MINISTRY OF CONSTRUCTION

ENERGY EFFICIENT BUILDINGS

TRAINING MANUAL ON STRENGTHENING CAPACITY ON DESIGN, CONSTRUCTION, ACCEPTANCE AND ENERGY MANAGEMENT

HANOI, SEPTEMBER 2021

Project on Energy Efficiency Improvement in the Commercial and High-Rise Residential Buildings in Viet Nam

Notice

This training manual was developed by Project on Energy Efficiency Improvement in the Commercial and High-Rise Residential Buildings in Viet Nam whithin the cooperation framework between the Ministry of Construction (MOC) and the United Nations Development Programme (UNDP) funded by Global Enviroment Facilities (GEF). The instructions and recommendations in this manual not to be taken to represent the views of MOC and UNDP.

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PREFACE

The National Technical Regulation on Energy Efficiency Buildings (QCVN 09:2017/BXD) regulated the technical requirements that must be complied in designs, new buildings and renovated buildings with a gross floor area of 2,500m2 or larger, it belongs to all kinds or a mixture of office buildings, hotels, hospitals, schools, commercial services and apartments.

*In order to enhance the capacity of effective implementation QCVN 09:2017/BXD and further widespread knowledge on energy efficiency buildings and the document "**Energy Efficiency Buildings. Training manual on strengthening capacity on design, construction, acceptance and energy management**" not only provide guidelines on the application of QCVN 09:2017/BXD, design solutions that meet requirements of the code, but also introduce the solutions that exceed the requirements of the code, financial analysis methods to select design options, construction works, acceptances and energy managements, examples of reality. This document can be used for reference to the investment construction project development, design, design verification, construction, inspection and acceptance of new buildings or retrofit existing buildings, energy management of buildings.*

This document has been compiled with the support of the Project "Energy Efficiency Improvement in Commercial and High-rise Residential Buildings in Viet Nam" (EECB project) within the cooperation framework between the Ministry of Construction and The United Nations Development Program (UNDP) with fundings of the Global Environmental Facility (GEF) and co-financed by Vietnamese agencies/organizations and businesses.

The document is compiled with the participation of authors from the universities, green building consultancy organizations, and energy efficiency of buildings. The process of compiling documents cannot avoid shortcomings. We look forward to receiving your feedbacks and suggestions. All comments should be sent to the Department of Science, Technology and Environment, Ministry of Construction and United Nations Development Program (UNDP).

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ABBREVIATIONS

AC	*Air-Condition*
ACH	*Air Change per Hour*
AHU	*Air Handling Unit*
Albedo	*Solar Reflectivity – SR*
AMCA	*Air Movement and Control Association*
ANSI	*American National Standards Institute*
ASHRAE	*American Society of Heating, Refrigerating and Air Conditioning Engineers*
BMS	*Building Management System*
COP	*Coefficient of Performance*
DSF	*Double skin façade*
EEBC	*Energy Efficient Building Code*
EECB Project	*The Project on Energy Efficiency Improvement in Commercial and High-Rise Residential Buildings in Viet Nam*
ET	*Thermal Efficiency*
FEG	*Fan Efficiency Grade*
HVAC	*Heating, Ventilation and Air Conditioning*
IRR	*Internal Rate of Return*
LCC	*Life-Cycle Cost*
LCCA	*Life Cycle Cost Analysis*
MEP	*Mechanical, Electric, and Plumping*
MOC/BXD	*Ministry of Construction*
NAV	*Net Annual Value*
NFV	*Net Future Value*
NPV	*Net Present Value*
NPW	*Net Present Worth*
OTTV	*Overall Thermal Transfer Value*
OTTVM	*Roof Overall Thermal Transfer Value*
OTTVT	*Wall Overall Thermal Transfer Value*
QCVN09:2017/BXD	*National Technical Regulations on Energy Efficiency Buildings*

R_0	*Thermal Resistance*
SC	*Shading Coefficient*
SHGC	*Solar Heat Gain Coefficient*
SL	*Stanby Loss*
SR	*Solar reflectance*
SRI	*Solar reflectance index*
TOR	*Terms of Reference*
TT-BXD	*MOC – Circular*
U_0	*Thermal Transmittance*
VAV	*Variable Air Volume*
VLT	*Visible Light Transmission*
VRF	*Variable refrigeration flow*
WWR	*Window-to-wall ratio*
UNDP	*United Nations Development Programme*
VAV	*Variable Air Volume*
VLT	*Visible Light Transmission*
VRF	*Variable refrigeration flow*
WWR	*Window-to-wall ratio*

[1] *https://www.sciencedirect.com/topics/engineering/solar-reflectance*

Chapter 01 APPROACH

1. INTERGRATED ENERGY DESIGN

Integrated energy design is a term used for the application of the integrated design approach to construction projects with the aim of optimizing a building's energy efficiency. The integrated energy design is carried out by a project team of architects, engineers,project owner, contractors(if any), project management consultant and operators (herein after called project team). This team will work together from the beginning of the project to set goals and effectively implement the proposed solutions.

The integrated energy design process consists of 7 steps as follows:

- **Step 1:** Make the commitment
- **Step 2:** Identify energy saving potentials
- **Step 3:** Set goals and propose energy-efficient design solutions
- **Step 4:** Identify and coordinate interactionsbased on rules
- **Step 5:** Analyze and evaluate the solutionon the overall impact on the project
- **Step 6:** Make a decision based on the life cycle cost of the project
- **Step 7:** Complete the process

Figure 0.1.Components of the project team by integrated design method

Step 1: Making commitments

The implementation of the integrated energy design process needs to start with the commitment of the investor with specific goals and tasks on the energy efficiency of the building discussed and proposed by the stakeholders to ensure that it is suitable to the capacity and conditions of the project and has high feasibility. These commitments need to be specified in the design tasks and construction investment projects and must be considered and implemented by the project team as soon as possible, often applied right from the concept design stage.

Step 2: Identifying potential energy savings

Each building type, such as office, school, retail, residence…has its own operational characteristics. Therefore, the project team needs as early as possible to collect energy-

using data of those buildings that relevant to the building will be designed for conducting analysis in order to identify the appropriate energy saving potentials.The graphs in Figure 1.2 below show differences in energy use between commercial and residential buildings in Singapore. In commercial buildings, energy is used primarily to operate the air conditioning system (accounting for 52% of the total), followed by the office and other equipments (25%), lighting (12%) and elevators (7%). Meanwhile, in residential buildings, the energy use concentrated in air conditioning system (30%), followed by the refrigerator (17%), lighting equipments, television and water heater are the same (9-10%). These are the key items needed to be focusing, considering to achieve the energy saving solutions for each type of buildings.

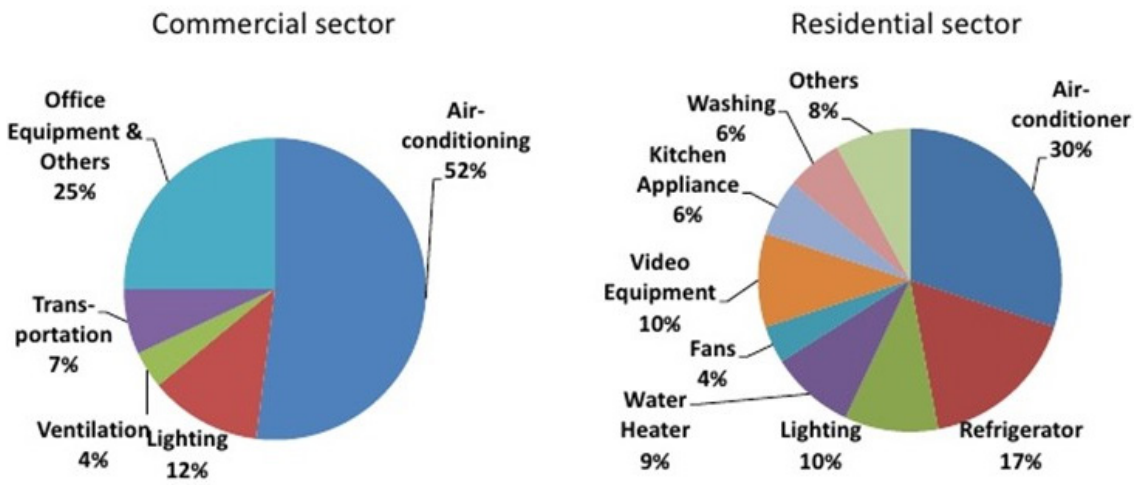


Figure 0.2. Detailed data on energy use of commercial buildings (left) and residential building (right) in Singapore in 2006[2]

In addition, the project team can also get inspiration from existing energy-efficient buildings with similarities in terms of scale and usage to understand energy saving solutions applied whether it reach or beyond QCVN09:2017/BXD requirements. However, it should be noted that the conditions of the external environment such as solar radiation, temperature, humidity, wind speed... are often different between locations due to the impact of surrounding buildings/environment that influence actual operations of the building.

Step 3: Defining goals for energy efficient design

At this step, the investorand the project team need discussing to identify specific energy saving goals toenable the overall achievement of goals as committed in Step 1. These objectives will often have to be higher than the requirements of current national design standards and regulations and must be quantifiable to serve as a basis for calculation and proposal of appropriate technical solutions.

[2] *Source: Office Building Energy Saving Potential in Singapore, Cui Qi, 2006; E2 Singapore, NEA, 2010*

Example: energy efficiency goals for a building envelope can be defined as follows:

- Window to wall ratio (WWR) of North and South façade: smaller than 50%

- Window to wall ratio (WWR) of East and West façade: smaller than 30%

- Solar heat gain coefficient (SHGC) of the glazing: smaller than 0.4 (possible to use shading devices)

- Thermal conductance (Uv) of the glazing: smaller than 1.6 W/m2.K,

- Thermal conductance (Uv) of the wall: smaller than 1 W/m2.K

- Thermal conductance (Uv) of the roof: smaller than 0.5 W/m2.K

Energy efficiency strategies proposed should focus on technical solutions that offer dual benefits. For example, LED lighting systems can achieve higher energy efficiency than fluorescent or incandescent lamps ...and they also have lower amount of heat radiating from the device into the space of use will help reduce the needed cooling capacity and operating costs of the air conditioning system. Similarly, the use of rooftop solar panels can both generate electricity and reduce heat radiation entering the building through the roof.It can also help reduce the cooling load of the air conditioning system and maintain better comfortable conditions especially in the attic.

Step 4: Coordinate project members to find integrative solutions

After establishing the goals, regular collaboration (often in the form of meetings) on professional contents between the members of the project team with investor and other stakeholders is important that conducive to the success of energy-saving solutions implementation.

As presented above, in the conventional design process, professionals like architects, structural engineers, MEP engineers, quantity surveyor... often work independently, propose solutions based on their own perspective, with limited discussion with other members especially the building's operator feedbacks. Therefore, the proposals are often not always the best option for both implementation and investment.

Step 5: Analyze and evaluate the solution on the overall impact on the project

During the design, construction and operation of the buildings, technical factors are often interrelated and influence each other, therefore, it is required that the project team carry out a review and analysis of the problem based on the level of impact on the overall project instead of a local assessment.The project team can use energy simulation software to support the analysis, compare and select optimal solutions.For example, the selection of glazing used toreduce thermal radiation transmission through the building envelope may affect the level of daylighting entering the building and external views. Therefore it is necessary to assess impacts in terms of the energy efficiency and occupant comfort... before making a decision.

Step 6: Make a decision based on the life cycle cost of the project

For each proposed solution, the project owner and project team needs to analyze and evaluate impacts and profitability based on the building life cycle cost, as a simple pay-back time period analysis does not always fully consider all related costs and benefits.

Step 7: Complete the process

Integrated design needs to be implemented from the beginning of the project and continues on the next stages of design, construction, acceptance and handover.

At each stage, integrated design is an iterative process of problem analysis, proposed solutions, evaluation & performance comparison of alternatives at building local and global levels to select the optimal solution, towards the set goals.

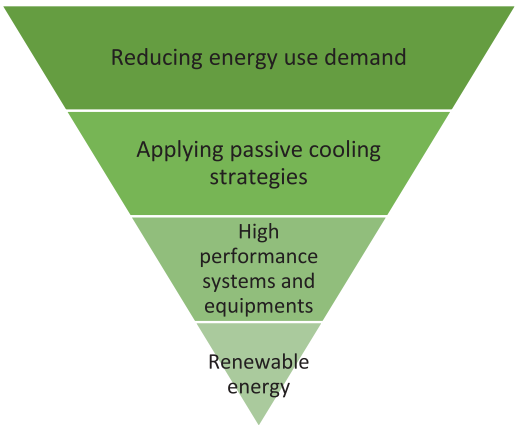


Figure 1.3. Ordered steps of the energy efficient building design approach

2. ENERGY EFFICIENT BUILDING DESIGN APPROACH

Following the integrated design process, in order to achieve the energy efficient building, the design should be approached as follows:

- Reduce energy demand
- Apply passive cooling solutions
- Use high-performance technical systems and equipment
- Use renewable energy

2.1. Reduce the energy demand

Reducing the energy demand of the building means to reduce the need of cooling load for the air-conditioning& ventilation system as well as the need to use lighting system and other electrical equipment.In order to achieve the goal of reducing cooling load for the building, architectural design plays a very important role. Optimizing architectural solutions towards passive design needs to start from studying the conditions of the external environment to propose appropriate solutions for the building's orientation, shape, envelope and layout of functional spaces to ensure a good ventilation and natural lighting for the inside.

The building envelope which consists of components in direct contact with the external environment such as walls, windows or glazing walls, floors (contact with the ground) and the roof should be designed using proper insulation materials to prevent heat transfer. In

addition, the design team should pay attention to potential shading solutions for windows and glazing walls that are adapted to each orientation in order to limit the solar radiation transmitted inside the building. With shading devices, the building can use popular glazing materials with reasonable price instead of having to use special and more expensive ones of low solar heat gain coefficient. This is to be considered as a solution that helps optimize investment costs.

For lighting systems, in order to reduce the electric load, beside the maximized use of daylighting, it is possible to consider adjusting the ambient lighting's intensity for occupied spaces. For example, today's offices mainly use computers, so it can be considered to adjust the general background brightness for the entire office space at a reasonable level for these activities. In case some areas need higher light intensity, additional lighting equipment such as desk lamps can be used. Reducing the ambient lighting brightness helps to save not only initial investment costs but also the cost to operate the lighting system in the future.

2.2. Apply passive cooling strategies

For tropical climate countries like Vietnam, in summer when the weather allows, it is possible to take advantage of using natural wind to ventilate and cool occupied spaces inside the building. The design of operable windows or glazing walls connected to the internal corridors and atriums can help to promote the ventilation. In addition, to enhance the level of ventilation, it is possible to use electric fans such as ceiling or wall-mounted fans as these devices consume less energy and usage space. The passive cooling methods will help to reduce significantly the need for air conditioning and ventilation systems in civil construction.

2.3. Using high performance systems and equipment

During the design phase, the suitable proposal, high-performance technological solutions for the engineering systems of the building (air conditioning, ventilation, lighting, etc.) should be requested by the investor, the design team and thorough researching and evaluation by stakeholders to ensure the best possible energy efficient operation. It should also be noted that new technology solutions often come with high costs because these solutions are not yet popular in the market, so it is necessary to have cost analysis and payback period calculation before making investment decisions.

For example, for an air conditioning system, it will be necessary to consider the Coefficient of Performance (COP) of the equipment, which is calculated as the cooling capacity per electrical capacity (unit: kW/kW). For large central airconditioning systems (also known as chiller systems), the integrated part-load value (IPLV) is also considered as an alternative to assess the performance, because most of the time the system is operating below its maximum power capacity, so the COP can not accurately reflect the performance of the system in practice.

Similarly, for lighting systems, when selecting a device, it is necessary to pay attention to the brightness (luminous flux) on the electrical power of the device (lm/w). A High value means that the equipment is highly energy efficient.

For hot water supply, the project team should consider selecting heat pumps or solar energy devices, as these technologies have better energy performance and are also more environmentally friendly compare to traditional technology such as electric resistance, gas, etc. fired ones...

In addition, this equipment can also be connected to individual sensors or connected to building management system (BMS) for monitoring. From real time measurement data reported by BMS, building operators can really detect problems of systems and equipment and then adjust t operational status to better and faster fit with the need of each occupied spaces.

Other electrical equipment such as computers, office equipment, household equipment... should also be taken into account for the energy efficiency of operations. In Vietnam, the Government and Ministry of Industry and Trade has recently issued regulations on energy labeling to help consumers assessing the energy consumption and EE of electric devices to make more appropriate choices.

2.4. Use renewable energy

Renewable energy sources help produce "clean" energy or, in other words, have little impact on the environment due to the exploitation of available natural conditions such as wind energy, solar energy, thermal energy, biomass energy etc. However, due to the early of the development, the costs for installing renewable energy systems in fact are still relatively high. Thus, in order to promote the application of renewable energy, it is needed to benefit from governmental supporting policies in terms of technique and financing for manufacturers, investors and end-users.

The most popular renewable energy's applications for buildings are solar energy including solar rooftop photovoltaic (PV) and solar water heater. These systems are suitable for exploitation in hot and humid weather conditions, especially in the central and southern regions of Vietnam. However, up to now, the contribution's level of renewable energy to building's total energy demand is still low, averagely accounting for only about 2-3%. Several building types such as schools, factories, etc. have a large potential for using solar PV, solar hotwater systems because of their large available surface and relatively low ration GFA/ building height. The system can be installed on the roof, canopy of outdoor playgrounds or even parking area. Besides, the location and direction of solar panels should be carefully considered before installation to maximize the performance of the system. Surrounding buildings also may have significantly impact to the electricity production when providing shading for hours.

The energy efficient design approach is now being applied widely for high-performance, green building projects...to optimize both the energy performance and investment costs. In summary, optimizing the energy use should start from energy demand's reduction within building.

Afterwards high-performance systems & equipment and then renewable energy shall then be planned appropriately depending on particular project technical and economic conditions.

3. ENERGY SIMULATION SOFTWARE TO SUPPORT INTEGRATED DESIGN PROCESS

3.1. Introduction of the energy simulation software

The design of energy efficient buildings is mainly based on energy use parameters in order to be able to calculate, analyze and propose appropriate solutions. Therefore, the project team should consider of using simulation softwares to support their design work. Today, thank to the development of computer technology, building energy simulation softwares have a number of significant improvements of both functionality as well as the calculation's accuracy.

Energy simulation software basically consist of 3 main parts:

- ***User interface:*** allow user to input data for the model. The information includes weather data, building form, building materials, MEP systems, number of occupants, operational schedules for occupied spaces.

- ***Calculation engine:*** to perform the simulation based on input data to calculate the estimated energy consumption and other. The calculation engine is the most important part and need to be tested for calculation's accuracy before using. Some popular energy calculation engines are DOE-2, Energyplus, Apache…

- ***Graphics, reports:*** simulation results can be displayed in the form of charts or reports including information on the use of energy for every occupied space and the entire building for 1 year period. This information can also be broken down in more details, in terms of day, week, month depending on the purpose of the analysis. Other output parameters such as user's comforts, the operation of spaces and equipment are described in detail in reports.

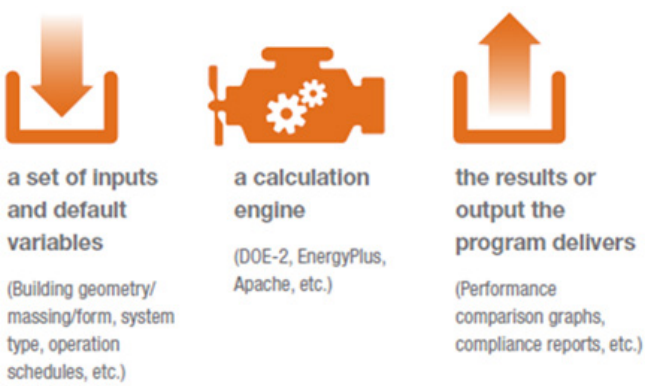


Figure 1.4. The main functions of energy simulation software[3]

[3] *Source: An Architect's Guide to Integrating Energy Modeling in the Design Process*

Energy simulation software can be classified as free-to-use or paid software. The free-to-use software are developed by research organizations and universities with the purpose of widely promoting the application of energy simulation for research, training and consulting on energy efficiency for construction works, thereby bringing benefits to the community. The most commonly free-to-use softwares today are Openstudio, Equest. The disadvantages of these softwares are slow upgrading features as well as fixing bugs, and the interface is also not really user-friendly. Commercial software, on the other hand, are developed by software companies that aim at improving limitations of free software. The most popular commercial energy simulation softwares today are Designbuilder, IES-VE ... The biggest barrier for the wide usage of these softwares is that users will have to pay a perpetual license or an annual subscription based on the time of use. The license fees of commercial softwares are still relatively high compared to the average income of Vietnamese that somehow limits access to the software, particularly from students, lecturers of universities and small and medium-sized consulting firms.

Creating and editing the building geometry function is still limited with energy simulation softwares. Therefore, some softwares allow users to import models from other softwares such as Sketchup, Rhino and BIM software (ARCHICAD, Revit...). In addition to the ability to perform energy simulations, some commercial software such as Designbuilder, IES-VE, etc. also integrate other important features such as Sun path, Daylighting simulation, Computational fluid dynamic (CFD) simulation, Building Energy Optimization analysis, Cost analysis, Green Building certification (LEED, LOTUS),thereby helping the design team to fully evaluate the building's performance, occupant comforts and efficiency of investment while avoiding the troubles that can be encountered when using many different software to perform these jobs seperately.

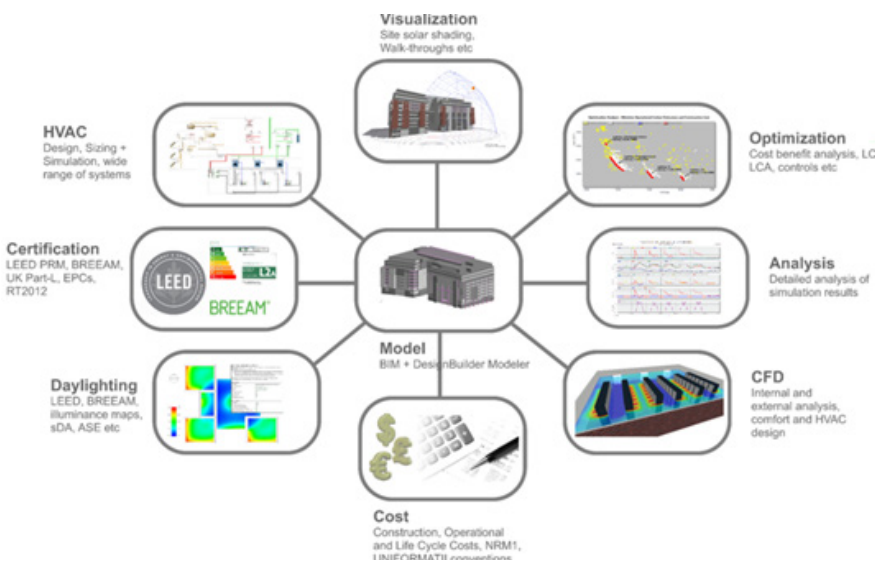


Figure 1.5. Features included in Designbuilder software[4]

[4] *Source: Designbuilder Vietnam*

3.2. Energy modelling

The energy modelling is a virtual or computerized simulation of a building focusing on energy use analysis, estimating green house gas emissions, utility bills and life cycle costs of alternative energy systems to determine the most efficient design.

Before conducting energy simulation, the project team needs to define scenarios with specific information for the building operation. The following models are often used:

- ***Designed model:*** is the model that describe exactly the current design of the building from the architecture shape, space arrangement, building materials, building service systems, operational schedules, occupant's number in each space, etc.

- ***Business as usual (BAU) model:*** is the model that has similar architecture shape, space arrangement, operation schedule and occupant's number of the design. However, the building materials, MEP systems (including equipment's specifications) may different as they represent the popular use in the market for similar building type, size and construction costs.

- ***Baseline model:*** baseline model can be difined differently for different analyzing purposes. In the case of energy efficient design the baseline model is the model that has similar architecture shape, space arrangement, operation schedule and occupant's number of the design. The building materials, MEP systems (including equipment's specifications) are extracted from the current Energy Efficient Building Codes and related standards.

- ***Proposed model:*** is the model that has similar architecture shape, space arrangement, operation schedule and occupant's number of the design. The building materials, MEP systems (including equipment's specifications) are proposed by the architects and engineers in order to achieve the goals of energy efficiency and cost optimization.

Among above models, the first three models usually do not have big changes in input parameters during the implementation of simulation, analysis and solution proposal. The proposed model, on the other hand, will often be adjusted in accordance to scenarios defined by the project team to enable comparison and find the optimal solution. For example, the proposed model can have several options for glazing materials (1-layer glass, 2-layer glass, reflective glass, low-e glass, etc.), insulation for exterior walls, floors and roofs or parameters of the lighting systems, air conditioning & ventilation systems, etc.

Energy simulation softwares are obviously effective supporting tools to design energy efficient buildings. However, in the process of performing simulations, many parameters need to be gathered to build up the energy model. In case extracting information, data key-in are not

done correctly, it will greatly affect the reliability of simulation results, therefore it is necessary to have a qualified energy simulation expert to get involved to perform all such simulation calculations, analysis and solution proposals.

Chapter 02

ENERGY EFFICIENT BUILDINGS

1. BUILDING ENVELOPE

1.1. Introduction

The building envelope is the interface between the indoor and the outdoor environment. The envelope design and construction determines the amount of energy required to maintain occupant visual, thermal comfort and well-being. One of the best options to save energy is to define a design strategy for a high performance building envelope.In the scope of this document, there are no further analysis about safety factor of structure and economy. When designing a building envelope, it is necessary to consider local climatic characteristics to come up with a suitable design strategy. In hot and humid climates, when implementing a passive design strategy for the building envelope, the main challenges that need to be oversome, are reducing heat transfer, solar radiation accumulation, ensuring ventilation and moisture control in the building. Commonly used effective solutions can be: wall structures with high Thermal Resistance (R0), low thermal mass, high insulation walls and roof, multi-layer materials, etc.

A double skin façade (DSF) strategy may be considered as an advance design strategy due to the complexity of thermal behaviour and air flow pattern involved in its design. Glazing properties, type and position of shading devices, structure and depth of air cavity and size of openings are identified as parameters affecting the thermal and energy performance of buildings with DSFs. However, the inclusion of this type of facade in the design standards still requires further study due to high costs.

As regards façade structural components (including solid walls, roofs, fenestration and shading device elements), the fenestration rate is one of the most importantcomponents that can address the complex requirements of visual comfort, thermal comfort, connectivity to the outside environment and energy consumption of buildings.

In hot climates, it is necessary to limit glazed areas facing East, West, Northeast, and Northwest orientations because the amount of heat transferred into the building in summer in these directions is very large. The North and South orientations are the highest priorities for the fenestrations, depending on the size and location, the windows should still be considered to be designed with shading devices to avoid direct radiation and inconvenience glare. One strategy to increase the reflected light, reduce glare is to use internal light shelves dividing windows with two tiered glazed parts: the superior part glazing with a high visual light transmittance (VLT) and inferior part glazing with a low VLT -to limit glare but still ensuring good external

views. With this strategy, it is possible to encourage optimal visual comfort by utilizing diffuse and reflected light from the light shelves into the back of the room.

Figure 2.1. Intermediate light shelves reducing glare and evenly distributing daylight in a space[5]

1.2. Design solutions

1.2.1. General principles

The envelope performance can be affected by three parameters:

- Fenestration design parameters such as: glazing types, window area (WWR) and shading;

- Building material properties such as: insulation materials with low thermal conductivity and high thermal resistance, low U-value; materials with good mechanical properties withstand effects from the environment, moisture resistant, anti-mold materials;

- Site parameters such as building orientation and climatic features.

The envelope design strategy should follow the following general requirements:

- Avoid heat in the summer by implementingpassive measures such as shading and/or envelope insulation, planting trees, natural ventilation;

- Avoid glazed main façade facingwestern/eastern orientations to prevent overheating in summer. Use naturally ventilated spacesto benefit from main winds in summer (south, southeast) and to avoid cold winds (northeast direction) in winter.

- Minimize functional spaces without natural ventilation or ventilated buffer zones.

- Walls facing East, West,South West orientations and roofs must be insulated and shaded to reduce direct solar radiationcomply with Vietnamese standards and regulations.

- In the Northern regions of Vietnam featuring cold winters, vapor condensation on the ground floor (1st floor) often happend when the floor surface's temperature is lower than the ambient air dew point temperature. Well insulated hollow floorsand low effusivity building materials should be used to limit this issue. The floor surface should use a hygroscopic material.

[5] *Source: http://www.2030palette.org/intermediate-light-shelves/*

- Using high albedo (SRI) materials on exterior surfaces of the building, and low emissivity coating with low solar heat gain coefficient to minimize the heat load on the building's facades in summers.

For humid tropical climates, it can be divided into three types of space (three ventilation mode): mechanically ventilated space (closed space using air conditioning or heating systems); naturally ventilated space (opened space); and combined space.

- ***Mechanically ventilated space (closed space):*** used in functional public buildings such as offices, commercial center, administrative buidings, museums e.t.The operating time of these spaces is mainly taking place during the day time, most of the thermal comfort depends on the HVAC system(the North regions of Vietnam have hot and cold seasons, whereas Central and SouthernVietnamfeature mainly a hot season al year around). The envelope requires a tight design, featuring good insulation, creating a delay of heat radiation entering the space in the building (using thermal mass) to reduce the cooling load at peak times, when the outside temperature is much different from the thermal comfort zone.To evaluate the effectiveness of the building envelope, it is possible to use the method of calculating the U-values of the wall the roof and roof, the SHGC value of the glazing or the OTTV heat transfer value of the total enclosure of the building.

- ***Naturally ventilated space (opened space):*** For school buildings, lecture halls, or other temporary space occupied e.t. In these spaces, building envelope is required low U-value, open spaces, and good natural ventilation.

- ***Mixed mode ventilation:*** usually used in offices, apartment buildings, private houses, where the building operation is often flexible under two modes of mechanical ventilation or natural ventilation depending on the outside temperature and humidity conditions. The buildings with mix mode ventilation should be considering good insulation, against cold monsoon in winter and natural ventilation in the summer, combined with the use of table fans, ceiling fans, etc. as specified in TCVN 5687: 2010Ventilation – Air-conditioning – Design Standard. In NorthernVietnam, where there is a cold humid climate in the spring (from January to March, humidity may reach 80-100%, the temperature 7-10^{0}C), enhancing natural ventilation will bring moisture into the building, causing condensation on the floor, where the temperature's surface often reach the dew point. Good insulated ground floor and operating mechanical ventilation (closed space) during this time are the best ways to improve comfort.

The following main components of the building envelope should be considered for design solutions:

- External walls insulation

- Roof insulation

- Fenestration solutions: designed Solar Heat Gain Coefficient (SHGC) and the Window to Wall Ratio (WWR); shading devices element.

- Envelope design's requirement with the value Overall Thermal Transfer Value (OTTV)

1.2.2. External wall insulation design

The wallsshould be designed to ensure adequate insulation, using low U-value, low thermal conductivity materials. In tropical or equatorial climate regions, where annual temperatures are relatively high but mid-night and day temperature amplitude is low (less than 7°C), using thermal massis an ineffective strategy [2][3][4]. Therefore well-insulated materials such as lightweight concrete, and AAC block should be the priority.

The external building's walls should be considered with requirement of total thermal resistance $R_{0.min}$ as follow:

$$R_{0.min} \geq 0{,}56;\ (m^2.K/W) \tag{2.1}$$

The determination of R_0, (m^2.K/W) of external building's walls is described:

$$R_0 = \frac{1}{h_N} + \sum_{1}^{n} \frac{b_i}{\lambda_i} + R_a + \frac{1}{h_T};\ (m^2.K/W) \tag{2.2}$$

$$R_0 = 1/U_0 \tag{2.3}$$

where:

h_n, h_T the outer and inner surfaces heat exchange coefficients of the enclosure structure, respectively (allowed Appendix 3, QCVN 09:2017/BXD), W/(m^2.K);

bi thickness of i-th material layer, m;

λi coefficient of thermal conductivity of the i^{-th} layer of material in the enclosure structure (Appendix 2, QCVN 09:2017/BXD), W/m.K;

n number of material layers of the enclosure structure;

R_a thermal resistance of the air layer inside the enclosure structure, if applicable (Appendix4, QCVN 09:2017/BXD), m^2.K/W.

