-02R,

WWR 50%

Roof: Roof-02R

Group 1 OTTV 99.75 W/m²

RTTV 3.45 W/m²

Model 2-Group 1 (b)

Curtain Wall Glass

Win-05R,

WWR 100%

Roof: Roof-02R

Group 1 OTTV 90.84 W/m²

RTTV 3.45 W/m²

Even though choosing reflective glass 8 mm or even double insulating glass with an air gap in the middle (Double Insulating glass 6-12-6 mm). In that case, it will not meet the OTTV criteria of ≤ 50 W/m². However, the high-efficiency glasses will help reduce the heat load entering into the building by 15-17%. To meet the minimum BEC criteria, the facility must design using very high energy efficiency equipment systems, as well as consider adding a second internal wall with an insulating barrier on the back of the curtain glass.

Model 2-Group 1 (c)

Curtain Wall Glass

Win-03R,

WWR 50%

Roof: Roof-02R

Group 1 OTTV 83.85 W/m²

RTTV 3.45 W/m²

Model 2-Group 1 (d)

Curtain Wall Glass

Win-04R,

WWR 50%

Roof: oof-03R

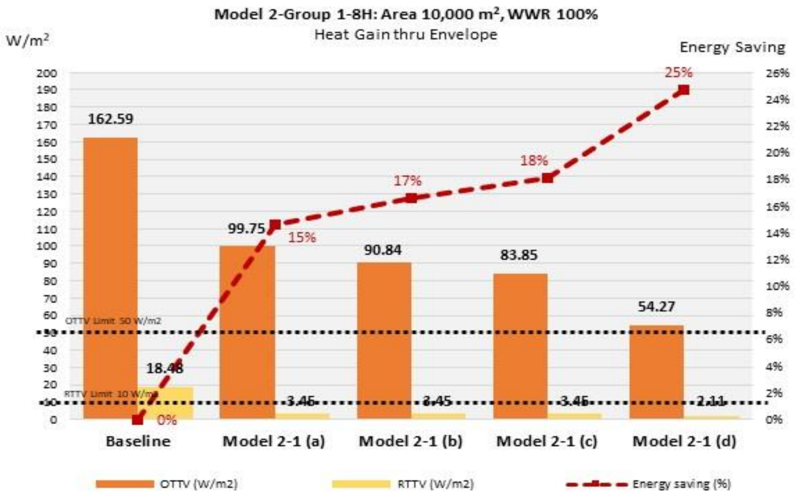
Group 1 OTTV 54.27 W/m²

RTTV 2.11 W/m²

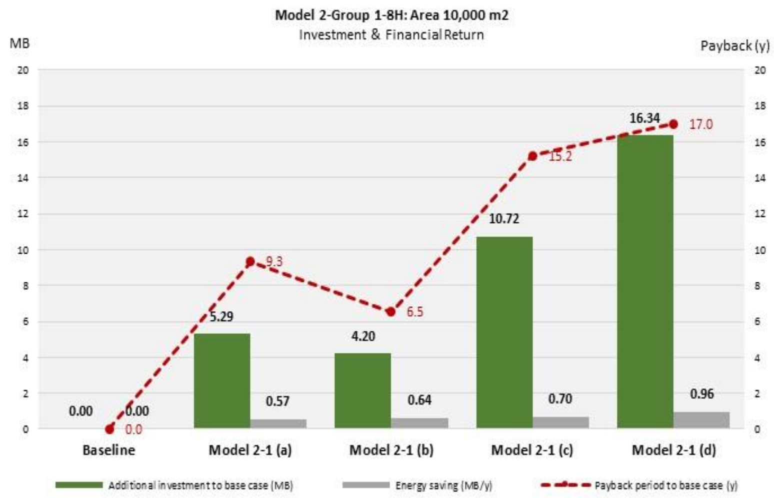
Even choosing a higher-efficiency glass, e.g., Double Glazing Low-E or Double Glazing Heat Stop-Low E with higher efficiency, adding insulation to the roof, and painted with light color or heat reflective paint. These results will help somewhat improve a better OTTV value, but it still does not pass the OTTV ≤ 50 W/m² criteria. As well as it needs to integrate design with high-efficiency facility/or high-efficiency equipment systems. Therefore, it will help to reduce the heat transfer into the building by 18-25%.

Model 2 (Group 1) - Energy Saving Potential

Energy saving potential



Financial return on investment



For a building designed as a curtain wall with all external walls being glass (WWR100%), a tremendous amount of heat transmitted through a glass wall is much more than an opaque wall. To pass OTTV lower than ≤ 50 W/m² is quite difficult, whether using reflective glass or even double clear glass with an air gap insulation. Therefore, a building with a curtain wall should consider choosing a higher-efficiency glass, e.g., Double Glazing Low-E or Double Glazing Heat Stop-Low E with higher efficiency, rather than clear glass or reflective glass. It will help better protect heat transfer through the glass wall. In addition, an approach to reduce the area of translucent walls should be considered; by reinforcing the second layer of solid insulation wall at the back of the curtain wall.

By an estimate, by choosing high-efficiency glass such as Double Glazing Low-E or Heat Stop-Low E glass, and adding insulation on top of ceiling roof, will result in air conditioners cooling load reduction by 18-25%, equal to approximately potential energy saving of 0.70-0.96 million baht/year. However, to pass the minimum OTTV criteria, it needs to integrate design with high-efficiency facility/high-efficiency equipment systems, including considering installing an additional Renewable Energy system to reduce the total energy consumption of the building to pass the BEC reference standard (Option 2).

Model 2 (Group 2)

Group 2 – 12 Hr/day

Baseline

Curtain Wall Glass
Win-01R,
WWR 100%
Roof
Roof-01R

Group 2 OTTV 123.48 W/m^2
RTTV 19.28 W/m^2

Baseline building material is assumed to be the same as Model 2-Group 1. The wall structure is a curtain wall with all green float glass with a 100% WWR ratio, and the roof is concrete and gypsum board ceiling without insulation.

Compared with its model baseline, the envelope changing to high-efficiency glass and better insulation significantly reduced heat gain. It would have reduced the energy consumption of the air conditioning system.

Model 2-Group 2 (a)

Curtain Wall Glass
Win-02R,
WWR 50%
Roof
Roof-02R

Group 2 OTTV 74.81 W/m^2
RTTV 3.72 W/m^2

Model 2-Group 2 (b)

Curtain Wall Glass
Win-05R,
WWR 100%
Roof
Roof-02R

Group 2 OTTV 71.29 W/m^2
RTTV 3.72 W/m^2

Even though choosing reflective glass 8 mm or even double insulating glass with an air gap in the middle (Double Insulating glass 6-12-6 mm). In that case, it will not meet the OTTV criteria of ≤ 40 W/m^2. However, the high-efficiency glasses will help reduce the heat load entering the building by 11-12%. To meet the minimum BEC criteria, the facility must design using very high energy efficiency equipment systems, as well as consider adding a second internal wall with an insulating barrier on the back of the curtain glass

Model 2-Group 2 (c)

Curtain Wall Glass
Win-03R,
WWR 50%
Roof
Roof-02R

Group 2 OTTV 61.60 W/m^2
RTTV 3.72 W/m^2

Model 2-Group 2 (d)

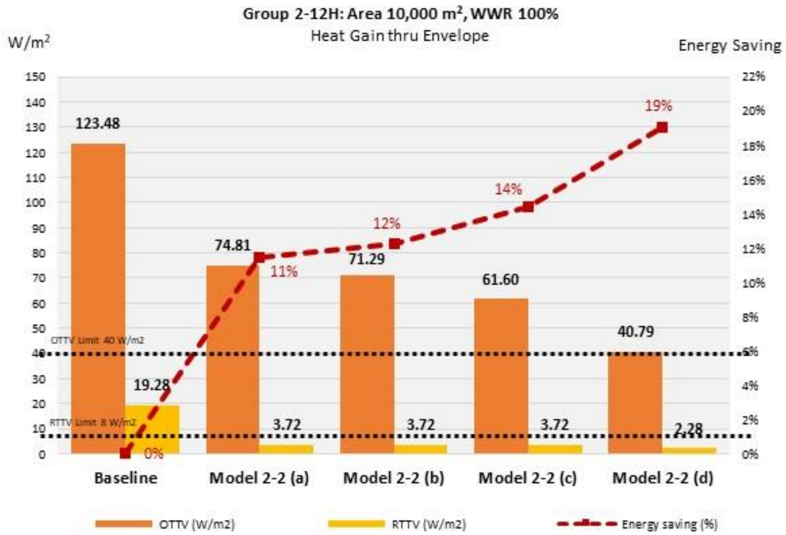
Curtain Wall Glass
Win-04R,
WWR 50%
Roof
Roof-03R

