ERIA Research Project Report 2021, No. 14

Technical Guidelines for Energy Efficiency and Conservation in Commercial Buildings

Edited by

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Technical Guidelines for Energy Efficiency and Conservation in Commercial Buildings

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Preface

Energy efficiency and conservation (EEC) is one of the key energy policies. Some may say that EEC is akin to new oil and gas discoveries; that is why it is also referred to as hidden energy. Many countries, including developing countries, have EEC policies. However, their implementation is often a different story as most developing countries cannot implement EEC programmes substantially due to a lack of EEC expertise and experience. Therefore, the preparation of general EEC guidelines will be useful and effective for EEC planning and implementation in developing countries.

In essence, EEC contributes towards reduced energy consumption of factories and commercial buildings. The final energy consumption computation has two other subsectors – transport and residential – but they have different energy benchmarking criteria. For the transport sector, improving fuel economy means fuel consumption divided by drive distance. In contrast, for the household sector, this means education and campaign as well as minimum energy performance standard and labelling of appliances. Thus, the Economic Research Institute for ASEAN and East Asia (ERIA) prepared the EEC guidelines for commercial buildings because of commercial buildings' significant increase. Yet energy-intensive industries, such as iron and steel as well as paper and pulp, are not major economic activities in ASEAN countries.

This EEC guideline for commercial buildings comprises three major parts: technical, regulatory, and economical. The technical part consists of passive and active design measures. Passive design measures introduce energy conservation through architectural design. On the other hand, active design measures introduce energy efficiency methodology through engineering design and the selection and operation of energy-efficient equipment and systems such as air-conditioning, chillers, boilers, and lighting. The regulatory part introduces a standard & labelling system for appliances, building energy intensity labelling, or energy efficiency indicators. The EEC concept and implementation will bring monetary benefits to EEC investors. The chapter on economic analysis describes methods of economic evaluation, illustrative exercises, and energy service companies.

We highly recommended the following to realise significant energy savings: (i) appropriate energy efficiency regulations prepared by the concerned government agencies and offices; and (ii) the appropriate EEC technologies from passive and active design measures with reference to results of economic analysis, such as the internal rate of return and payback period as outlined in this guideline. ERIA hopes this guideline will contribute to promoting and successfully implementing EEC in the Philippines and other ASEAN countries.

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List of Abbreviations and Acronyms

ACMV	air-conditioning and mechanical ventilation
BCA	Building and Construction Authority (Singapore)
BEI	building energy intensity
CO2	carbon dioxide
DOE	Department of Energy (Philippines)
EEC	energy efficiency and conservation
EEI	energy efficiency indicator
EMS	energy management system
ESCO	energy service company
EUI	energy use intensity
EUMB	Energy Utilization and Management Bureau
GFA	gross floor area
IEA	International Energy Agency
IRR	internal rate of return
IRROE	internal rate of return on equity
IRROI	internal rate of return on investment
LED	light-emitting diode
OTTV	overall thermal transfer value
PESLP	Philippine Energy Standards and Labeling Program
PV	photovoltaic
ROE	return on equity
ROI	return on investment
SEU	significant energy user
SHGC	solar heat gain coefficient
TWh	terawatt-hour
VLT	visible light transmission

Executive Summary

Energy supply is one of the most fundamental infrastructures needed for the development of society and economic growth. Energy use must be rational and efficient to avoid the unnecessary wastage of depleting resources and harmful environmental impacts, such as pollution and global warming. Buildings consume a significant amount of energy. Optimising energy efficiency in a building is a much more cost-effective measure to reduce carbon emissions than turning to renewable energy solutions without addressing efficient energy use in buildings. Energy efficiency solution combines energy efficiency and conservation (EEC) measures, which need not be expensive and use advanced technology. Unlike renewable energy, the approach to adopting EEC strategies requires a combination of early planning and collaborative team efforts by architects, quantity surveyors, engineers, and building professionals at the beginning of a project. These guidelines provide cost-effective and practical measures and economic analysis in EEC for new and existing commercial buildings.

These guidelines were prepared to help policymakers, department officers, and building professionals better understand the basics of energy efficiency for commercial, institutional, and multi-unit residential buildings in hot and humid climates. These were primarily written as a guide to address the basic issues on efficient energy use in buildings concerning the design and evaluation of EEC measures, including economic viewpoints, to complement the 'Guidelines on Energy Conserving Designs of Buildings' of the Philippine Department of Energy (DOE). These guidelines, however, do not cover specific issues concerning the operation and maintenance of building systems. It is recommended that such specifics come from other sources. These guidelines discuss mainly the design of buildings and their mechanical systems, which are the significant energy users (SEUs) in terms of major shares of energy use in buildings in hot and humid climates. Therefore, these guidelines focus on the more critical aspects that affect efficient energy use in buildings without considering heating systems, commonly found in temperate climates.

These technical guidelines explain the fundamentals of energy efficiency in commercial buildings. Firstly, we need to identify the EEC of lighting, air-conditioning, and mechanical ventilation (ACMV) systems that are targeted. We also need to discuss a holistic approach to designing energy-efficient buildings by adopting a combined strategy of passive and active design measures. This approach requires early efforts in planning and designing by a multi-disciplinary design team that comprises architects, engineers, surveyors, landscape designers, etc. In addition to the existing Philippine Energy Standards and Labeling Program (PESLP) for energy-consuming products, building energy intensity (BEI) labelling may be done to enable the DOE to set up benchmarking targets for various building categories or subsectors after establishing the system and collecting sufficient building information and annual energy consumption data. BEI labelling can measure or indicate the energy performance of buildings of the same category or subsector for design and building operation purposes. A BEI labelling system will enable setting measurable goals in building energy performance benchmarking, which will be vital in achieving EEC success in commercial buildings. These guidelines were prepared to complement the DOE's existing guidelines, with three key concepts in mind:

- adopting holistic EEC strategies through a strategic combination of early planning and collaborative team efforts by architects, surveyors, engineers, and building professionals in design and construction through passive and active EEC measures

- using EEI or BEI labelling to achieve a low BEI, set as measurable goals and benchmark targets for various types of commercial buildings.

- adopting a balanced approach through economic justification with economic analysis of EEC measures under reasonable energy prices, in other words, marketed energy prices.

Chapter 1

Introduction

The Economic Research Institute for ASEAN and East Asia (ERIA) held an energy efficiency and conservation (EEC) workshop – 'The Second Energy Efficiency and Conservation (EE&C) Policies in ASEAN' – on 23 April 2019 in Manila, Philippines – in collaboration with the Institute of Energy Economics, Japan (IEEJ). ERIA also held a bilateral meeting with the Department of Energy Philippines (DOE) to discuss ERIA's support to the department regarding the preparation of the EEC implementation road map in the Philippines. Subsequently, ERIA submitted the scope of work to DOE's Energy Utilization and Management Bureau (EUMB) – 'Preparation of Energy Efficiency Roadmap for the Philippines' – which contained EEC fundamentals. These fundamentals comprise a (i) review and preparation of a legislative framework of EEC sub-decrees, (ii) strengthening of energy service companies (ESCOs), (iii) growing of energy managers, (iv) installation of a standard and labelling system, (v) mandatory collection system of energy consumption data from designated factories and commercial buildings, and (vi) enhancement of education and campaign.

Also, based on the 'Energy Efficiency and Conservation Act', signed on 12 April 2019, the DOE sent ERIA an EEC road map, covering various action plans for the final energy consumption sectors in two periods: medium term (2019–2022) and long term (2023–2040). Upon the EUMB/DOE's request, ERIA revised the existing scope of work to be consistent with the action plans of the road map. ERIA experts visited Manila to attend the project's first working group meeting on 29 November 2019 and confirm the contents of the revised scope of work to EUMB. After the first working meeting, the contents of the scope of work were fixed: (i) important points of the EEC Act; (ii) review and revision of the existing document, namely, 'Guidelines on Energy Conserving Design of Buildings'; (iii) introduction of highly efficient vehicles; (iv) preparation of energy efficiency indicators (EEIs) of commercial buildings.

The EUMB, however, decided to make a change and requested ERIA to shift to more EEI studies. Based on EUMB's request, ERIA revised the scope of work again and submitted it to the DOE in January 2020. The revised scope of work contains the following: (i) important points of the EEC Act, and (ii) support to the DOE to prepare the EEIs in the commercial and road transport sectors, including EEI lectures and pilot energy consumption surveys.

ERIA was supposed to hold a second working meeting in Manila from 30 March to 1 April 2020 to kick off the two energy consumption surveys to be conducted by local consultants. But due to the COVID-19 pandemic in Asia, ERIA postponed such a meeting to the middle of 2020. After that, the DOE requested ERIA to expand the scope of work to include EEI preparation in the industry and household sectors with energy consumption surveys. In this regard, ERIA and the DOE held a virtual meeting on 24 July 2020 to discuss the scope of work with detailed reviews. Finally, both sides agreed to the following contents of the EEC project for the Philippines in 2020–2021:

- preparation of the EEIs of commercial buildings, including energy consumption surveys
- preparation of EEIs of factories, including energy consumption surveys

- change of the project name to ‘Preparation of Energy Efficiency Indicators of Commercial Buildings and Industrial Factories in the Philippines’
- change of project term from October 2020 to February 2021

ERIA and the DOE discussed the following during a virtual meeting on 8 September 2020 to kick off this project:

- introduction of questionnaires to be used for the energy consumption surveys in the industry and commercial sectors, with illustrations of expected output from the surveys
- terms of reference for local consultants to conduct the surveys
- list of candidates from local consultants.

After the meeting on 8 September, the DOE identified two local consultants and requested them to submit their proposals, including cost estimations, to the DOE and ERIA. But both consultants informed the DOE and ERIA that, due to the COVID-19 pandemic, the energy consumption surveys would be difficult to implement because enumerators could not visit commercial buildings and factories to conduct surveys and collect energy consumption data. Thus, ERIA decided to postpone the surveys for the following year (2021) after the COVID-19 pandemic eases.

By January 2021, COVID-19 was still ravaging the Asian region. Thus, ERIA proposed to the DOE that the surveys be conducted under a new project in 2021–2022, pending any improvement in the pandemic situation. Meanwhile, the DOE agreed to implement the following activities under the current project:

- conduct a capacity building training on EEC (25–28 January 2021)
- prepare an EEC guidebook.