The wall spreadsheet R_0 (BE01) is accessible on the web-site of MoC http://tietkiem nangluong.xaydung.gov.vn/.

1.2.3. Roof insulation design

When designing roof insulation, it should be considered the solutions using the cool roof materials, green roofs, and double roofs as below:

Cool roofs are typically white and have a smooth surface. An SRI of 78 or higher is recommended [5], [6], [7]. A high reflectance keeps much of the solar energy from being absorbed while a high thermal emissivity surface radiates away any solar energy that is absorbed, allowing the roofs to cool down more rapidly. Commercial roof products that qualify as cool roofs fall into three categories: single ply, liquid applied, and metal panels. Examples are presented in Table 2.1.

Table 2.1. Example of Cool Roofs

Cool roof types	Products	Reflectance	Coefficient Emission	SRI
Single ply	white polyvinyl chloride (PVC)	0.86	0.86	107
	white chlorinated polyethylene (CPE)	0.86	0.88	108
	white chlorosulfonated polyethylene (CPSE)	0.85	0.87	106
	white thermoplastic polyolefin (TSO)	0.77	0.87	95
Liquid applied	white elastomeric, polyurethane, acrylic coating	0.71	0.86	86
	white paint (on metal or concrete)	0.71	0.85	86
Metal panels	factory-coated white finished	0.90	0.87	113

Green roofsare built up as a series of layers, with each performing a specific function. The most typical build-up is shown below and includes (Figure 2.2):

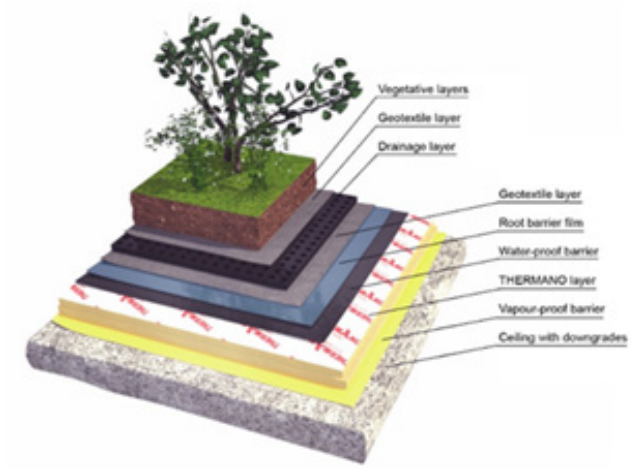


Figure 2.2. Structure of a green roof

- the roof structure (roof deck)
- thermal insulation
- waterproofing layer
- protection layers (including the option of
- a protection mat and/or root barrier layer)
- drainage layer
- filter sheet
- growing substrate
- vegetation

In accordance with the type of usage, construction factors and maintenance requirements, green roofs are typically divided into three major groups: extensive, intensive and semi-intensive roofs. The extensive type has a relatively thin layer of growing medium of around 6-20 cm thickness, typically grows moss, sedums, herbs and grass and requires less maintenance. The intensive green roof needs a thicker depth of growing medium of about 20-100 cm, requires irrigation and permanent maintenance. The semi-intensive green roof is a combination of both extensive and intensive types; however, the extensive type must represent 25% or less of the total green roof area.

Double roofsthe roof is designed with a roof shading for the purpose of ensuring the convection air layer for quick heat ventilation is an effective roof insulation structure. The shading structure layer of double roofs must be at least 0.3 m from the roof surface to ensure adequate ventilation between the roof layer and the shading layer (a two-layer roof with convection air layer in between).

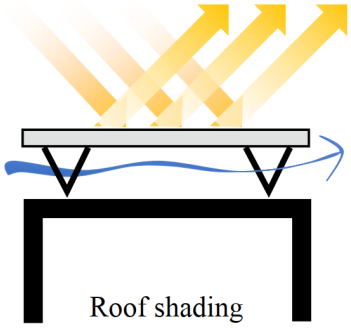


Figure 2.3. Double roofs

It should be noted that in hot climates with high level of diffuse radiation like Vietnam, the roof shading structure only helps to prevent heat gain by direct radiation.

1.2.4. Design for transparent parts

Windows and doors arrangement should be placed in the most favorable positions for natural ventilation and to limit the amount of sunlight enteringoccupied areason East-West directions. Supply-air louvers and exhaust-air louvers shall be located on different wall surfaces. In case the space cannot be directly ventilated, it is necessary to define solutions to takebenefits of indirect winds and cross-ventilation.SHGC QCVN09 code requirement depends on the WWR:Using a low SHGC windows with high VLT ensuresenough visual light transmission and reduce heat gain. For windows without any sunshading device, the maximum SHGC values of glazed windows are determined for each façade(north and south orientations (amplitudes of fluctuations within ± 22,5^0), as regards other orientations, they must meet the values in Table 2.2 below.

Table 2.2. WWR-related SHGC for glazing (QCVN 09:2017/BXD)[6]

WWR (%)	SHGC		
	North	South	Other
20	0,90	0,90	0,80
30	0,64	0,70	0,58
40	0,50	0,56	0,46
50	0,40	0,45	0,38
60	0,33	0,39	0,32
70	0,27	0,33	0,27
80	0,23	0,28	0,23
90	0,20	0,25	0,20
100	0,17	0,22	0,17

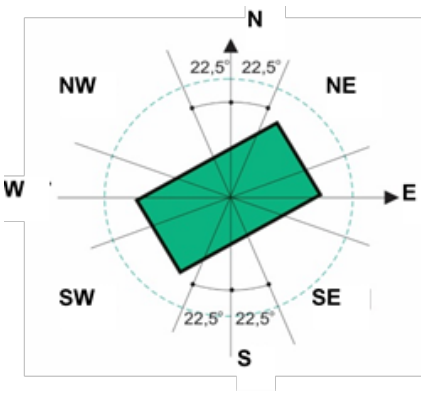
Note:

- WWR shall be calculated for each of the façades then averaged for the entire building;

[6] *Source: QCVN 09:2017/BXD*

- The SHGC value of each facade or of the entire building can be determined by the average value of the Area-Weighted Average of the transparent parts on the building's facade:

$$SHGC = \frac{\sum_{i=1}^{n} (SHGC_i \times A_i)}{A_1 + A_2 + ... A_n} \quad (2.4)$$



Hình 2.2. Cấu tạo mái xanh

In which: $SHGC_i$, A_i là giá trị SHGC is, respectively, SHGC value and area number of transparent surface number *i (i=1, n)*. In case the facade has a shading structure, the SHGC coefficient in table2.2is allowed to be adjusted by multiplying it by a coefficient A (the coefficient is in the lookup table of QCVN 09:2017/BXD).

$$SHGC_K = SHGC_{không\ KCCN} \times A \quad (2.5)$$

SHGC test certificates for glazing must be provided by the manufacturer. If the manufacturer uses the shading coefficient (SC) parameter instead, the following formula should be used:

$$SHGC = SC \times 0,87 \quad (2.6)$$

For hot climates with a high solar radiation like Vietnam, reducing direct heat radiation with a shading structure from the outside proved to be the most effective solution. Shading structure shape and dimension should be checked and evaluated according to the Sun pathway to ensure meeting shading requirements all year round.

The shading structure analysis software calculates the reduction coefficient of solar radiation both directly and through the glass window for 5 common types of shading structure and calculated on 16 directions. This is a useful tool for architects to calculate when choosing shading structure for the project. This software is available on the website of the Ministry of Construction http://tietkiemnangluong.xaydung.gov.vn/

Shading structure design for a building facade follows two steps:

- **Step 1:** calculation of the duration of insolation from sunlight direction: it depends on the building's location and of its windows' orientation.

- **Step 2:** determination of the reasonable type and dimensions of shading devices based on the parameters of the window and the requirement from step 1 compromise between active shading and additional shading (curtain, louver) to achieve rationality solution.

1.2.5. The envelope design using OTTV calculation

Exterior wall above the ground surface (opaque parts of the wall) of the air-conditioned spaces shall maintain a minimum overall thermal resistancevalue $R_{o.min}$ no smaller than 0,56 m^2.K/W.

Flat roofs and roofs with gradient of less than 15^0 placed directly above the air-conditioned spaces shall maintain a minimum overall thermal resistancevalue $R_{0.min}$ no smaller than 1.00 m^2.K/W.

To support in calculating R_0, architects can use BE01 (for wall) and BE02 (for roof) checklists which were uploaded on the website of the Ministry of Construction http://tietkiemnangluong.xaydung.gov.vn/ to check whether $R_{o.min}$ has met or not.

It should be noted that when calculating for the opaque parts of the exterior wall according to $R_{o.min}$, it is necessary to ensure the ratio WWR and SHGC of the transparent part of the exterior wall according to Table 2.2 above (or Table 2.1 in QCVN 09:2017/BXD)). The design of the building envelop according to $R_{o.min}$ is simple and convenient for architects. However, it is required that $R_{o.min}$ of all walls in all directions must reach at least a value of 0.56 m^2.K/W or more and $R_{o.min}$ of all roofs, must reach at least a value of 1,0 m^2.K/W or more. This is one of the limitations for architects in design of the facade and roof structure of the building. For example, on a roof with a glass sunroof with SHGC greater than 0.3 to get light, the roof will not achieve the $R_{o.min}$ value according to QCVN 09:2017/BXD.

In order to facilitate architects in design of facades, building roofs, exterior walls and roofs of air-conditioned spaces, it is possible to check the envelope design solution by calculating the OTTV.

1.2.6. The envelope design using OTTV calculation

If the aforementioned requirements for R0 and SHGC are not applicable, the overall thermal transfer value (OTTV) of the opaque and transparent parts of building envelope shall be applied; and required as follow:

$OTTV_T$ for wall is no greater than 60 W/m^2;

$OTTV_M$ for roof is no greater than 25 W/m^2.

$OTTV_T$ is calculated by the formula:

$$OTTV_T = \frac{\sum_{i=1}^{n}[\alpha_i \times U_{0,Ti} \times m_i \times (TD_{eq,i} - \Delta T) \times A_{Ti}] + \Delta T \times \sum_{i=1}^{n}(m_i \times U_{0,Ti} \times A_{Ti})}{A_0} + \frac{\sum_{i=1}^{n}[\beta_i \times K_{cs,i} \times I_{0,i} \times A_{Ki}] + \Delta T \times \sum_{i=1}^{n}(U_{0,Ki} \times A_{Ki})}{A_0}, (W/m^2) \quad (2.7)$$

In which:

$K_{cs,i}$: SHGC of glazing;

A_{Ti}, A_{Ki}: Wall, glazing area of the wall, glazing numberi (m^2);

A_o: Wall area including windows areas (m^2);

β: shading coefficient based on shading devices (1/A);

$U_{0,Ti}$: U_0 of Wall number i (W/m^2K);

i: the different types of walls/glazing number i;

n: the number of walls/glazing types;

ΔT: difference of temperature between inside and outside (°C);

$TD_{eq,i}$: difference of equivalent temperature, including the effect of solar radiation on wall (°C);

I_o: Solar radiation on wall and glazing (W/m^2).

The software to calculate and check OTTV and shading structure are accessible on the website of MoChttp://tietkiemnangluong.xaydung.gov.vn/

1.3. Case study

1.3.1. Assess the envelope design through total thermal resistance index R0 for walls, roof and SHGC for glass

BUILDING: THE GOLDEN LOTUS BUILDING PROJECT

(Demonstration building of EECB project)

- Type: Mixed use offices and commercial buildings
- Address: № 7, Nam Quoc Cang street, Pham Ngu Lao, District 1, Ho Chi Minh City
- Land area: 996.5 m^2
- Construction area: 597.5 m^2
- Total floor area: 6,210.2 m^2

The building uses two types of walls:

- *W1: Aggregate concrete brick walls have the following structure: 15 mm plastering mortar, 200 mm AAC bricks.*
- *W2: Reinforced concrete walls structure: 15 mm plastering mortar, 800 mm thick reinforced concrete;*

Roof includes the following structural layers:

- N18 mm outside titles
- 20 mm conventional mortar
- 50 mm of slope concrete and waterproofing
- 250 mm of insulation panel
- 200 mm of reinforced concrete
- 15 mm conventional mortar

N6: as N5, additioning 184 mm air gap and 15mmair gap above plaster ceiling 1

- Glazing types:

K1: $SHGC_1$=0,49

Objective: Analyze the design solution of building envelopes using energy efficiently, check the compliance of the building envelope design according to QCVN 09:2017/BXD as regards U-value of walls and roof

To check the compliance of the building envelope design with the QCVN 09:2017/BXD requirements, the specifications of exterior walls and roof are included in the BE01, BE02(on MOC websitehttp://tietkiemnangluong.xaydung.gov.vn/).

Table BE01. Evaluaation of $R_{o.wall}$ for W1 and W2

BE01	Heat transfer through the building wall (W1)			
	Material layers, outside in	**Thickness *(mm)***	**Thermal conductivity *(W/mK)***	**Total thermal resistance *(m^2K/W)***
	Inner surface heat exchang			**0,13**
1	Interior plaster	15	0,8	0,02
2	AAC bricks	200	0,16	1,25
3	Exterior plaster	15	0,5	0,03
	Outer surface heat exchang			**0,04**
	R_{min} according toEEBC (m^2K/W)	**0,56**	**R-value (m^2K/W)**	**1,47**
	U_{max} according toEEBC (W/m^2K)	**1,80**	**U-value (W/m^2K)**	**0,68**
Qualified				

BE01	Heat transfer through the building wall (W2)			
	Material layers, outside in	**Thickness *(mm)***	**Thermal conductivity *(W/mK)***	**Total thermal resistance *(m^2K/W)***
	Outer surface heat exchang			**0,13**
1	Exterior plaster	15	0,8	0,02
2	Reinforced concrete	800	0,16	0,94
3	Interior plaster	15	0,5	0,03
	Inner surface heat exchang			**0,04**
	R_{min} according to QCVN09:2013/BXD (m^2K/W)	**0,56**	**R-value (m^2K/W)**	**0,73**
	U_{max} according to QCVN09:2013/BXD (W/m^2K)	**1,80**	**U-value (W/m^2K)**	**1,36**
Qualified				

Table BE02. Calculation of $R_{o.for\ building\ roof}$ N5, N6

BE02	Heat transfer through the building roof N5			
	Material layers, top down	**Thickness *(mm)***	**Thermal conductivity *(W/mK)***	**Total thermal resistance *(m^2K/W)***
	Outer surface heat exchang			**0,17**
1	Outside titles	18	0,58	0,03
2	Conventional mortar	20	0,8	0,03
3	Slope concrete and waterproofing	50	1,28	0,04
4	Insulation panel	250	0,31	0,81
5	Reinforced concrete	200	1,55	0,13
6	Conventional mortar	15	0,8	0,02
	Inner surface heat exchang			**0,04**
	R_{min} according to QCVN09:2013/BXD (m^2K/W)	**1,00**	**R-value (m^2K/W)**	**1,19**
	U_{max} according to QCVN09:2013/BXD (W/m^2K)	**1,00**	**U-value (W/m^2K)**	**0,84**
Qualified				

In order to assess the compliance with QCVN 09:2017/BXD for glazing, it is necessary to determine the SHGC coefficient of the exterior glazing based on the WWR coefficient for each facade of the calculated work and compare with the requirements in Table 2.2.

WWR-related SHGC for glazing for the building

Category \ Facade	Southeast	Northeast	Northwest	Southwest
Correction factor for the shading structure (A)	1	1	1	1
Window area	386	220	214	221
The total area of the wall	1340	589	1040	589
WWR (%)	28,8	37,35	20,57	37,5
SHGCmax according to QCVN09:2017/BXD	**0,60**	**0,49**	**0,79**	**0,49**

According to the table WWR-related SHGC, the project should use a glazingtype with $SHGC_{max}$ = 0.49, that ensure compliance with standards QCVN09:2017/BXD.

1.3.2. Assess the envelope design through OTTV calculation

BUILDING: HIGH-RISE AND COMMERCIAL BUILDINGS Y1 (CAPITA LAND FELIX VISTA)

(Demonstration building of EECB project)

- Type: apartments with commercial podium buildings
- Address: Area Y1, Thanh My Loi Ward, District 2, Ho Chi Minh City
- Land area: 2.1 ha
- Construction area: 10,153 m^2
- Total floor area of B building: 34 674 m^2

The building uses two types of walls:

- *WW1: Aggregate concrete brick wall of the following composition: 15 mm and 20 mm plastering mortar, reinforced concrete bricks 190 mm thick.*
- *W2: Reinforced concrete wall structure: 300 mm thick reinforced concrete;*

Roof includes the following structural layers:

- *50 outside mortar; 50 mm polystyrene insulation panel*
- *20 mm conventional mortar; 26 mm of slope concrete and waterproofing; 200 mm of reinforced concrete; 12 mm conventional mortar*

Glazing types:

- K_1: *SHGC1=0,49, VLT1=0,66,* $U_{1\text{- summer day}}$ *= 5,07 W/m²K;*
- K_2: *SHGC1=0,58, VLT1=0,65,* $U_{1\text{- summer day}}$ *= 5,6 W/m²K;*

Objective: Analyze the design solution of building envelopes using energy efficiently, check the compliance of the building envelope design according to QCVN 09:2017/BXD through OTTV

It is possible to use the formula (2.7) to calculate OTTV. The result of the OTTV calculation for the building B is given below:

OTTV calculation for building B

		Northeast	Northwest	Southeast	Southwest	Summarize
W_1	A_{W1}	0,00	1.488,00	1.572,78	0,00	
	m_1	0,84	0,84	0,84	0,84	
	α_1	0,40	0,40	0,40	0,40	
	$U_{o,W1}$	1,34	1,34	1,34	1,34	
	$TD_{eq,1}$	13,35	13,35	12,19	12,19	
	ΔT	2,67	2,67	2,67	2,67	
W_2	A_{W2}	757,60	203,70	662,40	757,60	
	m_2	0,45	0,45	0,45	0,45	
	α_2	0,40	0,40	0,40	0,40	
	$U_{o,W2}$	2,65	2,65	2,65	2,65	
	$TD_{eq,2}$	13,35	13,35	12,19	12,19	
	ΔT	2,67	2,67	2,67	2,67	
$W_{1'}$ (Buffer space area)	$A_{W1'}$	975,40	1.163,00	1.407,80	975,40	
	$m_{1'}$	0,45	0,45	0,45	0,45	
	$\alpha_{1'}$	0,40	0,40	0,40	0,40	
	$U_{o,W1'}$	0,00	0,00	0,00	0,00	
	$TD_{eq,3}$	13,35	13,35	12,19	12,19	
	ΔT	2,67	2,67	2,67	2,67	
K_1	A_{K1}	0,00	2.879,50	2.260,95	0,00	
	$SHGC_1$	0,49	0,49	0,49	0,49	
	$I_{o,1}$	248,40	248,40	221,40	221,40	
	β_i (1/A)	1,00	1,00	1,00	1,00	
	$U_{o,K1}$	5,07	5,07	5,07	5,07	
	ΔT	2,67	2,67	2,67	2,67	
K_2 (with balcony)	A_{K2}	0,00	388,80	305,07	0,00	
	$SHGC_1$	0,49	0,49	0,49	0,49	
	$I_{o,2}$	248,40	248,40	221,40	221,40	
	β_i (1/A)	0,63	0,63	0,57	0,57	Depth is 1200, Window height 2400 mm
	$U_{o,K2}$	5,60	5,60	5,60	5,60	
	ΔT	2,67	2,67	2,67	2,67	
K_2 (kitchen area)	A_{K2}	107,00	0,00	0,00	107,00	
	$SHGC_2$	0,58	0,58	0,58	0,58	
	$I_{o,2}$	248,40	248,40	221,40	221,40	
	β_i (1/A)	0,53	0,53	0,47	0,47	Kitchen depth 1800, Window height 2400 mm
	$U_{o,K2}$	5,60	5,60	5,60	5,60	
	ΔT	2,67	2,67	2,67	2,67	

		Northeast	Northwest	Southeast	Southwest	Summarize
q_{1_W1}		0,00	13.760,98	6.699,86	0,00	20.460,84
q_{1_W2}		3.852,43	1.035,82	3.002,49	3.434,00	11.324,74
q_{1_W1}		0,00	0,00	0,00	0,00	0,00
q_{2_W1}		0,00	8.600,61	4.697,64	0,00	13.298,25
q_{2_W2}		2.407,77	647,39	2.105,21	2.407,77	7.568,14
q_{2_W1}		0,00	0,00	0,00	0,00	0,00
q_{3_K1}		0,00	350.481,22	245.281,42	0,00	595.762,64
q_{4_K1}		0,00	38.979,50	30.606,25	0,00	69.585,76
q_{3_K1}		0,00	29.763,01	18.911,90	0,00	48.674,91
q_{4_K1}		0,00	5.813,34	4.561,41	0,00	10.374,74
$q_{3\_K1'}$		8.156,46	0,00	0,00	6.450,74	14.607,20
$q_{4\_K1'}$		1.599,86	0,00	0,00	1.599,86	3.199,73
A_o		1.840,00	6.123,00	6.209,00	1.840,00	16.012,00
OTTV						**49,64**
Requirements of OTTV in regulation						60,00

Conclusion: The two mentioned projects supported by the EECB technical assistance are good examples of compliant building envelop design of walls, roof and glass types with QCVN 09:2017/BXD. Most wall structures provide enough insulation or have a guaranteed thickness to reduce U-value to comply with Umax = 1.8. Building roofs use multi-layered materials, ensuring good insulation, i.e., Umax value not exceeding the allowable limit of 1. Glazing selectedhas been defined based on the required SHGC values, determined based on the facade's oreintation and the WWR ratio.The alternative calculation used to evaluate the energy performance for the buildings using the HVAC systems can be performed through the OTTV calculation. The example calculated for the Capita Land Felix Vista project shows that the building is designed with building envelop to ensure energy efficiency according to QCVN 09:2017/BXD.

2. DAYLIGHTING

2.1. Introduction

Daylighting is the use of windows and skylight to allow natural light inside the building. Daylighting is composed of a mix - direct sunlight, diffuse skylight, light reflected from the ground and surrounding elements.

Direct sunlight is characterized by very high intensity and varies by season, time of day, location and sky conditions. The illumination produced on the surface of the earth may be more than 100,000 lux. This natural light source can carry a large amount of heat and cause glare, so it is not recommended to exploit without passive and proactive design measures to reduce the light intensity.

Diffuse skylight is sunlight that is scattered by the atmosphere and clouds, creating diffused light with a soft brightness, carrying less solar irradiation. The illumination of fully cloudy skies can reach 10,000 lux in winter and 30,000 lux in summer. This natural light source is generally recommended for daylighting.

Reflected light is the result of two light sources reflected on the surfaces around the building such as ground, trees, neighbor buildings... This light source is greatly influenced by situation around the building, which in some cases may cause glare.

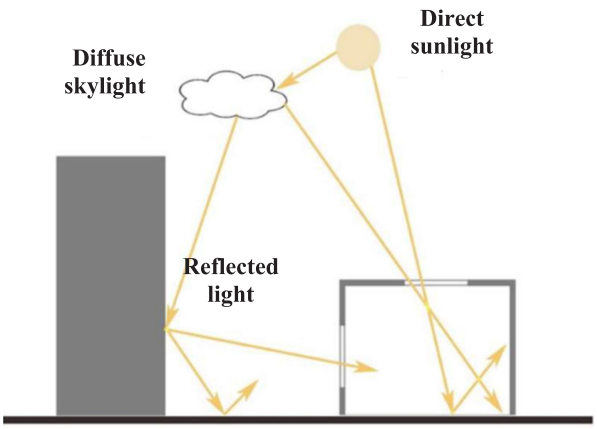


Figure 2.4. The components of daylight (Source: Velux)[7]

The benefits of daylighting:

- Reduce operating costs by turning off or reducing power of lighting fixtures,

- Improves the life cycle cost of lighting fixtures,

- Reduce greenhouse gas emissions by reducing electric power consumption of artificial lighting,

- Increases working efficiency as well as visual comfort and health improvement.

2.2. Design solutions

2.2.1. Expanding daylighting zone

A daylighting zone is the space adjacent to the window with a depth determined by 1.5 to 2 times the height from the floor to the upper edge of window glazing. In practice, the amount of natural light penetrating into building depends on building direction, location, WWR, glazing type, passive design, and elements around the building. Therefore, daylighting simulation is recommended to correctly identify daylighting zones.

[7] *Source: Berkeley Lab*

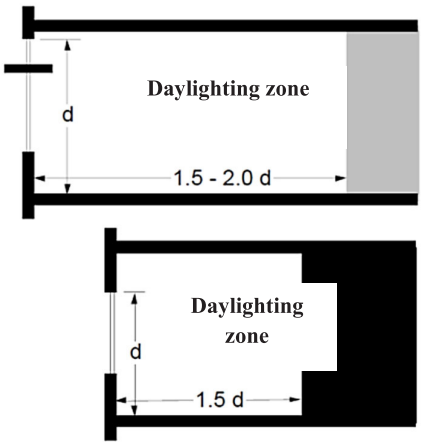


Figure 2.5. Daylighting zone defined by rule-of-thumbs[8]

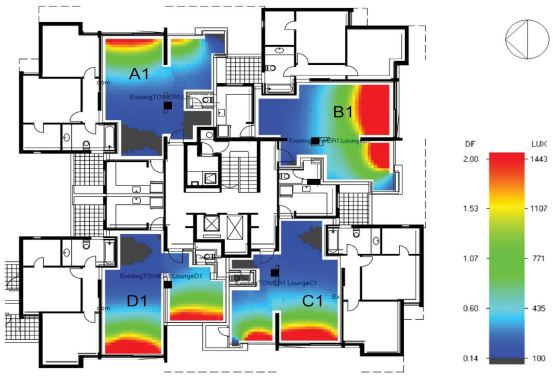


Figure 2.6. Daylighting zone determined by energy simulation software[9]

2.2.2. Exterior shading and light reflection

Exterior shading and light reflection design reduce heat absorption from direct sunlight and diffuse deeply natural light into the building by using reflected shelves and overhang, horizontal and vertical side fins, light reflection systems. The right combination between choice of location, reasonable WWR, improved walls and ceiling reflection, allows natural light to be distributed deeper and more uniformly.

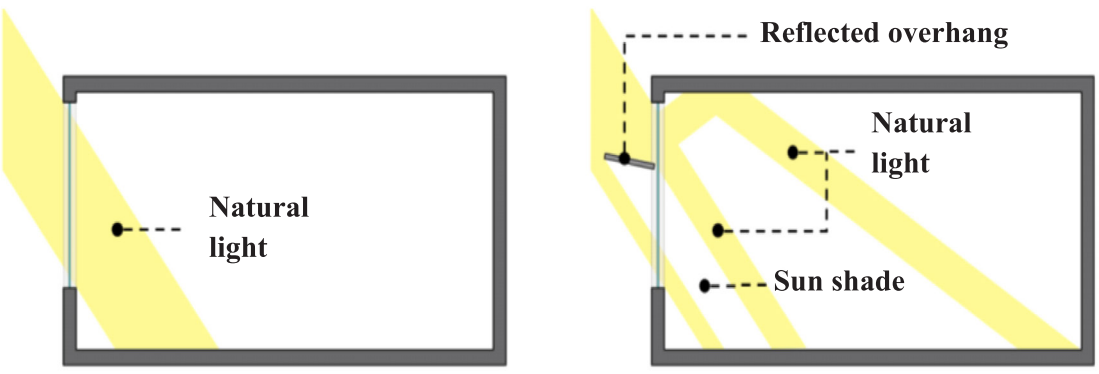


Figure 2.17. Expanding daylighting zone with reflective overhang[10]

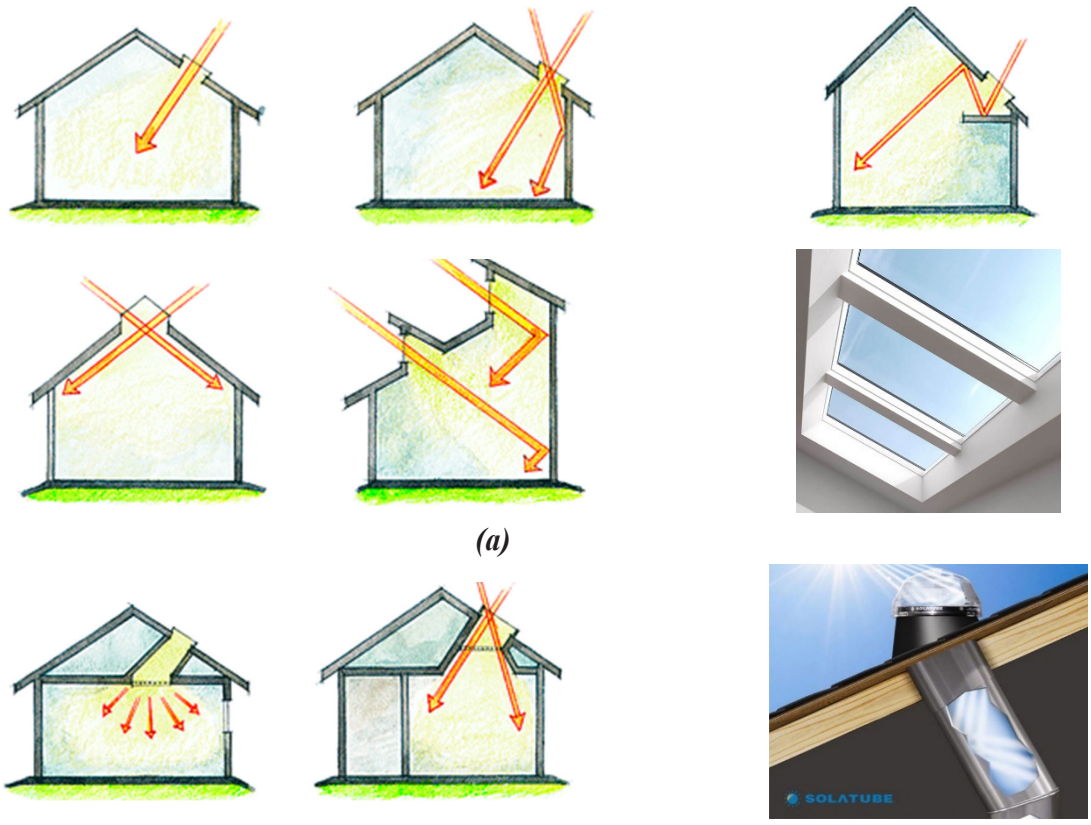
2.2.3. Skylight and light tubes

Skylight and light tubes help bringing natural light into space that couldn't receive natural light from windows. Skylight may only naturally illuminate attic space, but lightwell design (combination of skylight and cascading) and light tube technology allow natural light to penetrate deeply inside the building.

[8] *Source: Berkeley Lab*

[9] *Source: designbuilder.co.uk*

[10] *Source: Energy and Buildings Journal*



(a)

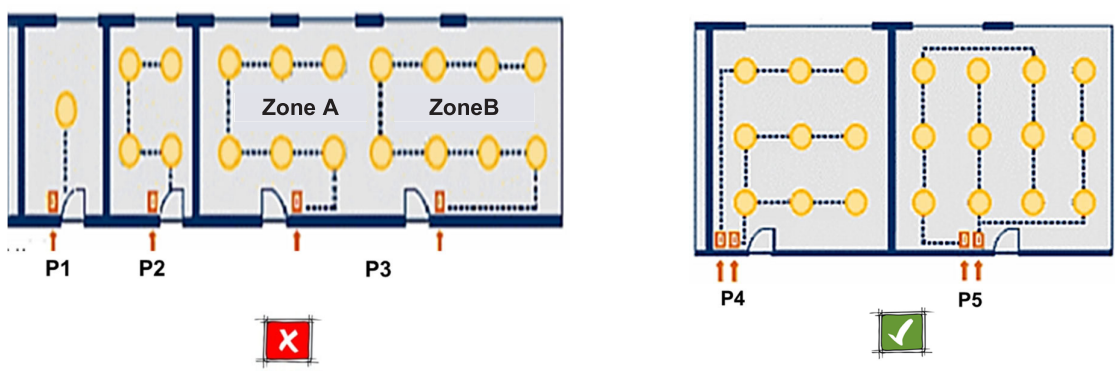
(b)

Figure 2.8.Skylight (a) and light tube (b) design strategies[11]

2.2.3. Artificial lighting control in daylighting zone

a) Lighting control circuit layout

Artificial lighting in daylighting zones should be potentially switched ON/OFF independently. In fact, separated control circuits help reducing lighting energy consumption by allowing users to manually turn on/off lighting fixtures in daylighting zones. Inappropriate layout may cause artificial lighting to be forced in ON mode even though provided natural illuminance is enough.