Group 2 OTTV 40.79 W/m^2
RTTV 2.28 W/m^2

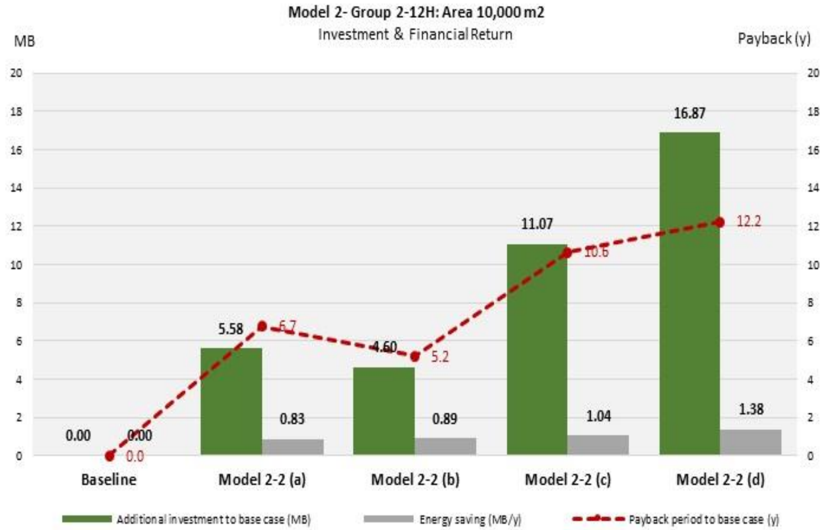
Even choosing a higher-efficiency glass, e.g., Double Glazing Low-E or Double Glazing Heat Stop-Low E with higher efficiency, adding insulation to the roof, and painted with light color or heat reflective paint. These results will help somewhat improve a better OTTV value, but it still does not pass the OTTV ≤ 40 W/m^2 criteria. As well as it needs to integrate design with high-efficiency facility/or high-efficiency equipment systems. Therefore, it will help to reduce the heat transfer into the building by 14-19%.

Model 2 (Group 2) - Energy Saving Potential

Energy saving potential



Financial return on investment



For high rise buildings Group 2 built with curtain wall, to pass OTTV lower than ≤ 40 W/m² is quite more difficult, whether using reflective glass or even double clear glass with an air gap insulation.

By an estimate, by choosing high-efficiency glass such as Double Glazing Low-E or Heat Stop-Low E glass, and adding insulation on top of ceiling roof, will result in air conditioners cooling load reduction by 14-19%, equal to approximately potential energy saving of 1.04-1.38 million baht/year. However, to pass the minimum OTTV criteria, it needs to integrate design with high-efficiency facility/high-efficiency equipment systems, including considering installing an additional Renewable Energy system to reduce the total energy consumption of the building to pass the BEC reference standard (Option 2)

Model 2 (Group 3)

Group 3 – 24 Hr/day

Baseline

Curtain Wall Glass

Win-01R,

WWR 100%

Roof

Roof-01R

Group 3 OTTV 75.59 W/m²

RTTV 13.12 W/m²

The baseline is assumed to be the same Model 2-Group 1 and Group 2.

Despite working 24 hours a day, the air conditioning system's workload from the heat transferred through the building envelope will be more effective during the day than at night.

Model 2-Group 3 (a)

Curtain Wall Glass

Win-02R,

WWR 50%

Roof: Roof-02R

Group 3 OTTV 45.84 W/m²

RTTV 2.60 W/m²

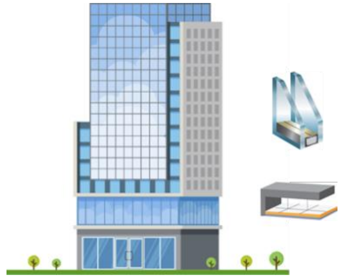
Model 2-Group 3 (b)

Curtain Wall Glass

Win-05R,

WWR 100%

Roof: Roof-02R



Group 3 OTTV 43.53 W/m²

RTTV 2.60 W/m²

Even though choosing reflective glass 8 mm or even double insulating glass with an air gap in the middle (Double Insulating glass 6-12-6 mm). In that case, it will not meet the OTTV criteria of ≤ 30 W/m². However, the high-efficiency glasses will help reduce the heat load entering the building by 7-9%. To meet the minimum BEC criteria, the facility must design using very high energy efficiency equipment systems, as well as consider adding a second internal wall with an insulating barrier on the back of the curtain glass

Model 2-Group 3 (c)

Curtain Wall Glass

Win-03R,

WWR 50%

Roof: Roof-02R

Group 3 OTTV 37.81 W/m²

RTTV 2.60 W/m²

Model 2-Group 3 (d)

Curtain Wall Glass

Win-04R,

WWR 50%

Roof: Roof-03R

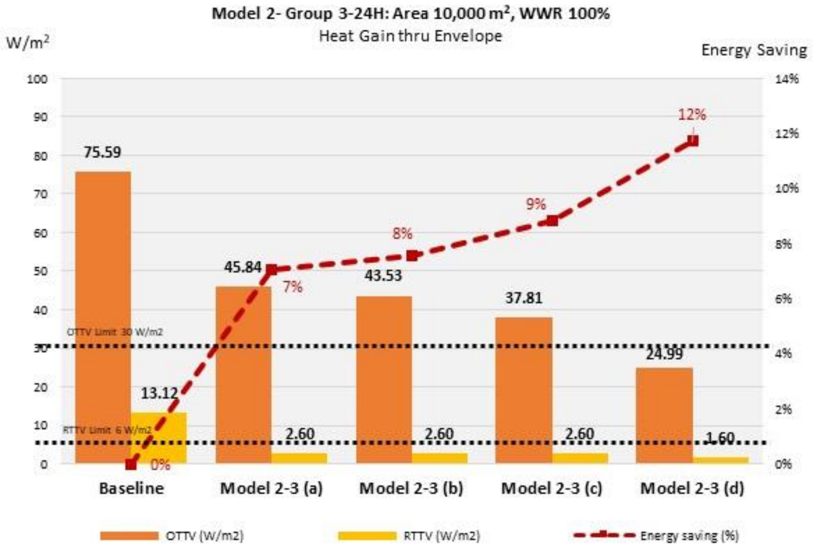
Group 3 OTTV 24.99 W/m²

RTTV 1.60 W/m²

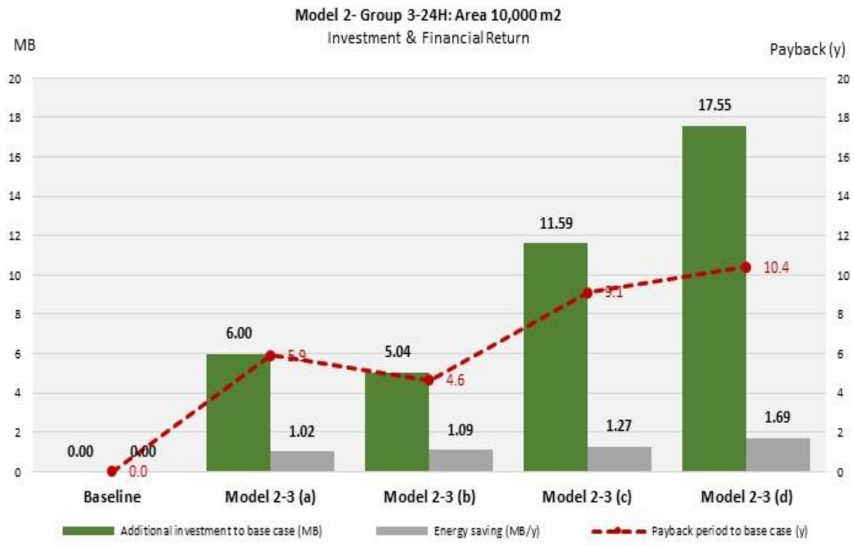
Even choosing a higher-efficiency glass, e.g., Double Glazing Low-E or Double Glazing Heat Stop-Low E with higher efficiency, adding insulation to the roof, and painted with light color or heat reflective paint. These results will help somewhat improve a better OTTV value, but it still does not pass the OTTV ≤ 30 W/m² criteria. As well as it needs to integrate design with high-efficiency facility/or high-efficiency equipment systems. Therefore, it will help to reduce the heat transfer into the building by2%.