Again, ERIA organised a virtual meeting on 22 March 2021 to discuss with the EUMB/DOE the contents of the capacity-building training. The training was planned for April 2021. However, the capacity-building training could not be conducted due to the busy schedule of the DOE. Finally, the project supporting the EUMB/DOE in 2019–2020 was reduced only to the preparation of an EEC guidebook in commercial buildings. This should be a useful guidebook that will complement the DOE’s Guidelines on Energy Conserving Designs of Buildings in implementing EEC in the Philippines.

Chapter 2

Fundamentals of Energy Efficiency in Buildings

2.1 Background

These technical guidelines were prepared to help policymakers, department officers, and building professionals better understand the basics of energy efficiency in commercial, institutional, and multi-unit residential buildings in hot and humid climates. These guidelines were primarily written to address the basic issues on the efficient use of energy in buildings concerning the design and evaluation of EEC measures. However, these guidelines do not cover specific issues on the operation and maintenance of building systems. Such specifics are recommended to come from other sources of such topics.

These guidelines discuss mainly the design of buildings and their mechanical systems, which are the significant energy users (SEUs) in terms of major shares of energy use in buildings in hot and humid climates. Therefore, these guidelines focus on the more critical aspects that affect energy use in buildings without considering heating systems, commonly found in temperate climates.

Despite the current economic downturn brought about by the COVID-19 pandemic, primary energy demand and electricity demand in ASEAN countries are expected to continue their trend of rapid growth under the post-pandemic era. Therefore, energy efficiency will continue to be significant in governments' energy planning.

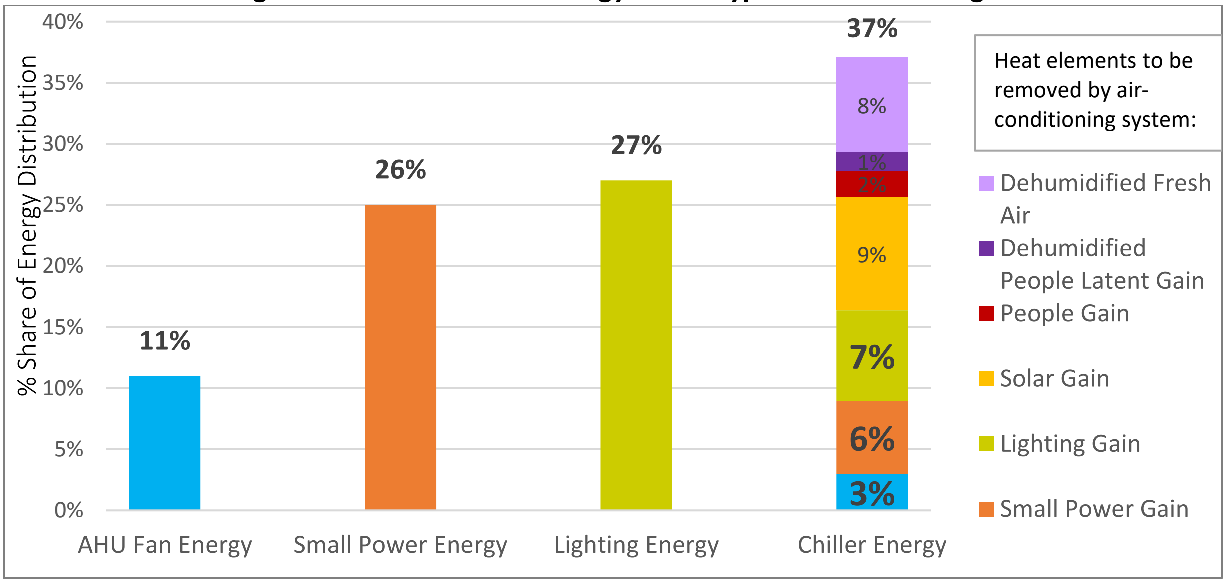
2.2 Energy-use Breakdowns in Commercial Buildings

Before discussing energy efficiency in buildings, it is prudent to understand and identify the SEUs in building services. These guidelines intend to focus on SEUs in commercial buildings to achieve significant energy savings. According to the International Energy Agency (IEA, 2019), electricity use for air conditioning in ASEAN countries increased 7.5 times over 30 years, from 10 terawatt-hours (TWh) in 1990 to almost 75 TWh in 2017. China and India have seen a comparable increase in cooling-related electricity use during the same period.

It is interesting to note that air-conditioner ownership is still relatively low in the ASEAN region. Around 15% of households in ASEAN countries have an air conditioner, compared with 90% of households in some developed economies. However, almost 80% of households in Singapore and Malaysia are reported to have an air conditioner. About 10% of other ASEAN countries are reported owning an air conditioner, which suggests significant potential for an air-conditioner market in several countries. IEA 2019 also indicates that as the standard of living in a country improves, its population will likely increase the use of air conditioners. Similarly, as economic activities increase and livelihoods improve, access to electricity and cooling requirements will increase. The demand for air-conditioning services and, hence, for electricity will increase with rapid urbanisation across the region, including the Philippines.

As reported in the Public Works Department Malaysia 2013, the Danish International Development Agency (Danida) conducted a study in 2005 in Malaysia on the reformulation of the overall thermal transfer value (OTTV) in Malaysian Standard 1525. Danida produced a typical energy-use breakdown in typical office buildings (Public Works Department Malaysia, 2013) in Malaysia (Figure 2.1). This chart shows that the combined share of energy consumption by air-conditioning and mechanical ventilation (ACMV) system, comprising chiller energy and energy of air-handling unit fan, is 49% for typical office buildings in Malaysia. Figure 2.1 also shows the percentage breakdown of the shares of various heat elements to be removed by the air-conditioning system for occupants' thermal comfort. These heat elements are (i) dehumidified fresh air ventilation, (ii) dehumidified people's latent gain, (iii) sensible heat gain from occupants, (iv) solar heat gain, (v) lighting heat gain, (vi) small power heat gain, and (vii) fan heat gain. Figure 2.1 shows the remaining typical shares of small power and lighting energy use at 25% and 26%, respectively.

Figure 2.1: Breakdown of Energy Use in Typical Office Buildings



AHU = air-handling unit.
Source: Public Works Department Malaysia (2013).

The Energy Commission of Malaysia conducted an energy consumption survey in the commercial sector and reported the findings in the National Energy Balance (Malaysia) 2016. The commission's studies collected data from 12 main categories in the commercial sector (Table 2.1) from the 12 states of Peninsular Malaysia. The surveys were conducted in Peninsular Malaysia and collected annual energy data from 5,000 business premises from 2014 to 2016. For this report, the latest data for 2016 were reviewed to establish the latest energy-use breakdowns in Malaysia (Table 2.1).

Table 2.1: 12 Main Categories of Commercial Buildings in the Energy Consumption Survey Conducted in Malaysia

1. Wholesale and Retail Trade	7. Travel Agencies and Tour Operators
2. Transportation and Storage	8. Public Administration
3. Accommodation and Food Service	9. Education
4. Information and Communication	10. Human Health and Social Work
5. Selected Services	11. Arts, Entertainment, and Recreation
6. Professional, Scientific, and Technical	12. Other Services

Source: National Energy Balance (Malaysia) 2016 published by Energy Commission Malaysia, 2018.

Table 2.2: Final Electricity Consumption by Aggregated Categories in Malaysia's Commercial Sector, 2016

Category	Space Cooling (GWh)	Water Heating (GWh)	Lighting (GWh)	Other Use (GWh)	TOTAL (GWh)
Wholesale and Retail Trade	2,116.80	45.33	1,116.87	1,253.76	**4,532.76**
Transportation and Storage	969.50	5.82	436.57	751.66	**2,153.75**
Accommodation and Food Service	630.02	127.18	331.29	548.17	**1,636.83**
Information and Communication	1,651.15	150.75	762.45	1,588.44	**4,152.78**
Selected Services	2,270.49	–	1,254.17	1,880.72	**5,405.92**
Professional, Scientific, and Technical	194.35	–	118.65	272.92	**585.92**
Travel Agencies and Tour	8.65	0.01	2.92	9.28	**20.86**

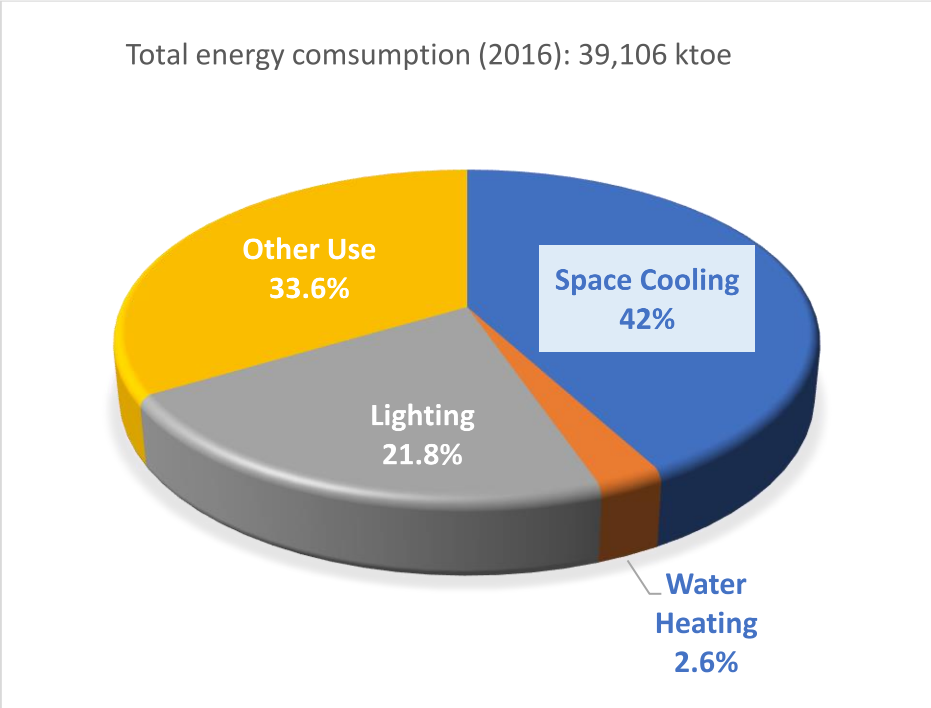
Public Administration	2,946.31	262.71	1,418.34	2,267.82	**6,895.18**
Education	1,339.60	–	673.90	1,139.99	**3,153.49**
Human Health and Social Activities	2,120.27	200.57	1,103.11	1,516.59	**4,940.04**
Arts, Entertainment, and Recreation	343.17	40.51	223.79	284.82	**892.29**
Other Service Activities	1,860.37	201.76	1,074.17	1,599.88	**4,736.19**
Total GWh	**16,440.66**	**1,034.62**	**8,516.23**	**13,114.06**	**39,106.00**
% Share	**42**	**2.6**	**21.8**	**33.6**	**100**

Source: National Energy Balance (Malaysia) 2016 published by Energy Commission Malaysia, 2018.