(a) *(b)*

Figure 2.9. Inappropriate (a) and appropriate (b) lighting circuits layout for daylighting zone

[11] *Source: Green Building Advisor*

b) Daylight sensors and control systems

Photosensors (ambient light sensors) are important to automatically enable a control of artificial lighting in balance with natural light by reducing or increasing luminous intensity to meet illuminance requirement on working plane. Photosensors can be integrated into lighting fixtures either as a stand-alone wired or wireless connection to lighting fixtures. The ideal disposition of stand-alone photosensor should be at height of working plane for measured value as required illuminance.

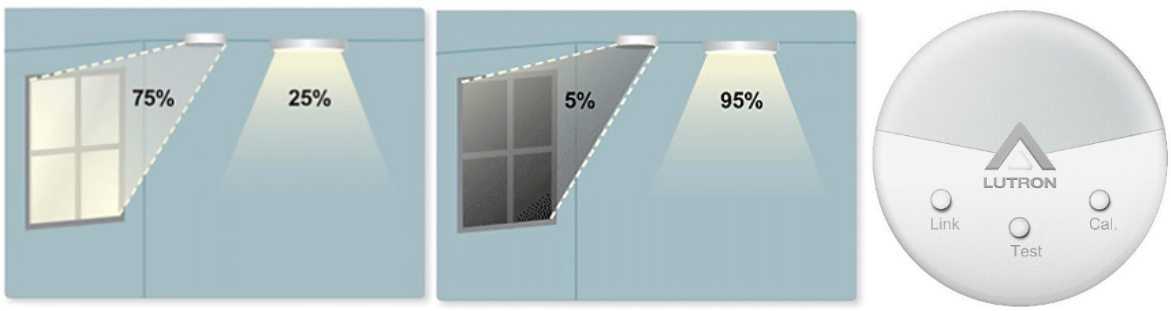


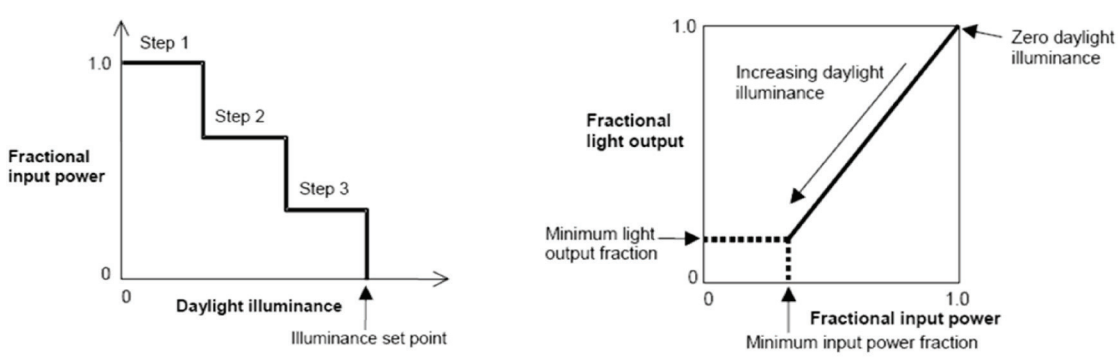
Figure 2.10. Control artificial lighting according to natural lighting by using photosensor

Photosensors can control groups (by area) or individual lighting fixtures and there are 3 potential system to control illuminance levels:

- Automatic ON/OFF control replaces manual switch,

- With Linear control, the overhead lights dim continuously and linearly from maximum power/luminous intensity output to minimum power/luminous intensity output as the daylight illuminance increases,

- Stepped control allows to switch lighting on/off according to the availability of natural daylight in discrete steps. Whereas the Linear control described above provides precisely controlled illuminance by dimming the lights, the stepped control models block of lights is switching on/off according to the electric lighting requirement.



(a) ***(b)***

Figure 2.11. Illuminance level control (a) and dimming control (b)[12]

[12] *Source: designbuilder.co.uk*

2.3. Case study

NEW ADMIN AND EDUCATIONAL BUILDING, COLLEGE OF URBAN WORKS CONSTRUCTION

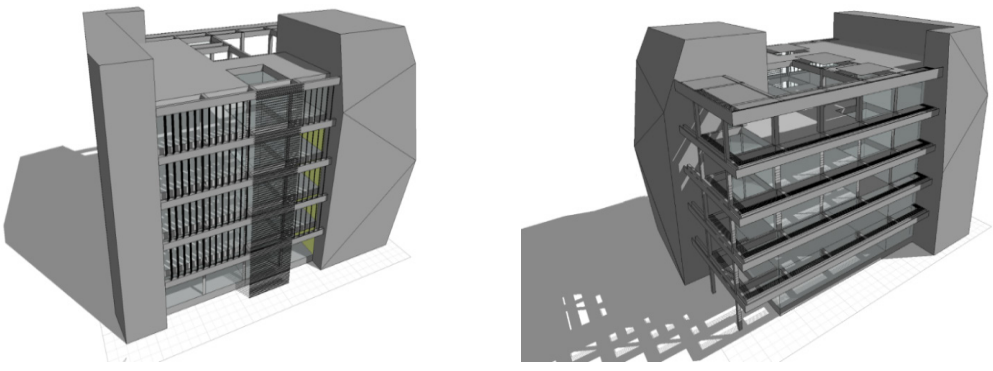
(Demonstration building of EECB project)

- Type: School, research center
- Investor: College of Urban works construction
- Address: Yen Thuong, Gia Lam, Hanoi
- Total height: 5 floors
- Total floor area: 3.875m^2

The main function of each floor include:

Floor	Function	Overall
1st floor	Exhibition, Workshop	Mixed use function: Office and School
2nd floor	Exhibition, Workshop, Laboratory	
3rd floor	Library, Multimedia room, Classroom	
4th floor	Office, Meeting room	
5th floor	Multi use space, Kitchen	

The building facade is mostly enclosed by glazing with a combination of passive design strategies (external louvers, beam) to benefit from diffused light and limiting direct sunlight ingress into the building. In addition, lightwell material is made of transparent material to allow natural light to penetrate deeply into the building.



(a) *(b)*

Figure 2.12. Southeast (a) and Northwest (b) building facade with shading elements

Natural lighting requirement of QCVN 09:2017/BXD: in office space, classrooms and library reading rooms with natural lighting, an artificial lighting control solution shall be used.

The design evaluation for compliance with regulation is described as follows:

- Identify spaces related to daylighting requirement

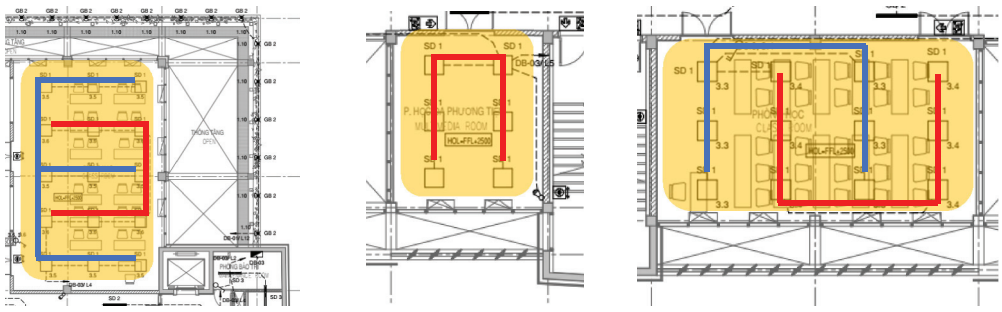
▪ 3rd floor: Library, Multimedia room, classroom

▪ 4th floor: Office

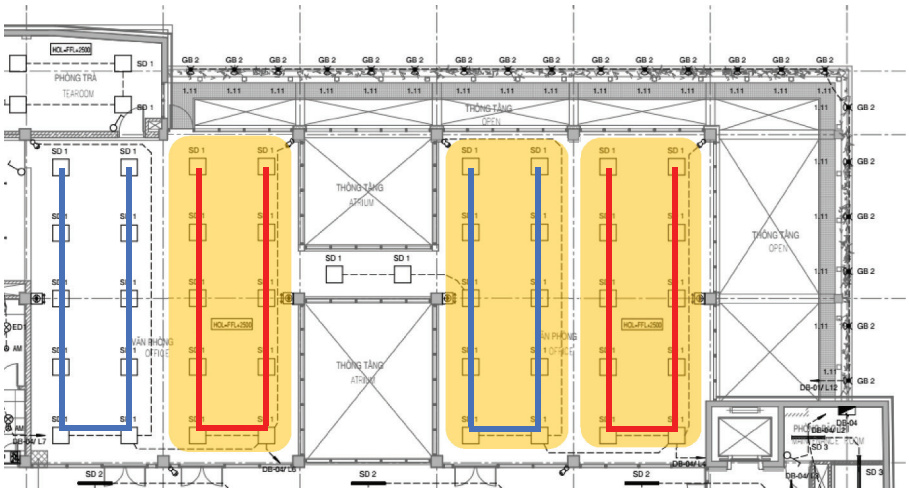
- Identify daylighting zone: the height from the top edge of glazing to the floor is determined to 3 meters. Because of no reflection strategy, daylighting zone is determined with depth of 4.5m from glazing...

▪ 3rd floor: The entire space of library, multimedia room and the classroom is completely in daylighting zone.

▪ 4th floor: Most space are located in daylighting zone



(a)



(b)

Daylighting zone *Lighting circuit* *Glazing*

Figure 2.13. Daylighting zone on the 3rd floor (a) and 4th floor (b)

- Identify artificial lighting adjustment solutions

▪ Floor 3: All spaces can all be considered as daylighting zones therefore lighting control layout complies with QCVN 09:2017/BXD. In addition, two different and complementary lighting circuits have been designed to allow only half of artificial lighting when needed.

▪ Floor 4: Artificial lighting in daylighting zone is controlled by separated control circuits, thus lighting control complies with QCVN 09:2017/BXD.

SEASONS AVENUE MO LAO APARTMENT, HANOI

- Type: High-rise apartment building
- Investor: Capita Land Investment Co., Ltd - Hoang Thanh
- Address: Co Ngua, Mo Lao, Ha Dong
- Total height: 4 floors
- Total floor area: 196.792 m^2

The project is a high-rise apartment building consisting of 4 buildings S1-S4, in which, 2nd floor to 5th floor of buildings are used as open indoor parking area for natural ventilation and daylight.

Garage lighting control requirement of QCVN 09:2017/BXD: For areas within a distance of 6 meters from the exterior wall that have glazing/openings of WWR ≥ 40%, lighting control shall be installed for reducing the lighting power.

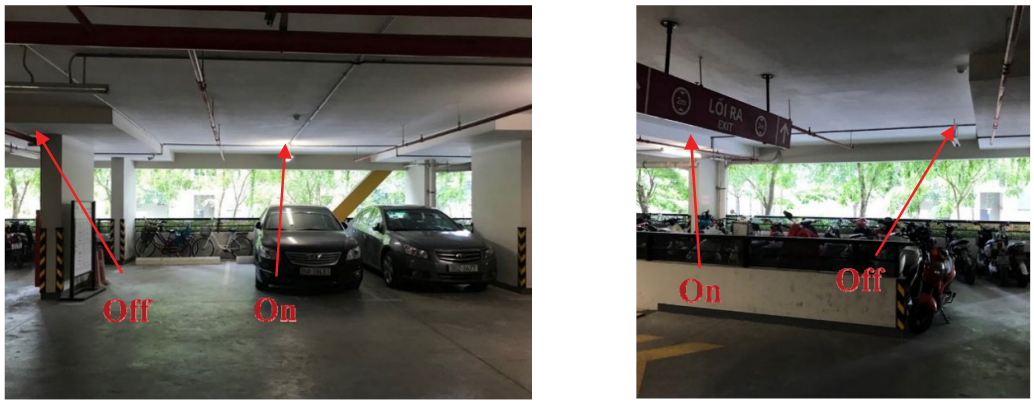


Figure 2.14. The lighting system near the wall is staggered on and off

The daylighting zone is defined as the space with a depth of 6 meters from external walls. In daylighting zones, lighting control circuits are alternated to each commend 50% of the total lighting power installed. Thus, lighting control for this parking area complies with the QCVN 09:2017/BXDregulation.

3. ARTIFICIAL LIGHTING

3.1. Definition

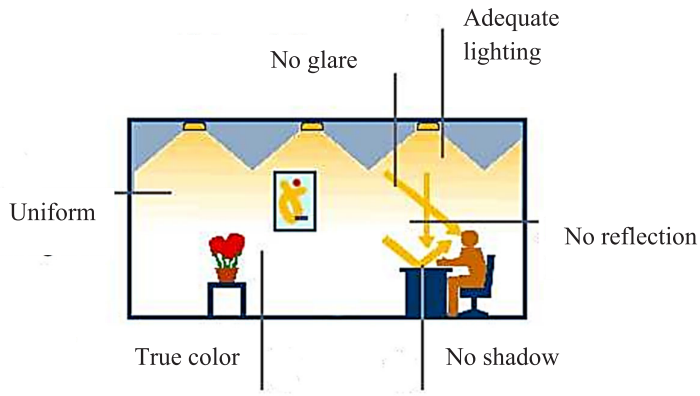


Figure 2.15.General requirements for artificial lighting to ensure visual comfort[13]

Artificial lighting is used to obtain the required illuminance. The light intensity can be increased or decreased, directed, focused and colored. This allows artificial lighting to create a variety of different effects.Artificial lighting can be categorized as indoor lighting or outdoor lighting. This document focuses only on energy efficiency measures related to indoor lighting.

3.2. Design solutions

3.2.1. Reduce lighting power density

Lighting Power Density (LPD) is defined as the rated wattage of lighting fixtures per square meter of floor area, in W/m^2. LPD is an effective way to assess about lighting systems efficiency and potential energy saving. Currently, popular lighting design softwares (like DIALux, DIALux EVO, AGI32, ...) support the calculation of LPD based on selected lighting fixtures specifications and required illuminance.

$$\text{Lighting power density (W/m}^2\text{)} = \frac{\text{Total power of lighting fixtures (W)}}{\text{Total floor area (m}^2\text{)}} \quad (2.8)$$

3.2.2. High efficiency lamps

The lamp efficiency or luminous efficiency is expressed as the ratio of the luminous flux (lm) and rated power (W), in lm/W. High efficiency lamps can produce more luminous flux than conventional lamps of same rated power. Luminous efficiency can be found or calculated based on technical parameters from product catalogue or box cover or lamp body. High efficiency lamp can be identified through the Vietnamese energy efficiency label.

[13] *Source: Energy Saving Office*

$$\text{Lamp efficiency (lm/W)} = \frac{\text{Luminous flux of lamp (lm)}}{\text{Power of lamp (W)}} \quad (2.9)$$

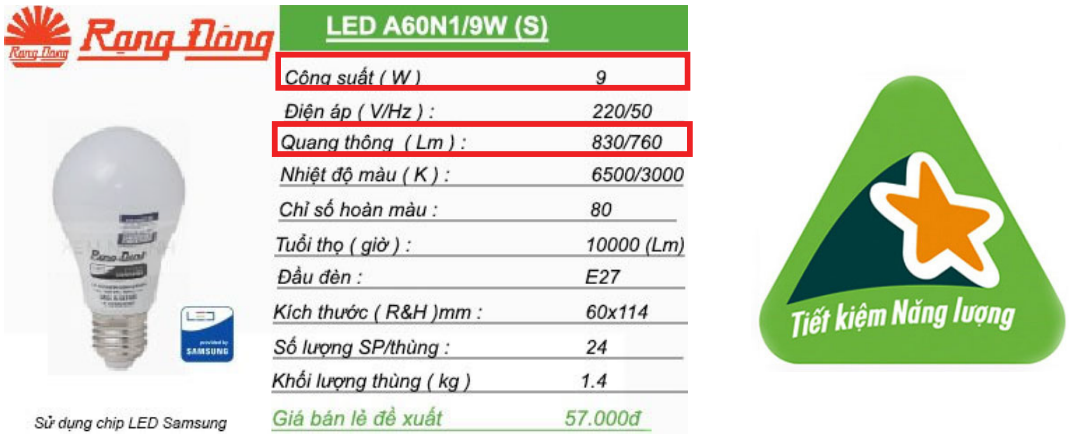


Figure 2.16. Technical parameters of lamps and Vietnamese energy efficiency label[14]

High efficiency lamps are recommended to ensure that artificial lighting design can meet minimum illuminance requirements (specified in Annex C of QCVN 12:2014/BXD) without exceeding the maximum LPD (specified in Table 2.5 of QCVN 09:2017/BXD).

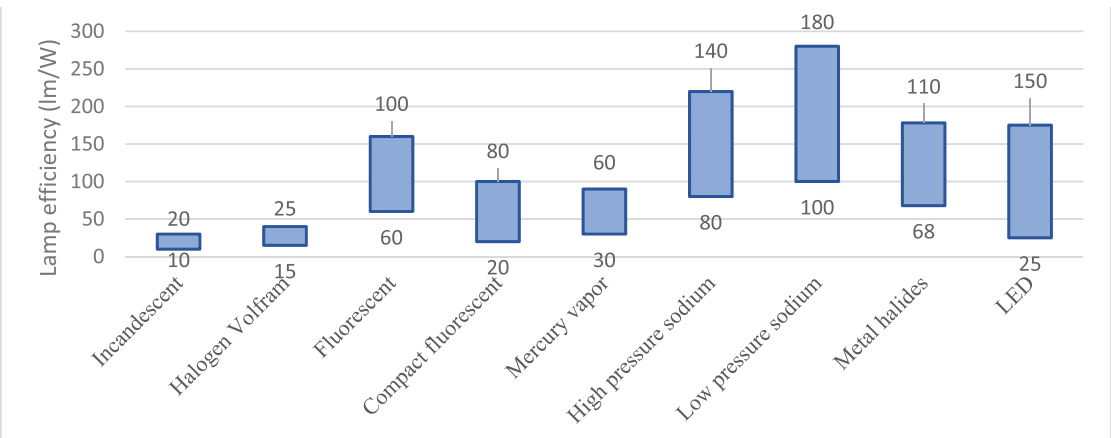


Figure 2.17. Range of luminous efficiency of common lamp types

3.2.3. Light Reflectors

The light of lamp is basically emitted in all directions. One part of light source illuminates the work plane, the rest illuminates the surrounding space and may cause glare. reflector is recommended to reflect light emitted in other direction of the eyes and focus most of light towards working plane. In practice, lighting fixture with suitable reflector can increase the illuminance on the working plane in comparison to stand-alone lamp. There are 2 common types of reflectors:

[14] *Source: Rang Dong*

- **Diffuse reflector:** reflective coating with paint or white powder, 70-80% reflectance but declining in time. It is usually applied to task lights for avoiding glare.

- **Specular reflector:** Reflective layer is polished or mirror-like, 85-96% reflectance and decline less in time. It is usually applied to ceiling cladding (light trays) for focusing light on working plane as much as possible.

Note for design

Besides lamp efficiency, it is also important to consider on other requirements in lighting design such as color temperature, color rendering index, uniformity, ceiling and wall minimum illuminance for visual comfort.

The illuminance (in lux) level at working plane is proportional to the square of the distance between lamp and the working plane (square meter), so closer the lamp is installed, more illuminance will be provided to the working plane. However, the lower the lamp is, the smaller the illuminated surface, then more lamps may be needed to be installed to provide enough illuminance everywhere needed.

$$\text{Illuminance (lux)} = \frac{\text{Luminous intensity (cd)}}{(\text{Distance between lamp and working plane})^2(\text{m}^2)} \qquad (2.10)$$

For fluorescent lamps, the power consumption of the ballast shall also be included when calculating the total power consumption of the lighting fixture, so it is recommended to use electronic ballasts (low power consumption) instead of traditional ferromagnetic ballasts (which consumes more energy).

Artificial lighting systems that meet minimum illuminance requirements and maximum LPD requirements need to be physically tested to:

- Compare the minimum illuminance specified in QCVN 12:2014/BXD with the measured illuminance.

- Compare the maximum lighting power density specified in QCVN 09:2017/BXD with the measured power of the lighting system or the calculated power from thequantity multiplied by the rated power of lighting fixture, divide for the total illuminated floor area.

3.2.4. Automatic control systems

a) ON/OFF timer

ON/OFF timer is a simple and especially effective measure for spaces with fixed or little variable operation schedules of lighting system. This measure does not reduce the LPD but limits forgetting to switch OFF lighting fixtures which results to wasted power. There are two common types of ON/OFF timers:

- **Timer relay:** It is composed of an ON/OFF relay and of a mechanical or electronic timer. Such an equipment is designed to be installed in electrical cabinets and to be operated independently with manual or automatic ON/OFF switches.

Figure 2.18. Electronic and mechanical timer switch[15]

- **Smart switch:** comes in the form of touch or mechanical button switch. The equipment is designed to replace traditional switch with default manual ON/OFF function. Timer and remote control feature need to be configured via software application or smart home virtual assistant.

b) Occupancy sensor

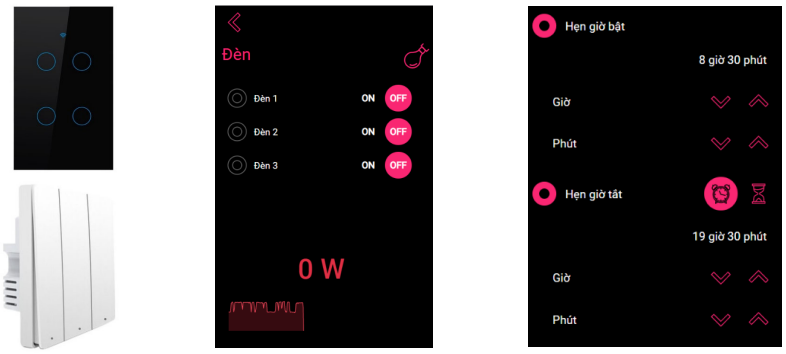


Figure 2.19. Smart switch and user interface for remote control and timer[16]

Occupancy sensor is used to identify human activity in the artificially illuminated space, thereby switching ON/OFF lighting fixtures when activity/no activity is detected in that space. There are two common types of occupancy sensor:

- **Passive infrared sensors (PIR)** determine human presence through the difference between the infrared wavelengths emitted by the human body while moving through space. This sensor has the advantage of being low cost, with wide viewing angle, high sensitivity and easy adjustability. However, when the user is not moving for a certain time, the sensor cannot detect the person.

- **Ultrasonic sensors** determine human presence by using ultrasonic waves emitted at high frequencies, undetectable by humans or animals, to determine the change in distance

[15] *Source: ecomm.com.vn*

[16] *Source: ioteamvn.com*

to determine activity or no activity. However, the disadvantage of this sensor is that it has a narrow viewing angle and limited detection distance.

Passive infrared sensor (PIR) is the most frequently used type. In some cases, dual technology occupancy sensors are using these two technologies simultaneously to enhance accuracy in determining the user's presence in space.

(a) *(b)*

Figure 2.20. Passive infrared sensor (PIR) (a) and ultrasonic sensor (b)

Lighting fixtures could be directly controlled by integrated sensors or remotely control by stand-alone sensors through smart home or building management systems. Potential energy savings when using occupancy sensors can reach from 13% to 90% depending on space type.

Table 2.3. Potential level of energy savings when presence sensor is appliedin some typical areas (Source: US Energy Department)[17]

Space type	Energy saving (%)
Private office	13 to 50
General office	20 to 28
Classroom	40 to 46
Meeting	22 to 65
Toilet	30 to 90
Lobby	30 to 80
Warehouse / cabinet	45 to 80

3.3. Example

3.3.1. Compliance with the maximum light power density requirement

Artificial lighting systems of a convention centerare designed as described in the table below

Space name	Function	Area (m^2)	Lamp type	Number	Power (W)
Gallery	Exhibition	120	LED-SD1	12	41
Conference room	Seminar	55	LED-SD1	12	41
Control room	Office	20	LED-SD1	4	41
Warehouse	Warehouse	26.5	LED-SD4	4	28
Technical Department	Technical	14.5	LED-SD4	2	28
Lobby	Lobby	99	LED-ED1	28	11
Electrical Room	Technical	12	LED-SD3	2	56
Restroom	Resting	12	LED-SD3	2	56

[17] *Source: ioteamvn.com*

The LT02 spreadsheet of QCVN09:2017/BXD Checklist on Energy Efficiency Building on MOC website is used to assess the compliance of the lighting power density requirement (tietkiemnangluong.xaydung.gov.vn).

- Enter the name of space, floor area and building function,
- Fill lamp types, quantities and rated powers into Type 1 column.

				Type 1			
	Name of space/ Quantity *(Spaces having same function and lighting design can be combined)*	**Function** *(Select the most suitable space in the list below)*	**Square** *(m^2)*	**Type**	**Quantity**	**Oats (W)**	**Total**
1	Gallery	Convention center*	120	SD1	12	41	492
2	Conference room	Convention center*	55	SD1	12	41	492
3	Control room	Convention center*	20	SD1	4	41	164
4	Warehouse	Convention center*	26,5	SD4	4	28	112
5	Technical Department	Convention center*	14,5	SD4	2	28	56
6	Gallery	Convention center*	99	ED1	28	11	308
7	Conference room	Convention center*	12	SD3	2	56	112
8	Control room	Convention center*	12	SD3	2	56	112

The calculation results for each space are shown in the Calculation column and compared with the compliance conditions of the Regulations shown in the Code Compliance column.

Calculate			Compliance	
Lighting capacity *(W)*	**Lighting capacity density** *(W/m^2)*		**Lighting capacity** *(W)*	**Lighting capacity density** *(W/m^2)*
492	4,1		1800	15,0
492	8,9		825	15,0
164	8,2		300	15,0
112	4,2		397.5	15,0
56	3,9		217.5	15,0
308	3,1		1485	15,0
112	9,3		180	15,0
112	9,3		180	15,0

Evaluation result shows the LPD of whole building in compliance with QCVN 09:2017/BXD.

359	**Compliance**	**1.848**	**5**		**5.385**		**15**
m^2		**Watt**	**W/m²**		**Watt**		**W/m²**
Total sqm		**Design**			**Compliance requirement from QCVN09 2017**		

3.3.2. Energy-efficient artificial lighting design for classrooms

The classrooms are 15m long, 10m wide and 3.5m high, designed with artificial lighting to achieve an average illuminance of 300 lux on the working plane 0.8m high (compliance with minimum illuminance requirements specified in QCVN 12:2014/BXD). Design of artificial lighting for classrooms is realized with DIALux Evo software.

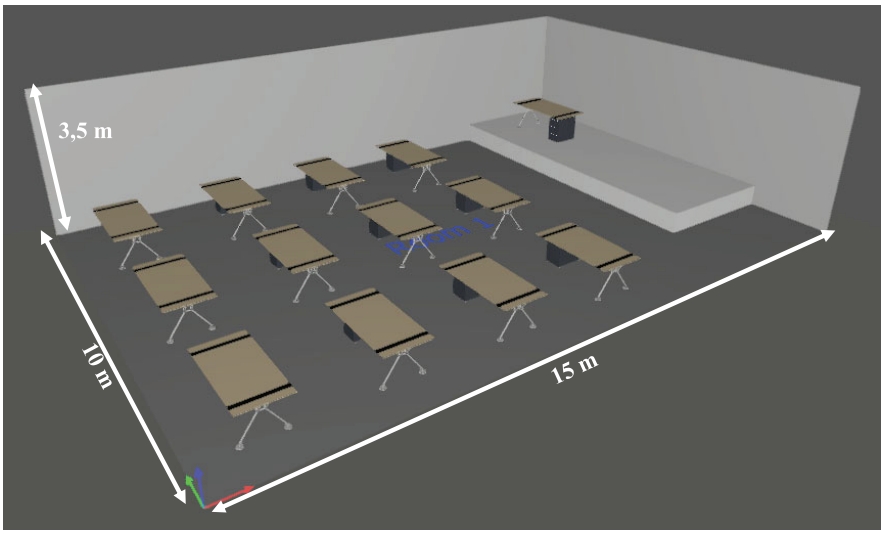
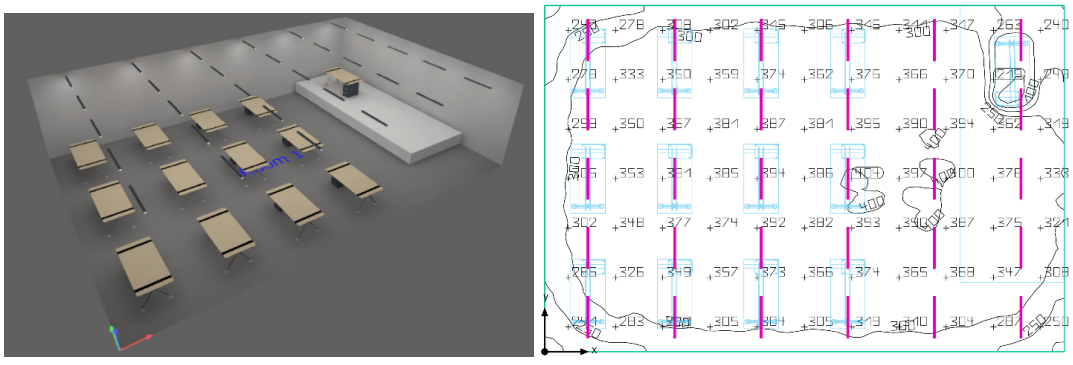


Figure 2.21. Classroom size and interior layout

Case 1: Using a T8 fluorescent tube with length of 1.2m, luminous flux of 2500 lm, rated power of 60 W without reflector. The design software proposes to equip 30 lighting fixtures for the classroom. The average calculated illuminance is 335 lux, execeeding the required illuminance level of (300 lux) set in the QCVN 09:2017/BXDand the LPD lighting power density is 12 W/m^2, then complying with the requirements of the maximum LPD (12 W/m^2) specified in QCVN 09:2017/BXD.



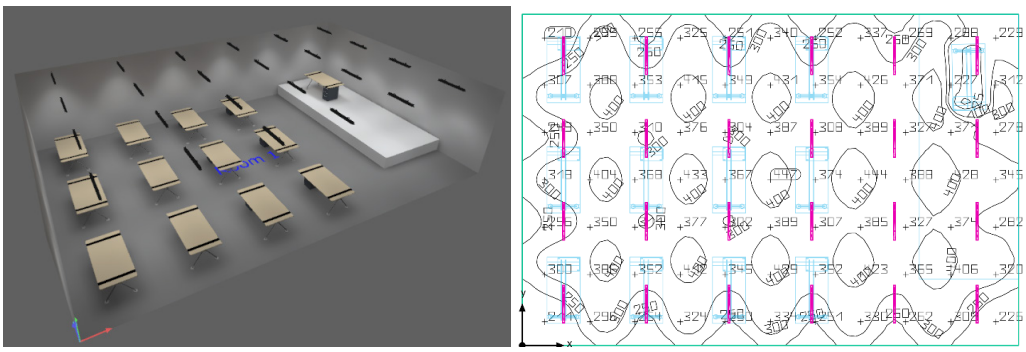
Results

	Symbol	Calculated	Target	Check
Workplane	Ē	335 lx	≥ 300 lx	✓
	g_1	0.20	-	-
Consumption values	Consumption	3450 kWh/a	max. 5300 kWh/a	✓
Lighting power density	Room	12.00 W/m^2	-	-
		3.58 W/m^2/100 lx	-	-

Figure 2.22. Lighting design results using T8 fluorescent tube without reflector

Case 2: Using a T8 fluorescent tube with length of 1.2m, luminous flux of 2500lm, rated power of 60W with a reflector. Thanks to reflectors that focus most of light on working plane, the design software proposes to equip 24 lighting fixtures for the classroom. The average calculated illuminance is 330 lux, achieving the required illuminance (300 lux) and the LPD

is 9.6W/m², complying with the requirements for the maximum LPD (12 W/m²)specified in QCVN 09: 2017/BXD, 20% less energy consumption compared to case 1.