Model 2 (Group 3) - Energy Saving Potential

Energy saving potential



Financial return on investment



For high rise buildings Group 2 built with curtain wall, to pass OTTV lower than ≤ 30 W/m² is quite more difficult, whether using reflective glass or even double clear glass with an air gap insulation

By an estimate, by choosing high-efficiency glass such as Double Glazing Low-E or Heat Stop-Low E glass, and adding insulation on top of ceiling roof, will result in air conditioners cooling load reduction by 14-19%, equal to approximately potential energy saving of 1.27-1.69 million baht/year. However, to pass the minimum OTTV criteria, it needs to integrate design with high-efficiency facility/high-efficiency equipment systems, including considering installing an additional Renewable Energy system to reduce the total energy consumption of the building to pass the BEC reference standard (Option 2)

Model 3 (Group 1)

Group 1 – 8 Hr/day

Baseline

Opaque

Wall-01R

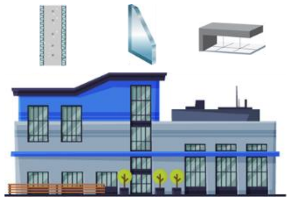
Window Glass

Win-01R,

WWR 50%

Roof

Roof-01R



Group 1 OTTV 104.01 W/m^2

RTTV 18.48 W/m^2

Baseline Model 3 is assumed to be a 2-story low-rise rectangular building, 50 x 100 m. It is a typical design of traditional small and medium modern trade, department store and shopping center building. It is assumed the building envelope materials used with opaque wall with a regular plastered concrete wall, transparent green-float glass with 50% WWR ratio, and the roof is concrete and gypsum board ceiling without insulation.

Model 3-Group 1 (a)

Opaque

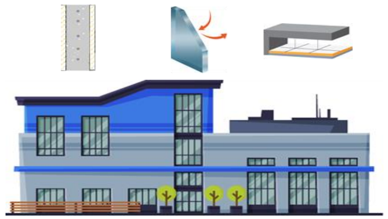
Wall-02

Glass

Win-02R,

WWR 50%

Roof: Roof-02R



Group 1 OTTV 61.76 W/m^2

RTTV 3.45 W/m^2

If the wall is concrete and the glass is 8 mm reflective glass at 50% WWR and the building wall color will be light color or heat-reflective color. Although it cannot pass the OTTV threshold of ≤ 50 W/m^2, it could reduce the heat load into the building by 9%.

Model 3-Group 1 (b)

Opaque

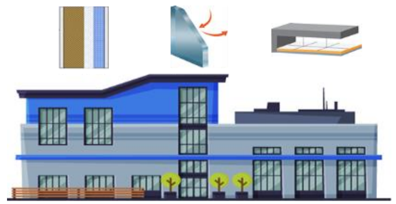
Wall-02R

Glass

Win-02R,

WWR 50%

Roof”Roof-02R



Group 1 OTTV 47.22 W/m^2

RTTV 3.45 W/m^2

Changing to a reflective glass 8 mm with 50% WWR, adding insulation on concrete wall and top ceiling roof, light color. It will result in OTTV passing the threshold of ≤ 50 W/m^2, thereby reducing the heat load entering the building by 10%.

Model 3-Group 1 (c)

Opaque

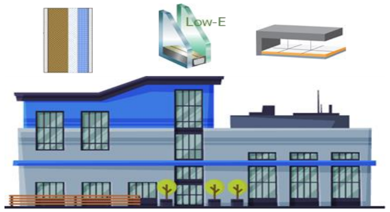
Wall-02R

Glass

Win-03R,

WWR 50%

Roof: Roof-02R



Group 1 OTTV 43.71 W/m^2

RTTV 3.45 W/m^2

Changing to a double glazing Low-E 6-12-6 mm and add insulation on concrete wall and top ceiling roof. It will result in OTTV passing the threshold of ≤ 50 W/m^2, thereby reducing the heat load entering the building by 11%.

Model 3-Group 1 (d)

Opaque

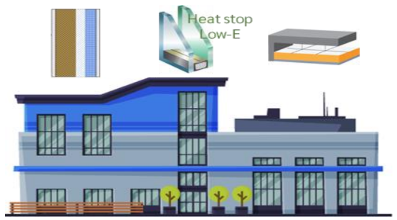
Wall-02R

Glass

Win-04R,

WWR 50%

Roof: Roof-03R



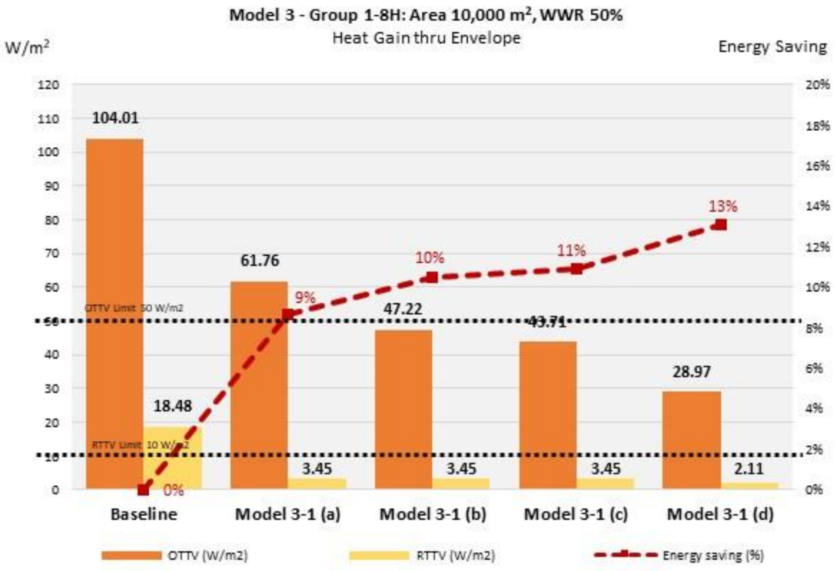
Group 1 OTTV 28.97 W/m^2

RTTV 2.11 W/m^2

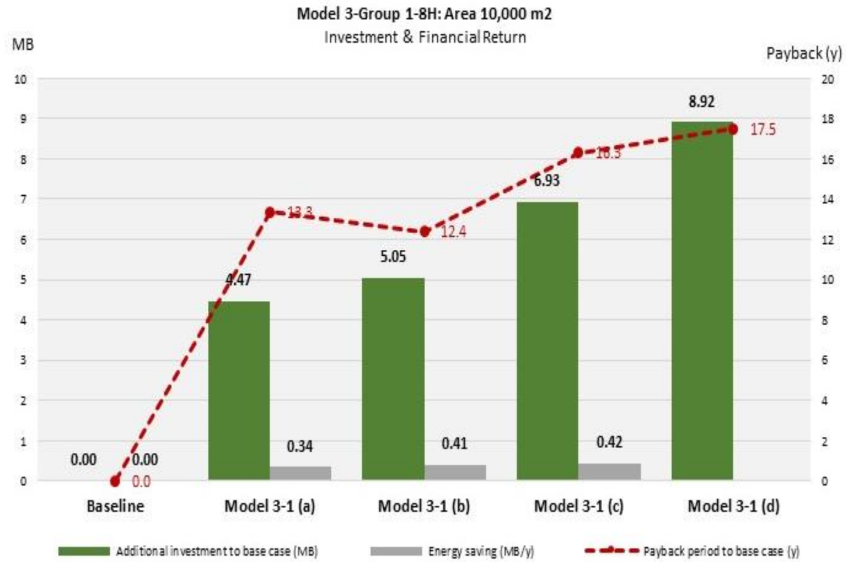
If changing to a more high-efficiency glass of Double Glass Heat Stop Low-E 24 mm, even with 50% WWR, it will pass the HEB standard at OTTV ≤ 30 W/m^2. Thereby, it will reduce the heat load entering the building by 13% compared to the baseline scenario.