Based on the data in Table 2.2, Figure 2.2 shows the average energy-use breakdowns for various building services in commercial buildings (that include the 12 categories of buildings in Table 2.1) in Malaysia. Figure 2.2 shows the average electricity consumption breakdowns based on the surveys conducted in Malaysia's 12 commercial sub-sectors. Similar to the findings of Danida in 2005 for typical office buildings in Malaysia (refer to Figure 2.1, showing 49% for space cooling), the majority share of electricity consumption in the commercial sector is substantially taken up by space cooling at about 42% for the 12 categories of commercial buildings (Figure 2.2). Lighting takes up a significant proportion of electricity consumption at 21.8%. Other use at 33.6% was reported, but there were no further breakdowns, comprising lifts and escalators, refrigerators, computers, office equipment, etc. The difference between the energy-use breakdowns in Figure 2.2 and Figure 2.1 is that the former was based on the national survey data obtained from the 12 main categories of commercial buildings listed in Table 2.1. The energy-use breakdowns in Figure 2.1 were based on DANIDA's data specifically obtained from typical office buildings. In any case, both the analyses in Figures 2.1 and 2.2 show that the largest share of energy use is air-conditioning systems.

Based on the findings discussed above and the IEA 2019 report on the future of cooling in Southeast Asia, we can conclude that space cooling or ACMV systems would consume the largest share of energy in commercial buildings. The second-largest share of energy consumption in commercial buildings should be lighting.

Figure 2.2: Average Electricity Consumption Breakdowns Based on Surveys Conducted in Malaysia's 12 Commercial Sub-sectors



Source: National Energy Balance (Malaysia) 2016 published by Energy Commission Malaysia, 2018.

2.3 Fundamentals of Energy Efficiency in Buildings

Based on Section 2.2, it would be prudent to focus on space cooling amongst the building services to achieve significant energy savings. Furthermore, since space cooling consumes a substantial share of the energy use in buildings, it is suggested that the fundamentals of energy efficiency should focus on understanding the fundamental physics in thermal comfort requirements in buildings.

For most modern buildings in hot and humid climates, the ACMV is essential for building services. It is essential because building occupants demand thermal comfort. Thermal comfort is a moving target and is complex because it is subject to expectations, perceptions, cultures, and behaviours. Comfort perception changes as occupants change to light or heavy clothing and reduce or increase their physical activities. Based on the recommendation of ASHRAE, ACMV designers are expected to satisfy only 80% of occupants so that building owners do not need to overspend on oversized ACMV equipment.

2.3.1 Passive design measures

Before discussing ACMV systems, it would be strategic to consider optimising passive design measures before optimising active design measures. As Figure 2.1 illustrates, the objective of ACMV systems is to remove the heat elements prevalent in buildings. A substantial proportion of these heat elements are due to solar heat gains. Passive design measures would involve essentially architectural, site planning, and landscaping design. Therefore, adopting an integrated approach through architectural, site planning, landscaping, and engineering in active design measures (refer to Section 2.2) in designing energy-efficient buildings would optimise energy efficiency. The basic approach to good passive design is to orient, shade, insulate, ventilate, and daylight buildings.

In other words, the objective of the passive design measures is to minimise solar heat gains through the building envelope that shapes a building. Buildings primarily provide an internal environment suitable for occupying the building. After the passive design measures are optimised and solar heat gains minimised, the cooling loads of a building can be reduced. Hence, the ACMV system capacity can be reduced, resulting in savings in equipment costs and operating costs. The key factors to be considered in the building envelope approach to minimise solar heat gains include the following: site planning and orientation, daylighting, façade design, natural ventilation, thermal insulation, and strategic landscaping.

2.3.2 Active design measures

After the passive cooling strategies are optimised, the next step would be to adopt active design measures. As discussed in Section 2.2, prioritised efforts in energy efficiency in commercial buildings should be accorded to ACMV system designs. Fundamentally for thermal comfort, an air-conditioning system in a commercial building removes heat from the establishment to maintain it at a certain temperature. Typically, the heat elements that are to be removed from a commercial building by the air-conditioning system are as follows:

- Solar radiation gain – the heat gain due to solar radiation through building windows is known as solar radiation sensible heat gain.
- Conduction gains due to building fabric – the temperature gradient between outdoor and indoor spaces will cause conduction heat gain through the building fabric.
- People sensible gain – the sensible heat gain from people is the heat emitted by people in air-conditioned spaces.
- Dehumidification of people latent gain – the latent heat gain from people is the moisture emitted by people in air-conditioned spaces.
- Dehumidification of fresh air ventilation – the mechanical ventilation and infiltration of outdoor air into air-conditioned spaces brings along the moisture content of outdoor air.
- Outdoor air ventilation sensible gain – the outdoor air ventilation and infiltration into air-conditioned spaces bring along heat content of the outdoor air.
- Small power gain – all electrical equipment plugged into power points in a building result in heat in air-conditioned spaces.
- Lighting gain – all electrical energy used by lighting would end up as heat within a building.

Depending on the cooling load, most commercial buildings would have a centralised ACMV system typically comprising of (i) a chiller plant, (ii) chilled water pumps, (iii) condenser water pumps, (iv) cooling towers, and (v) an air-distributing system (an air-cooled system does not have condenser water pumps and cooling towers). Based on the fundamental requirements of an ACMV system discussed above, the following areas should be prioritised for active EEC measures in a commercial building: chiller system efficiency, lighting efficiency, small power load, fan efficiency, and control of outdoor air intake and infiltration.

Chapter 3

Passive Design Measures

3.1 Introduction

It is cost-effective to adopt passive design measures as a first step in optimising energy efficiency in commercial and residential buildings. As discussed in Chapter 1, almost 50% of energy consumption is typically used in cooling for thermal comfort in hot and humid climates. Therefore, measures discussed in this chapter should be prioritised and employed as extensively as possible. It makes sense to optimise passive cooling strategies by adopting passive design measures, which are essentially architectural. Passive design measures aim to optimise (i) passive cooling strategies, i.e. minimise heat gains in buildings; and (ii) environmental cooling through natural means such as vegetation, landscaping, and shading.

Buildings primarily provide an internal environment suitable for occupancy in buildings. Therefore, the architectural passive design should consider the building's site environment. The key passive design measures are discussed below.

3.2 Site Planning and Orientation

It is important to consider site planning and orientation in designing a new building on the green field. The primary objective of good orientation in the equatorial region is to avoid exposing building openings to intense solar radiation as the sun travels east to west. As a general rule, orientate the building layout as much as possible, such that a building's main long axis with more openings or glazing would face north to south, and the narrow ends of the building would face the east–west direction (Figure 3.1). The idea is to minimise the exposure of building openings to the east–west sun travel direction as much as possible.

The orientation of buildings can contribute to the immediate microclimate of open spaces by providing shade and shadow to the immediate surroundings that will benefit the indoor areas adjacent to it.

Figure 3.1: Long Directional Axis of Building (in Blue) Should Face North and South As Much As Possible

Source: Author.

3.3 Daylighting

Before considering efficient electrical lighting, daylight harvesting in a building should be incorporated to provide lighting requirements where possible during the daytime. Building occupants will benefit from a proper daylight harvesting design that provides a better working environment and improved energy efficiency. Conversely, improper daylight harvesting design may cause glare discomfort, excessive heat gain, increased thermal discomfort, and high energy consumption in buildings.

The simplest way to describe daylight distribution, penetration, and intensity is daylight factor (DF), expressed as a percentage. It is the ratio of the internal space illuminance ($E_{internal}$) at a point in a room to the instantaneous external illuminance ($E_{external}$) on a horizontal surface (equation 1).

$$DF = \frac{E(internal)}{\mathrm{E(external)}}\ x\ 100 \qquad \text{-----------------}\ (1)$$

Where:

DF = daylight factor (%)

E(internal) = horizontal illumination of reference point indoor (Lux)

E(external) = horizontal illumination of unobstructed point outdoor in an overcast sky condition (Lux)

As a guide, the brightness inside a building and the associated distribution can be broadly classified by the daylight factors described in Table 3.1, based on Malaysian data given in MS1525:2019. In general, a daylight factor of 1.0–3.5 is recommended. The introduction of daylighting will save energy through energy conservation without switching on artificial electrical lighting, which would reduce lighting energy emissions that the ACMV system needs to remove.

Table 3.1: Daylight Factors and Impact

Daylight Factor	Lighting	Glare	Thermal Comfort	Appearance and Energy Implication
> 6.0	Intolerable	Intolerable	Uncomfortable	The room appears strongly daylit. Artificial lighting is rarely needed during the day, but thermal problems due to solar heat gains and glare may occur.
3.5–6.0	Tolerable	Uncomfortable	Tolerable	
1.0–3.5	Acceptable	Acceptable	Acceptable	The room appears moderately daylit. It is generally a good balance between lighting and thermal aspects. Supplementary artificial lighting may be needed in dark areas due to the effect of layout or furniture arrangement.
< 1.0	Perceptible	Imperceptible	Acceptable	The room looks gloomy; artificial lighting is needed most of the time.

Source: Department of Standards Malaysia (2019).