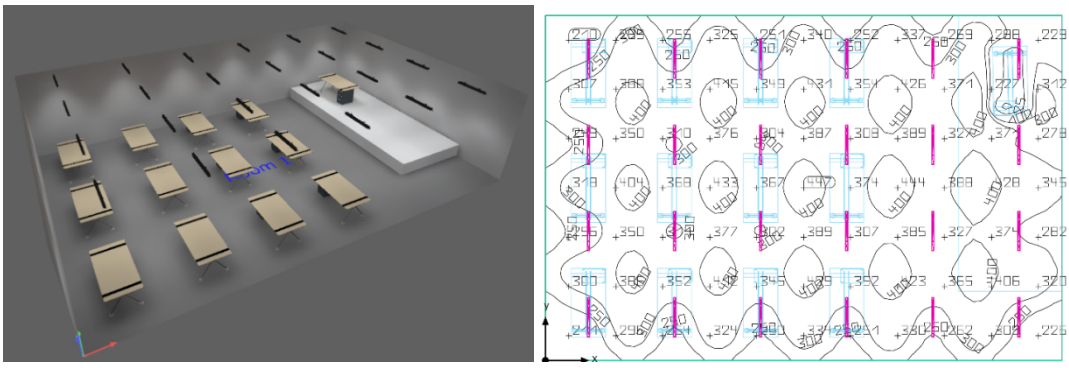


Results

	Symbol	Calculated	Target	Check
Workplane	Ē	330 lx	≥ 300 lx	✓
	g_1	0.073	-	-
Consumption values	Consumption	2750 kWh/a	max. 5300 kWh/a	✓
Lighting power density	Room	9.60 W/m²	-	-
		2.91 W/m²/100 lx	-	-

Figure 2.23. Lighting design simulation results using T8 fluorescent tube with reflector

Case 3: Using a T8 LED tube with length of 1.2m, luminous flux of 2500lm, rated power of 18W with a reflector. In this case, there is no change in average calculated illuminance and illuminance distribution in comparisonwith case 2 (required illuminance archived). However, thanks to higher luminous efficacy of LED compared to fluorescent lamps, the calculated LPD is 2.88W/m², saving 70% of the power consumption compared to case 2 and 76% compared to case 1.



Results

	Symbol	Calculated	Target	Check
Workplane	Ē	330 lx	≥ 300 lx	✓
	g_1	0.073	-	-
Consumption values	Consumption	830 kWh/a	max. 5300 kWh/a	✓
Lighting power density	Room	2.88 W/m²	-	-
		0.87 W/m²/100 lx	-	-

Figure 2.24. Lighting design simulation results using T8 LED tube lights with reflector

3.3.3. Vung Tau DIC Hotel (Demonstration building of the EEBC project)

- Type: Hotel
- Investor: Development Investment Construction J.S Corporation (DIC Corp)
- Address: 169 Thuy Van, Vung Tau
- Total floors: 35 floors (basement: 4, tower block: 27) –Height maximum: 100m
- The total floor area: 32.110m2 (not including the basement). The total floor area of basement: 6031,8m^2

The project goal is to adopt a design that reduces 20% of energy consumption compared to the minimum requirements specified in QCVN09:2017/BXD. For design evaluation and analysis, the 15th floor of the building has been selected as a typical floor.

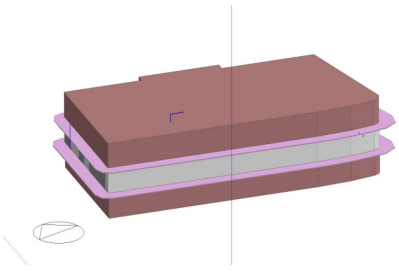


Figure 2.25. Typical floor simulation model

The design strategy of the LPD was evaluated through energy simulation on Design Builder software with 4 different cases: 11 W/m^2 (maximum LPD for Hotel Building specified in QCVN09:2017/BXD), 8.8 W/m^2, 6.6 W/m^2 and 4.4 W/m^2. The simulation results show that energy savings of typical floors can reach 12% of total energy consumption when LPD light power density is 4,4 W/m^2.

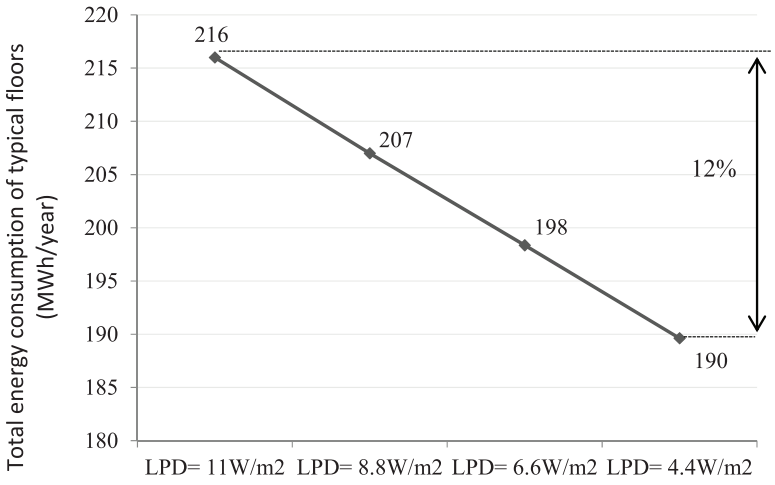


Figure 2.26. Vung Tau DIC hotel's total energy consumption of typical floor, calculated from energy simulation using different lighting power density

4. HVAC SYSTEMS

4.1. Definition

4.1.1. Ventilation

Ventilation process is essentially the process of changing the "polluted" air in the room/ building by outside fresh air.Each specific space can be naturally ventilated (passive) or mechanically/forced ventilated (pro-active - artificial ventilation or mechanical ventilation).

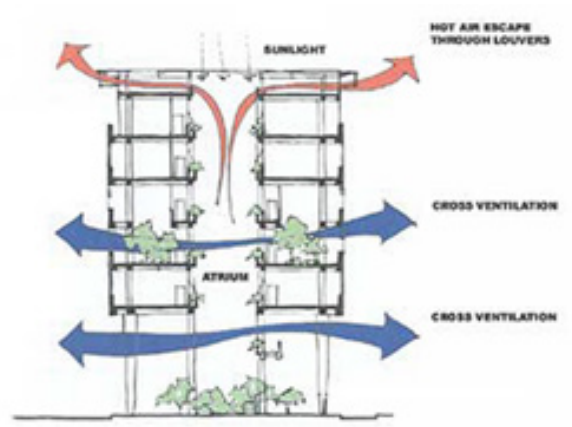


Figure 2.27.Natural ventilation[18]

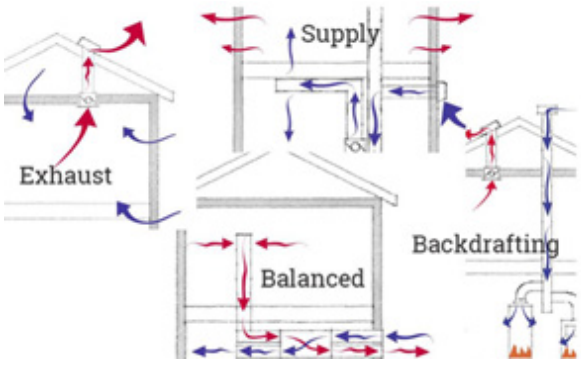


Figure 2.28. Forced ventilation[19]

Fresh air is drawn in through an air "intake" vent and distributed throughout the building by fans and a ducted distribution system. Specialized fans and ducts can be used for ventilation because fans help make cooling and ducts will deliver fresh air into the building. Mechanical ventilation is the process of exchanging air inside an enclosed space. Indoor air will be drawn out and replaced regularly with fresh air from external source.Types of mechanical ventilation are illutrated as follows:

Figure 2.29.Types of mechanical ventilation

4.1.2. Air conditioning

Air conditioning creates the thermal comfort in the building. Air conditioning can be any form of cooling or heating to regulate the air environment, and is typically it aims at creating adequate thermal comfort.An air conditioner is a type of machine, a system which is designed to take the heat load out of an area in a building using a cooling cycle.

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[18] *Source: https://urban.gamersta.com/conceptdiagram-facade-concept-diagram-conceptdiagram/*

[19] *Source: https://www.bpihomeowner.org/blog/technically-speaking-whole-house-mechanical-ventilation*

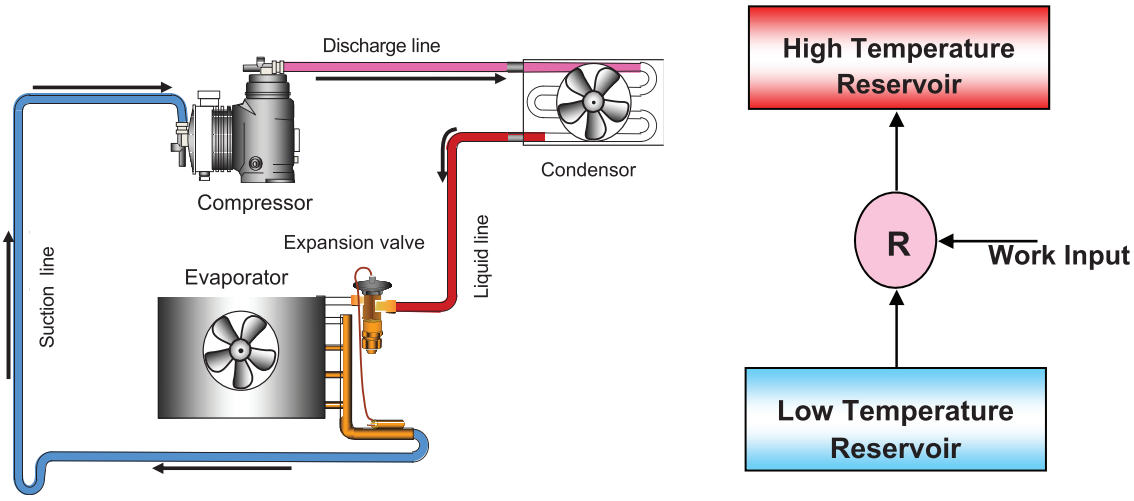


Figure 2.30. Typical airconditioning system principle (direct-cooling)

Two main types of air conditioning system:

Direct expansion (DX) system and indirect expansion systems (chilled water system), among other types:

- Unitary air conditioner (windowtype)
- Split air conditioner(1 indoor and 1 outdoor units)
- Multi splits air conditioning system
- Packaged air conditioner

Direct expansion air conditioning system

- Centralized airconditioning systems
  - VRF/VRV system (DX system)
  - Air-cooled chiller
  - Water-cooled chiller
  - Absorption chiller

Indirect expansion air conditioning system

Depending on the application and the scale of the building's air conditioning needs, an air conditioning system can be designed using a variety of options combining various types of air conditioning equipment. These options include: air conditioning, 2 units air conditioning, fan units in large air conditioning systems, and cooling air supply controllers in large air conditioning systems.

4.2. Design solutions

4.2.1. Take advantage of open spaces for natural ventilation in the building

In order to take advantage of open spaces for natural ventilation in the building, the following issues should be consideringduring the design strategy:

- Use architectural and passive design strategies to increase ventilation efficiency and prevent short-circuiting of airflow delivery.

- Appropriate architectural solutions to design windows to take advantage of natural ventilation, cross ventilation or stack ventilation need to be specifically studied regarding the area and location of doors that can be opened.

- Air inlets should not be obstructed by buildings, trees, signs or indoor partitions.

- In order for temperature difference to produce a motive force, there must be vertical distance between openings; vertical distance should be as great as possible.

Notes for design:

Notes when setting up a natural ventilation space are ventilation holes, openable windows on the wall or on the roof.

- Neither the building nor the ventilation facilities should be arranged the ventilation according to a certain windward

- Air vents should not be blocked by other buildings, trees, signs or room partitions.

- The maximum air flow through the building is reached when the inlets and outlets are of the same dimension.

- In order for force of temperature difference to operate to maximum advantage, the vertical distance between inlet and outlet opennings should be as great as possible.

- Vents near neutral pressure level areas have low effectiveness for ventilation.

- Openings much large than the calculated areas are somtimes desirabe, especially when changes in the occupancy are possible or to provide for extremely hot days. The opennings should be easily accessible by the users.

- The ratio of the area of ventilation holes and windows that can be opened or closed on the wall or on the roof adjacent to the outside space compared to the used area (floor area) must not be smaller than 5% according to QCVN 09:2017/BXD regulations.

The method of applying open space design in accordance with QCVN 09:2017/BXD is illustrated as follows:

Step 1: Identify all rooms and room areas contiguous to the outside space.

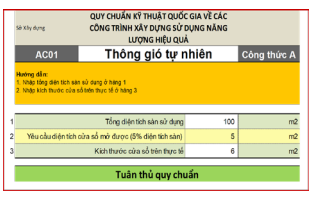
Step 2: Determine space and calculate floor area

Step 3: Use support tools to calculate the required minimum opening area according to floor area (must not less than 5%)

Step 4: Design windows and vents of suitable sizes and meet the minimum openable area.

Building plan

The floor area adjacent to the outside space is 100 m^2



QUY CHUẨN KỸ THUẬT QUỐC GIA VỀ CÁC CÔNG TRÌNH XÂY DỰNG SỬ DỤNG NĂNG LƯỢNG HIỆU QUẢ

Số Xây dựng

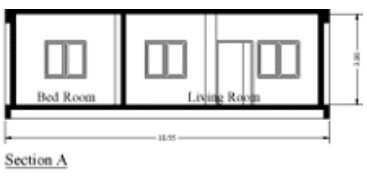
AC01	Thông gió tự nhiên	Công thức A

Hướng dẫn:
1. Nhập tổng diện tích sàn sử dụng ở hàng 1
2. Nhập kích thước cửa sổ trên thực tế ở hàng 3

1	Tổng diện tích sàn sử dụng	100	m2
2	Yêu cầu diện tích cửa sổ mở được (5% diện tích sàn)	5	m2
3	Kích thước cửa sổ trên thực tế	6	m2

Tuân thủ quy chuẩn

Minimum area to be opened to the outside = 100m^2 x 5% = 5 m^2



Design 3 openable windows with an area of 2 m^2 = 3x2m^2=6m^2

4.2.2. Ventilation for parking areas

Closed parking lots should be equipped with CO sensors connected to the ventilation system so that when the CO concentration reaches a certain limit, the ventilation system receives a signal to increase the ventilation speed. The system reduces harmful CO concentrations while conserving energy by reducing the number of hours of operation or the flow rate of the exhaust fan.An interesting design for a mechanically ventilated parking area is to use the air released from the main ventilation system of the building as fresh air intake for the parking area. In such system, relatively cool air is supplied to the parking area.

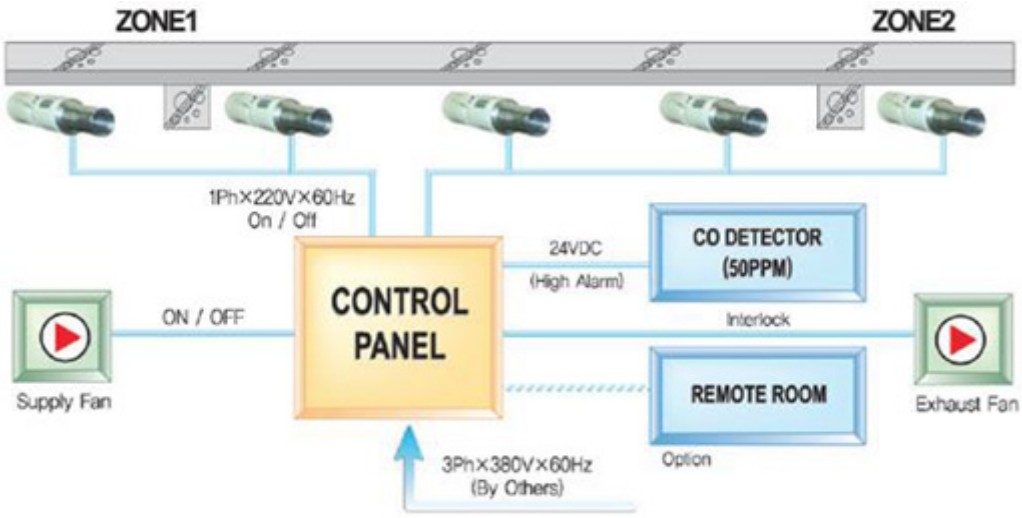


Figure 2.31. Mechanical ventilation system with CO sensor for automatic control and operation

Notes for design

The design of the ventilation system for the parking lot must meet the requirements of QCXDVN 05:2008/BXD as follows:

- For openable doors/windows for natural ventilation, total area of openable natural ventilation doors/windows, holes may be opened outward with sizes not less than 25% of two sided wall area or not less than 1/20 of parking spaces.

- For natural ventilation in combination with mechanical ventilation, the size of openable windows should not be less than 1/40 of parking spaces and air change hour not less than 3 times per hour.

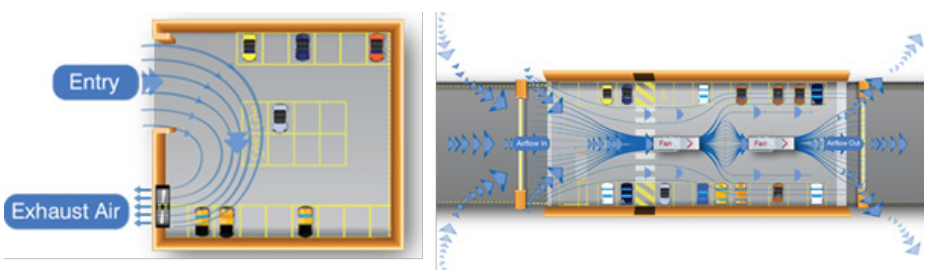


Figure 2.32. Mechanical ventilation system with CO sensor for automatic control and operation for parking spaces

4.2.3. Minimum mechanical ventilationflow rates

A mechanical ventilation system shall provide fresh air into the building, and at the same time shall push/suck out the indoor pollutant air for better indoor air quality, improving thermal comfort.This system provides stable air flow from outside into the building and at the same time purifies and dries the air. However, supplying too much fresh air and exceeding necessary levelwill cost a lot of energy and unnecessarily drain out the cooled air. Therefore, it's supposed to provide a suitable, stable and minimum fresh air flow rate according to each function and each area of the building to regulate the air flow more efficiently.

Notes for design

Minimum flow rates of mechanical ventilation must ensure ventilation requirements according to Vietnam Construction Code QCXDVN 05:2008/BXD as follows:

▪ For residential buildings:

Table 2.4. Minimum mechanical ventilation flow rates for residential buildings according to used space

Area	Minimum exhaust flow rates (not frequently use), l/s	Minimum exhaust flow rates (frequently use), l/s
Kitchen	30	13
Shower	15	8
Toilet	6	6

Table 2.5. Minimum general mechanical ventilation flow rates

Number of rooms	1	2	3	4	5
Minimum ventilation flow rates (l/s)	13	17	21	25	29

▪ For office buildings:The general ventilation flow rate of fresh air must not less than 5.5 (l/sec)/person

Table 2.6. Minimum mechanical ventilation flow rate for office building

Minimum mechanical ventilation flow rate for office building	
Room	**Minimum Exhaust Effuence**
Room with frequently used printer, copier (usage: over 30 minutes per hour)	20 (l/s)/machine in use (if the machine is continously in use, apply general ventilation rate).
Toilet and shower of office	Irregular ventilation with rate of 15 (l/s)/shower head or tub; 6 (l/s)/urinal or toilet.
Kitchen	Irregular ventilation (but at the same time with food processing) with rate: - 15 l/s for microwave oven - 30 l/s with hood directly on top of one stove

4.2.4. Automatic control device for ventilation fan motors

Automatic control for switching fan on and off is essential and a simple and convenient measure to apply to areas requiring ventilation with infrequent operating schedules and low usage frequency. This control method will bring very high energy efficiency to fans with large

installed capacity, specifically according to the QCVN 09:2017/BXD for all ventilation fans with installed capacity from 0.56 kW or more (except fans in continuous VAC systems). This method also helps minimize the fact of forgetting to turn off fans when not in use and then avoid wasting electricity.

Popular and efficient types of control device that allow on/off setting on timer for ventilation fans aretimer switch (timer replay).The features of this device are as follows:

- The components include electrical circuits switching relay (on/off) and either mechanical timer or electronical timer.

- The equipment is usually designed to be installed in an electrical cabinet and operates independently with manual or automatic on/off control.

Figure 2.33.Electronic and mechanical timer switches[20]

4.2.5. Minimum efficiency of air conditioning system

Air conditioning related energy consumption is usually the base load of the largest energy consumption center in commercial buildings in tropical regions, according to statistics compiled from JICA (2009), air conditioning systems account for 47 - 65% of total power consumption of the building.[21]

The energy consumption of air conditioning systems can be reduced by:

Notes for design

When selecting the type of air conditioning equipment, the minimum efficiency of the air conditioning system should be considered, the larger the COP, the higher the energy

[20] *Source: ecomm.com.vn*

[21] *Source: JICA – 2009*

efficiency and the COP must meet the requirements of QCVN 09:2017/BXD, which states that air conditioners and chillers must have a minimum COP efficiency index as stated in the below table 2.9:

Selecting air conditioning system type will depend on the following main factors:

- The size of the building, the need for cooling loads and air conditioning for the building
- Cooling method selection for air conditioning system
- High efficiency air conditioners and chillers
- Optimized control technology (VSDs for pumps, fans) for the chiller system
- Proper insulation of chilled water supply & return piping

Table 2.7. Coefficient of Performance of direct cooled electric air conditioner[22]

Type of equipment	Cooling capacity, kW	COP_{Min}, kW/kW	Test procedure
Unitaryair conditioner	-	2,80(*)	TCVN 6576:2013 TCVN 7830:2015 TCVN 10273-1:2013
Split air-conditioner	< 4,5	3,10(*)	
	≥ 4,5 and < 7,0	3,00(*)	
	≥ 7,0 and < 12,0	2,80(*)	
Air-cooled air conditioner	≥ 14 and < 19	3,81	TCVN 6307:1997 or ARI 210/240
	≥ 19 and < 40	3,28	ARI 340/360
	≥ 40 and < 70	3,22	
	≥ 70 and <223	2,93	
	≥ 223	2,84	
Water-cooled air conditioner	< 19	3,54	ARI 210/240
	≥ 19 and < 40	3,54	ARI 340/360
	≥ 40 and < 70	3,66	
	≥ 70 and < 223	3,63	
	≥ 223	3,57	
Water-cooled and evaporating air-conditioner	< 19	3,54	ARI 210/240
	≥ 19 and < 40	3,54	ARI 340/360
	≥ 40 and < 70	3,51	
	≥ 70 and < 223	3,48	
	≥ 223	3,43	
Air-cooled condenser units	≥ 40	3,07	ARI 365
Water-cooled or evaporating condenser units	≥ 40	3,95	

Table 2.8. Coefficient of Performance of Chillers[23]

Type of equipment	Cooling capacity, kW	COP_{Min}, kW/kW
Air-cooled electric chiller. Attached or split condenser	All	2,80
Water-cooled piston electricchiller	Similar to requirements of the electric rotary screw/ scroll water-cooled chiller	

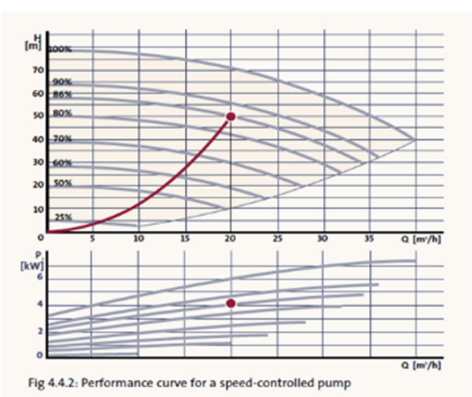
[22] *Source: QCVN 09:2017/BXD*

[23] *Source: QCVN 09:2017/BXD*

Type of equipment	Cooling capacity, kW	COP_{Min}, kW/kW
Water-cooled screw/scroll electric chiller	< 264	4,51
	≥ 264 and < 528	4,53
	≥ 528 and < 1055	5,17
	≥ 1055	5,67
Water-cooled centrifugal electric chiller	< 528	5,55
	≥ 528 and < 1055	5,55
	≥ 1055 and < 2110	6,11
	≥ 2110	6,17
Air-cooled absorption chiller, single effect	Tất cả	0,60(*)
Water-cooled absorption chiller, double effects	Tất cả	0,70(*)
Absorber chiller, double effects, indirectly fired	Tất cả	1,00(*)
Absorber chiller, double effects, directly fired	Tất cả	1,00(*)

4.2.6. Design automatic control variable speed drives for cooling tower fans, pumps with a capacity of greater than or equal to 5 HP (3.7kW) of centralized air conditioning system

For centralized air conditioning systems using chillers, using variable speed drives can reduce power consumption for pumps and fans by adjusting the motor speed according to demand.



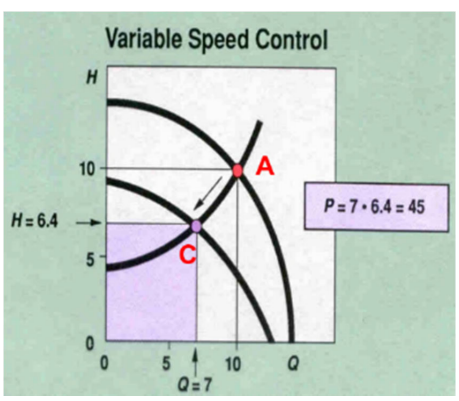


Figure 2.34. Variable speed drives controlling the pumps and fans motors[24]

The method of adjusting the flow and head is done through the inverter, which changes the pump characteristics while keeping the pipeline curve characteristics constant. The figure

[24] *Source:https://www.indiamart.com/proddetail/danfoss-variable-speed-drive-19609279791.html*

below shows that compared to point A, point C with a lower pump speed than point A will also have a lower flow and head and meet the required demand. This adjusted method provides the highest energy efficiency by avoiding the losses caused by the throttle or by-pass valve.

According to the formula, the energy saving potential is obtained by exponential 3 relationship between power and speed.

$$\frac{Q_2}{Q_1}=\frac{N_2}{N_1} \quad \frac{H_2}{H_1}=\left(\frac{n_2}{n_1}\right)^2 \quad \frac{N_2}{N_1}=\left(\frac{n_2}{n_1}\right)^3$$

Variable speed drives / Variable frequency drives (VSD/VFD) can be equipped on many devices:

- Pumps in primary and secondary chilled water lines (chiller)
- Pumps for condensing lines
- Pumps for heating circuits
- Fans in AHU, VAV boxes, cooling towers.

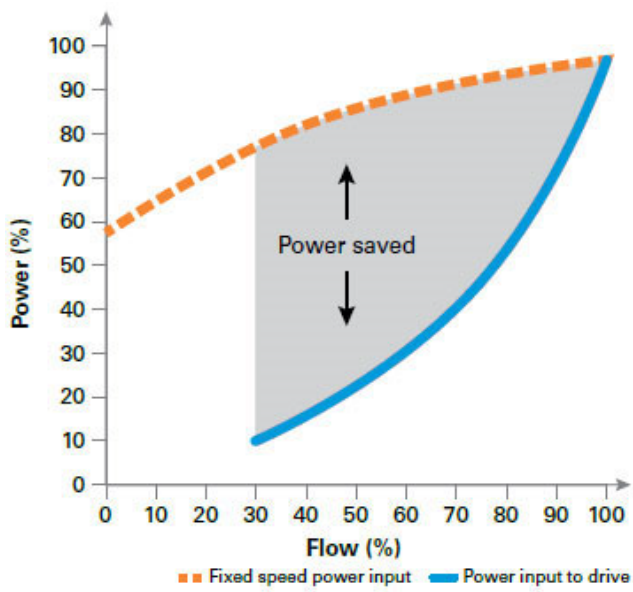


Figure 2.35.A typical (throttle valve and damper) VSD/VFD control for pumps and fans[25]

As it can be seen in the figure, a 50% reduction in the flow rate of a conventional throttle reduces the pump input power from 100% to 86% (rated power). With the frequency converter, it will make much more sense to reduce the power input, down to 22% of rated power.

Optimizing the air flow control through the VSD control fan with the combination of opening/closing the valve helps reduce the cool air flow of AHU fans, reducing energy consumption and then bringing energy efficiency, typically as follows:

[25] *Source: http://www.gozuk.com/applications/variable-frequency-drive-in-fans-system.html*

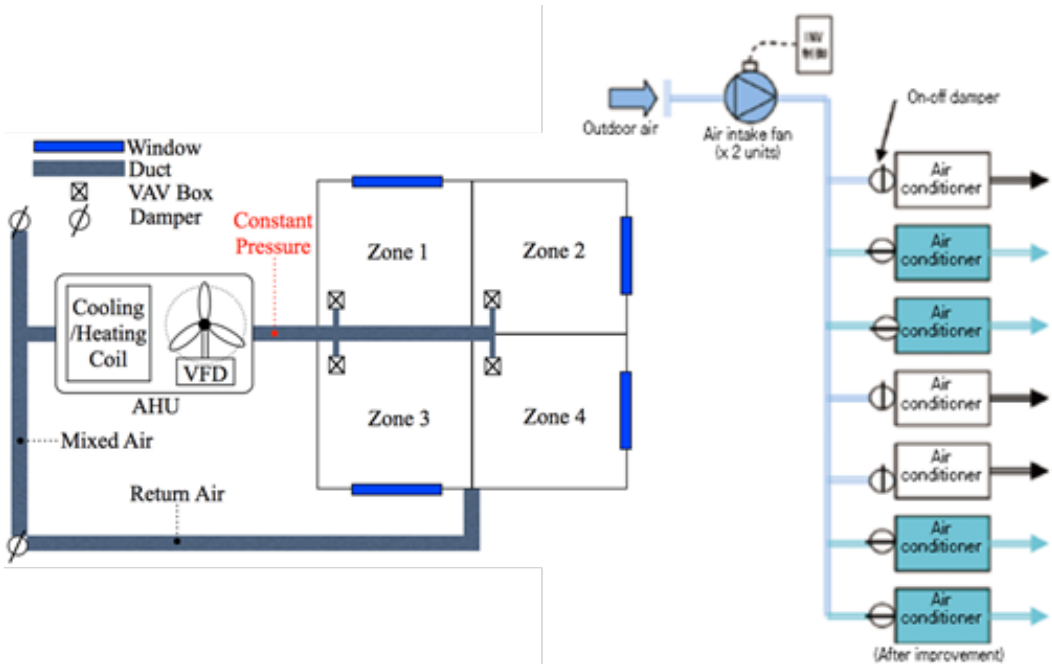


Figure 2.36.VFD to optimize the AHU fans

4.2.7. Use high performance fans

Fans used in a central air conditioning system are mainly supply and return fans in AHUs. The energy consumed by a fan depends on the amount of moving air and pressure that the fan must generate. ASHRAE 90.1-2010 Standard, Energy Standard for Buildings, propose the fan power limitation for the air conditioning system based on flow rate and many other related factors such as noise level.

Notes for design

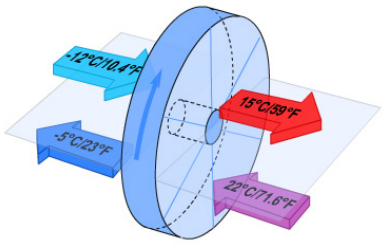
Anappropriate fan selection for the higher operating efficiency will bring high efficiency. At that time, the energy efficiency of fan's operation will increase due to low fan motor power requirement. Fans of large nominal power capacity from 3.7 kW or more, must have a fan efficiency class greater than FEG 67 (determined by AMCA 205 standard) specified in QCVN 09:2017/BXD.