Model 3 (Group 1) - Energy Saving Potential

Energy saving potential



Financial return on investment



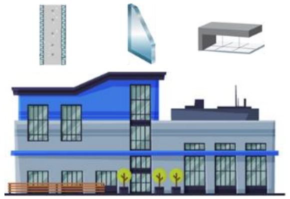
For this type of low-rise building, heat through the roof accounts for >35% of the total amount of heat transferred through the entire building's envelope. Adding insulation to the rooftop should be emphasized first; to reduce the heat transferred from the roof as much as possible. It also should consider using an insulated concrete or lightweight concrete wall with a reflective glass of at least 8 mm thickness; to meet the BEC minimum requirements. By an estimate, improving the efficiency of OTTV and RTTV to reduce the amount of heat transfer through the building envelop will result in air conditioners cooling load reduction by 9-13%, equal to approximately potential energy saving of 0.34-0.42 million baht/year. For buildings that do not require high investment costs and intend to design with a standard concrete opaque wall with 6 mm clear window glass, the WWR ratio used should be less than 15%. In addition, this type of BEC building has great potential to generate electricity from solar energy due to having a large rooftop area; installing Rooftop Solar PV generating system will help reduce energy costs.

Model 3 (Group 2)

Group 2 – 12 Hr/day

Baseline

Opaque
Wall-01R
Window Glass:
Win-01R,
WWR 50%
Roof:
Roof-01R



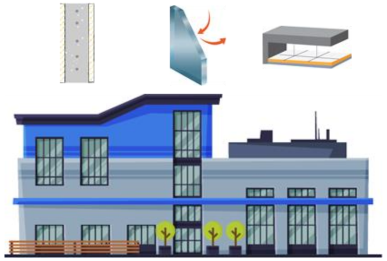
Group 2 OTTV 84.13 W/m²
RTTV 19.28 W/m²

Baseline building material is assumed to be the same as Model 3 -Group 1, the materials used are combination of plastered concrete wall, transparent green-float glass with 50% WWR ratio, and the roof is concrete and gypsum board ceiling without insulation.

Note that the saving percentage for Group 2-12Hr is lower than Group1 because the building operates both day and partially at nighttime. The annual energy savings for Group 2-12Hr is the lower due to building operating hours.

Model 3-Group 2 (a)

Opaque
Wall-02
Glass: Win-02R,
WWR 50%
Roof: Roof-02R

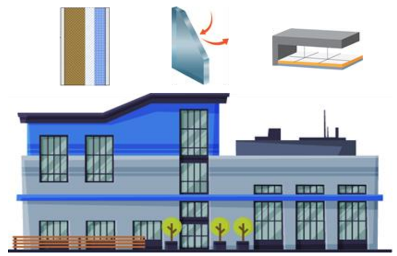


Group 2 OTTV 52.34 W/m²
RTTV 3.72 W/m²

If the wall is concrete and the glass is 8 mm reflective glass at 50% WWR and the building wall color will be light color or heat-reflective color. Although it cannot pass the OTTV threshold of ≤ 40 W/m², it could reduce the heat load into the building by 7%.

Model 3-Group 2 (b)

Opaque
Wall-02R
Glass: Win-02R,
WWR 50%
Roof: Roof-02R

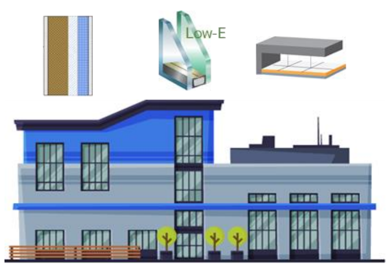


Group 2 OTTV 37.53 W/m²
RTTV 3.72 W/m²

Changing to a reflective glass 8 mm with 50% WWR, adding insulation on concrete wall and top ceiling roof, light color. It will result in OTTV passing the threshold of ≤ 40 W/m², thereby reducing the heat load entering the building by 9%.

Model 3-Group 2 (c)

Opaque
Wall-02R
Glass: Win-03R,
WWR 50%
Roof: Roof-02R

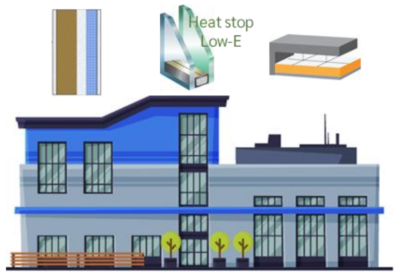


Group 2 OTTV 32.68 W/m²
RTTV 3.72 W/m²

Changing to a double glazing Low-E 6-12-6 mm and add insulation on concrete wall and top ceiling roof. It will result in OTTV passing the threshold of ≤ 40 W/m², thereby reducing the heat load entering the building by 10%.

Model 3-Group 2 (d)

Opaque
Wall-02R
Glass: Win-04R,
WWR 50%
Roof: Roof-03R

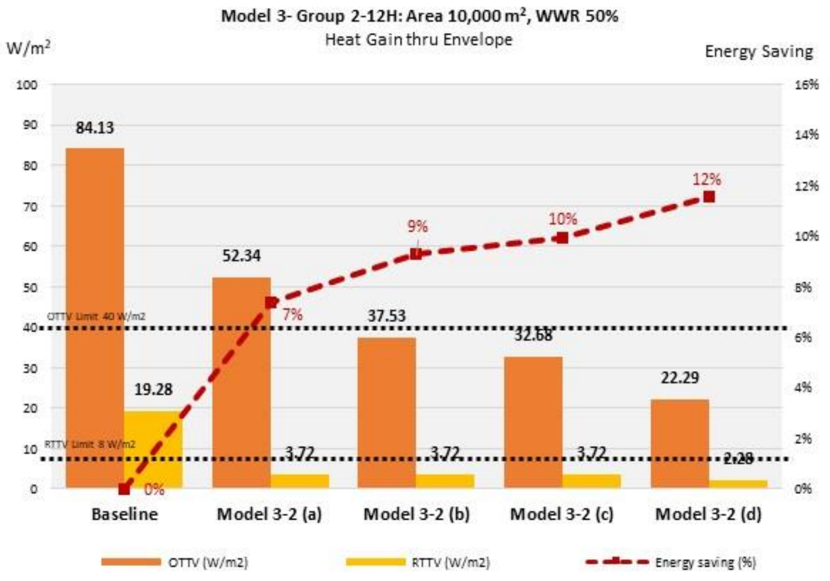


Group 2 OTTV 22.29 W/m²
RTTV 2.28 W/m²

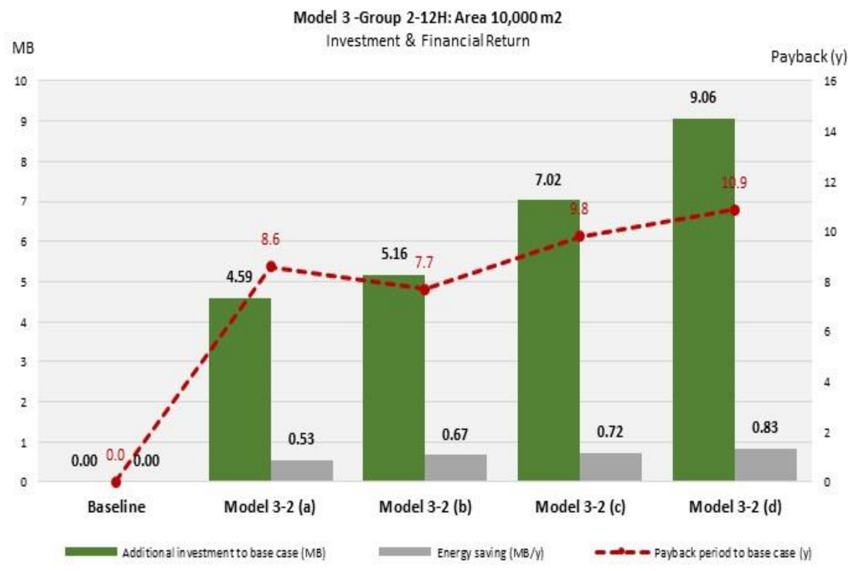
If changing to a more high-efficiency glass of Double Glass Heat Stop Low-E 24 mm, even with 50% WWR, it will pass the HEB standard at OTTV ≤ 25 W/m². Thereby, it will reduce the heat load entering the building by 12% compared to the baseline scenario.