3.4 Façade Design and Building Envelope

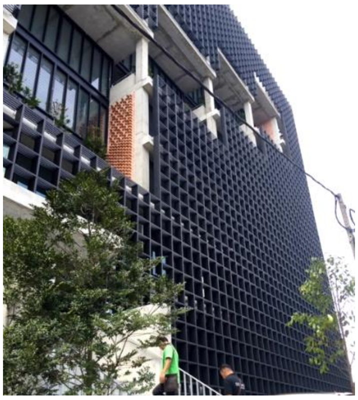
The façade design is an important part of passive design measures. This is where architects can deploy innovative ideas to minimise solar heat gains in buildings. The façade of a building is the external building envelope that determines the building's form and aesthetics. A good façade design using architectural treatments and suitable materials can help optimise daylighting and thermal comfort by minimising solar heat gains. A building envelope should be designed to block out heat into buildings via conduction and solar radiation. A properly designed envelope can greatly reduce the cooling load and, hence, the energy consumption of a building.

One way to quantify the performance of a building envelope is a design criterion known as overall thermal transfer value (OTTV). The OTTV is a useful indicator for non-air-conditioned buildings and partly non-air-conditioned buildings. The OTTV aims at achieving the design of a building envelope to reduce external heat gain and, hence, reduce the cooling load of ACMV systems. Reference is made to Section 5 of the Philippines's Guidelines on Energy Conserving Designs of Buildings (DOE, 2008) to determine the OTTV of a building envelope.

The OTTV of a building envelope is recommended not to exceed 50 W/m^2. However, this maximum value of the OTTV should be deliberated amongst stakeholders and decided by the DOE. Should the department wish to set a higher energy efficiency goal, this value can be set lower, but there will be cost implications for such a decision. For this report, the maximum OTTV value for a commercial building is set at 50 W/m^2. The OTTV is determined based on all external walls of a building. Achieving an OTTV not exceeding 50 W/m^2 can confirm that the design of the building envelope has incorporated measures to reduce external heat gain, hence, decreasing the cooling load of the ACMV system. Such effort will also result in reducing the ACMV equipment capacity.

The main façade design methods are summarised as follows:

Figure 3.2: Example of Façade Design with External Shading Devices



Source: Ar. Voon Kok Leong

Figure 3.3: Example of Egg-crate Façade Design

Source: Author.

1) Building envelope design to achieve the OTTV of external walls at 50 W/m^2 or less and roof OTTV of 25 W/m^2 or less
   a) Fenestration design and glazing selection
      i) Where possible, choose a building form and fenestration design that provide the least amount of glazing while maintaining the required aesthetic appearance of the building.
      ii) The correct selection of glazing properties can help reduce the OTTV value, reduce the cooling load, and increase energy efficiency.
      iii) As a selection guide, select glazing with a low solar heat gain coefficient (SHGC) to reduce the solar heat gain in building and high visible light transmission (VLT) to improve daylight harvesting.
      iv) It is advisable to make a balanced selection because glazing with low SHGC will likely have an unsatisfactory VLT, e.g. glazing with a VLT of less than 10% makes a building look dull from within due to the lack of daylight inside the building. For example, a high-performance low-e double glazing can get a low SHGC of less than 0.15 with a VLT of 25% or higher.
      v) As a general guide, it is possible to use the ratio of light to solar gain (VLT to SHGC, i.e. LSG [or light to solar gain]). The higher this ratio, the better it is for commercial buildings where daylight is harvested.
         - Single glazing without low-e properties has typical LSG values of 0.5 to 1.0.
         - Single glazing with low-e properties has typical LSG values of 1.05 to 1.3.
         - High-performance double glazing with low-e properties has typical values of 1.5 to 2.0.

   b) Building materials

      Suitable building materials with insulating properties can reduce a significant amount of energy consumption in a tropical climate. Outdoor air temperature is high during the daytime, while the air temperature inside air-conditioned spaces is set at 23^{0}C to 27^{0}C. Heat is conducted from the outside to the inside of a building. However, the outdoor air temperature is likely lower than the indoor air temperature during the night and early morning. Heat flow is then opposite to daytime conditions.

      Table 3.2 shows the difference in the energy-saving potential for wall materials with a lower coefficient of heat transfer (U-value). The estimated values given in Table 3.2 are based on an energy simulation study reported in BSEEP 2013. The simulation study model was based on a square building, without external shades and with a service core in the centre of the building. The high, medium, and low night-time baseloads refer to a night baseload of 50%, 35%, and 10% of the daytime peak load, respectively. Table 3.2 shows that the lower the wall material's U-value, the lower is the simplified energy index. This index provides an easy method to estimate the energy reduction due to the wall U-value selection in a hot and humid climate.

Table 3.2: Comparison of Estimated Energy (Electricity) Reduction of Various Wall Materials under Three Baseload Scenarios

Case	Description	ASHRAE U-value (W/m^2K)	Wall Simplified Energy Index (kWh/y per m^2 of wall area)		
			High night-time baseload	Medium night-time baseload	Low night time baseload
1	Concrete wall, 100 mm	3.40	55	32	28
2	Brick wall, 115 mm	2.82	52	30	25
3	Brick wall, 220 mm	2.16	50	27	22
4	Double brick wall with 50 mm cavity, 300 mm	1.42	48	25	20
5	Autoclave lightweight concrete, 100 mm	1.25	47	24	18
6	Autoclave lightweight concrete, 150 mm	0.94	45	22	17
7	Autoclave lightweight concrete, 200 mm	0.75	45	22	16

Source: Extracted from Public Works Department Malaysia (2013).

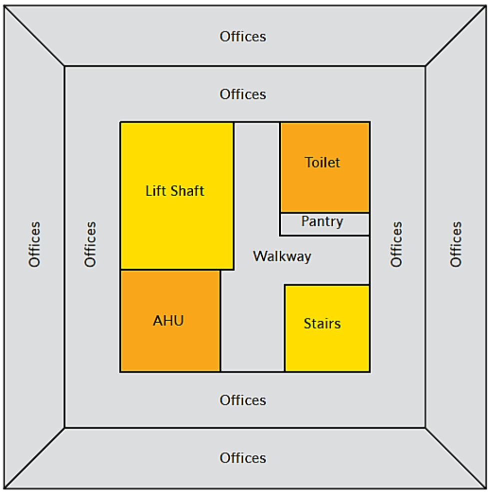
c) Core location

i) To place the service core (comprising lift core, services, etc.) to serve as a buffer zone to reduce the impact of solar radiation in the air-conditioned space of a building, e.g. core location facing the east or west. Sometimes due to other architectural considerations, it may not be possible to select an ideal core location. The designers should then consider using the next best option if the best option is not available.

ii) The objective of the core location is to increase the effectiveness of the façade design in reducing solar heat gains.

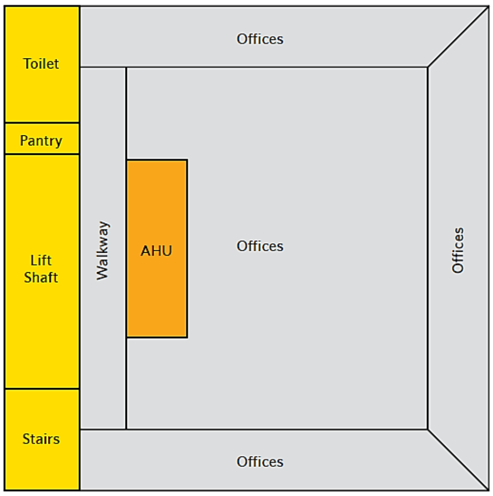
iii) Comparing Figures 3.4 and 3.5 as illustrations of a core location design, a square building with a centre core has a better view out and more glazing area; a square building with a side core facing west has less view out and less glazing area. However, in terms of solar heat gains, OTTV, and building energy performance (BEI value), the square building with a centre core facing west performs better (Figure 3.5).

Figure 3.4: Square Building Centre Core



Source: Public Works Department Malaysia (2013).

Figure 3.5: Square Building Side Core West



Source: Public Works Department Malaysia (2013)

3.5 Natural Ventilation

Ventilation, the movement of air, has three useful functions:

1) It provides the fresh air needs of building occupants.
2) It maintains the thermal comfort of building occupants.
3) It cools down the interior building space when outdoor air is cooler.

ASHRAE Standard 62.1 – Ventilation for Acceptable Indoor Air Quality – specifies ventilation requirements. From the energy efficiency perspective, conditioning ventilation air properly is expensive, especially in hot and humid climates. It costs money to clean outdoor air, dry it, cool it, and push it into the breathing zone. Nevertheless, for health reasons, it is necessary to introduce outdoor air to air-conditioned spaces. There are particular periods, such as mornings and evenings, during which natural ventilation can cool offices and other areas with fresh air. Air flushing of building spaces may be considered during these periods. However, security, ambient exterior noise levels, outdoor air quality, outdoor air temperatures, humidity, weather conditions, etc. should also be considered.

Under the current COVID-19 pandemic situation, ASHRAE's Position Document on Infectious Aerosols recommends increased ventilation and filtration for air-conditioned spaces provided by ACMV systems because such measures can reduce the airborne concentration of COVID-19, and, thus, the risk of transmission through the air.

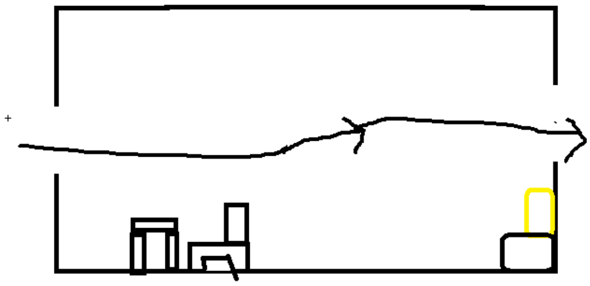
Natural ventilation uses natural forces of wind and buoyancy to deliver sufficient fresh air and air change to ventilate enclosed or semi-enclosed spaces. Natural ventilation without mechanical means should be considered in the design of common facilities – such as lobbies, corridors, staircases, toilets, and semi-enclosed parking and canteen areas – to achieve energy efficiency.

The two methods for providing natural ventilation are:

1) Cross ventilation (wind driven)

Figure 3.6 shows cross ventilation, which is wind driven across a building space through windows.