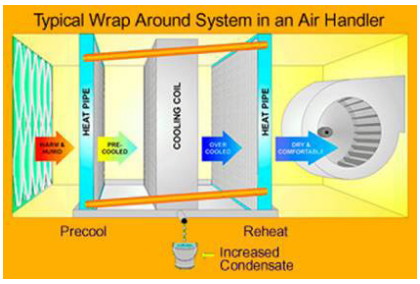
Fans must have a manufacturing label on the cabinet showing their diameter, revolution speed, required power of the motor, the minimum fan efficiency at full load as a basis for testing when installation, and commissioning stages.For the fan selection, it is important to choose the right fan and at the same time to meet other requirements such as fan noise because a quieter operation will be more efficient and reliable.

4.2.8. Heat recovery systems

Heat recovery systems are used almost mandatorily for air conditioning systems when using AHU that can help recover the enthalpy energy for more energy efficiency to the air conditioning system. Energy recovery units allow the entering outside air to exchange heat and

moisture with the building's exhaust air through the exchanger such as a desiccant-coated wheel or a special sheet of material in a flat stream arrangement. (flat-plate, counter-flow arrangement). The successful use of these recovery devices depends on many factors, the most important of which is the climate parameters (such temperature, moisture, etc.).





Enthalpy Wheel[26] ***Heat pipe*** ***Plate heat exchanger***

Figure 2.37. Exemple of heat recovery devices

Typical heat exchanger types used in the AHU:

- Thermal/enthalpy wheel: 80% - 85%
- Plate heat exchanger: 80%
- Heat pipe: 45% -65%
- Run around (or wrap-around) coil: 55% - 65%

Notes for design

Design and select AHU's energy recovery unit in the air conditioning system when there is a high demand for ventilation flow, fresh air supply is used through the AHU.

The different Heat exchanger types have different properties that should be considered when being selected:

- Plate heat exchanger: This is the simplest form of heat exchange which requires the least maintenance, however, this system offers a relatively low heat recovery efficiency.

- Run around (or wrap-around) coil: is generally limited to situations where the air streams are separated and no other type of device can be utilised since the heat recovery efficiency is lower than other forms of air-to-air heat recovery. Moreover, this system also requires more complex maintenance according to used time.

- Heat wheel: has a relatively high heat recovery efficiency but the extraction air flows can be contaminated and affect the supply air inlet, so it may not be suitable for places with contaminated return air such as hospitals.

4.2.9. Insulation materials

Insulation is used for the distribution pipeline of chilled water, refrigerant piping and cool air supply of air conditioning systems to prevent heat loss due to contact with the distribution pipe surface.

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[26] *Source "Enthalpy Wheel": https://www.wolf.eu/en/air-handlingexpert/technology/heat-recovery/thermal-wheel-heat-exchanger/*

Insulation material shall be selected according to the material properties as follows:

- Thermal conductivity coefficient
- Hygroscopic degree
- Compressive strength
- Fire resistance
- Chemical and biological sustainability...

When choosing insulation materials, in addition to depending on the factors mentioned above, it should be paid attention also to insulation efficiency to ensure a harmonious balance according to economic efficiency between the insulation costs (type of material and thickness) with the cost savings due to heat loss. If the insulation uses a material with a very good insulation coefficient, or a large thickness, the insulation effect is better, but at the same time, the material investment cost is also too high, it will not bring economic efficiency in this case.

4.3. Example

New admin and educational building, College of Urban works and construction (see part 2.3.1).

The design and installation of ventilation and air conditioning systems not only comply with QCVN 09/2017/BXD but also go beyond the EEBC with energy saving solutions as follows:

- The design aims toward the use of maximizing natural ventilation (with multiple openable windows).

- The building uses a central air conditioning water-cooled chiller system with a capacity of about 80 RT combined with a Concrete Core Activated system (i.e. radiant cooling system) supplied with cool water from the geothermal system.

- Centralized air conditioning and ventilation systems are designed and installed with a view to improving the energy efficiency of building operations. All chillers are connected to BMS and have a central control room for the air conditioning system.

- The building has CO2 sensors installed in areas with a high concentration of people to monitor air quality to improve the performance of the ventilation and air conditioning system.

Chiller system (TECS-W092L-E) with a capacity of 325 kW is used to cool the air conditioning system with a COP of 5.17 in accordance with QCVN 09/2017/BXD.

Cooling (Gross value)		
Capacity control	%	91,2
Cooling capacity	kW	325
Compressors power input	kW	62,8
Total power input	kW	62,8
EER	kW/kW	5,17
ESEER Calculated	kW/kW	9,50

Below is a table of performance of TECS-W0921L-E chiller vs QCVN09:2017/BXD as follows:

Department of Construction	VIETNAM BUILDING ENERGY EFFICIENCY CODE						
AC02			Air conditioning Efficacy Calculator				
Instruction: 1. Select cooling type in column E 2. Enter number of units of exact same size and COP, size of unit and designed COP in column F, G and I							
Air-conditioner calculation: Min Air conditioning Efficacy Calculator							
	Cooling Type *(Select from pulldown menu)*	**Number of units of exact same size and COP**	**Size of unit** *(kW cooling)*	**Minimum Required COP**	**Design COP**	**Other requirements**	**Compkiance check**
1	Water-cooled screw/screw electric chiller <150 TR	1	92,41	5	5,17	Setting water flowrate 13 litre/min, additional flow rate into condensate, and ventilation fan with power of 35 - 40 W/Tc 1 - 1,4%	Complies
If more than 10 cooling types of equipment used, expand list by clicking on "+" on left *If the cooling type is not listed above, enter additional information from row 58 (after expanding)*							
			Total cooling tons	92,41			
				Total Design Ton - Weighted COP			5,17
				Total Code Required Ton - Weighted COP			5,00
				Meets requirements			

The air conditioning system's pumps and cooling towers with an electrical capacity of 5.5 kW are all equipped with an variable speed drive (VSD) complying with QCVN09/2017/BXD. Polyurethane material is used to insulate the cold water pipes of the system, with a thickness of 25mm.Polyurethane foam material with a thermal conductivity coefficient of 0.034 W/m.K.

Three AHUs installed in floors 2, 5 and attic are equipped with heat recovery systems and the efficiency is in accordance with QCVN 09/2017/BXD.

The results achieved from energy simulation for the design of air conditioning system installed for New admin and educational building, College of Urban works and construction as below.

Annual energy saving of air conditioning system

No	Total energy consumption per year (kWh/m²/year)	BAU case	EEBC case	Proposed case 1
1	HVAC (kWh/m2/year)	79	57	35
	Percentage of Energy saving compare to EEBC case (%)			**39%**
2	Ratedcooling capacity (kW)	365	342	325
	% reduction compared to EEBC case			5%

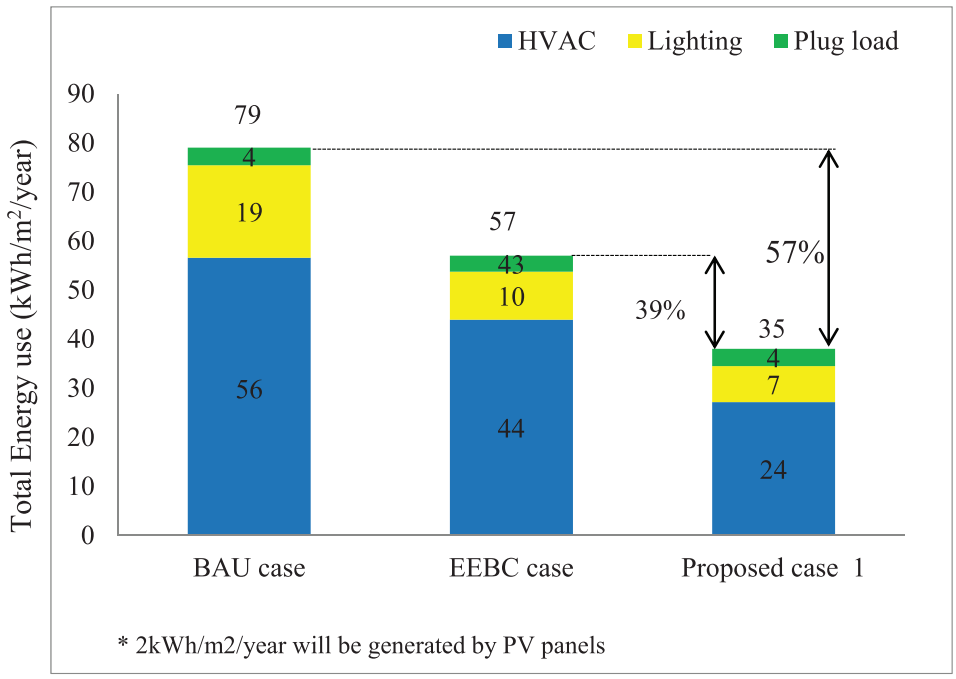

Figure 2.38. Total Energy Use (kWh/m2/year)

5. OTHER ELECTRICAL EQUIPMENTS

All 3-phase (50Hz) motors, regardless of being manufactured as an independent equipment or as a part of a building equipment, shall comply with the requirements of EEBC QCVN 09:2017/BXD. Motor efficiency shall be dertemined as per NEMA MG-1.

5.1. Definition of electrical motor efficiency

The electrical motor efficiency is determined by the effective power (mechanical power) divided by the engine input power (electrical power). The mechanical power is always less than input power due to power losses in friction, resistance and inductance of the Stator (iron core and coil) and the Rotor (coil).

5.2. Selection of electrical motor

High efficiency motor means small power losses, thereby increasing energy efficiency. Motor efficiency must be higher than the minimum efficiency specified in Table 2.6 of QCVN

09: 2017/BXD.The motor efficiency and other technical parameters to assess compliance with QCVN 09:2017/BXD can be found on motor label. The motor label, located on the motor casing/housing is featuring technical information including Rated power (kW or HP), Rotation speed (rpm), Efficiency at full-load (%), Rated voltage by (V), Rated current by Y/Δ connection(A), Power factor (cosφ), Ingress Protection (IP 23: open motor, IP 55: enclosed motor), performance standard and other parameters.

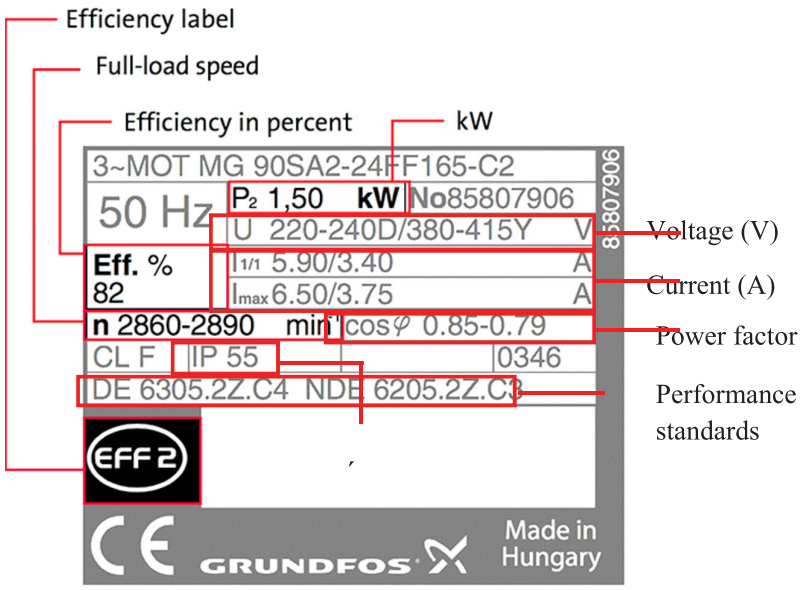

Figure 2.39.Label of 3-phase induction motor 1.5kW[27]

Notes for design

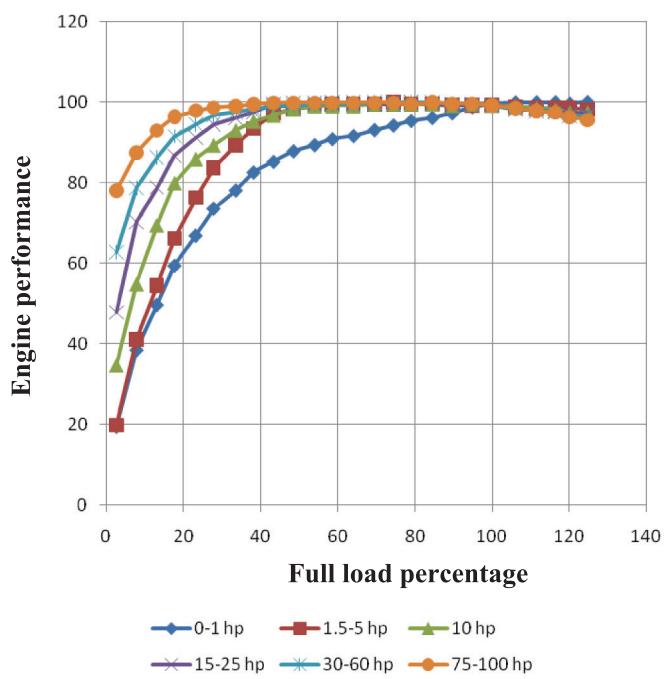

Figure 2.40. Induction motors efficiency in full load percentage and capacity[28]

[27] *Source Grundfos*

[28] *Source Hydraulic Institute*

The design documents must fully state the technical requirements of the electric motor, as a basis for testing on the production label on the case, which shows the minimum efficiency value at full load. This information is used as a basis for inspection when installing, testing and accepting electric motors for the project. Select the motor to operate at full load to limit the motor operating at low load because the motor efficiency at low load is significantly reduced.

5.3. Example

Compliance of motor efficiency:

Assessment of the 2 selected Siemens enclosed electric motors (IP 55) with specification mentioned in the table below in compliance with the minimum efficiency specified in Table 2.6 of QCVN09: 2017/BXD.

Specification of 11kW-Siemen motor-2 poles-IP55

Rated output at 50 Hz	Frame size	Operating values at rated output							Order No.	Price	Weight
		Rated speed at 50 Hz	Rated torque at 50 Hz	Efficiency Class according to CEMEP	Efficiency at 50 Hz 4/4-load	Efficiency at 50 Hz 3/4-load	Power factor at 50 Hz 4/4-load	Rated current at 400 V, 50 Hz	For Order No. supplements for voltage and type of construction, see table below		IM B3 type of construction approx.
P_{rated} kW	FS	n_{rated} rpm	T_{rated} Nm	EFF	η_{rated} %	η_{rated} %	$\cos\varphi_{rated}$	I_{rated} A			m kg
2-pole, 3000 rpm at 50 Hz, temperature class 155 (F), IP55 degree of protection, for use according to CEMEP											
11	160 M	2945	36	EFF1	91	91	0.9	19.4	1LA9 163-2KA□□		73

Specification of 11kW-Siemen motor-4 poles-IP55

Rated output at 50 Hz	60 Hz	Frame size	Operating values at rated output						Order No.	Price	Weight
			Rated speed at 50 Hz	Rated torque at 50 Hz	Efficiency at 50 Hz 4/4-load	Efficiency at 50 Hz 3/4-load	Power factor at 50 Hz 4/4-load	Rated current at 400 V, 50 Hz	For Order No. supplements for voltage and type of construction, see table below		IM B3 type of construction approx.
P_{rated} kW	P_{rated} kW	FS	n_{rated} rpm	T_{rated} Nm	η_{rated} %	η_{rated} %	$\cos\varphi_{rated}$	I_{rated} A			m kg
4-pole, 1500 rpm at 50 Hz, 1800 rpm at 60 Hz, temperature class 155 (F), IP55 degree of protection, with increased output, used as temperature class 155 (F)											
11	12.65	132 M	1450	72	86	86	0.82	22.5	1LA9 133-4LA□□		60

- EP05b QCVN09 checklist is used to assess the compliance of electric motors efficiency (tietkiemnangluong.xaydung.gov.vn). Fill in motors rated power, number of poles in the spreadsheet and it shall provide automatically the minimum required motor efficiency specified.

- Fill in the value of efficiency at full-load in the actual motor efficiency column and the checklist will automatically check the compliance status, as mentioned below.

Rated power *(kW)*	Motor type (IP)	Number of poles	Motor efficiency in compliance to EEBC of VN *(%)*	Actual motor efficiency *(%)*	Evaluation
(1)	(2)	(3)	(4)	(5)	(6)
11.1	Enclosed	2-poles	91	91	**Compliance**
11.1	Enclosed	4-poles	92,4	86	**Non compliance**

6. WATER HEATING SYSTEM

6.1. Definition

Selection of water heater types that serve domestic purposes, sanitation, heat supply and other uses will depend on function and scale of buildings, (such as hospitals, hotels, etc.). The typical and efficient of water heating systems can be listed as follows:

6.1.1. Service Water Heating System using Heat Recovery

Instead of rejecting heat through a cooling tower/outdoor unit, heat is recovered from condenser through a heat exchanger to generate this free hot water.

Characteristics of this type of equipment are as follows:

- Hot water is produced through the heat exchanger that recovers the waste heat of condensing units after the compression stage. The hot water temperature can reach 50^0C.

- Common heat recovery systems are suitable for Hotels, Supermarkets, Hospitals (temperature of hot water demand is around 50^0C – 60^0C).Benefits from recovered heat

- Profit heat to heat water
- Reduce heating load, (heat is not released into the environment)
- Reduce electricity consumption of the auxiliary-cooled device as well as to improve energy efficiency of the air conditioning system.
- Reduce the energy cost and emissions to environment.

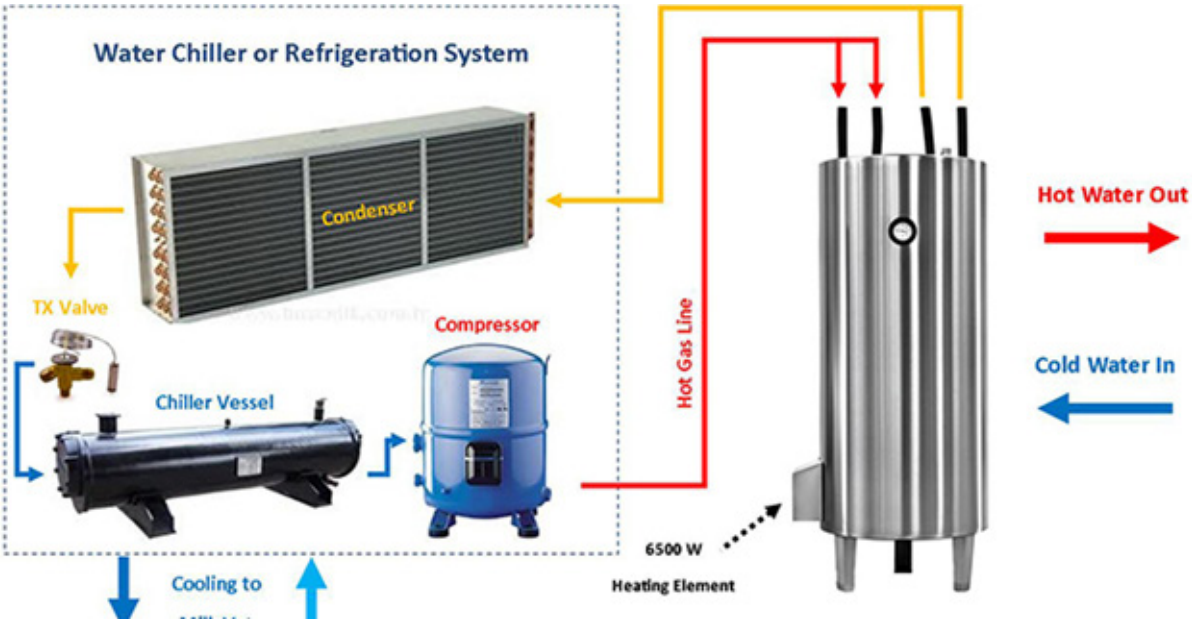

Figure 2.41. Illustrations of air conditioner cooled by water and heat recovery system

6.1.2. Solar thermal watersystems combined with heat pumps

Solar thermal water heating combined with heat pump can take the advantage of solar radiation to heat up the water at the priority heating loop into the hot water storage tank, while the secondary heating loop of heat pump can be heated up and maintain the required temperature when the natural conditions are not favorable in terms of solar radiation neither the peak water demand is high at night time, this system can take advantage and operate flexibly due to the following advantage:

- Supplying hot water source with comfortable, stable, and at a reasonable temperature.

- Can save a lot of energy costs when compared to water heaters used by fuel or direct electric heater.

- Safety ensured for the users

- Reducing the operation and maintenance costs.

- Reducing CO_2 emissions as a friendly environment.

The diagram ofsolar thermal water heating system combined withheat pump is shown as follows:

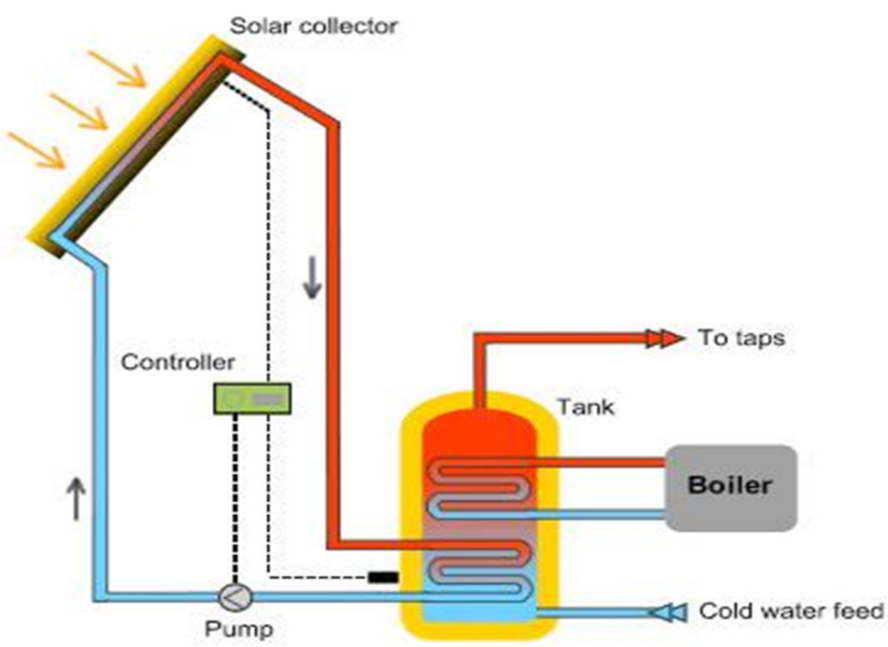

Figure 2.42. Illustration of diagram of solar thermal water heating system combined with heat pump

6.1.3. Heat pump system

The working principle is illustrated as follows:

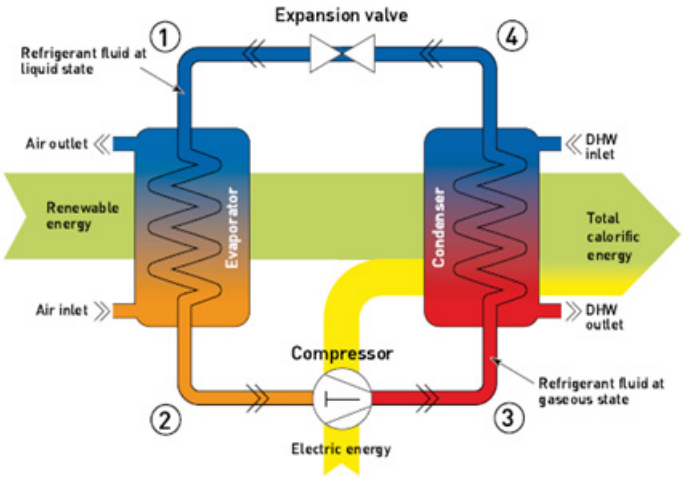

Figure 2.43. Operating principle of heat pump

There are two types of heat pumps commonly used: residential heat pumps and industrial heat pumps.

No	Type of heat pumps	Characteristics
1	Residential heat pump	- Rating capacity from 1 to 1.5 HP - Install in the technical room/outdoor space
2	Industrial heat pump	- Large scale and size - Thecapacity significantly fluctuates from a few tens of kW to more.

The advantages of heat pump:

Electricity consumption is much lower, only about 30% compared to other systems using electric heaters. Ability provides hot water to multiple rooms. There are 02 common types of heat pumps is based on water source or air source. With water source heat pumps, dissipates cooling by way of water source, so that using water pipe of the water chiller system to pre-cooling water. For air source heat pumps, dissipates cooling by air source that can be using outside air to provide cooled air.

Figure 2.44. Residential and industrial heat pumps

6.1.4. Hot water heater/ Fuel Water Boiler

Operating principle: The fuel is burnt and produces hot gases that pass through a heat exchanger where the heat is transferred to water.

Characteristics:

- Condensing boilers are high-energy-efficient boilers that incorporate an extra heat exchanger in which hot exhaust gases lose much of their energy to pre-heat the water.

- The efficiency of water heater and boiler is defined by manufacturers.

Illustration image of fuel-fired water heater and boiler is in the following:

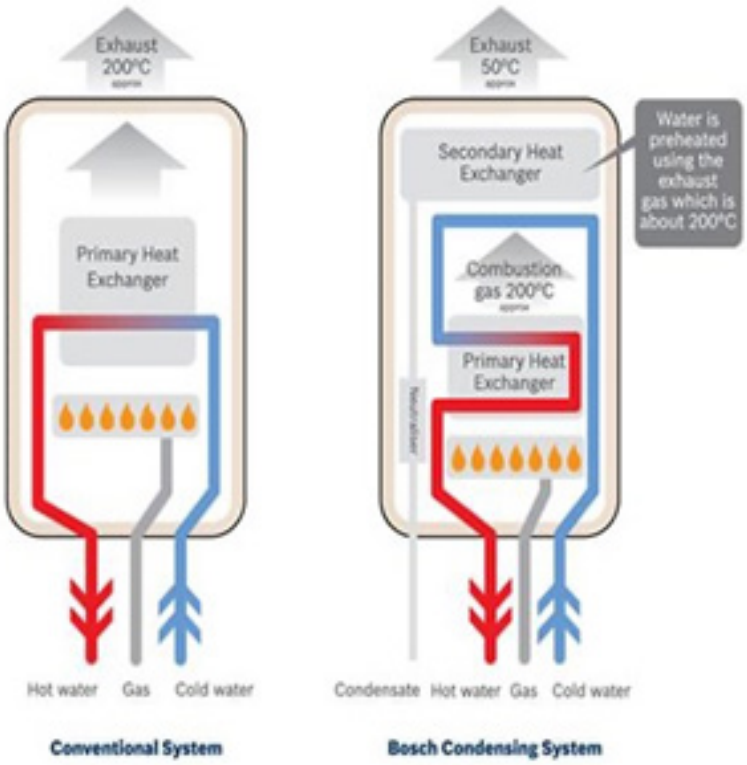

Figure 2.45. Gas-fired water heater

Figure 2.46. Oil-fired water heater, boiler

6.1.5. Electrical Water Heater

There are 02 types of electrical water heaters: direct heater (tankless water) and indirect heater (stroring water).

a. Electricaldirectwaterheater(tankless water) has working principles as below:

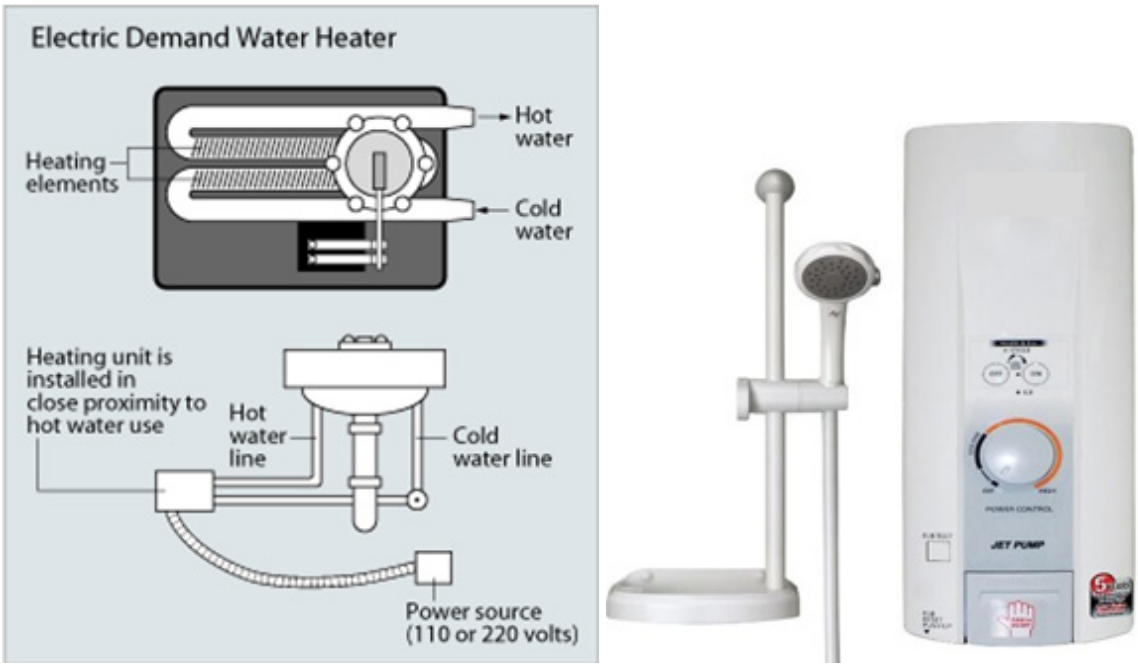

Figure 2.47. Principle of electric water direct heater(tankless water)

Features of the electric tankless water heater are follows:

- Direct water heater can provide almost instantaneous and continuous hot water as the water flow is directly heated through electrical resistor.

- Power rating: 3.5 - 4 kW.

- One unit can only provide hot water for one room.

- Cheap installation costs and does not require space.

- Recommended solution for low hot water demand such as residential building (one family with only one bathroom).

- However, due to the hot water demand in households will focus on the peak time (while many electric devices such as lamps, TVs, air conditioners, etc. are in use at 5pm-7pm for example), and additionally, the efficiency of electric tankless water heater is less 3 – 4 times than the efficiency of water heater using heat pump. Therefore, it easily causes the overload or shortage of electricity supply from the national grid. For that reason, it impacts on the power demand management from the authorities.

b. Electricalindirect water heater (with storage tank)

The operating principle of electriacal indrect water heater with storagewater is illustrated as follows:

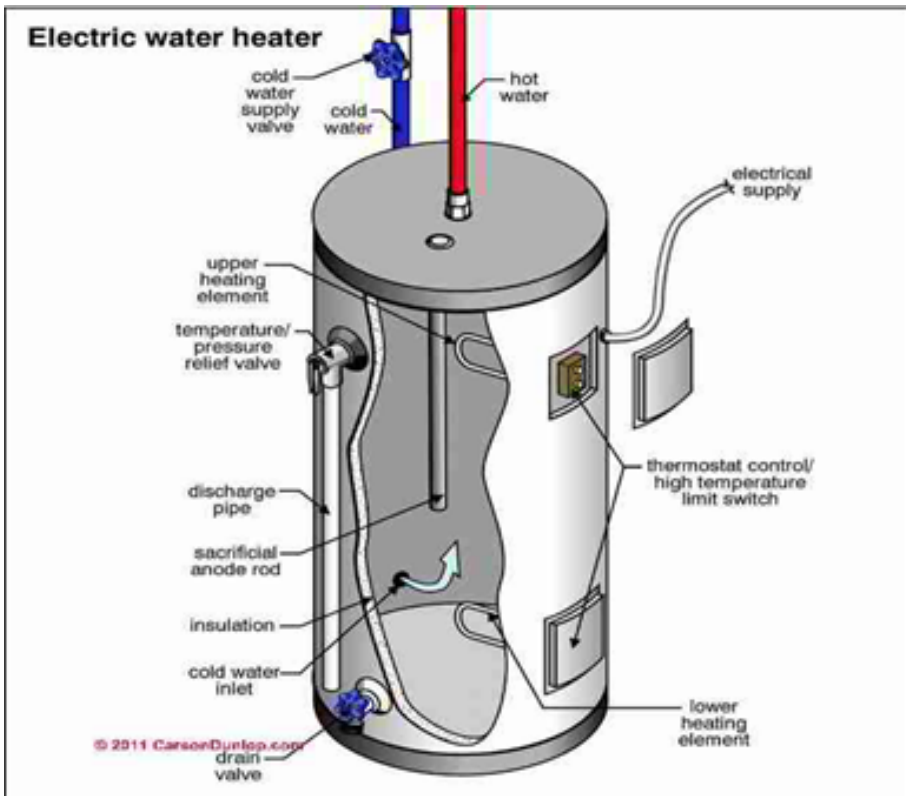

Figure 2.48.Principle of electriacal indrect water heater with storage water

Features of electric storage water heater are follows:

- An electric resistor is heating up the water tanks until the set point temperature is reached. A thermostat is starting another heating cycle when the temperature of water has dropped below the temperature set point.