Model 3 (Group 2) - Energy Saving Potential

Energy saving potential



Financial return on investment



For low-rise building Model 3 Group 2, it also should consider adding insulation to the rooftop, using an insulated concrete or lightweight concrete wall with a reflective glass of at least 8 mm thickness; to meet the BEC minimum requirements. For buildings that do not require high investment costs and intend to design with a standard concrete opaque wall with 6 mm clear window glass, the WWR ratio used should be less than 15-20%.

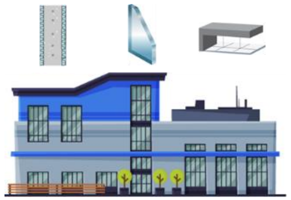
By an estimate, improving the efficiency of OTTV and RTTV to reduce the amount of heat transfer through the building envelop will result in air conditioners cooling load reduction by 7-12%, equal to approximately potential energy saving of 0.53-0.83 million baht/year.

Model 3 (Group 3)

Group 3 – 24 Hr/day

Baseline

Opaque
Wall-01R
Window Glass
Win-01R,
WWR 50%
Roof
Roof-01R



Group 3 OTTV 51.74 W/m^2
RTTV 13.12 W/m^2

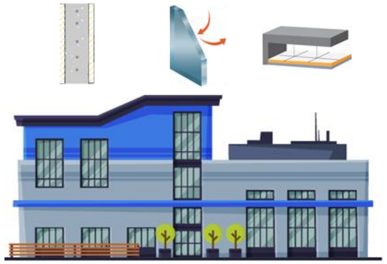
The baseline is assumed to be the same Model 3-Group 1 and Group 2.

Despite working 24 hours a day, the air conditioning system's workload from the heat transferred through the building envelope will be more effective during the day than at night.

However, using high-efficiency building materials would reduce the heat load transferred into the building; as a result, it reduces the air system's energy consumption by 5-7%.

Model 3-Group 3 (a)

Opaque
Wall-02
Glass
Win-02R,
WWR 50%
Roof: Roof-02R

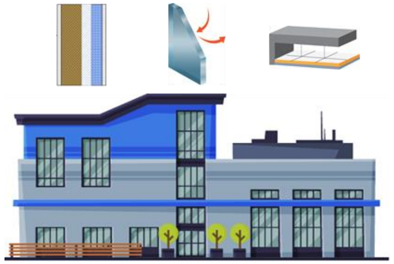


Group 3 OTTV 32.12 W/m^2
RTTV 2.60 W/m^2

If the wall is concrete and the glass is 8 mm reflective glass at 50% WWR and the building wall color will be light color or heat-reflective color. Although it cannot pass the OTTV threshold of ≤ 30 W/m^2, it could reduce the heat load into the building by 5%.

Model 3-Group 3 (b)

Opaque
Wall-02R
Glass
Win-02R,
WWR 50%
Roof: Roof-02R

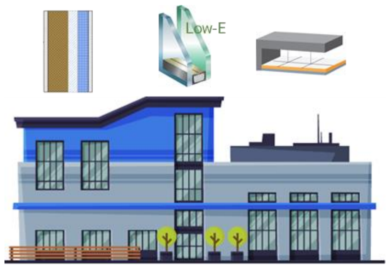


Group 3 OTTV 22.91 W/m^2
RTTV 2.60 W/m^2

Changing to a reflective glass 8 mm with 50% WWR, adding insulation on concrete wall and top ceiling roof, light color. It will result in OTTV passing the threshold of ≤ 30 W/m^2, thereby reducing the heat load entering the building by 6%.

Model 3-Group 3 (c)

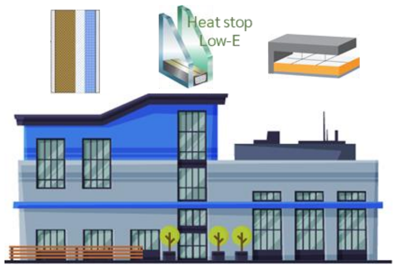
Opaque
Wall-02R
Glass
Win-03R,
WWR 50%
Roof: Roof-02R



Group 3 OTTV 20.05 W/m^2
RTTV 2.60 W/m^2

Model 3-Group 3 (d)

Opaque
Wall-02R
Glass
Win-04R,
WWR 50%
Roof: Roof-03R

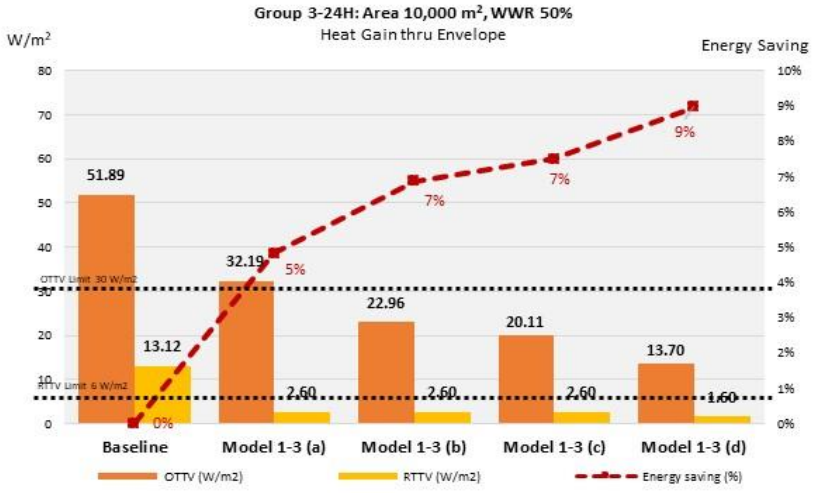


Group 3 OTTV 13.66 W/m^2
RTTV 1.60 W/m^2

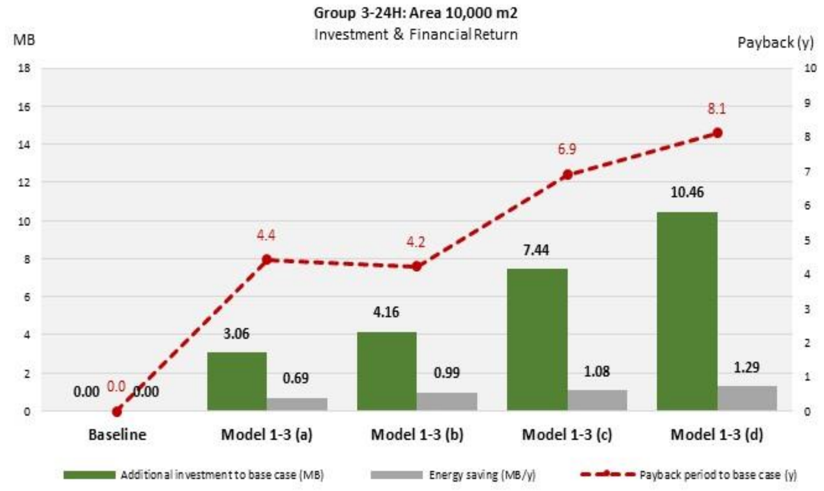
Adding insulation on a concrete wall and top ceiling roof and changing to a more high-efficiency glass of Double glazing Low-E 6-12-6 mm or Double Glass Heat Stop Low-E 24 mm will pass the HEB standard at OTTV ≤ 25 W/m^2. However, it will reduce the heat load entering the building by 6-7% compared to the baseline scenario.

Model 3 (Group 3) - Energy Saving Potential

Energy saving potential



Financial return on investment



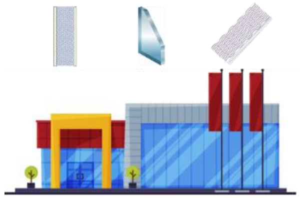
For low-rise building Model 3 Group 3, it also should consider adding insulation to the rooftop, using an insulated concrete or lightweight concrete wall with a reflective glass of at least 8 mm thickness; to meet the BEC minimum requirements.
However, changing to a more high-efficiency glass, e.g., double glazing low-E or higher efficiency, may be unsuitable and not attractive because of low return on investment.