Figure 3.6: Building Section Showing Cross Ventilation

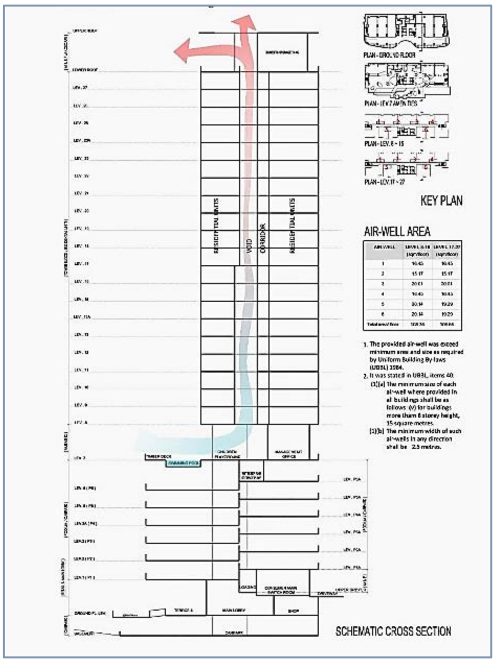


Source: Department of Standards Malaysia (2019), redrawn by Aidan Leong.

2) Stack ventilation (buoyancy driven)

Figure 3.7 shows stack ventilation, which is buoyancy-driven and is commonly incorporated in high-rise buildings through void spaces or atriums.

Figure 3.7: High-rise Building Section Showing Stack Ventilation



Source: Author.

3.6 Strategic Landscaping

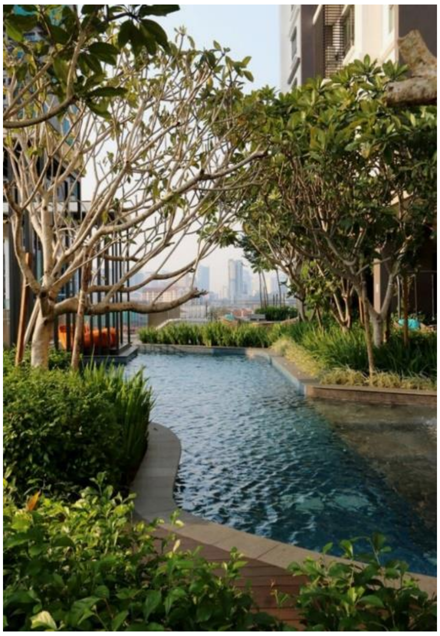
This measure is suitable for a highly urbanised area, where the surrounding area of a building is densely built up without much greenery. Strategic landscaping in a building development can reduce heat gain. Strategic landscaping aims to create a cooler microclimate around the building and reduce the urban heat island effect. The surroundings of highly urbanised and built-up areas are usually significantly warmer than the rural and less built-up areas.

Figures 3.8 and 3.9 illustrate some methods that can be deployed to create a cooler microclimate around a building:

- Maximise the area available around a building for landscape (Figure 3.9)
- Incorporate aquascape or water body (Figures 3.8 and 3.9)

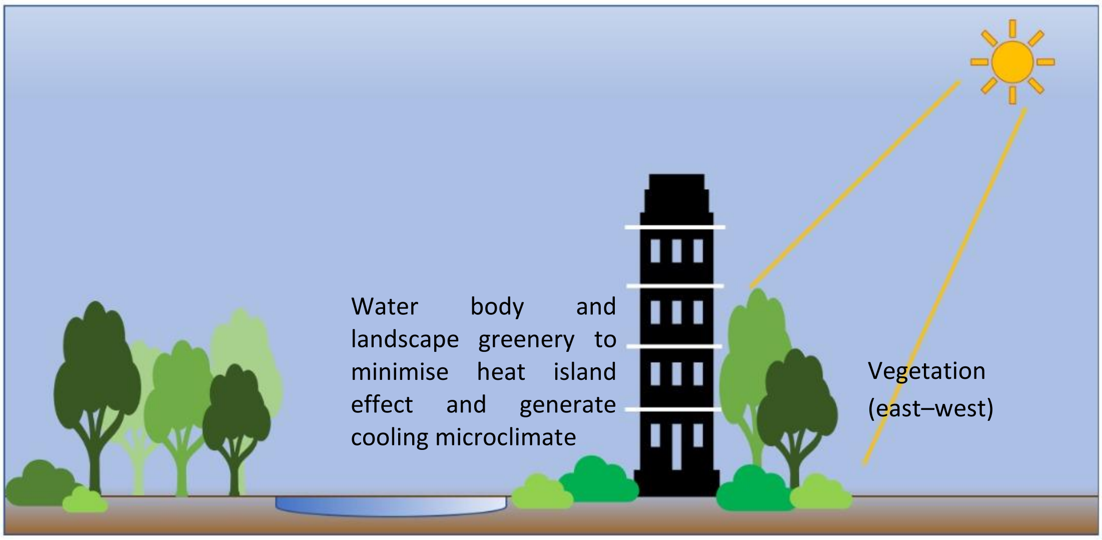
The appropriate plant types and high reflectance materials for the hardscape area will help decrease the solar absorption of the hard surfaces, hence, reducing the urban heat island effect. This can be achieved by selecting materials with a high solar reflectance index. For example, trees and shrubs near façades facing east and west can provide external shading to reduce solar heat gain into the buildings (Figure 3.9).

Figure 3.8: Illustration of Water Body and Shrubs Near Façades Facing West



Source: Author.

Figure 3.9: Illustration of Strategic Landscaping to Create a Cooler Microclimate



Source: Department of Standards Malaysia (2019), redrawn by Hayley Leong.

Chapter 4

Active Design Measures

4.1 Introduction

A combined approach adopting passive design measures – to optimise daylighting and thermal comfort by minimising solar heat gain – before adopting active design measures would be a holistic and sustainable approach to designing an energy-efficient building. Many active design measures can be considered. However, these guidelines focus on SEUs and EEC measures discussed in Chapter 2, namely, ACMV systems and energy management systems (EMSs). In general, the selection of efficient equipment and systems should be prioritised. However, economic evaluation will justify any additional investment for the selection. The appropriate EMS that enables real-time monitoring and controlling with optimisation capabilities can achieve energy savings.

4.2 Efficient Lighting

Using efficient lighting has an added advantage besides saving lighting energy. The added benefit is the reduced heat emission from lights due to the lower wattage of efficient lighting. The first law of thermodynamics says that energy cannot be created or destroyed. Therefore, 100% of the electricity used by light fittings will become heat energy when lights are switched on in a building. Given this reduced heat emission from efficient lighting, the cooling load for ACMV systems will be reduced. Hence, the ACMV equipment capacity can be downsized, which can be translated into savings in equipment and subsequent operating energy costs.

For efficient lighting design, refer to DOE's Guidelines on Energy Conserving Designs of Buildings (DOE, 2008). In addition to complying with the requirements and selection of electric lights with high efficacy as stated in the said guidelines, five basic recommendations will lead to efficient lighting in a building, namely:

1) Use natural daylighting as much as possible.
2) Ensure the installed lighting power density (W/m^2) is as low as possible while providing the required amount of light and quality according to the DOE Guidelines, 2008.
3) Select lights with high luminous efficacy, an indicator of the efficiency of the lamps, and is defined by equation 2 below. Higher efficacy values indicate higher lamp efficiency, producing more light for the same energy used.

$$Efficacy = \frac{Lumen}{Watt} \text{ ---------------------- (2)}$$

4) Use light-emitting diode (LED) lights for general lighting, with additional task lights to provide the required lighting lux level, hence, resulting in energy savings.

5) Ensure that electrical lights are switched off when not required or partially switched off when basic lighting is required in unoccupied areas through sensors. When daylight is harvested in an office space, ‘auto-off and manual-on’ control is recommended. This means that electrical lights are automatically switched off whenever the measured daylight is adequate. Still, the building occupants need to manually switch on the lights when daylight drops below the preset lux levels. However, it is advisable to switch on the lights automatically when the measured daylight drops below the desired lux level in public or common areas.
6) Appropriate light zoning provides a quick and easy way to reduce energy consumption in a building. Appropriately designed light zoning allows switching off when the space is unused or when daylight is available, such as in areas adjacent to windows. In addition, segregation of areas according to their respective functions and operating schedules for emergency, night lighting, and security lighting will help further reduce lighting energy due to the difference in operating requirements.

As a general rule, it is advisable to make early plans for various operating requirements such as night lighting, security lighting, fire safety lighting, and other building functional requirements. Energy efficiency considerations during the operation stage will be incorporated during the design stage. The lighting system should be properly commissioned and fine-tuned. For example, the position of motion and photosensors, timing devices, and others may need to be adjusted to optimise lighting performance.

4.3 Air-conditioning and Mechanical Ventilation (ACMV) System

As discussed in Chapter 2, space cooling requirements are the most significant energy user in a building in hot and humid climates. The cooling load calculation of a building determines the air-conditioning capacity of the ACMV system to be installed in a building. The correct sizing of the ACMV equipment depends on this cooling load calculation, which largely impacts capital costs during the building construction phase, and later the operating cost during building occupancy and operation. On the other hand, if the ACMV system is undersized, the building will not be provided with adequate cooling and cannot function properly to meet the requirements of its occupants.

The cooling system design loads for the ACMV system and equipment sizing should be determined following the DOE Guidelines 2008 and the ASHRAE *Handbook of Fundamentals* (ASHRAE, 2017).

The cooling load of space is a simple summation of all the heat generated internally and heat gains from external sources. The heat generated internally is commonly known as the internal cooling load, while the heat gains from external sources are known as the external cooling load, as outlined below.