- Tank insulation and its time-based standby losses are very important parameters when considering energy efficiency.

- Power rating: 3.5 - 4 kW

- One hot water tank (30 – 80 liters) can provide hot water to multiple bathrooms in residential buildings.

- Cheaper installation costs also but require much electricityto heat up the entire tank.

6.2. Design solutions

6.2.1. Efficiency of water heating equipment

The design and calculation of load of the hot water system is based on the hot water temperature and demand of the system, and in accordance with the manufacturer's recommendations. The selection of a water heater system should considerits efficiency and the following aspects:

- For buildings that use heat pumps for hot water demand, these heat pumps can be also used for water heating. Electric water heaters can use heat source provided from another place

instead of direct heating. Therefore, they can save up to 2 – 3 times higher than the energy consumption of conventional resistive water heater.[29]

- Most water heating systems have hot water storage tanks. Since water is continuously heated inside tanks, energy is wasted even when not in use. Using instantaneous hot water can help reduce these losses. For storage tanks, insulation of the tanks also reduces some of the losses. These heaters are small and can be installed under the sink.

Notes for design

Water heating systems, boilers that supply hot water must have the minimum efficiency as table 2.7 ofQCVN09:2017/BXD requirement stated below:

Types of Equipment	Minimum efficiency (E_T), %
Gas-fired storage water heaters	78
Gas-fired instantaneous water heaters	78
Gas-fired hot water supply boilers	77
Fuel oil-fired hot water heaters and supply systems	80
Dual fuel gas/oil-fired hot water supply boilers	80
Firewood/paper-fired boiler of 10÷350 kW output	60
Boilers of 10÷2000 kW, burnt with molded brown coal	70
Boilers of 10÷2000 kW, burnt with anthracite coal	73
Electric resistance water heaters	Emin = 5,9 + 5,3$V^{0,5}$ (W)

Notes:

• *The minimum efficiency of gas or oil-fired water heater is determined as the Thermal Efficiency (ET) which includes heating loss from heater's compartments.*

• *The minimum efficiency of resistive water heater is determined from the maximum Standby Loss (SL) when the temperature difference between hot water and surrounding environment is 400C. In the above formula, V is the capacity measured in liters.*

• *Tests shall be performed in accordance with the ANSI ZZ21.10.3 or other standards applicable to buildings.*

For heat pumps, the minimum COP must be as follows:

Type of Equipment	Minimum efficiency ET, %
Air-source heat pumps	≥ 3,0
Water-source heat pumps	≥ 3,5
Air conditioners with heat recovery:	
For hot water supply	≥ 3,0
For air conditioning and hot water supply	≥ 5,5

[29] *Source:https://www.energy.gov/energysaver/heat-pump-systems#:~:text=For%20climates%20with%20moderate%20heating,-to%20furnaces%20and%20air%20conditioners*

6.2.2. Minimum insulation value for hot water pipes

Properly insulate hot water pipes to reduce heat losses, especially if the pipe passed through cooling spaces. Insulation also reduces the time needed to get hot water in faucets or showerheads after turning them on. This reduces water wastage. To calculate the insulation value of pipes, it should refer to the table of pipe insulation values according to American standard ASHRAE 90.1-2010.

6.2.3. Maximum hot water temperature control

Maximum temperature control by limiting the water temperature when in use that avoids the hot water production higher than essential demand e.g domestic purposes and services, will be causing waste and safety less when used.The temperature controller shall be installed to limit water temperature as it is a simple and low-cost energy-saving solution.Most water heaters have designed a thermostat to adjust the temperature of hot water. Thus, the thermostat shall be limited at a maximum temperature of water delivered i.e. at the faucet or bathtub.

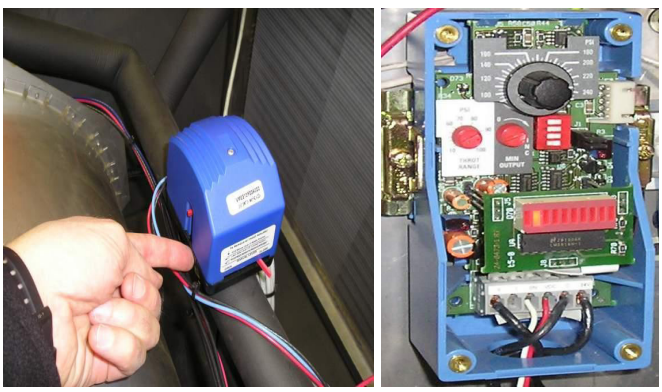

Figure 2.49. Hot water control system through a thermostat

6.2.4. Use renewable energy for water heating

Solar thermal water heating systems use the plentiful solar energy available to heat water. The amount of hot water supplied by the solar collectors depends on the number of available solar units, roof area, available space, shading, direction and angle of the collectors and type of solar collector (panel or tube).

Take the most of roof area that can be capable of installing a solar water heating system for generating hot water demand. During the less sunny days of the year, if the capacity of the solar water heating system is not sufficient, and it is advised to use an electric or heat pump system for backup or complement.

When a centralized water heating system is powered by a solar thermal system combined with a heat pump, the related energy consumption can be reduced up to 80% in comparison with the energy consumption of an electric water heater.

Advantages of Solar water heating systems:

- Safety: safer operations than electric or gas/fuel heaters; reasonable hot water temperature around 45-60°C.

- High life span (~20 years).

- Energy saving.

- Reduce cost of operation and maintenance.

- Save installation space inside the building, only need space on the rooftop.

- Provide additional shading on the rooftop, therefore reduce the heat gain through the roof and the cooling demand.

- For the environment: reduce CO_2 emission.

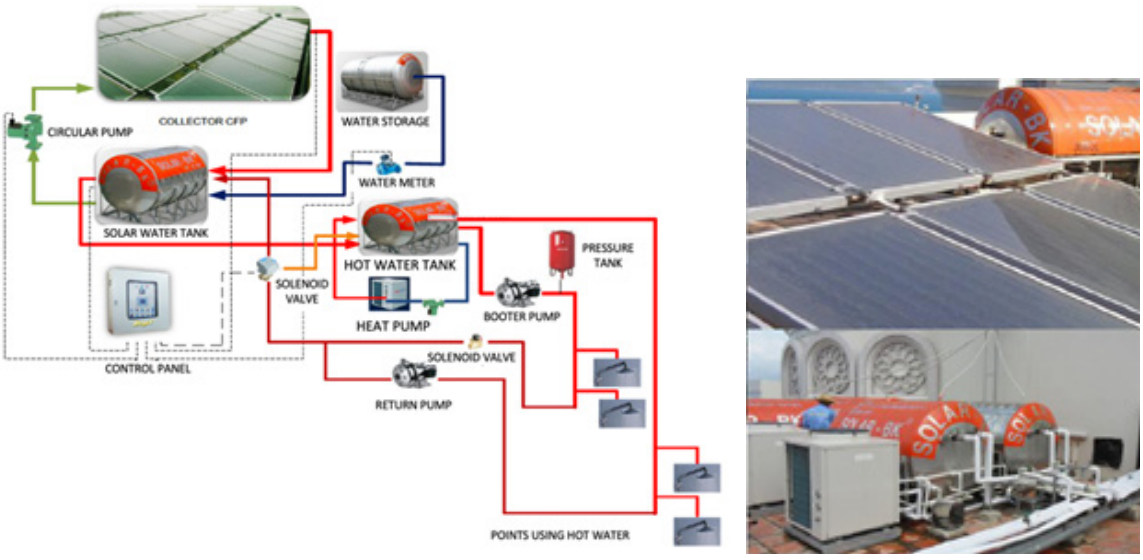

Figure 2.50. Actual design diagram of Solar water heater combined with heat pump[30]

6.3. Example

One hotel has 189 guess rooms, and each room is equipped with one resistive water heater (direct heater).

Types of the water heater are as follows.

- Installed capacity of each water heater: 3.9 kW/unit

- Expected daily electricity consumption on average of one water heater: 4.8 kWh

- Average occupancy rate: 70%

- Expected total electricity consumption of hot water supplies in a year on average: 231,790 kWh/year.

- Required investment: 500 million VND

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[30] *Source:https://www.energy.gov/energysaver/heat-pump-systems#:~:text=For%20climates%20with%20moderate%20heating,-to%20furnaces%20and%20air%20conditioners*

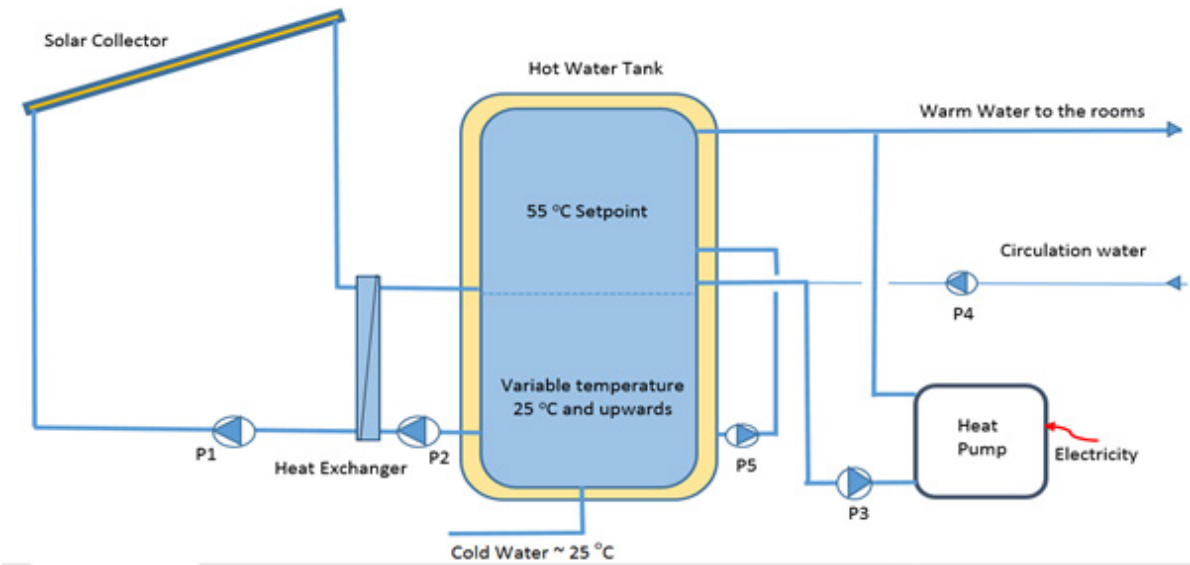
Proposed measure of hot water supply system that swiches to the solar water heater combined with backup heat pump is desiged as below.

- 80% of hot water demand is supplied from the solar water heater with rating capacity of 25m^3 per day, 20% of hot water demand is supplied from the heat pump system with u units of 2*10HP, the COP is designed 3.76 (to comply QCVN09:2017/BXD requirement)

- Insulated hot water pipe distribution with rockwool material.

- Setting the maximum temperature of water delivered to piping connection not to excced 43°C.

- Total required investment: 2.7 billion VND



CHARACTERISTICS

1. Direct heating, water can heat up 55 to 60^{0}C
2. Cover power coating
3. LCD display
4. On/Off timer
5. Flow switch protect
6. Pressure protect
7. Automatic antideforst for works in all climatic conditions

Figure 2.51. Principle diagram of Solar water heater combined with backup heat pump[31]

[31] *Source: Megasun*

Model No.	UNIT	MGS-2HP-D	MGS-3HP-D	MGS-5HP-D	MGS-10HP-D	MGS-15HP-D
Heating capacity (kW)	kW	6.5	10.6	18.0	35	44
Productivity average	L/H	155	245	420	650	1150
Input power	kW	1.75	2.8	4.68	9.3	11.4
Rate current	A	9	13	9	18	23
Power source	V/PH/HZ	220/50HZ	380/3PH/50HZ			
Compressor type		Rotary	Scroll			
Compressor unit	Unit	1	1	1	2	2
Fan	Unit	1	1	1	2	2
Rated outlet water temperature	℃	55℃				
Max outlet water temperature	℃	60℃				
Working temperature	℃	-10℃ to 45℃				
Noise	dB (A)	<60	<60	<65	<60	<60
Compressor manufacturer		Panasonic/Copeland				
Refrigerant		R417A				
Controller		Auto intelligent controller				
Inlet water pipe size (mm)	mm	25	25	25	40	40
Case dimension (LxWxH)	mm	1140x440x650	750x690x870	750x690x1060	1484x730x1060	1420x725x1365
Net weight	Kg	63	100	165	280	360

For this case, the differential investment by that hotel is around 2.2 billion VND for the measure of water heater using heat pump. The saving of electricity consumption for hotel is about 178,090 kWh/year, equivalent to 452 million VND/year. The simple payback period is then 4.9 years.

7. BUILDING RENOVATION DESIGN

The renovation of existing construction works towards energy savings should be considered the process of investment construction projects and building renovation design. Depending on the policy of the investors, the building renovation can be implemented in the form of small repairs (items) or large-scale renovation and repaired in order to improve work efficiency and meet the energy saving requirements during operation at the same time.

The contents of building renovation towards energy savings may include the following items:

- Building envelop: perhaps there are some alternatives to the envelop structures; repaint the exterior walls; replace doors and glass walls with energy efficiency, ensure natural lighting and ventilation and additional shade structures, etc;

- Power supply and lighting systems: perhaps there are plans to repair, replace and upgrade high-efficiency lighting devices, and additional control devices; construct and re-install the entire power supply and lighting systems;

- Ventilation and air conditioning systems: perhaps there are plans to repair or replace inefficient equipments and pipes with more energy efficient ones; or construct and install the entire building ventilation and air conditioning systems. Other technical systems of buildings, including elevators, water supply and drainage systems, fire protection equipment systems, etc. In the plan to renovate these systems, perhaps there are plans to repair options, replace, upgrade electrical equipments such as electric motors, pumps, hot water supply equipments, etc.

Notes for designing to building renovation

- The contents of the renovation design of existing buildings are implemented according to the construction investment projects, the design task has been approved by the investors.

- The renovation design for the structural casing, power supply lighting systems, ventilation and air conditioning systems and other technical systems on the energy use of building following the instructions in Chapter 2.

- Need to survey and assess the bearing capacity structural components when designing and installing new equipments to ensure the safety of structure, especially heavy equipments.

8. DESIGN, CONSTRUCTION AND ACCEPTANCE EXAMINATION

8.1. Design document examination

The examination of design products shall be implemented in accordance of current laws. Accordingly, the construction design products are examined by the design consultancy organizations (internal examination), investors (hired verification consultants); appraisal of state management agencies before granting construction permits.

Basing on examining the design documents include:

- Construction investment project reports, design tasks already approved by the investors;

- Technical design drawings, construction technical drawings; explanations, specifications (if any) and previous design drawings approved by the investor;

- The regulation QCVN 09:2017/BXD, other related national technical regulations and technical standards on the construction works approved by the investors in the investment project;

- The regulations of the Ministry of Construction on the materials use in construction works.

The principles of examining design documents, including design drawings, explanations, specifications (if any):

- Check the compliance with requirements stated in construction investment projects, design tasks approved by the the investors;

- Check the suitability of the design against the approved previous step design contents.

During the examination, the checklist, the support calculation tools of OTTV and the shade structure (on the page http://tietkiemnangluong.xaydung.gov.vn/ of the Ministry of Construction) and energy simulation software shoul be used to check the suitability of the design solution with the regulation QCVN 09:2017/BXD and the assessment of the energy efficiency of design solutions.

8.2. Construction and acceptance examination

The construction and acceptance process shall comply with the current law. Accordingly, the investors, construction contractors and supervisors of the consulting organization are responsible for the examination and acceptance.

The quality examination and acceptance of items and the entire construction for the casing structure and the construction technical systems include the following main contents:

- Check the quality of products, materials and equipments before putting into construction and installation: certificate of manufacturer's specifications (by specialized laboratories) or testing organization to ensure the suitability of design requirements.

- Check the conformity to the finished item with the approved design.

- Check the operational efficiency of the construction equipment systems through operation and trial run.

During the field examination, specialized measuring tools and equipments can be used to check and assess the quality. The content and process of measurement and assessment are implemented according to appropriate technical standards.

Chapter 03 INVESTMENT FINANCIAL ANALYSIS

1. INTRODUCTION

1.1. Purpose and meaning of investment financial analysis

During the design phase, investors' ideas shall materialize into several design alternatives. In order to choose the most suitable design options, it is common that designers will propose more than one feasible design scenario for comparison and final selection. For example, when designing an air-conditioning system, engineers can come up with a variety of options but with different initial capital investments and operating costs. On that basis, decision-makers need comprehensive and scientific methods to be able to compare and choose the best economical alternative. Thus, the analysis of investment finance plays a significant role, which is can be considered as a determining factor to the appearance, convenience of the buildings, and the investment efficiency of the project.

1.2. Financial analysis methods

In order to analyze related investment for every design alternative, it is possible to use three main analysis approaches:

1.2.1. Method using static indicators

The static indicator is the one that does not take into account the time value of money and are usually applied for small-scale projects. There are several common static indicators, such as (i) costs for a unit of product, (ii) profit per unit of product, and (iii) profitability of investment capital.

The most significant advantage of using these indicators is the simple calculation process. However, because they do not consider the time value of money, these indicators do not fully reflect the economic nature of investment alternatives. Therefore, this method is suitable for the financial analysis of short-term investment options or small-scale projects in the pre-feasibility study stage.

1.2.2. Method using dynamic indicators

In contrast to static indicators, dynamic ones take into account the time value of money over the entire life cycle of investment alternatives. Common analytical criteria include:

- Net Present Value Analysis (NPV)
- Net Future Value Analysis (NFV)

- Annual Cash Flow Analysis

- Internal Rate of Return (IRR) Analysis

- Life Cycle Cost Analysis (LCCA)

1.2.3. Other financial analysis methods

(This kind of analysis comprises several techniques as follows:

- Benefit-Cost Ratio Analysis (BCR)

- Payback Period Analysis.

However, this document only introduces and guides the usage of some of the most common methods to select design alternatives in the following sections.

2. NET PRESENT VALUE ANALYSIS METHOD

2.1. Relevant definitions

a) The definition of Net Present Value (NPV)

Net Present Value (NPV) is the difference between the present value of cash inflows and of cash outflows over a period of time or over the whole life of an investment discounted to the present time. Thus, it can be understood that NPV represents the total net profit generated by the project converted to the present time. NPV is usually used in capital budgeting and investment planning to analyze the profitability of a project.

b) Cash flow and Cash flow diagram

Cash flow is the net amount of cash and cashequivalents being transferred into and out of a business. In order to determine the NPV of design alternatives or projects, forecasting their cash flows is essential. Cash flow can be illustrated in a table or chart. However, the latter is more intuitive, easy to follow, and more concise than the former..

The cash flow diagram is a graph that represents the value of cash inflows and outflows over a period of time or the entire life of projects. The inflows values are represented by upward arrows, whereas the outflows values indicate by downwards arrows as the following:

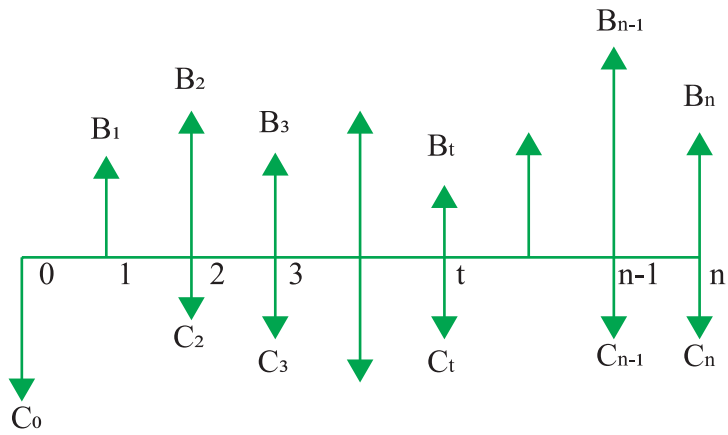


Figure 3.1. Cash flow diagram

In a cash flow diagram, the value of cash inflow is denoted by Bi, while the value of cash outflow is denoted by Ci, i is represented for years (0≤i≤n).

2.2. The determination of NPV

Net Present Value of cash flow can be computed based on the following equation:

$$NPV = PB - PC = \sum_{t=0}^{n} \frac{B_t}{(1+r)^t} - \sum_{t=0}^{n} \frac{C_t}{(1+r)^t} = \sum_{t=0}^{n} \frac{B_t - C_t}{(1+r)^t} \qquad (3.1)$$

Where:

PB: the present value of inflow.

B_t: cash inflows in the tth year, which may include the following kinds of benefits:

(i) Revenue from sales including taxes; (ii) Salvage value from assets liquidation when at a specific time during projects' life cycle and at the end of projects, and

(iii) The recovered value of spent initial working capital at the end of projects.

PC: the present value of outflow.

C_t: disbursements in the tth year, including: (i) Investment costs for fixed assets (machinery, factories...) and working capital needed; (ii) Project operating costs, e.g. electricity, water costs,...

n: the lifetime of the plan or the calculation period

r: the minimum acceptable rate of return

The values, i.e receipts/disbursements in equation (1) are conventionally considered at the end of each year, excepting at year 0 (assuming it is the investment completed time and start exploiting the project). Therefore, if we separate the quantities corresponding to year 0, the formula to determine NPV will be as follows:

$$NPV = -V + \sum_{t=1}^{n} \frac{B_t}{(1+r)^t} - \sum_{t=1}^{n} \frac{C_t}{(1+r)^t} \qquad (3.2)$$

In the case of projects with equal annual cash inflows and outflows (Figure 3.2), and having salvage value from assets liquidation, working capital recovery, assets that do not fully

depreciate, and non-depreciated assets (if any) at the end of the project's lifetime, the formula to compute NPV as follows:

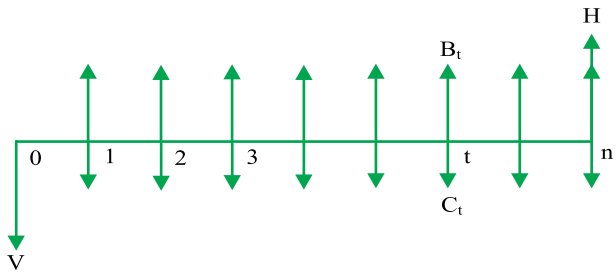


Figure 3.2. Equal cash flow diagram

$$NPV = -V + (B_t - C_t) \times \frac{(1+r)^n - 1}{(1+r)^n . r} + \frac{H}{(1+r)^n} \qquad (3.3)$$

Where:

V: the project's total investment capital which is determined when start exploiting a project.

Bt: cash inflow (t=1÷n)

Ct: cash outflow (t=1÷n)

H: salvage value from assets liquidation, working capital recovery, assets that do not fully depreciate, and non-depreciated assets (if any) at the end of the project's lifetime

n: project's lifetime

2.3. Using NPV to analyze investment alternatives

The process to use NPV as a criterion to compare and analyze design alternatives is described in Figure 3.3.

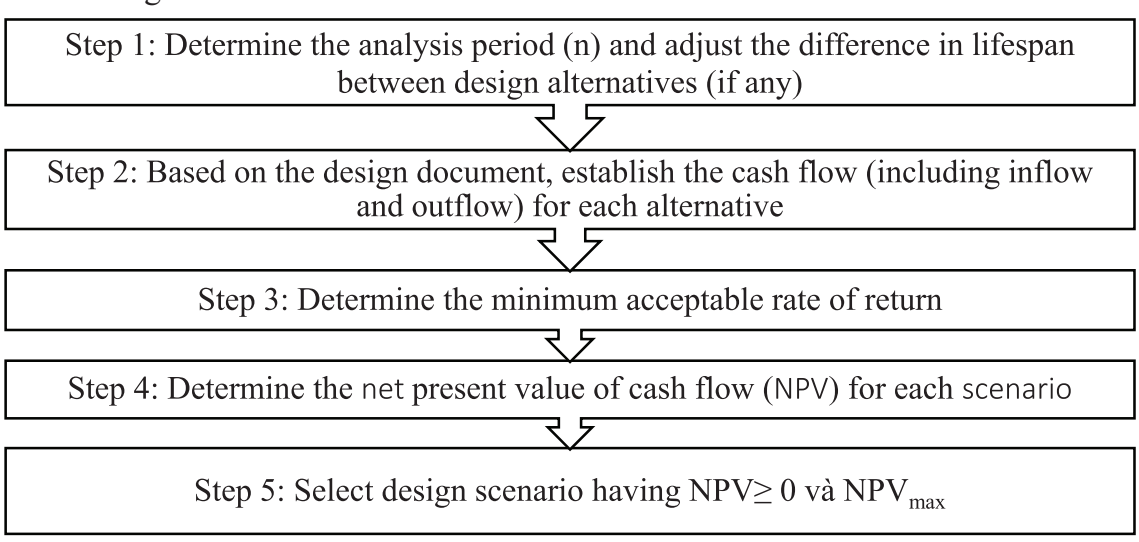


Figure 3.3. The process to use NPV as a criterion to compare and analyze design alternative

Notes: In the process shown in Figure 3.3, the necessary condition for the alternative to be selected is that it must be worth for investing, that is, it must satisfy the condition that NPV ≥ 0.

2.4. Example

2.4.1. Example 1

The design consultant is considering using one of two types of air conditioners to minimize investment costs. The relevant data are as follows:

Types of air conditioners	Investment cost	Lifespan	Electricity cost saved
A	1.000$	5 years	300$/year
B	1.350$	5 years	300$/year 1, and it will increase by $ 50 annually

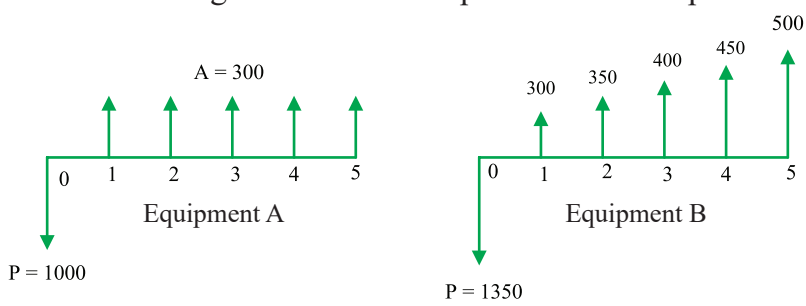
With an annual interest rate is 7%, which type of air-conditioner should be selected?

Solution:

Based on the sequence shown in Figure 4.3, the calculation is performed as follows:

- **Step 1:** the analysis period (n) selected is 5 years, which is equal to the lifespan of both types of conditioners.

- **Step 2:** the cash flow diagrams of the two options are developed as follows:



- **Step 3:** the minimum acceptable rate of return is chosen equal to the interest rate (7%)

- **Step 4:** calculate NPV for each option.

$$NPV_A = -1.000 + 300\times\left[\frac{(1+0,07)^5 - 1}{(1+0,07)^5.0,07}\right] = 230 \text{ (USD)} \qquad (3.3)$$

$$NPV_B = -1.350 + \frac{300}{(1+0,07)^1} + \frac{350}{(1+0,07)^2} + \frac{400}{(1+0,07)^3} + \frac{450}{(1+0,07)^4} + \frac{500}{(1+0,07)^5} = 262,4 \text{ (USD)}$$

- **Step 5:** compare and select alternative

Alternative B has a higher NPV than alternative B and NPV_B >0. Therefore, Alternative B shall be selected.

2.4.2. Example 2

In order to improve the building›s performance from a design baseline, the consultant proposed two alternatives in terms of glazing, air conditioning, and lighting systems with related information as the following table:

Proposed alternatives	Total investment costs of glazing, air conditioning, and lighting systems	Lifespan of equipment	Annual electricity savings compared to the baseline design

Alternative 1	12,992 (million VND)	15 years	2,091 (million VND)
Alternative 2	27,263 (million VND)	15 years	3,741 (million VND)

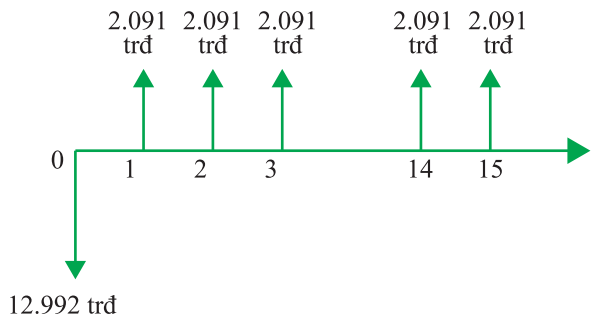
It is assumed that the interest rate is 7% per year, and the two alternatives cannot have salvage value from the liquidation of assets. Which design scenario is better?

Solution:

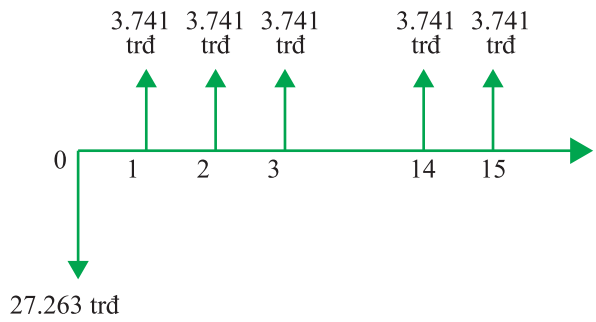
Based on the process shown in Figure 4.3, the calculation is performed as follows:

- **Step 1:** the analysis period (n) is selected to be 15 years

- **Step 2:** the cash flow diagrams of the two options are developed as follows:



Cash flow diagram of alternative 1



Cash flow diagram of alternative 2

- **Step 3:** the minimum acceptable rate of return is chosen equal to the interest rate (7%)

- **Step 4:** calculate NPV for each alternative:

$$NPV_1 = -12{,}992 + 2{,}091 \times \left[\frac{(1+0.07)^{15}-1}{(1+0.07)^{15}\times 0.07}\right] = 6{,}052.65 \text{ (million VND)}$$

$$NPV_2 = -27{,}263 + 3{,}741 \times \left[\frac{(1+0.07)^{15}-1}{(1+0.07)^{15}\times 0.07}\right] = 6{,}809.71 \text{ (million VND)}$$

- **Step 5:** compare and select design alternative

Alternative 2 has the highest NPV_2 is >0, thus it is the best one compared to alternative 1 and it shall be selected.

2.5. Advantages, disadvantages, and scope of application

a) Advantages

- The process of comparing and selecting options takes into account any changing status of cash flows in projects over time.

- This approach considers the entire life of the project;

- This approach takes into account the time value of money;

- Factors like cash flow slippage, economic inflation, and changes in the exchange rate are considered.

- NPV is the basis for determining the internal IRR rate of return, and payback period in case of taking into consideration the time value of money.

- NPV is an indication that directly reflects the performance of investment alternatives or projects by net profit at the time of analysis (the present time). Therefore, NPV is the most important indicator, which should be prioritized to use when comparing and choosing the alternative.

b) Disadvantages

- This method is only suitable for perfect capital market conditions, which is very difficult to guarantee in practice;

- It is very difficult to accurately determine revenues and expenditures for future years, especially when the project life is long-lasting;

- The process of computation is complicated when having a cash flow changing from negative to positive many times;

- The calculation result depends greatly on the minimum acceptable rate of return (r), while it is difficult to determine exactly this factor. Specifically, any fluctuation of r also makes the NPV value change, affecting the selection of alternatives.