Model 4 (Group 1)

Group 1 – 8 Hr/day

Baseline

Opaque
Wall-03R
Window Glass
Win-01R,
WWR 50%
Roof: Metal Roof-04R



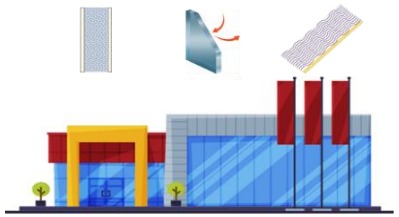
Group 1 OTTV 88.72 W/m^2
RTTV 157.35 W/m^2

Baseline Model 4 is assumed to be a 2-story low-rise rectangular building, 50 x 100 m. It is a typical design of small and medium modern trade. Materials used with opaque wall with a lightweight concrete wall, transparent, green float glass with 50% WWR ratio, and the roof is a metal sheet without insulation.

The buildings that use uninsulated metal sheets have a very high heat transfer through the roof.

Model 4-Group 1 (a)

Opaque
Wall-03R
Glass: Win-02R,
WWR 50%
Roof: Metal Roof-05R

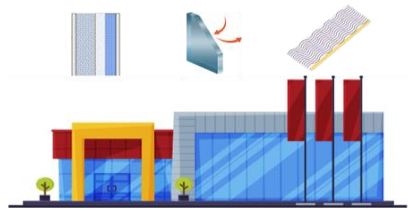


Group 1 OTTV 52.95 W/m^2
RTTV 6.15 W/m^2

If PU insulation is added to the roof and painted with reflective color paint, the building could be meet the RTTV threshold level at ≤ 10 W/m^2. Although it cannot pass the OTTV threshold of ≤ 50 W/m^2, lightweight concrete walls without insulation and reflective color paint could reduce the heat load into the building by 37%.

Model 4-Group 1 (b)

Opaque
Wall-04R
Glass: Win-02R,
WWR 50%
Roof
Metal Roof-05R

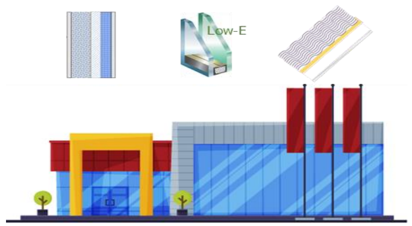


Group 1 OTTV 47.31 W/m^2
RTTV 6.15 W/m^2

If using lightweight concrete with insulation, and added insulation on the roof and painted with reflective color paint, the OTTV value can meet a threshold of ≤ 50 W/m^2, and meet RTTV ≤ 10 W/m^2, and could reduce that heat load to buildings by 38%.

Model 4-Group 1 (c)

Opaque
Wall-04R
Glass: Win-03R,
WWR 50%
Roof: Metal Roof-06R

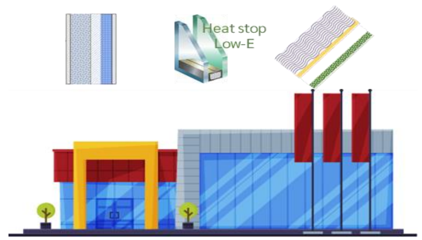


Group 1 OTTV 43.79 W/m^2
RTTV 5.09 W/m^2

Changing to a double glazing Low-E 6-12-6 mm and add insulation on a lightweight concrete wall and PU insulation on top ceiling roof. It will result to pass BEC threshold of OTTV≤50 W/m^2, and RTTV≤10 W/m^2, thereby reducing the heat load entering the building by 38%.

Model 4-Group 1 (d)

Opaque
Wall-04R
Glass: Win-04R,
WWR 50%
Roof: Metal Roof-07R

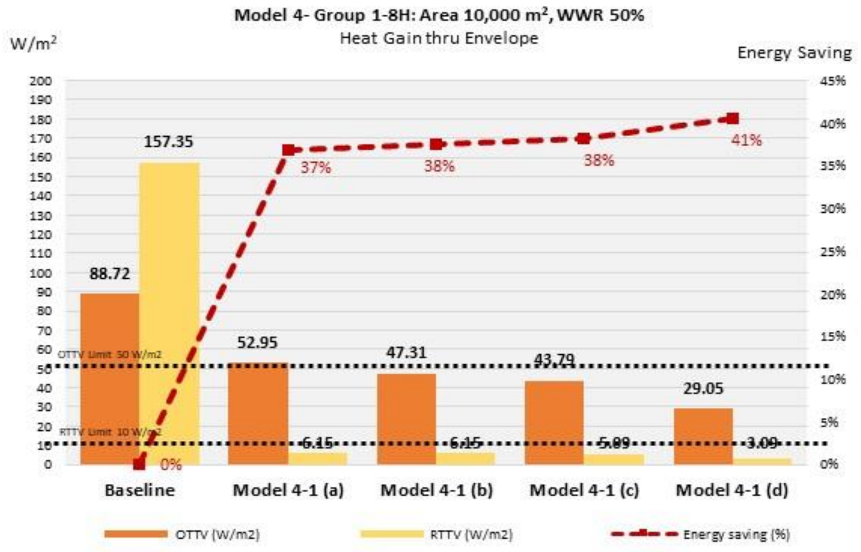


Group 1 OTTV 29.05 W/m^2
RTTV 3.09 W/m^2

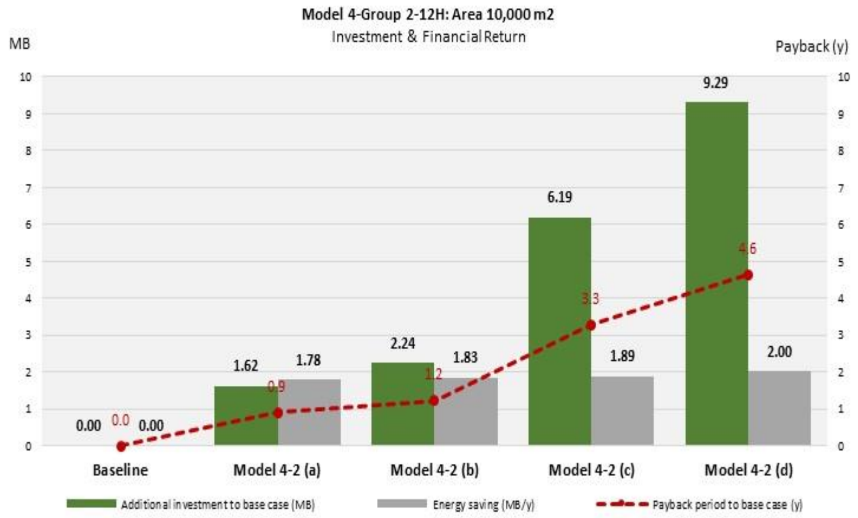
Changing to a double glazing Low-E 6-12-6 mm and add insulation on concrete wall and top ceiling roof. It will result to pass HEP standard of ≤30 W/m^2, and RTTV≤10 W/m^2, thereby reducing the heat load entering the building by 41%.

Model 4 (Group 1) - Energy Saving Potential

Energy saving potential



Financial return on investment



For low buildings with lightweight concrete walls and uninsulated metal sheet roofs, heat through the top ceiling accounts for >35% of the total amount of heat transferred through the entire building envelope. Adding insulation to the rooftop should be emphasized first; to reduce the heat transferred from the roof as much as possible. It also should consider using an insulated concrete or lightweight concrete wall to meet the BEC minimum requirements. By an estimate, improving the efficiency of OTTV and RTTV to reduce the amount of heat transfer through the building envelope will result in air conditioner cooling load reduction of around 37-38%, equal to approximately potential energy saving of 1.78-1.83 million baht/year. The additional incremental cost is about 162-244 baht/sqm. The payback period does not exceed 1.5 years. However, changing to a more high-efficiency glass, e.g., double glazing low-E or higher efficiency, may be unsuitable and not attractive because of low return on investment.

Model 4 (Group 2)

Group 2 – 12 Hr/day

Baseline

Opaque

Wall-03R

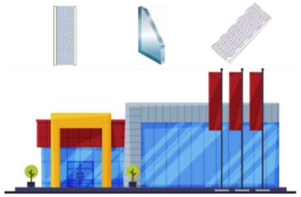
Window Glass

Win-01R,

WWR 50%

Roof

Metal Roof-04R



Group 2 OTTV 68.32 W/m^2

RTTV 104.48 W/m^2

Baseline building material is assumed to be the same as Model 4 -Group 1, the materials used are combination of plastered concrete wall, transparent green-float glass with 50% WWR ratio, and a concrete roof and gypsum board ceiling without insulation.