1) Internal cooling loads or heat gains comprise the following:
   a) occupants (may be either sensible or latent heat)
   b) electrical lights (sensible heat)
   c) equipment and appliances (sensible heat)
2) External cooling loads or heat gains comprise the following:
   a) heat transmission through building structure as a result of conduction, convection, and radiation (sensible heat)
   b) solar radiation through fenestrations (sensible heat)
   c) conductive heat gain transmitted through fenestrations (sensible heat)
   d) outdoor ventilation and infiltration air (sensible and latent)

Based on the above list of internal and external heat gains, cooling loads of ACMV systems' sizing and selection can be reduced if some internal and external heat gains can be minimised. In designing energy-efficient ACMV systems, the following measures should be considered:

1) Reduce lighting and equipment loads.
2) Minimise heat gains through building envelope as much as possible through strategic fenestration and shading devices.
3) Specify building functions according to the owner's project requirements and determine cooling loads without overloading with safety factors to ensure that the ACMV system is not oversized. Judicious application of diversity factors is important to the tight control in the sizing of equipment for optimum efficiency and operation of the ACMV system.
4) Zone perimeter areas separately and design local air distribution system with increased cooling capacity for spaces with the significant glazed area.
5) Use energy recovery wheels to precool outdoor ventilation air.
6) Use a demand-controlled ventilation strategy to minimise intake of outdoor air based on demand, with carbon dioxide (CO_2) sensors.
7) Minimise infiltration of outdoor air through entrance doors by designing vestibules or sensor-controlled doors to avoid entrance doors frequently left wide open.
8) Inform the design of schedules of occupancy and use in a building early during the planning stage so that designers can efficiently select equipment and configuration and ancillary control systems.
9) Consider using variable speed drives to efficiently control fans and pumps to match airflow and water flow according to the load requirements. Consider controls using pressure reset based on measured feedback on systems with variable flow.
10) System selection and configuration should consider the extent of redundancy. Redundancy allows a spare capacity such that a single piece of equipment can be down for maintenance, and the rest of the system can still operate at some level. If incorporated into the sizing of the duty equipment, redundancy in equipment capacity should include efficiency devices, such as variable speed drive, high efficiency motor, efficient unloading devices, multi-compressors, water-cooled magnetic bearing chillers, etc. This is to achieve optimised equipment or system efficiency when operating at varying loads. For instance, a chiller configuration may comprise 3 x 50% capacity. This would be a two-run or one-standby operation or a one-run or two standby operation giving flexibility in matching varying cooling load requirements while maintaining high equipment or system efficiency as much as possible. Compared to a 2 x 100% chiller configuration, a 3 x 50% chiller configuration would provide a greater opportunity to achieve higher system efficiency.

4.4 Energy Management System (EMS)

The EMS is a subset of the building automation system (BAS) function. It is a computer-based automated system that monitors and controls all energy-related systems in building services. With the advancement in BAS technology and the advent of the Internet of Things, an integrated building management system can provide more options and scopes in energy management. However, a basic EMS should be able to

1) gather and analyse data from every energy user in a building;
2) identify problems and trend tracking by analysing both single-variable and multi-variable data;

3) provide monitoring and initiate alerts if the building's energy consumption or building energy performance parameters, such as EEI or BEI (refer to Chapter 5), exceed the preset benchmark parameters;

4) integrate equipment and other subsystems with control systems to perform optimisation, such as:

a) scheduling and manual overriding
b) controlling set points for key operating parameters
c) optimising the system and equipment
d) reporting and recording operational alarms
e) ensuring the correct and safe sequence of operation, including maximum demand limiting functions

5) identify energy wastage and perform optimisation;

6) analyse and benchmark the building's energy performance against national benchmarks when they are available.

EMS implementation is already starting to be a common system in new buildings because of the following EMS benefits:

1) It provides real-time remote monitoring and integrated control of a wide range of connected systems, modes of operation, energy use, environmental conditions, and others to be monitored. It also allows hours of operation, set points, etc. to be adjusted to optimise performance and comfort.
2) An EMS informs and enables the building staff to predict problems and provide a schedule for maintenance programmes.
3) It allows facilities to power equipment only when needed, eliminating the waste of lighting, heating, and cooling portions of the building that are unused around the clock. The US Green Building Council claims that the scale of savings that EMS can achieve ranges from 10% to 25%. If the EMS is operated properly, it should optimise energy use without compromising comfort or performance.
4) An EMS allows records of historical performance to be kept, enables the benchmarking of performance against other buildings or records of the same building, and may help automate report writing.
5) It can perform its functions completely automatically, day in, day out, year after year, without the need for much interaction. However, a 'system downtime' is not acceptable for many users or owners, such as in data centres or healthcare facilities. Therefore, systems need to be robust, reliable, and able to adapt or expand with the need of the customers.
6) An EMS can provide educational dashboard information at a suitable public access area of a building, showing the status of building energy performance and carbon emission reduction. This will help generate greater EEC awareness amongst building occupants and the general public while meeting corporate social responsibility and expectations.

For building management, options are now available to monitor the EMS online and from a web-based information system. The system can be applied and developed to monitor and analyse the real-time energy performance of multiple buildings offsite. The data processed and analysed by EMS can be used for in-house energy management reporting and updating purposes. In addition, options are available to develop the administration of external reporting to a dedicated agency or body with the authorities, such as the DOE, to collect energy building information and energy consumption data. Designated establishments can upload such building information and data to a web-based energy management information system administered by the DOE. An example of such web-based energy management information system is the Building Control Information System (BCIS). The BCIS can facilitate the data collection, analysis, and tracking of building energy performance by the DOE. However, the implementation of such a system is subject to many considerations, such as security, information disclosure regulations, industry acceptance, investments, development of skilled workforce resources, etc.

Chapter 5

Energy Efficiency Regulations

5.1 Introduction

The DOE (2016) formulated the 'Implementing Guidelines on Philippine Energy Standards and Labeling Program (PESLP) for Energy-Consuming Products'. These guidelines stipulate the rules, procedural requirements, and imposition of penalties. The PESLP provides particular product requirements for air conditioners, refrigerating appliances, television sets, and lighting products. It also specifies performance and testing requirements for energy-consuming products, effectively defining the maximum amount of energy consumed by a product in performing a specified task. The PESLP details specific minimum energy efficiency levels to the respective products.

Labelling programmes for electrical appliances and equipment are widely recognised as highly cost-effective energy efficiency policy measures and are part of EEC measures. However, the PESLP should have a greater impact on the residential sector than the commercial sector. Nevertheless, this programme will contribute to the energy efficiency targets of the commercial sector in terms of promoting greater use of energy efficiency–labelled appliances in commercial buildings.

The sections below discuss the effective promotion of EEC in commercial buildings through possible regulatory measures in EEI building labelling. Through EEI building labelling, building energy performance and benchmarking can be quantified and measurable. It can be established as a dedicated tool for driving the energy efficiency agenda in commercial buildings.

5.2 Energy Standards and Labelling Programme

The PESLP has been well established for energy-consuming products. The author opines that the PELSP by itself may not be able to achieve high impacts in energy savings. The objectives of energy savings can be greatly enhanced if EEI building labelling is established.

In the overall context, EEI building labelling can be established as a dedicated tool that can set benchmark targets to achieve greater energy savings in commercial buildings. This energy efficiency building labelling programme should be developed as a regulatory requirement, similar to the PESLP for appliances.

5.3 Energy Efficiency Indicators (EEIs)

In the overall context of building energy performance, what is the appropriate energy efficiency benchmarking tool? Buildings can be benchmarked and compared using the EEI method. The EEI concept is best explained by a pyramid of indicators presented by the International Energy Agency (IEA, 2014a) (Figure 5.1). IEA (2014a) aims to provide the necessary tools to initiate or further develop in-depth indicators to support the development of effective energy efficiency policies. This method can be adapted and established as an energy efficiency benchmarking tool to quantify and monitor national building energy performance for commercial buildings exceeding a certain size, which the DOE should determine after deliberation and consultation with stakeholders in the Philippines.

Figure 5.1 explains the various levels of indicators and shows how indicators are organised into a hierarchy. The top of the pyramid shows the total energy consumption of the commercial sector or share of each energy source of the total commercial sector energy consumption mix as an aggregated indicator. The IEA's concept of EEIs is a 'pyramidal approach' starting from the most aggregated level at level 1 to the most disaggregated level at end-use energy consumption by services, e.g. ACMV, lighting, lifts and elevators, and escalators, etc. at level 3. The level 2 indicator computation is recommended to be used as a rating tool for building energy performance. For this purpose, the term 'building energy intensity' (BEI) is used instead of EEI to differentiate the indicators from other sectors, such as the industry sector EEI, which has a different definition. The IEA defines EEI as follows:

$$EEI = \frac{Energy\ Consumption}{Activity\ Data} \text{ ------------------------ (3)}$$

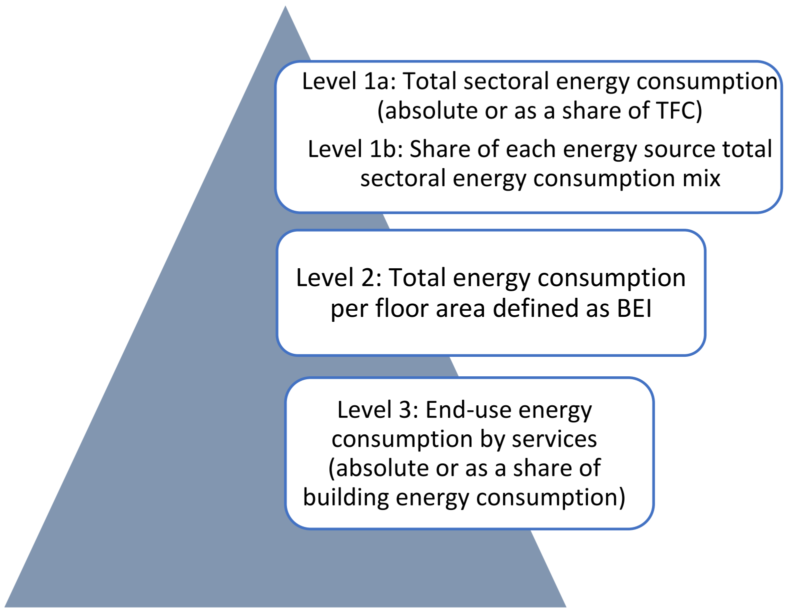
Where:

EEI = energy efficiency indicator

Energy consumption is measured in energy units.

Activity data are measured in physical units (e.g. gross floor area [GFA] for buildings)

Figure 5.1: Pyramid of the Commercial Sector, EEI



BEI = building energy intensity, TFC = total final consumption.
Source: Adapted from IEA (2014a).

BEIs are a ratio of yearly energy consumption (measured in energy unit, kWh) to the GFA (measured in square metres) under level 2 in Figure 5.1. For a meaningful comparison, the BEI values should be compared with buildings within the same building subsector or category. In other words, the BEIs of office buildings, retail malls, hotels, hospitals, etc. should be compared within the same category or type of building because different building categories have different operating functions and durations. Based on IEA's definition of EEI, it is possible to establish building energy performance benchmarking for each respective category or subsector of the commercial sector provided that sufficient relevant data are disclosed by the respective subsectors and analysed by the DOE.