- Does not clearly reflect the profitability of investment capital.

c) Scope of application

- Using to evaluate a single alternative

- Using to compare and select the best alternatives regardless of their life cycle. In this case, the cash outflow and inflow of each alternative have to be determined clearly to use as input for the NPV calculation.

- However, this method does not clearly reflect the profitability of investment capital. Thus, it is needed to combine NPV with relative criteria like IRR to get a holistic viewpoint when evaluating alternatives.

3. INTERNAL RATE OF RETURN ANALYSIS

3.1. Definition

Rate of Return (IRR) is defined as the interest rate paid on the unpaid balance of a loan such that the payment schedule makes the unpaid loan equal to zero when the final payment is made.

If stated in terms of investment, IRR can be defined as the interest rate earned on the unrecovered investment such that the payment schedule makes the unrecovered investment equal to zero when the final payment is made.

3.2. The determination of IRR

Based on the definition, IRR can be determined by the following formula:

$$NPV = \sum_{t=0}^{n} \frac{B_t - C_t}{(1+IRR)^t} = 0 \qquad (3.4)$$

Where:

PB: the present value of inflow

PC: the present value of outflow

IRR: the internal rate of return

B_t: receipts in the tth year

C_t: disbursements in the tth year

n: the calculation period

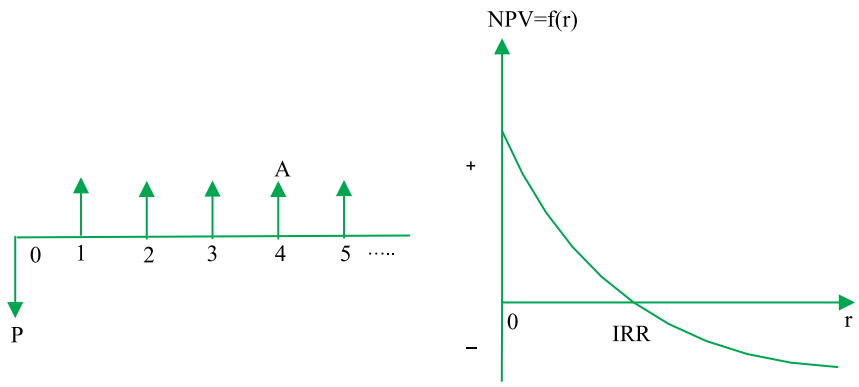


Figure 3.4. The graph shows the correlation between the NPV and the IRR of the investment cash flow

In case annual cash inflows and outflows are equal (Figure 3.2), and the project can get salvage value from (i) the liquidation of assets, (ii) recovery value of working capital, (iii) the value of the assets that have not been fully depreciated, (iv) or the value of the assets are not depreciated (if any).Assuming that year 0 is the time of starting to operate a project, and knowing the total initial investment of the project, the formula for determining the IRR is below (formular 3.5)

$$-V + (B_t - C_t) \times \frac{(1+IRR)^n - 1}{(1+IRR)^n.IRR} + \frac{H}{(1+IRR)^n} = 0 \qquad (3.5)$$

Where:

V: initial investment at the start of the project

Bt: annual receipts (t=1÷n)

Ct: annual disbursements (t=1÷n)

H: salvage value from the liquidation of assets, recovery value of working capital, the value of the assets that have not been fully depreciated, and the value of the assets is not depreciated (if any)

n: project's lifespan

To determine IRR based on the above equations, one of the following methods can be used:

(i) Using the gradual testing method. Particularly, trying to gradually test different values of IRR until the result of equation (4) or (5) is zero, that value is the IRR of the project.

(ii) Use linear interpolation or extrapolation methods to find calculate IRR. This method, although only providing approximate results, are easier to implement and save time than the gradual testing method. If the linear interpolation method is used, the calculation steps are as follows:

+ Choose the rate of return r1 to make NPV1 calculated based on the (4) or (5) equation is > 0.

+ Choose the rate of return r2 to make NPV2 calculated based on the (4) or (5) equation is < 0.

+ Compute IRR based on the following formula:

$$IRR = r_1 + \frac{NPV_1}{NPV_1 + |NPV_2|}(r_2 - r_1) \qquad (3.6)$$

When using Equation (6) to determine IRR, it should be noted that the closer the NPV1 and NPV2 values are to 0, the more accurate IRR will be.

3.3. Using IRR to analyze investment finance of alternatives

The process to calculate IRR to analyze investment options is as Figure 3.5.

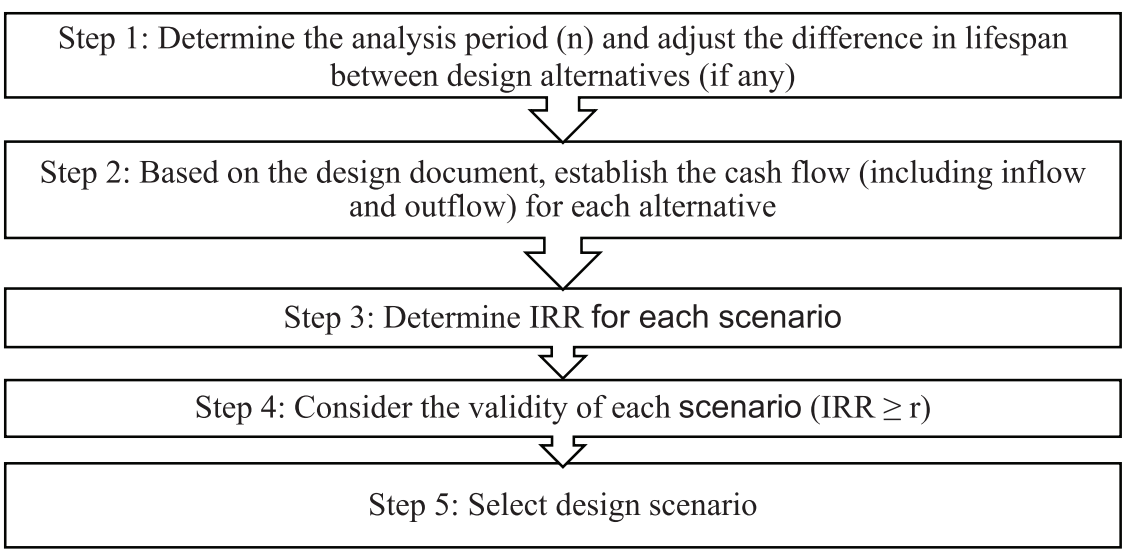


Figure 3.5. The process to calculate and select an alternative using IRR

Notes:

- The analysis period (n) will be chosen equal to the lifespan of alternatives if there is no difference between them. On the contrary, the analysis period is usually chosen as their lowest common multiple;

- At step 4, if the alternative under consideration has an internal rate of return lower than r, i.e IRR <r, it must be removed from the analysis process, because it is not worth investing.

- At step 5, the selection of alternative will be based on one of the following two cases:

a) **1st case:** If the investment capital of the two options is equal, the one with the larger IRR will be selected.

b) **2nd case:** If the given options have differences in initial investment capital, the selection process will be based on the efficiency of the investment increment ΔV as follows:

+ Determine IRR1 of the plan which has lower investment then compare it with the minimum acceptable interest rate. If IRR1 is lower than r (IRR1<r), it must be removed from the analysis process. On the contrary, if IRR1 ≥ r, then this alternative qualifies for comparison.

+ Develop an investment incremental cash flow (ΔV flow) by subtracting (-) the cash flow of the larger investment capital alternative and the cash flow of the lower investment capital one.

+ Determine IRRΔV of the investment incremental cash flow.

+ Choose a better alternative based on one of the following two cases:

- If $IRR_{\Delta V} \geq r$: the larger investment capital alternative is selected.
- If $IRR_{\Delta V} < r$: the lower investment capital alternative is selected.

3.4. Example

The design consultant is considering using one of two types of glazing, air conditioning, and lighting systems for an office building in Hanoi. The related information as the following table.

Proposed alternatives	Total investment costs of glazing, air conditioning, and lighting systems	Lifespan of equipment	Annual electricity savings compared to the baseline design
Alternative 1	15,992 (million VND)	12 years	2,691 (million VND)
Alternative 2	29,263 (million VND)	12 years	3,941 (million VND)

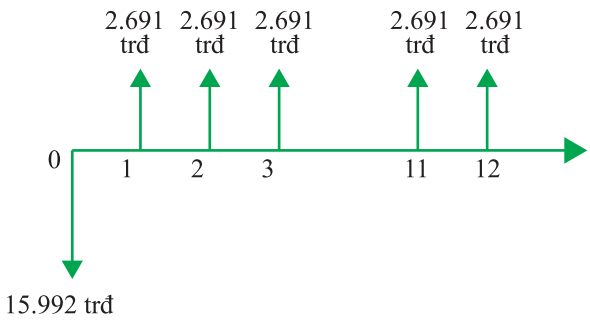
It is assumed that the minimum attractive rate of return is 7% per year, and the two alternatives cannot have salvage value from the liquidation of assets. Which design scenario is better?

Solution:

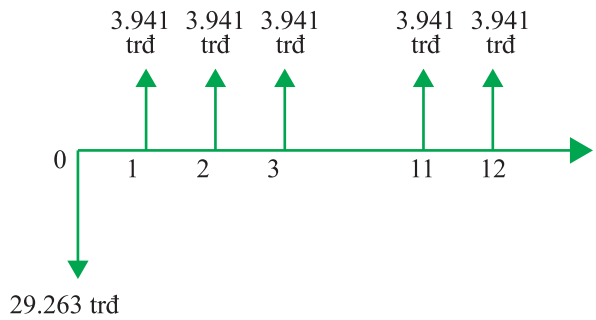
Based on the process shown in Figure 3.5, the calculation is as follows:

- Step 1: the analysis period (n) is selected to be 12 years

- Step 2: develop the cash flow for each alternative



Cash flow diagram of alternative 1



Cash flow diagram of alternative 2

- Step 3: determine IRR for each alternative based on equation (3.5)

Alternative 1: the equation for determining IRR1 is as follows:

$$-15.992 + 2.691 \times \left[\frac{(1+IRR_1)^{12}-1}{(1+IRR_1)^{12}\times IRR_1}\right]=0$$

+Choose $IRR_a = r_a = 12.9$ %, NPV_a is computed to be 4.43 (million VND)

+ Choose $IRR_b = r_b = 13$ %, NPV_b is computed to be -67.66 (million VND)

Use formula (6) to interpolate IRR_1:

$$IRR1 = 12{,}9 + \frac{4{,}43}{4{,}43+67{,}66} \times (13-12{,}9) = 12{,}906\ \%$$

Alternative 2: the equation to compute IRR_2 is as follows:

$$-29.263 + 3.941\times\left[\frac{(1+IRR_2)^{12}-1}{(1+IRR_2)^{12}\times IRR_2}\right]=0$$

+ With $IRR_a = r_a = 8.2\%$, NPV_a is calculated to be 131.37 (million VND)

+ With $IRR_b = r_b = 8.3\%$, NPV_b is calculated to be -19.48 (million VND)

Based on furmula (6) IRR_2 can be interpolated as follow:

$$IRR2 = 8{,}2 + \frac{131{,}37}{131{,}37+19{,}48} \times (8{,}3-8{,}2) = 8{,}287\ \%$$

Step 4: consider the counted worthy to be invested of each alternative.

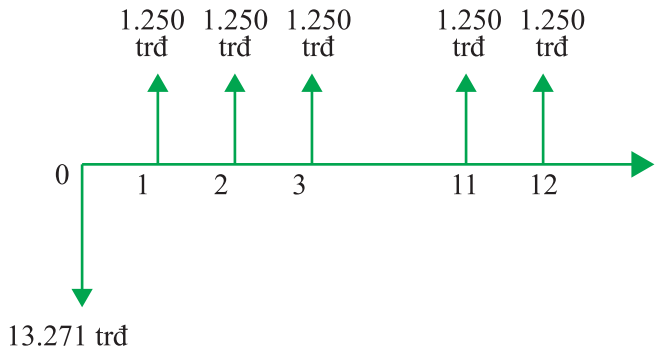
+ The 1st alternative has $IRR_1 = 12.906\ \% > 7\%$, thus it is worthy to be invested.

+ The 2nd one has $IRR_2 = 8.287\ \% > 7\%$, hence it is worthy to be invested.

Therefore, both options are eligible to be taken into consideration.

Step 5: compare and select the best alternative: because the two given options have differences in initial investment capital, the selection process will be based on the efficiency of the investment increment ΔV as follows:

+ Develop an investment incremental cash flow (ΔV flow) as follows:



The investment incremental cash flow diagram

+ Determine $IRR_{\Delta V}$ of the investment incremental cash flow based on equations (5) and (6). Particularly, the equation to compute $IRR_{\Delta V}$ as the following:

$$-13.271 + 1.250\times\left[\frac{(1+IRR_{\Delta V})^{12}-1}{(1+IRR_{\Delta V})^{12}\times IRR_{\Delta V}}\right]=0$$

+ With $IRR_{\Delta Va} = r_a = 1.5$ %, it is calculated that $NPV_{\Delta a}$ equal to 363.38 (million VND)

+ With $IRR_{\Delta Vb} = r_b = 2$ %, it is calculated that $NPV_{\Delta b}$ equal to -51.82 (million VND)

Using the formula (6) to interpolate $IRR_{\Delta V}$:

$$IRR\Delta V = 1,5 + \frac{363,38}{363,38+51,82} \times (2-1,5) = 1,94\%$$

+ Compare and select the better option: because $IRR_{\Delta V}$ = 1.94% < r =7%, the lower investment capital alternative shall be selected, i.e the alternative 1 is economically justified.

3.5. Advantages, disadvantages, and scope of application

a) Advantages

- The process of comparing and selecting options takes into account any changing status of cash flows in projects over time.

- This approach calculates interest for all years throughout the life of the project;

- This approach takes into account the time value of money;

- Factors like cash flow slippage, economic inflation, and changes in the exchange rate can be considered when using IRR to compare and select design options.

- IRR clearly reflects the profitability of investment capital.

b) Disadvantages

- The usage of IRR to compare and select design alternatives only suitable for perfect capital market conditions, which is very difficult to guarantee in practice;

- It is very difficult to accurately determine revenues and expenditures for future years, especially when the project life is long-lasting;

- The process of computation is complicated when having a cash flow changing from

negative to positive many times;

c) Scope of application

- This method is able to use for evaluating a single alternative or project.

- IRR analysis also can use to compare and select the best alternatives regardless of their life cycle.

- To be applied this method, the cash outflow and inflow of each alternative have to be determined clearly to use as input for the NPV calculation.

- However, this method does not clearly reflect the absolute monetary efficiency that the project will be received. Thus, when using IRR as a criterion, it must be combined with absolute efficiency indexes, such as NPV.

4. LIFE CYCLE COST ANALYSIS METHOD

4.1. Definition

4.1.1. Life Cycle Cost

Life Cycle Cost (LCC) is the total cost incurred in all phases over the life cycle of a project such as investment preparation, investment implementation, operation, and demolition phases. In case of construction products, LCC includes (a) costs for project development and construction (initial investment cost), (b) costs for operating, maintenance, and refurbishing/ retrofitting; (c) costs for the liquidation of assets, demolition construction works, and (d) other expenses (if any).

To determine the LCC of a construction product, it is necessary to use a variety of inputs, including:

- Data related to the initial investment costs.

- Data on incurring costs in the operation phase, such as electricity expense costs, and repairs, and maintenance of construction products costs, etc.

- Other data needed to determine demolition cost.

4.1.2. Life Cycle Cost analysis method

LCC analysis is a comprehensive approach that takes into account the total costs of purchasing, owning, and disposing/(destroying) products in general and construction in particular. This method may consider one or several different stages over the entire life of products. The results of the LCC calculation can be used to support investment decision making, selection of investment options/ design alternatives, etc.

4.2. The determination of Life Cycle Cost

When considering the monetary value over time, the life cycle cost of a building can be expressed in terms of time as present, future or evenly converted to an equivalent uniform annual amount over one life cycle of the alternative. Depending on each case, the calculation formula of LCC will have a certain difference.

4.2.1. The present value of LCC

This approach converts all costs incurred over the life of a construction product to the present time (analysis time) based on a certain discount rate. The formula for determining the LCC, in this case, is as follows:

$$LCC_{ĐĐ}^{P} = \sum_{t=0}^{n} \frac{C_t}{(1+r)^t} \quad (3.7)$$

In the case of alternatives with equal annual cash flow, LCC can be computed as the following formula:

$$LCC_{ĐĐ}^{P} = V + C_t \times \left[\frac{(1+r)^n - 1}{(1+r)^n.r}\right] + \frac{H}{(1+r)^n} \quad (3.8)$$

Where:

$LCC_{ĐĐ}^{P}$: LCC converted to the present time

V: initial investment costs

Ct: cash outflow in year t

n: the life cycle of construction products or the duration of the analysis period.

H: salvage value from assets liquidation, working capital recovery, assets that do not fully depreciate, and non-depreciated assets (if any) at the end of the project's lifetime

r: the discount rate is used to adjust cash flow (%)

4.2.2. The future value of LCC

In this case, all costs incurred over the life of a construction product are converted to a point of time in the future, which usually is the end of the alternatives' lifespan. This calculated process uses a certain discount rate. The formula for determining the LCC is as follows:

$$LCC_{ĐĐ}^{F} = \sum_{t=0}^{n} C_t\,(1+r)^t \quad (3.9)$$

Where:

$LCC_{ĐĐ}^{F}$: LCC adjusted to the end of construction products/alternatives' lifetime

Ct: cash outflow in year t

n: the life cycle of construction products or the duration of the analysis period

r: the discount rate is used to adjust cash flow (%)

4.2.3. The annual value of LCC

In this approach, all cash flows are converted to an equivalent uniform annual amount over one life cycle of the alternative based on the following equation:

$$\mathrm{LCC}_{ĐĐ}^{A} = \sum_{t=0}^{n} C_t \frac{r(1+r)^t}{(1+r)^t - 1} \qquad (3.10)$$

Where:

$LCC_{ĐĐ}^{A}$: the annual worth of LCC

Ct: cash outflow in year t

n: the life cycle of construction products or the duration of the analysis period

r: the discount rate is used to adjust cash flow (%)

4.3. Using Life Cycle Cost analysis to analyze investment finance of alternatives

The order of using LCC analysis method for comparing alternatives as follows:

Step 1: Determine the analysis period (n) and adjust the difference in lifespan between design alternatives (if any)

↓

Step 2: Develop the cash flow for each alternative

↓

Step 3: Determine the discount rate is used to adjust cash flow

↓

Step 4: Compute the present value (or future value, annual equal value) of LCC for each alternative

↓

Step 5: Select alternative having LCC_{min}

Figure 3.6. The order of using LCC analysis method for comparing alternatives

4.4. Example

The design consultant proposed two design scenarios related to using glazing, air conditioning, and lighting systems for an office building. It is assumed that the interest rate is 7% per year, and the two alternatives cannot have salvage value from the liquidation of assets. The related information as the following table.

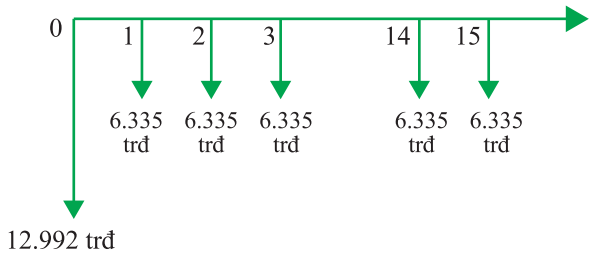
Proposed alternatives	**Total investment costs of glazing, air conditioning, and lighting systems**	**Lifespan of equipment**	**Annual electricity savings compared to the baseline design**
Alternative 1	12,992 (million VND)	15 years	6,335 (million VND)
Alternative 2	27,263 (million VND)	15 years	4,685 (million VND)

Solution:

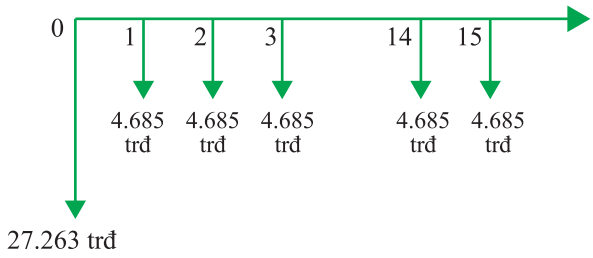
The process of calculating LCC and using it to compare alternatives as follows:

- Step 1: the analysis period (n) is selected to be 15 years

- Step 2: develop the cash flow for each alternative as the following figure:



Cash flow diagram of alternative 1



Cash flow diagram of alternative 1

- Step 3: the discount rate is chosen equal to 7%

- Step 4: determine LCC for each alternative. In this example, LCC of alternatives is converted to the present time based on equation (9) as follows:

$$LCC^{P}_{ĐĐ1} = 12{,}292 + 6{,}335\times\left[\frac{(1+0.07)^{15}-1}{(1+0.07)^{15}\times 0.07}\right] = 70{,}690.64 \text{ (million VND)}$$

$$LCC^{P}_{ĐĐ2} = 27{,}263 + 4{,}685\times\left[\frac{(1+0.07)^{15}-1}{(1+0.07)^{15}\times 0.07}\right] = 69{,}933.58 \text{ (million VND)}$$

- Step 5: compare and select the better alternative

Alternative 2 having a lower LCC compared to alternative 1, thus it is the better one shall be selected.

4.5. Advantages, disadvantages, and scope of application

a) Advantages

- This method takes the entire life cycle of alternatives into account.

- Taking time value of money into consideration;

- Factors like cash flow slippage, economic inflation, and changes in the exchange rate can be considered when using IRR to compare and select design options.

- Taking the total over the entire life of projects into account. In which, the initial investment capital is determined easily based on regulations of the Vietnamese government on construction investment management.

- The total costs that investors have to spend over the lifetime of projects are directly reflected at the time of analysis (the present time or projects' end-of-life time of time). Thus, LCC is very important to select an economically justified alternative.

b) Disadvantages

- Input data needed in calculating LCC is huge and very complicated to determine at the early phase of the project. For example, costs incurred during the operation, repair,

maintenance, and demolition phases over the project's lifetime are less likely to be computed exactly at the design phase.

- This approach only takes the cash outflows of alternatives into account without considering the cash inflows.

c) Scope of application

- This method is applied to compare and select the best alternative in case the life cycle of projects is long-lasting and the costs incurring over the operation repair, maintenance, and demolition phases are colossal and able to estimate.

- LCC is very suitable for comparing investment alternatives for projects that are difficult to determine or have no cash inflow over their lifecycle, for example, defense projects.

5. PAYBACK PERIOD ANALYSIS

5.1. Definition

Payback period is the required period of time for the profit or other benefits of an investment to equal the investment expenses.

In all situations, the criterion is to minimize the payback period. The determination of payback period is illustrated in the following section.

5.2. The determination of the payback period

5.2.1. If do not consider the time value of money

In this case, the payback period will be computed based on the following equations. Particularly:

- When the return from profit and annual depreciation is the same, the payback period will be determined by the formula (3.11)

$$T_{hv} = \frac{V}{L_n + K_n} \qquad (3.11)$$

Where:

T_{hv}: the payback period (year)

V: the initial investment cost

L_n: the annual net profit

K_n: the amount of annual depreciation

- If the return from profit and depreciation is not equal every year, use the amortization method to determine T_{hv} according to the formula (3.12)

$$V - \sum_{t=1}^{T_{hv}} (L_t + K_t) = 0 \qquad (3.12)$$

Where:

L_t: net profit in year t

K_t: depreciation amount in year t

Notes:

When the investment capital is required to spend more than one time to replace assets during the lifespan of the project, only the initial investment capital is taken into account.

When the investment capital is spent more than one time due to the application of construction method in terms of capacity, Thv may be calculated as follows:

- If each disbursement serves a specific part of the project and it is possible to determine the profit and the amount of the separate depreciation for that specific funding, the payback period is to be calculated as the formula (3.11) or (3.12).

- If each disbursement is to serve the project as a whole, it is needed to calculate the payback period for each. If at the end of the disbursement period, the invested capital has not been fully repaid, this remaining capital will be added to calculate the next payback period.

5.2.2. If taking into consideration the time value of money

In this case, the payback period can be determined based on the following formulas:

$$V - \sum_{t=1}^{T_{hv}} \frac{L_t + K_t}{(1+r)^t} = 0 \qquad (3.13)$$

Where:

V: the initial investment cost

L_t: the annual net profit in year t

K_t: the amount of annual depreciation in year t

r: the discount rate

The payback period also can be computed based on NPV as the equations (3.14) or (3.15);

$$NPV = V - \sum_{t=1}^{T_{hv}} \frac{B_t - C_t}{(1+r)^t} = 0 \qquad (3.14)$$

$$NPV = \sum_{t=0}^{T_{hv}} \frac{B_t - C_t}{(1+r)^t} = 0 \qquad (3.15)$$

Where:

V: initial investment costs

B_t: annual receipts (t=1÷n)

C_t: annual disbursements (t=1÷n)

Based on the project's cash flow chart, it can be determined that the payback period is the time when the cash flow changes from negative to positive.

To determine the payback period (T_{hv} in this case can use the linear interpolation or extrapolation methods with the following steps:

+ Choose T_{hv1} to make NPV_1 calculated based on equation (3.14) or (3.15) is > 0.

+ Choose T_{hv2} to make NPV_2 calculated based on equation (3.14) or (3.15) is < 0.

+ Compute Thv based on the following formula:

$$T_{hv} = T_{hv1} + \frac{NPV_1}{NPV_1 + |NPV_2|}(T_{hv2} - T_{hv1}) \quad (3.16)$$

When using equation (16) to determine T_{hv}, it should be noted that the closer the NPV_1 and NPV_2 values are to 0, the more accurate T_{hv} will be.

5.3. Using payback period analysis to analyze investment finance of alternatives

5.3.1. If do not consider the time value of money

In this case, the process of using payback period analysis comprises the following steps:

- Step 1: calculate the payback period of each plan according to formula (3.11) or (3.12)

- Step 2: choose the scenario with the smallest payback period

5.3.2. If taking into consideration the time value of money

In this case, the process of analyzing investment finance of alternatives will be done in the following order:

- Step 1: develop the cash flow diagram of each alternative

- Step 2: calculate the payback period of each alternative based on formulas (3.14), (3.15), and (3.16)

- Step 3: choose the option with the smallest payback period

5.4. Example

A design consultant is considering choosing one of two potential options for glazing, lighting equipment, and air conditioning as shown in the following table:

Proposed alternatives	Total investment costs of glazing, air conditioning, and lighting systems	Lifespan of equipment	Annual electricity savings compared to the baseline design
Alternative 1	12,992 (million VND)	15 years	2,091 (million VND)
Alternative 2	27,263 (million VND)	15 years	3,741 (million VND)

It is assumed that the interest rate is 7% per year. The two alternatives cannot have salvage value from the liquidation of assets.

Which design scenario shall be selected for each following case?

a. When do not consider the time value of money

b. When considering the time value of money

Solutions:

a) If do not consider the time value of money

In this case, the payback period of each alternative can be determined according to equation (12) as follows:

- *Alternative 1:*

This alternative having the total investment cost, and the annual electricity savings are 12,992 (million VND) and 2,091 (million VND), respectively. Thus, the payback period is calculated as the below:

$$T_{hv1} = \frac{V}{L_n + K_n} = \frac{12,992}{2,091} = 6.213\ (years)$$

- *Alternative 2:*

This alternative has a total investment cost of 27,263 (million VND), and an annual electricity savings of and 3,741 (million VND). Thus, the payback period is calculated as the below:

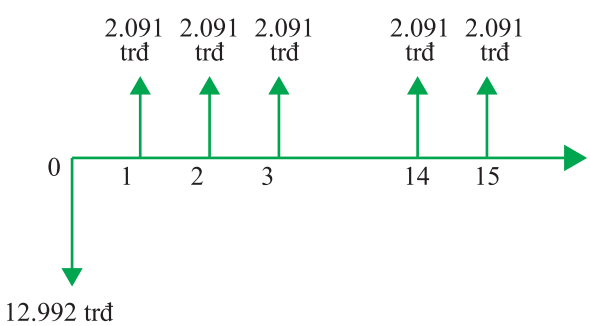
$$T_{hv2} = \frac{V}{L_n + K_n} = \frac{27,263}{3,741} = 7.288\ (years)$$

Therefore, the 1st alternative is chosen due to having a lower payback period.

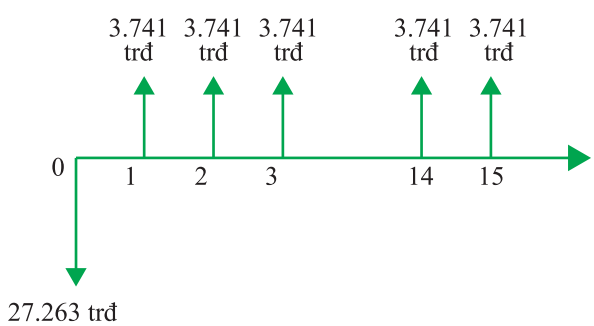
b) If taking into consideration the time value of money

In this case, the payback period can be determined based on the equation (15) and (16). The calculation for each alternative as follows:

- Step 1: develop the cash flow diagram of each alternative as the following figure:



Cash flow diagram of alternative 1



Cash flow diagram of alternative 2

- Step 2: determination the payback period of each alternative

Alternative 1:

The equation to compute the payback period as follows:

$$NPV_1 = 12.992 - 2.091 \times \frac{(1+0.07)^{T_{hv1}} - 1}{(1+0.07)^{T_{hv1}} * 0.07} = 0$$

+ With T_{hva} = 8 years, NPV_a is calculated to be 506.01 (million VND)

+ With T_{hvb} = 9 years, NPV_b is calculated to be -631.35 (million VND)

+ Using equation (16) to interpolate the payback period:

$$T_{hv1} = 8 + \frac{506,01}{506,01+631,35} \times (9\text{-}8) = 8,445 \text{ (năm)}$$

Alternative 2:

The calculating equation as follows:

$$NPV_2 = 27.263 - 3.741 * \frac{(1+0.07)^{T_{hv1}} - 1}{(1+0.07)^{T_{hv1}} * 0.07} = 0$$

+ With T_{hva} = 10 years, NPV_a is calculated to be 987.78 (million VND)

+ With T_{hvb} = 11 years, NPV_b is calculated to be -789.54 (million VND)

+ Using equation (16) to interpolate the payback period of alternative 2 as follows:

$$T_{hv2} = 10 + \frac{987,78}{987,78 + 789,54} \times (11\text{-}10) = 10,556 \text{ (năm)}$$

- Step 3: The alternative 1 should be selected due to its lower payback period

5.5. Advantages, disadvantages, and scope of application

a) Advantages

- If do not consider the time value of money, this technique is very simple and easy to use

- If taking the time value of money into consideration, this technique has several advantages as follows:

• Considering the time value of money

• Factors like cash flow slippage, economic inflation, and changes in the exchange rate are considered

b) Disadvantages

- This technique is only an approximate economic analytical calculation.

- All costs and returns before the payback period are included in the calculation regardless of the differences in their timing.

- All economic consequences occurring after the payback period are not taken into account.

- Because this is an approximate calculation, using this technique may or may not provide insight about the finally correct alternative.

c) Scope of application

The payback period analysis method should only be used to compare and select short and simple investment options due to its disadvantages.

Chapter 04

ENERGY MANAGEMENT

1. INTRODUCTION

According to Verein Deutscher Ingenieure (VDI), an organization has more than 150,000 of engineers and scientists, energy management is defined as follows: "Energy management is the process of optimizing the energy consumption to conserve usage for the best possible results. The final goal of this process is not only cost savings but also the achievement of environmental sustainability."

Energy management is a key to save energy in each organization's energy consumption. The majority of the importance of energy efficiency comes from global energy conservation needs, emission reduction targets and regulatory requirements.

When mentioning energy savings, energy management, they are the process of monitoring, controlling and conserving energy in a building or an organization. Typically, this involves the following steps:

- Measure energy consumption and data collection.

- Look for opportunities to save energy and estimate how much energy each opportunity could save. Basically, meter data will be analyzed to find and quantify energy consumption, bring out energy savings by replacing equipments (e.g. lighting) or by renovating the insulation of meter building.