Model 4-Group 2 (a)

Opaque

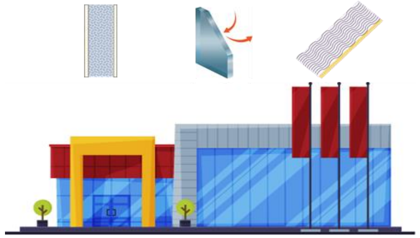
Wall-03R

Glass: Win-02R,

WWR 50%

Roof: Metal

Roof-05R



Group 2 OTTV 42.28 W/m^2

RTTV 4.37 W/m^2

If PU insulation is added to the roof and painted with reflective color paint, the building could be meet the RTTV threshold level at ≤ 8 W/m^2. Although it cannot pass the OTTV threshold of ≤ 40 W/m^2, lightweight concrete walls without insulation and reflective color paint could reduce the heat load into the building by 25%.

Model 4-Group 2 (b)

Opaque

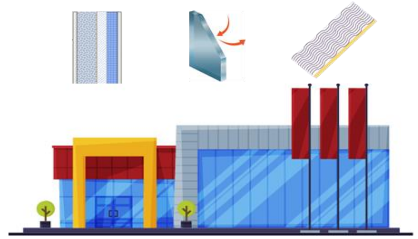
Wall-04R

Glass: Win-02R,

WWR 50%

Roof: Metal

Roof-05R



Group 2 OTTV 37.34 W/m^2

RTTV 4.37 W/m^2

If using lightweight concrete with insulation, and added insulation on the roof and painted with reflective color paint, the OTTV value can meet a threshold of ≤ 40 W/m2, and meet RTTV ≤ 8 W/m2, and could reduce that heat load to buildings by 25%.

Model 4-Group 2 (c)

Opaque

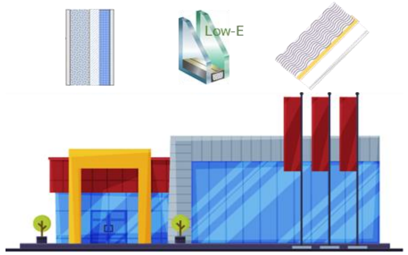
Wall-04R

Glass: Win-03R,

WWR 50%

Roof"Metal

Roof-06R



Group 2 OTTV 32.49 W/m^2

RTTV 3.74 W/m^2

Changing to a double glazing Low-E 6-12-6 mm and add insulation on a lightweight concrete wall and PU insulation on top ceiling roof. It will result to pass BEC threshold of OTTV≤40 W/m2, and RTTV≤8 W/m2, thereby reducing the heat load entering the building by 26%.

Model 4-Group 2 (d)

Opaque

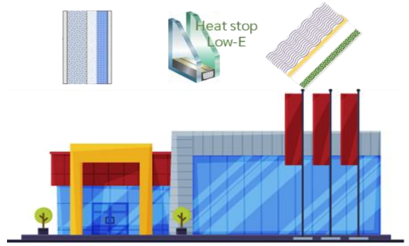
Wall-04R

Glass: Win-04R,

WWR 50%

Roof: Metal

Roof-07R



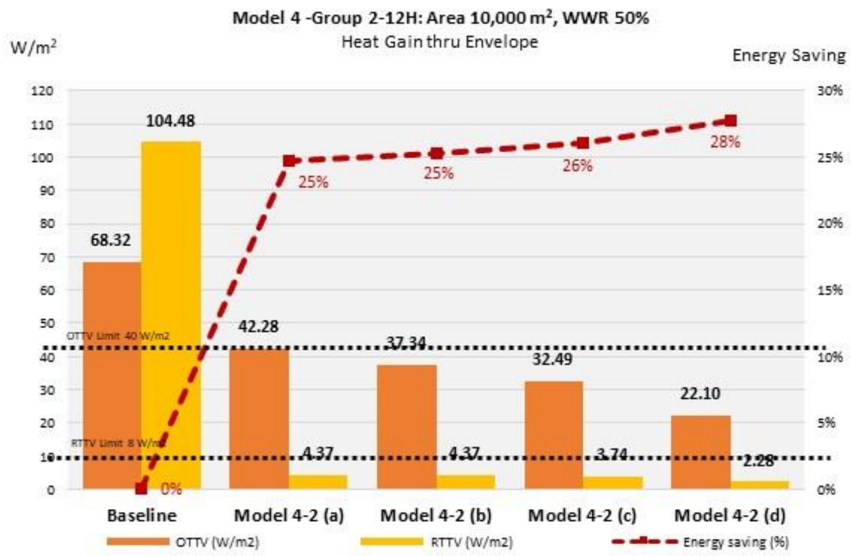
Group 2 OTTV 22.10 W/m^2

RTTV 2.28 W/m^2

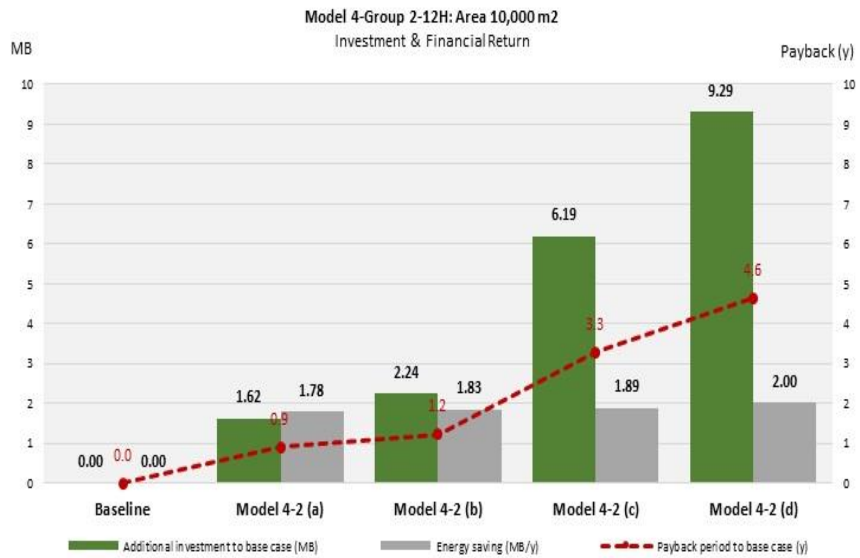
Changing to a double glazing Low-E 6-12-6 mm and add insulation on concrete wall and top ceiling roof. It will result to pass HEP standard of ≤25 W/m^2, thereby reducing the heat load entering the building by 41%.

Model 4 (Group 2) - Energy Saving Potential

Energy saving potential



Financial return on investment



For low-rise building Model 4 Group 2, it also should consider adding insulation to the rooftop, using an insulated concrete or lightweight concrete wall with a reflective glass of at least 8 mm thickness; to meet the BEC minimum requirements. By an estimate, improving the efficiency of OTTV and RTTV to reduce the amount of heat transfer through the building envelope will result in air conditioners cooling load reduction by 25%, equal to approximately potential energy saving of 1.78-1.83 million baht/year. The additional incremental cost is about 162-244 baht/sqm. The payback period does not exceed 1.5 years. However, changing to a more high-efficiency glass, e.g., double glazing low-E or higher efficiency, may be unsuitable and not attractive because of low return on investment.

Model 4 (Group 3)

Group 3 – 24 Hr/day

Baseline

Opaque

Wall-03R

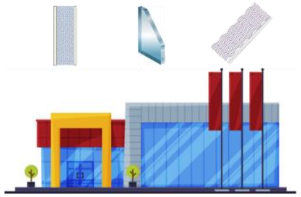
Window Glass

Win-01R,

WWR 50%

Roof: Metal

Roof-04R



Group 3 OTTV 41.48 W/m^2

RTTV 64.56 W/m^2

The baseline is assumed to be the same Model 4-Group 1 and Group 2.

Despite working 24 hours a day, the air conditioning system's workload from the heat transferred through the building envelope will be more effective during the day than at night.