The BEIs of buildings are computed at the subsector level and are calculated by the formula in equation 4 below.[1] The BEI is essentially a ratio of yearly energy consumption to GFA. However, to accurately represent and fairly compare the energy intensity throughout the building, energy use in the car park area, which is usually not air-conditioned, and in the data centre, where a high concentration of continuous energy use is expected, are excluded in the computation. The floor vacancy rate is only considered when the BEI is computed for an occupied building after completion and occupancy. For design submission, the building is usually considered fully occupied. The ratio of average weekly working hours to weighted weekly operating hours is used to adjust buildings with different weekly operating hours from the national average weekly operating hours, such as office and retail buildings. This adjustment or normalisation aims to fairly compare energy performance between different buildings of the same category. Key variables to be considered for normalisation include operating hours and floor occupancy rate.

$$BEI = \frac{(TBEC - CPEC - DCEC)}{(GFA - CPA - DCA) - (GLA \ x \ FVR)} \ x \ \frac{AWH}{WOH} \qquad \text{-----------} \ (4)$$

Where:

BEI	= total energy consumed in a building in a year, expressed as kWh per gross floor area (m^2)
TBEC	= total yearly building energy consumption (kWh/y)
CPEC	= yearly car park energy consumption (kWh/y)
DCEC	= data centre energy consumption (kWh/y)
GFA	= gross floor area (m^2)
CPA	= car park area (m^2)
DCA	= data centre area (m^2)
GLA	= gross lettable area (m^2)
FVR	= floor vacancy rate (%)
AWH	= average weekly operating hours (hours/week)
WHO	= weighted weekly operating hours (hours/week)

[1] Green Building Index Malaysia, www.greenbuildingindex.org (accessed 3 October 2021).

5.4 BEI Labelling

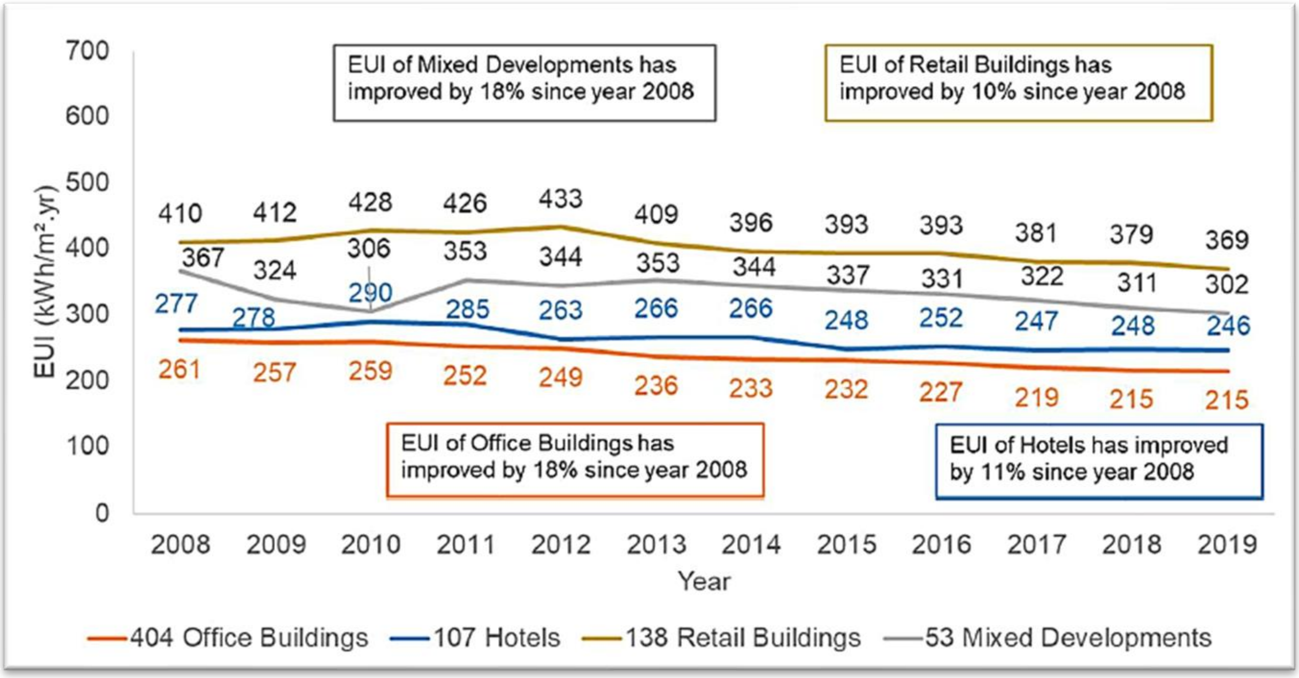
For this report, the establishment of EEIs for commercial buildings is suggested to be named BEI labelling. Singapore's Building and Construction Authority (BCA) named the EEI energy use intensity (EUI). BEI labelling can be a tool to drive the agenda of energy efficiency in commercial buildings. As discussed previously, EEC building design would involve deploying a combination of passive and active design measures. BEI labelling would guide the design with targets and indications of the extent of energy efficiency that could be achieved in commercial buildings. The benefits of BEI labelling are summarised as follows:

1) If made mandatory for designated buildings, BEI labelling would allow the DOE to collect building information and energy consumption data annually to develop and monitor in-depth indicators for supporting and evaluating the development of various energy efficiency policies and measures. Upon the disclosure of sufficient data for various categories of commercial buildings by the respective subsectors, the DOE can establish and formulate benchmarking values for each category of commercial buildings. EEC implementation concerning the issuance of building permits for new and existing commercial buildings is the jurisdiction of the local government units.
2) The BEI is a key performance metric for commercial buildings. It provides a means of measurement and indication of the energy performance of buildings of the same category or subsector for design and building operation purposes. It is a key driver of design parameters throughout the project delivery and operational targets during building occupancy. The BEI value derived from a functional building is the combined result of energy efficiency and consumption behaviour or pattern of the building.
3) BEI labelling can set minimum building energy performance requirements for compliance by building owners, developers, and designers to ensure that the designated buildings attain the required benchmarking value, which confirms the achievement of minimum energy performance. BEI establishment would allow the DOE and the building industry to propagate and understand building energy performance. Building owners can proactively improve their building's energy performance by monitoring and comparing its annual energy performance against similar building types.
4) The publication of BEI trending can be a means of feedback to building owners to monitor and confirm how well their respective buildings have performed.
5) BEI labelling can be used as a guide and basis for assessing building energy performance by the building approving authority.
6) BEI labelling can be used to recognise energy-efficient buildings in the national energy efficiency award scheme as part of national EEC campaigns. Such campaigns can spur building owners to initiate and implement improvements in energy efficiency and generate greater awareness amongst the public and building occupants.
7) BEI labelling can help shape the property market through information transparency of buildings' energy performance compared to benchmarking values of the respective building categories or subsectors.

Figure 5.2 shows the average EUI trend by commercial building types in Singapore based on BCA's data collection since 2008. The collection of data has enabled the BCA to establish EUI trending and building energy benchmarking in Singapore. Based on the EUIs, an overall reduction in energy consumption can be derived. Figure 5.2 shows that the BCA could quantify overall energy efficiency achievements (in terms of average EUI) in Singapore as of 2019 compared to 2008. The achievements are summarised as follows:

1) Office buildings improved by 18%.
2) Hotels improved by 11%.
3) Mixed developments improved by 18%.
4) Retail buildings improved by 10%.

Figure 5.2: Illustration of the Application of EUI Monitoring in Singapore



EUI = energy use intensity.
Source: BCA (2020).

Table 5.1: Singapore's National Building Energy Benchmarks for Commercial Buildings, 2019

Building Type	Size	No. of Buildings (in 2019)	Average EUI (kWh/m^2y)	EUI of Top 10%	EUI Ranges (kWh/m^2y)			
					Top Quartile (1%–25%)	2nd Quartile (26%–50%)	3rd Quartile (51%–75%)	Bottom Quartile (76%–100%)
Office buildings	Large	173	≤212	≤115	≤147	147–196	196–270	>270
	Medium	133	≤222	≤90	≤125	125–175	175–245	>245
Hotels	All	90	≤272	≤199	≤226	226–268	268–352	>352
Retail buildings	Large	74	≤331	≤156	≤254	254–446	446–568	>568
	Medium	48	≤372	≤179	≤255	255–376	376–468	>468
Mixed developments	All	37	≤280	≤152	≤202	202–246	246–370	>370

*Large: Office buildings and retail buildings of GFA ≥15,000 m^2
*Medium: Office buildings and retail buildings of GFA ≥5,000 m^2 and <15,000 m^2
*Hotels and mixed developments: Buildings of GFA ≥5,000 m^2
Source: BCA (2020).

Table 5.1 illustrates how BCA Singapore analysed and computed national building energy benchmarks based on 555 medium and large-sized commercial buildings. The buildings were categorised by type and size to facilitate the benchmarking exercise. It is interesting to note that Table 5.1 provides an overall value of EUI for different building types. In general, the average EUI for large-sized commercial buildings is lower than that of medium-sized commercial buildings. Table 5.1 also shows that the top 10% of commercial buildings in Singapore have achieved impressive EUIs, i.e. these buildings are very energy efficient. For example, the top 10% of large office buildings in Singapore achieved 115 $kWh/m^2.y$, compared to the average EUI of 212 $kWh/m^2.y$.

5.5 Annual Mandatory Submission of Data

The implementation of BEI labelling requires the mandatory submission of building information and annual energy consumption data. The requirement for the mandatory submission may be based on the designated establishments defined in the Philippine EEC Act, i.e. Type 1 Designated Establishments (yearly energy consumption of 500,000 kWh to 4,000,000 kWh), and Type 2 Designated Establishments (yearly energy consumption of more than 4,000,000 kWh). However, for commercial buildings, it is more appropriate to set the criterion for mandatory submission of data to be based on the GFA of a building due to the following reasons:

1) It provides a means of predefining an appropriate level of minimum GFA (e.g. ≥4,000 m^2) for a building because it is not practical and viable for a small building to take up EEC measures.
2) Basing on the GFA is more definitive and relatively straightforward to implement for new building development projects. Unlike existing buildings, the annual energy consumption for a new building development project is only an estimation.