- Implement plans and solutions that lead to goals and opportunities for energy savings.

- Monitor by analyzing meter data, consider how energy saving solutions have performed.

2. LEGAL REQUIREMENTS ON ENERGY MANAGEMENT ACTIVITIES

2.1. The energy management is specified in the following documents:

- Law on Economical and Efficient Use of Energy (Articles 30, 32, 33, 34, 35, 36);

- Decree No. 21/2011/ND-CP dated March 29th, 2011 of the Government detailing the Law on Economical and Efficient Use of Energy measures for its implementation;

- Circular No. 39/2011/TT-BCT dated October 28th, 2011 of the Ministry of Industry and Trade on providing for training, grant of certification of energy managers and energy auditors;

- Circular No. 25/2020/TT-BCT dated September 29th, 2020 of the Ministry of Industry and Trade on preparing plan for Economical and Efficient Use of Energy and reports on the implementation thereof; implementation of energy accounting.

2.2. The energy audit must be conducted every 3 years for key energy users, including:

- Industrial and agricultural production facilities, transport units with gross annual energy consumption convert into tons of oil equivalent to 1000 tons or more (1000 TOE);

- Construction works are used as headquarters, offices, and houses; educational institutions, medical, entertainments, physical trainings and sports establishments; hotels, supermarkets, restaurants, department stores with gross energy consumption in a year converted into tons of oil equivalent to 500 tons or more (500 TOE).

2.3. The list of key energy users in Vietnam is specified in the Prime Minister's Decisions. Example: Decision No. 1577/QD-TTg dated October 12th, 2020 on the issuance of the List of Designated Energy Users in 2019 Accordingly, this list has 3006 of industrial constructions, construction works (offices, hotels) and it is divided by provinces and cities.

2.4. For key energy users, Law on Economical and Efficient Use of Energy (Article 33) also defines owner following:

- Build, implement and report on the implementation of yearly and five-year plans on economical and efficient use of energy;

- Apply to the energy management model under the guidance of competent state agencies;

- Energy audit is required every three years;

- Designate energy users

2.5. The requirements of ability for energy management or energy audit for individuals are specified in the Law on Economical and Efficient Use of Energy (Article 35), and Circular No. 39/2011/TT-BCT dated October 28th, 2011 of the Ministry of Industry and Trade Regulations on providing for training, grant of certification of energy managers and energy auditors. Accordingly, energy managers at key energy users must have an energy management certificate and auditors must have a practice certificate issued by the Ministry of Industry and Trade to those who pass the test for certification.

3. ENERGY MANAGEMENT MODEL

Key energy users must apply the energy management model as prescribed in Article 8 of Decree No. Decree No. 21/2011/ND-CP of the Government. The main content of this model is as follows:

a) Announce the goals and policies on economical and efficient use of energy of the facilities.

b) Develop yearly and five-year plans on economical and efficient use of energy of the facility; develop and implement measures for economical and efficient use of energy according to established objectives, policies and plans; define on the responsibility regime for each organization and individuals related to the implementation of plan on economical and efficient use of energy of facilities.

c) Have a network and an energy manager according to the criteria specified in Clause 1, Article 35 of the Law on Economical and Efficient Use of Energy.

d) Regularly check and monitor the energy consumption needs of vehicles and equipments on the entire production line, the situation of new installation, renovation and repair energy-using equipments of the department.

e) Implement the energy audit regime; propose and select to implement management and technological solutions for economical and efficient use of energy.

f) Periodically organize training courses for employees on economical and efficient use of energy.

g) Have a reward and punishment system to promote economical and efficient use of energy of the facilities.

4. ENERGY MANAGEMENT SYSTEM

Energy Management System (as EMS) is a system whose function is to improve efficiency and reduce energy consumption of an energy user of the facilities. After deploying the EMS, the energy user can implement energy usage plans and control energy efficiency.

The EMS system helps energy facility's leaders to make faster and more informed decisions by providing updated information. That allows for reducing the building operating costs, maximizing profits, increasing growth rate and improving property efficiency.

The energy management system allows managers to monitor energy consumption, analyze as well as optimize operating equipments, improve energy efficiency and analyze energy consumption of each device and system. This improves energy efficiency and power quality for energy saving achievement.

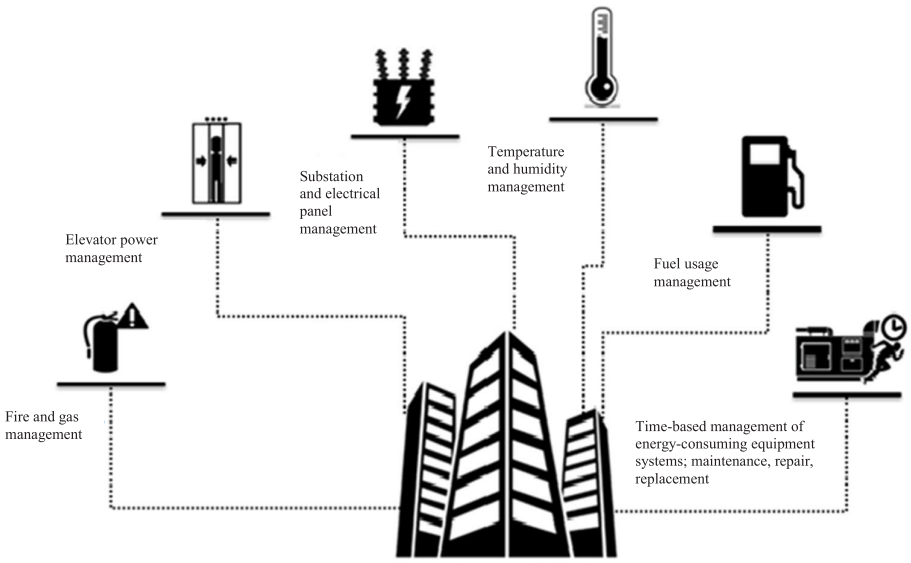


Figure 4.1. Energy Management System (EMS)

The content of the building energy management system can be implemented according to the guidance in the National Standard ISO 50001:2019 (ISO 50001:2018) Energy management systems. The requirements and user guide. According to this standard, the main content of the energy management system (Figure 4.2) includes:

a) Energy policy. The energy policy is a document issued by a building management organization which sets out commitments on energy efficiency goals and targets, and resources to maintain and improve the energy consumption system, support design and procurement for energy efficiency improvement.

b) Energy planning. In effect, it is a plan on energy use, which sets out energy goals, targets and requirements; energy baseline; energy efficiency index.

c) Apply and operate. This is a content related to the training, capacity building and awareness of managers; forming a document management system; control the operation of the energy consuming system; regulations on procurement of energy-using equipments in buildings.

d) Examination. This is the content of monitoring, measuring, analyzing and evaluating the situation of energy use; handle inadequacies in the use, management and operation of energy consumption system.

e) Assessment of the building management facility's leader. Based on the reports of the building energy management system, the owner will consider and make necessary decisions.

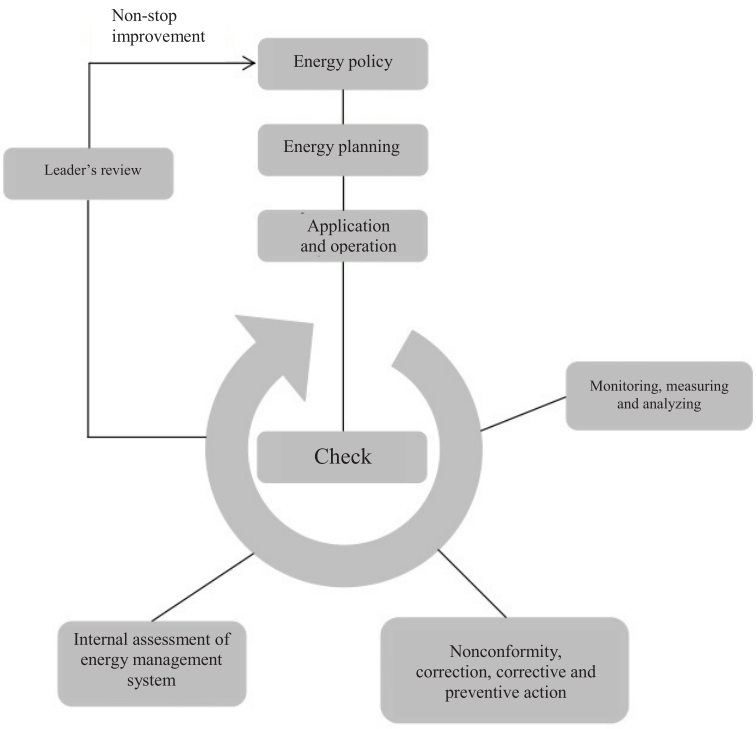


Figure 4.2. The energy management system model according to ISO 50001:2019

So we can see the majority of the contents of the energy management system according to the National Standard TCVN ISO 50001:2019 consistent with regulations on energy management model as prescribed in Decree No. 21/2011/ND-CP of the Government.

The followings are some contents related to the energy management model or energy management system as guided by ISO 50001:2019.

4.1. Energy Policy

The energy policy is a document issued by a building owner that provides commitment and support to the energy management system towards the goal of continuous improvement on energy efficiency.

The objective of the energy policy is to establish commitment documents and overall approach of used management organization to energy management.

The energy policy has the following characteristics:

- Eligible for the function and scale of energy use of buildings;

- Regularly reviewed and updated (e.g. annually) to ensure relevance to reality. This process of reviewing is usually part of a regular management review of the entire energy management system;

- Informed to all employees and management consulting organizations to demonstrate the commitment of the owners.

The policy should mention the following:

- Commitment to continual improvement of energy performance through the setting and achievement of relevant objectives and targets;

- Commit to providing the necessary resources to achieve its energy goals and targets;

- Commit to taking necessary measures to improve energy efficiency;

- Commit to complying with all legal requirements and other requirements on the energy use of buildings;

- Assist the design and purchase energy efficient products and services if economic conditions are feasible;

- The energy policy must be approved by the owners.

4.2. Energy action planning

Economical and efficient energy action plan is prescribed by law for key energy users. Accordingly, the sample content of the plan and report on implementing must comply with the instructions of the Ministry of Industry and Trade in the Circular No. 25/2020/TT-BCT dated September 29, 2020 of the Ministry of Industry and on preparing plan for Economical and Efficient Use of Energy and reports on the implementation thereof; implementation of energy accounting.

The content of this plan specifically demonstrates the energy policy commitments of the building owner, which translates the energy policy into specific actions to be taken over time (as defined in annual and 05 years) to improve energy efficiency with specific goals, targets, solutions and tasks.

According to ISO 50001:2019, building owners must establish, implement and maintain documented energy goals and targets at the functions, levels, processes or facilities or the appropriate facility within the organization; the time frame must be established to achieve these goals and targets. The targets and goals should be consistent with the energy policy. The objectives must be consistent with the targets. When setting and reviewing the targets and goals, the building owners have to calculate legal requirements and opportunities to enhance energy efficiency that has been identified in the energy review.

The building owners also have to consider financial, operational and business conditions, technological options and opinions of the interested parties; plans must to be implemented and maintained to achieve the goals and targets. The plans include: (1) Rules for responsibilities; (2) methods and time frame of the individual indicators; (3) Rules for test procedure, confirm energy efficient improvement solutions; (4) Rules for test procedures, result confirmation. The plans must be set up in writing and updated during the time period.

4.3. Applying and operation

The building owners must be applied and operated the plans that were announced.

Training, ability and awareness.

The building owners makes sure that all his employees are capable on the basis of skill training or eligible experience. Therefore, it is necessary to evaluate the needs related to energy management system operation in order to ensure that all individuals is aware of the energy policy; the procedures and the requirements of the power management of the power system; their role, responsibility and power in getting the requirements of the energy management systems; the benefit of improving efficiency; the impact of the fact or implicit activities on consumption, energy use and the operational method and their activities and behaviors contributed to achieve targets and goals as well as the implicit consequences of deviating from the protocol.

Information exchange.

The building owner must: (1) Exchange internal information about energy and power management of the building; (2) Establish and execute the process that can give an opinion or propose to improve the energy management system; (3) Decide to external information exchange on the energy policies, the power management and efficiency of the building and put into the writing this decision. If he decides to external information exchange, he has to organize and implement the method of the external information exchange.

4.4. Documents system

The documents of building energy management system are defined by the building owners.

The building owners must set up, apply and maintain information, paper forms of electronic or any media to describe the core elements of the energy management and interaction.

The documents of the energy management system may include:

- Scope and boundaries of the energy management;
- Power policy;
- Target, goal and plan
- Review and energy assessment;
- Duplicate of energy audit reports or energy assessment;
- Training plans;
- List of important operating parameters;
- Technical drawings of the devices, including the process and measurement devices (M&V) and process flow chart;

- Technical specifications of system of the energy-using devices;
- Energy Performance Indicators (EnPIs);
- Energy baseline;
- Operation logs;
- Maintenance and service documents;
- Minute of energy meetings;
- Other related documents were determined by the building owners.

The documents must systematically be updated, checked and managed. Here are some notes that help to deploy a systematic and simply management method (printing and digitalization).

- Approval for use to ensure they are correct. The approval must be done before the documents are placed in use.

- We need to review and update periodically to ensure that they do not expire, for example, when practice doesn't change. This is not a hard work as they often say. Many documents are not updated but they need reviewing periodically to make sure of this.

- Current revision must be clearly identified, and old versions must be archived to ensure the documents in use is lasted update.

- Documents must be valid.

- Documents must be properly located and identified. They can create and maintain the system of the folders, documents, listing all related documents. Their objective is to be able to refer to check the previous things happened.

4.5. Monitor, measurement and analysis

The building owners must ensure that key characteristics of activity determine energy efficiency that are monitored, measured and analyzed according to specific period of time. The key charateristics should include at least: (1) (SEU, Significant Energy Use) and other outputs of energy review; (2) Variables relevant to the SEUs; (3) Energy Performance Indicators (EnPls); (4) The effectiveness of plan on achieving the goals and targets; (5) The assessment of the actual energy consumption comparing to the expected.

The building owners must identify and periodically review their measurement needs; ensure that the equipments are used in the monitoring and measurement of key features gives accurate and reproducible data; the records and other methods of adjusting accuracy and reproducibility shall be maintained.

Monitoring, measuring, and collecting data on the typical status of energy use by taking data from the last 3 years of energy bills and using them to establish developments and trends. One useful method is to develop annual building energy usage trends, expecting energy use over the coming period.

It is possible to refer to the analysis of data from actual buildings (Figures 4.3, 4.4)

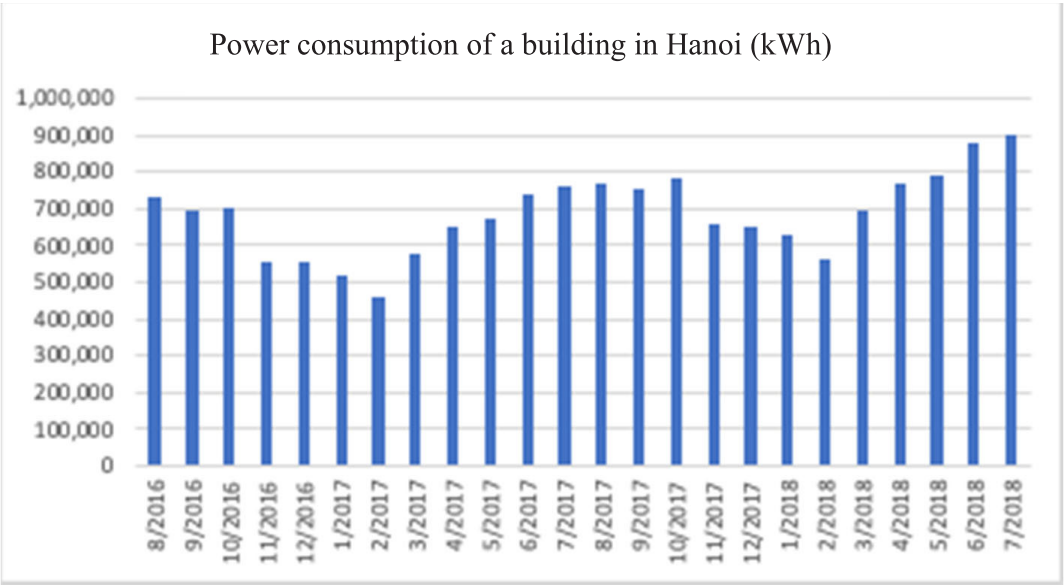


Figure 4.3. The power consumption trends (collected from electricity bills)

Figure 4.3 presents the monthly energy usage trend of a building in Hanoi. From there, the influence of season and background surcharge can be seen, for example, 460.000kWh/month.

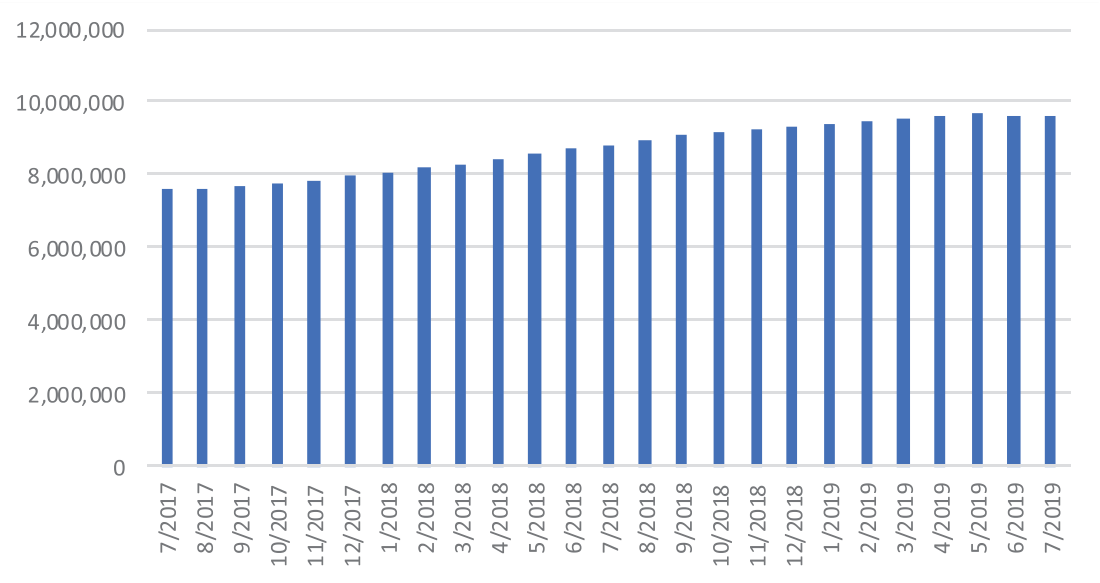


Figure 4.4. The energy usage trends over time (years)

- The trends in Figure 4.4 presents the same data, but represent by years. Each point on the chart is the sum of 12 bills from the previous year. With this representation, it allows identifying overall trends in energy use and it is useful for forecasting and estimating energy consumption.

- The figures in the chart above present that energy use has tended to increase over the years. In this case, the building owners need to understand the causes of these trends and changes.

When analyzing the data, it is necessary to forecast future energy use in order to set targets and indicators of energy efficiency, simultaneously estimate the cost of the following years.

4.6. Baseline and Energy Performance Indicators

4.6.1. Energy Baseline

As defined in ISO 50001:2019, an energy baseline is the quantitative references providing a basis for comparison of energy performance. Accordingly, (1) the energy baseline reflects a specified time period; (2) The energy baselines can be normalized using variables that affect energy use and/or consumption, e.g. production level, temperature over time (outside temperature, etc.) etc…; (3) The energy baseline is also used for determination of energy savings, as a reference before and after the implementation of energy performance improvement actions.

The building owners are responsible for establishing the energy baseline throughout using information from the initial energy review, taking into consideration the data period relevant to energy use and consumption of the organization. Changes in energy efficiency must be measured against these energy baseline(s). The adjustments of the baseline(s) must be implemented in one or more of the following cases: (1) Energy Performance Indicators (EnPls) no longer reflect the organization's energy use and consumption, or; (2) There are major changes to processes, operating patterns or energy systems, or; (3) According to a predetermined method.

At a simple level, the baseline could be the total amount of electricity and other fuels used up to the end of the year before the energy management system is implemented. The advantage of this approach is that it is simple to use by comparing to the year with this baseline. The disadvantage of this approach is that it does not involve the effects of the influencing factors. For example, the impact factor of weather or the power factor of building spaces on the electricity consumption of the building is for each month of the year.

Other energy baselines are often used to select a measure of specific energy consumption per unit floor area (kWh/m2 floor). This advantage of method is simple and it offers an opportunity to compare with other similar buildings as an energy benchmark.

The best method for baseline establishment is to use previously developed impact elements to make the used of energy predictions and compare with actual energy consumption. In this method, the baseline is the best straight line on the regression graph of the impact factor for energy use. As the result is improved, this baseline will go down.

Example of energy baseline used (Figure 4.5):

- A horizontal average baseline is generally appropriate when there are not many impact elements on building's energy consumption in the months of the year. Example: A shopping center in Ho Chi Minh City where outdoor temperature is stable and its business activities are less seasonal.

- Regressive baselines are particularly relevant when there are other elements that can affect the energy consumption of buildings. For example, the used ratio of hotel's room, outdoor weather, etc…

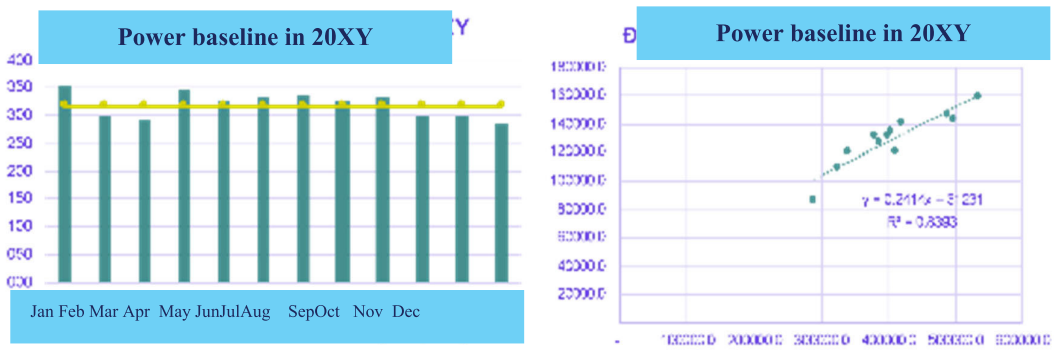


Figure 4.5. The types of energy baselines

4.6.2. Energy Performance Indicators (EnPIs)

According to ISO 50001:2019, the Energy Performance Indicator (EnPl) is the value or quantitative measure of energy performance, determined by the building owners (or hired qualified consulting organizations as prescribed by law). The Energy Performance Indicators can be expressed as a ratio, a simple ratio, or a more complex model.

These indicators are used during the plan building. Therefore we can monitor them during the stage is tested. These indicators may require modification when starting to use for their effective improvement.

There are some different opinions about the benefits of using simple ratios such as energy efficiency (kWh/m2). In this case, they are often used to establish energy ratings for types of bulidings and to compare with the types of specific buildings.

The energy performance indicators and the influence of impact factors can be established basing on the regression analysis of energy use for the impact factors. This is an ideal method for building and monitoring the energy performance indicators.

4.7. Examination and assessment

According to TCVN 50001:2019, the examination and assessment of the energy management system includes: (1) Monitor, measure and analyze (as stated above); (2) Assess compliance with legal requirements and other commitments with state management agencies; (3) Internal audit of the energy management system.

The building owners must conduct internal audits at predetermined intervals to ensure the energy management system: (1) Conforms to planned arrangements for energy management including the requirements of this standard; (2) Conforms to established energy targets and goals; (3) To be effectively applied and maintained and improved energy efficiency. The building owners shall build a plan and a schedule assessment that involve the status and importance of the processes and areas audited as well as the results of previous audits. The selection of auditors and the conduct of assessment must ensure the objectivity of assessment process. The records and the results of assessment shall be maintained and reported to the building owners.

4.8. Nonconformities, Prevention, and Correction

The building owners must deal with actual nonconformities and implicit problems by correcting and taking actions and preventing action, including the following contents: (1) Review nonconformities or implicit nonconformities; (2) Identify the cause of the implicit nonconformity or nonconformity; (3) assess the performance needs to ensure that nonconformities do not occur or recur; (4) Identify and implement appropriate measures; (5) Maintain records of corrective and preventive measures; (6) Review the effectiveness of corrective or preventive measures taken. The corrective and preventive actions should be appropriate to the severity of actual or implicit problems and energy performance consequences encountered. The building owners must ensure that any necessary changes are implemented to the energy management system.

5. ENERGY AUDIT

In order to use efficiently energy savings, firstly it is necessary to properly assess the current state of energy use of the object. The goal of an energy audit is to assess the current state of energy use, then identify solutions to reduce energy consumption and operating costs. The energy audit helps to reduce energy consumption in production and living systems while maintaining or improving line capacity, workforce productivity, human health, comfort and environmental safety and working environment. The centralized energy audit identifies energy saving opportunities and energy efficiency improvement potentials.

5.1. Legal requirements on energy audit

The energy audit activities are implemented in accordance with the Law on Economical and Efficient Use of Energy. Accordingly, the objects that need to be audited are key energy users (Article 30).

The energy audit is also recommended to apply to other works, especially in case it is necessary to renovate and repair buildings towards of energy savings.

The energy audit organizations must meet the requirements of the Law on Economical and Efficient Use of Energy (Article 34):

- Having a legal entity established in accordance with the law;
- Having an energy audit team who becomes certified energy auditors.
- Having vehicles and technical equipments for energy audit.

The content of the energy audit is specified in Article 9 of the Government's Decree No. 21/2011/ND-CP dated March 29, 2011:

- Survey, measure and collect data on the situation of energy use of the facilities.
- Analysis, calculation and assessment of the efficient energy use;
- Assessment of energy saving potentials;
- Proposal for energy saving solutions;
- Analysis of investment efficiency for the energy saving solutions.

The order of audit procedures and energy audit reports must follow the guidance in Circular No. 25/2020/TT-BCT dated September 29th, 2020 of the Ministry of Industry and Trade on preparing plan for Economical and Efficient Use of Energy and reports on the implementation thereof; implementation of energy accounting.

Energy audit procedures:

- Step 1: Determine the scope of the audit;
- Step 2: Establishment of the audit team;
- Step 3: Estimation of the time frame and cost;
- Step 4: Collection of the available data;
- Step 5: Inspection and measurement (define strategic measuring points; measuring equipment installation);
- Step 6: Methods of data collection and analysis (determination of energy saving potentials; determination of investment costs; database normalization; ensure the normal operation of the technology line).

Layout of the energy audit report:

- Chapter 1. Summary (summary of energy saving potential findings, sorted in order of priority; proposal for selection of investment priority solutions).
- Chapter 2. Introduction (a brief introduction to the audited establishment; organization of the audit force; overview and scope of work; contents of the energy audit reports).
- Chapter 3. Company activities (historical and current situation; structure of operations and production).
- Chapter 4. Description of the processes on the technology chain (production lines; energy saving potentials).

- Chapter 5. Energy demand and supply capacity (energy and water consumption demand; fuel parameters and characteristics, energy use; energy consumption rate).

- Chapter 6. Financial - technical constraints (technical - technological issues, environment; economic solutions and assessments).

- Chapter 7. Energy saving solutions (identification and detailed presentation of energy saving solutions; selected technical solutions; financial, energy and environmental analysis).

5.2. Building energy audit

The building energy audit, energy audit reports should comply with the guidance stated in Circular No. 25/2020/TT-BCT of Ministry of Industry and Trade. Accordingly, some of the company's introduction are understood as a building, the technology line is understood as a line of functional parts and energy-using equipment systems installed in the buildings, etc.

The following are some suggestions when performing a building energy audit and reporting:

5.2.1. Chapter 1. Summary

The main content of chapter one is to summarize the survey results, findings and assessment of the audit team on recommended energy saving opportunities. The energy saving opportunities are ranked in order of priority to help the building owners to decide which solutions will be implemented. Although it is only a brief summary, the reports should give a full picture of the energy saving opportunities findings that obtained from the energy audit, the main issue the chapter should be mentioned including:

- Summary of energy saving potentials for the proposed solutions;

- Ability to implement energy saving solutions and projects (presentation).

- Propose an implementation plan.

5.2.2. Chapter 2. Introduction

This chapter introduces and describes the scope of activities such as: the name and address of the audited building, the introduction of audit team, the names of members, the list of measuring equipments used during the period is surveyed at the facilities.

- The building is audited energy and the audit team (name and address of the building; name of the energy audit company, address; time of the energy audit; the members of the energy audit team).

- The scope of energy audit: audit of the entire building or an area of the building, etc.

- The measuring methods and equipments (listed by category).

5.2.3. Chapter 3. Building operations

This chapter describes the general operation of the building; (1) Describe the scale, function, architectural and construction characteristics, the energy-using equipment system of buildings, the building owners; (2) The annual energy consumption of buildings.

The content of this chapter requires the assistance of building energy simulation software, checklists to compare compliance with the requirements of national technical regulations (QCVN 09:2017BXD, QCVN 12:2014/BXD) or Building Energy Benchmarks; presenting data, graphs of energy use; preliminary assessment of energy saving potentials, good and bad characteristics/aspects in energy use of buildings; building operation mode.

5.2.4. Chapter 4. Description of building operations

This chapter includes a description of the technical system of energy consumption in the building, including the enclosure, ventilation and air conditioning systems, power supply and lighting systems, fire protection equipment systems and fire fighting, water supply and drainage equipment systems, elevator systems and other electrical equipments, building control management systems. The objective of chapter is to describe the operating process and detect the stages of inefficient energy use. These findings were drawn from observations during field surveys, discussions with engineers, technicians, and operators, and analysis of data obtained from facility's documents and read the data on meters; analyze the energy saving potentials detected respectively at the building components and systems.

5.2.5. Chapter 5. Energy supply capacity and demand

This chapter describes the input energy supply capacity and energy requirements of all energy-using equipments/systems of buildings. The description of the equipments attached to the test and evaluation results; pay attention to detect inefficient operating stages as identified above. In addition, the energy auditors should determine the building's energy consumption rate and compare with the building energy norm regulations.

In this chapter, data on electricity supply and consumption should be shown; schematic diagram of the energy supply system; electricity costs are applied according to the annual tariff; fuel consumption situation; water supply and consumption; energy efficiency of buildings (determined by the energy auditor).

5.2.6. Chapter 6. Financial and technical analysis

This chapter presents technical and financial content, and the constraints of current legislation. The content of chapter includes tables of key specifications and cost of energy use, detailed analysis and identification of energy saving opportunities:

- Comparison of current operating practice of equipments/systems with original design (if this document is available) and/or field measurements, identifying the causes of discrepancies;

- Identify areas for further study (if necessary);

- Identify energy saving opportunities and demonstrate their correctness (calculation of achievable energy savings potential and detailed description are included in the Appendix);

- Divide the group of proposed technical and management solutions;

- Investment costs to implement solutions (input ordinal numbers for the findings, detailed cost calculations, enclosed with diagrams and drawings, included in the Appendix);

- Compare to treatment options for each energy saving opportunity, select the appropriate option.

5.2.7. Chapter 7. Energy saving solutions

This chapter summarizes energy saving solutions, including detailed technical descriptions and cost estimates of energy saving opportunities.

- Use building energy simulation software, spreadsheets to calculate and evaluate the selected measures, including all necessary parameters and data included in the Appendix.

- Proposal of the implementation program;

- Propose the parties involved in the program implementation, identifying disadvantages, advantages and solutions of difficulty prevention.

- Summary of investment costs and payback period;

- Manage and set Specific Energy Consumption (SEC), compare with Building Energy Norm after implementing solutions;

- Propose an organization for energy management (e.g. need for benergy manager/ energy manager in the enterprises, define the functions and duties of the energy manager/ energy management board); the role of the building operation management department in terms of energy management, propose the installation of meters at the necessary locations, etc;). Determine the sustainable energy management strategy (policy, the company's long term, medium and short term goals on energy use, financial policy, human resource development, training, incentive policies encourage building owners to participate in energy savings, etc.).

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