Model 4-Group 3 (a)

Opaque

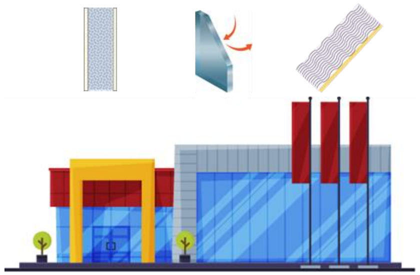
Wall-03R

Glass: Win-02R,

WWR 50%

Roof: Metal

Roof-05R



Group 3 OTTV 25.49 W/m^2

RTTV 2.69 W/m^2

If PU insulation is added to the roof and painted with reflective color paint, the building could be meet the RTTV threshold level at ≤ 6 W/m2. Although it cannot pass the OTTV threshold of ≤ 30 W/m2, lightweight concrete walls without insulation and reflective color paint could reduce the heat load into the building by 15%.

Model 4-Group 3 (b)

Opaque

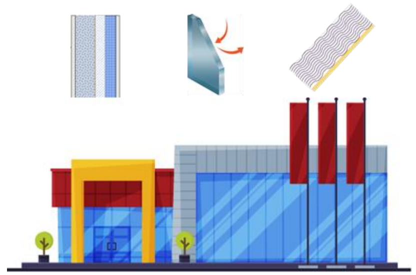
Wall-04R

Glass: Win-02R,

WWR 50%

Roof: Metal

Roof-05R



Group 3 OTTV 22.70 W/m^2

RTTV 2.69 W/m^2

If using lightweight concrete with insulation, and added insulation on the roof and painted with reflective color paint, the OTTV value can meet a threshold of ≤ 30 W/m2, and meet RTTV ≤ 6 W/m2, and could reduce that heat load to buildings by 16%.

Model 4-Group 3 (c)

Opaque

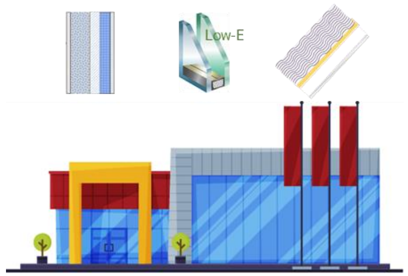
Wall-04R

Glass: Win-03R,

WWR 50%

Roof: Metal

Roof-06R



Group 3 OTTV 19.84 W/m^2

RTTV 2.26 W/m^2

Model 4-Group 3 (d)

Opaque

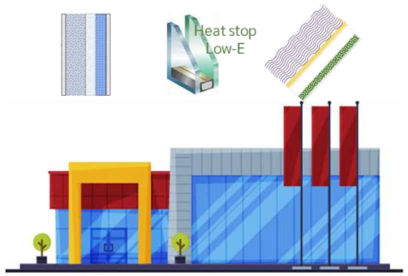
Wall-04R

Glass: Win-04R,

WWR 50%

Roof: Metal

Roof-07R



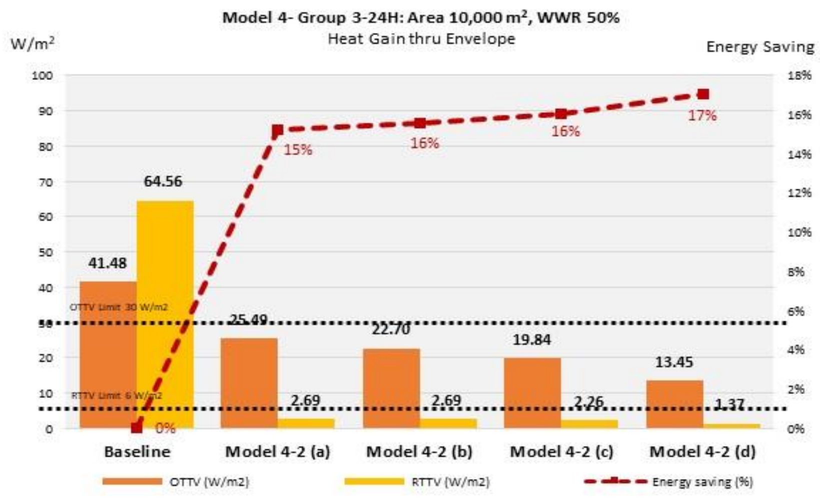
Group 3 OTTV 13.45 W/m^2

RTTV 1.37 W/m^2

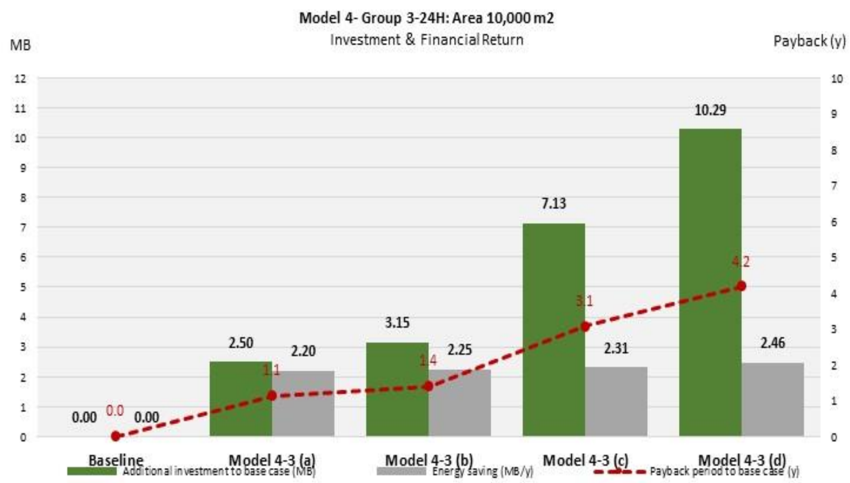
Adding insulation on a concrete wall and top ceiling roof and changing to a more high-efficiency glass, e.g., Double glazing Low-E 6-12-6 mm or Double Glass Heat Stop Low-E 24 mm, will pass the HEB standard at OTTV ≤ 25 W/m2. However, it will reduce the heat load entering the building by 16-17% compared to the baseline scenario.

Model 4 (Grouup 3) – Energy Saving Potential

Energy saving potential



Financial return on investment



For low-rise building Model 4 Group 3, adding insulation to the rooftop, using an insulated concrete or lightweight concrete wall with a reflective glass of at least 8 mm thickness; to meet the BEC minimum requirements. By an estimate, improving the efficiency of OTTV and RTTV to reduce the amount of heat transfer through the building envelope will result in air conditioners cooling load reduction by 15-16%, equal to approximately potential energy saving of 2.20-3.15 million baht/year. The additional incremental cost is about 250-315 baht/sqm. The payback period does not exceed 1.5 years. However, changing to a more high-efficiency glass, e.g., double glazing low-E or higher efficiency, may be unsuitable and not attractive because of low return on investment.

Conclusions

Although the BEC regulation allows, to pass BEC standard with only Option 2 whole building energy performance criteria is not the best option. Based on the statistics, designing a building to meet each system's minimum energy efficiency (BEC) criteria is not an impossibility. It can be achieved by using the technology and building materials continuously developed and are commercially available.

Most building developers/owners often focus on investing in high-efficiency types of equipment to reduce power consumption, e.g., use of high-efficiency air conditioner or lighting system. But does not pay much attention to designing with efficient performance building envelope to reduce the amount of heat transferred into the building, which is the main contributor to the cooling load of the building. As a result, facilities still need a lot of energy for air conditioning.

A good building design is critical for the overall building energy performance. It is not impossible to design a building to meet the OTTV and RTTV criteria according to the minimum energy efficiency BEC standards. Designing buildings to meet good energy efficiency standards, excellent functionality, and outstanding architectural design from the beginning will produce better results. The design should consider the internal and external factors that affect the external heat transfer through the building envelope, and use highly efficient technology and building materials that have been developed and commercially available.

Although some high-performance technologies may require a higher investment cost today, when technology becomes more commercially available and adopted, the price trend will be inevitably decrease. It will make investing in those technologies more attractive and worthwhile.

Glossary

BEC	Building Energy Code
COP	Coefficient of Performance
LPD	Lighting Power Density
OTTV	Overall Thermal Transfer Value (W/m^2)
RTTV	Roof Thermal Transfer Value (W/m^2)
SC	Shading Coefficient
SEER	Seasonal Cooling Energy Efficiency Ratio
SHGC	Solar Heat Gain Coefficient
U	Thermal conductivity of material (W/m^2 K)
VT	Visible Transmittance
WWR	Window-to-Wall Ratio