For BEI computation, the following building information should be submitted by owners of existing buildings or by the principal submitting persons (e.g. architects or consulting engineers) for new building development projects:

1) ownership and building functions (activity type, occupancy type, etc.);
2) building data (GFA, air-conditioning floor area, retrofitting works if renovation);
3) monthly and total annual energy consumption (electricity, diesel, natural gas, liquefied petroleum gas, etc.);
4) energy-use breakdowns (ACMV, lighting, lifts and escalators, hot water systems, etc.).

Chapter 6

Economic Analysis of EEC Projects

EEC regulations or sub-decrees are indispensable. EEC should bring some benefits to owners of factories and commercial buildings. Otherwise, EEC should never be promoted. Thus, the owners want to know the expected benefits of investing in energy-efficient equipment and facilities to reduce energy consumption. This chapter shows how to conduct an economic analysis on energy-saving projects to reduce energy consumption.

6.1. Economic Analysis Method

There are several ways to conduct an economic analysis of energy-saving projects.

1) Financial Statements

To do an economic analysis of energy-saving projects, we should first produce the income statement or profit and loss statement and the cash balance statement. The purpose of these financial statements is to achieve a precise economic analysis of energy-saving projects. These financial statements could be simple, not complicated, such as the financial statement of existing companies or organisations.

a) Income statement

The income statement clarifies the process of calculating income tax payments. The income statement comprises the following items:

i) Revenue: benefits from energy savings come from the replacement of low energy-efficient equipment to high energy-efficient equipment
ii) Operation and maintenance costs: costs to operate and maintain energy-efficient equipment to be installed
iii) Depreciation: refer to b)
iv) Interest payment (long): refer to c)
v) Interest payment (short): refer to c)
vi) Interest received: refer to c)
vii) Profit before tax: i – ii – iii – iv – v + vi
viii) Income tax: vii x income tax rate after adjustment of carrying over the income losses
ix) Profit after tax: vii - viii

b) Calculation of depreciation

The purpose of depreciation is to smooth a large amount of capital costs to annual costs in a certain period. However, it should not be an actual cost or expenditure and a presumed one. There are two calculation methods:

Straight-line method:

$DP_t = \frac{CC_0(1-sv)}{N}$

where,

DP_t: Depreciation at year t

CC_0: Initial capital cost at year 0

sv: Salvage value ratio

N: Depreciation period

t: 1,….,n

Accelerated method or Fixed-ratio method:

$DP_t = OSDP_{t-1}\ DPR$

$OSDP_t = OSDP_{t-1} - DP_t$

$OSDP_0 = CC_0 * (1-sv)$

where,

DPR: Depreciation ratio

$OSDP_{t-1}$: Outstanding of capital cost on book at year $t-1$

T: 1,…,n

c) Calculation of interests

The interest payment is the annual cost of external financing, such as borrowed money, from commercial and public banks. On the other hand, if this project has some remaining cash, it puts this cash in its savings account in commercial banks and gains interest. The calculation method of interest payment and interest received are shown below:

Payment (long):

$OSBM_t = OSBM_{t-1} - RP_{t-1}$

$INT_t = OSBM_t * ir$

where,

$OSBM_t$: Outstanding of long-term borrowed money at year t

INT_t: Interest payment (long-term) at year t

ir: Interest rate of long-term borrowed money

Payment (short):

If the project incurs a money shortage, this project must borrow short-term (less than 1 year) money from commercial banks. So that this project needs to pay a short-term interest, as calculated below:

If $SBM_{t-1} > 0$, $SINT_t = SBM_{t-1} \times sr$

where,

SBM_{t-1}: Short-term borrowed money at year $t-1$

$SINT_t$: Interest payment (short-term) at year t

sr: Interest rate of short-term borrowed money

Interest received:

If $ACF_{t-1} > 0$, $RINT_t = ACF_{t-1} \times ei$

where,

ACF_{t-1}: Accumulated cash flow at year *t-1*

$RINT_t$: Interest received at year *t*

ei: Rate of interest received

d) Cash balance statement

On the other hand, the cash balance statement comprises the following:

- Cash inflow
  i) Share capital
  ii) Borrowed money (long-term)
  iii) Borrowed money (short-term): refer to accumulated cash flow below
  iv) Profit after tax: from the income statement
  v) Depreciation: from the income statement
- Cash outflow
  vi) Capital costs
  vii) Repayment of long-term borrowed money refer to e)
  viii) Repayment of short-term borrowed money

  RSBMt = SBMt-1

  where,

  RSBMt: Repayment of short-term borrowed money at year *t*

  SBMt-1: Short-term borrowed money at year *t-1*
- Cash flow defined as Cash inflow – Cash outflow
- Accumulated cash flow

  If *ACFt* < 0, *SBMt* = - *ACFt*

  where,

  ACFt: Accumulated cash flow at year *t*

  SBMt: Short-term borrowed money at year *t*

e) Calculation of repayment of borrowed money

There are two methods to repay the principal of long-term borrowed money:

Straight-line method:

Repay the same amount of principal within the repayment period

$RP_t = BM_0/N$

where,

RP_t: Repayment at year *t*

BM_0: Initial borrowed money at year *0*

N: Repayment period

Straight payment (repayment + interest) method:

Repay the same amount plus interest within the repayment period

$$RI = \frac{BM_0 \cdot ir \cdot (1+ir)^N}{(1+ir)^N - 1}$$

where,

RI: Annual payment of repayment plus interest

$BM_{0:}$ Initial borrowed money at year 0

ir: Interest rate

N: Repayment period

$INT_t = OSBM_{t-1}*ir$

$RP_t = RI–INT_t$

$OSBM_t = OSBM_{t-1}-RP_t$

where,

INT_t: Interest payment at year t

$OSBM_{t-1}$: Outstanding of borrowed money at year $t-1$

RP_t: Repayment at year t

f) Production of the financial statements using the sample data

Using the sample data below, the financial statements are shown as Table 6.1 for the income statement and Table 6.2 for the cash balance table.

Description of Sample Data:

Factory A uses a manufacturing machine; its electricity expense has been increasing due to the machine's older age. Therefore, the owner of Factory A is considering replacing the old machine with a new one. Thus, the owner wants to know the economic feasibility of this EEC project through its financial statements. The assumptions of this EEC project are mentioned below:

Initial capital cost of energy-efficient-type equipment: US$70 million

Equity ratio: 30% of initial capital cost

Energy-saving amount: 100 GWh/year

Electricity price: 9.5 cents/kWh

Operating costs: US$10,000/year

Depreciation: 10 years straight-line method and 0 salvage value

Borrowed money: 10 years straight-line repayment method and 5% interest rate

Income tax rate: 50%

Income loss can be carried over within 5 years

Table 6.1 Income Statement for Economic Analysis (US$1,000)

Year	0	1	2	3	4	5	6	7	8	9	10
Benefits from energy saving		9,500	9,500	9,500	9,500	9,500	9,500	9,500	9,500	9,500	9,500
Operation cost		700	700	700	700	700	700	700	700	700	700
Depreciation		7,000	7,000	7,000	7,000	7,000	7,000	7,000	7,000	7,000	7,000
Interest payment (long term)		2,450	2,205	1,960	1,715	1,470	1,225	980	735	490	245
Interest payment (short term)			0	0	0	0	0	0	0	0	0
Interest received			44	96	157	227	307	387	468	554	645
Profit before tax		-650	-362	-64	242	557	882	1,207	1,533	1,864	2,200
Income tax							302	604	767	932	1,100
Profit after tax		-650	-362	-64	242	557	579	604	767	932	1,100

Source: Author.

The income statement indicates that this project lost income in the first 3 years. After that, this project can make a profit and pay income tax from the sixth year due to tax exemption regulations. The income loss can be carried over within 5 years.

Table 6.2. Cash Balance Statement (US$1,000)

Year	0	1	2	3	4	5	6	7	8	9	10
Cash inflow	70,000	6,350	6,639	6,936	7,242	7,557	7,579	7,604	7,767	7,932	8,100
Shared capital	21,000										
Borrowed money (long term)	49,000										
Borrowed money (short term)											
Profit after tax		-650	-362	-64	242	557	579	604	767	932	1,100
Depreciation		7,000	7,000	7,000	7,000	7,000	7,000	7,000	7,000	7,000	7,000
Cash outflow	70,000	4,900	4,900	4,900	4,900	4,900	4,900	4,900	4,900	4,900	4,900
Capital cost	70,000										
Repayment of borrowed money (long)		4,900	4,900	4,900	4,900	4,900	4,900	4,900	4,900	4,900	4,900
Repayment of borrowed money (short)											
Cash balance	0	1,450	1,739	2,036	2,342	2,657	2,679	2,704	2,867	3,032	3,200
Accumulation of cash balance	0	1,450	3,189	5,224	7,566	10,223	12,902	15,606	18,472	21,504	24,705

Source: Author.

The cash balance table indicates that this project never had a money shortage and its accumulated cash gained within 10 years is more than the share capital.

2) Cash Flow

Based on the financial statements, we produce a cash flow table. There are two types of cash flow tables: return on investment (ROI), based on the whole investment, and return on equity (ROE), based on equity. ROI analyses how much return is expected for the entire capital cost so that this cash flow just uses capital cost and benefits from energy savings. Table 6.3 shows the cash flow of the sample data.

Table 6.3: Cash Flow on ROI (US$1,000)

Year	0	1	2	3	4	5	6	7	8	9	10
Capital cost	70,000										
Benefits from energy saving		9,500	9,500	9,500	9,500	9,500	9,500	9,500	9,500	9,500	9,500
Operation cost		700	700	700	700	700	700	700	700	700	700
Cash flow on ROI	-70,000	8,800	8,800	8,800	8,800	8,800	8,800	8,800	8,800	8,800	8,800
Accumulated cash flow	-70,000	-61,200	-52,400	-43,600	-34,800	-26,000	-17,200	-8,400	400	9,200	18,000

ROI = return on investment.
Source: Author.

On the other hand, ROE analyses how much return is expected on equity or share capital using the following: profit after tax, depreciation, repayment (long-term), and equity or share capital.

Table 6.4 shows the cash flow of the sample data.

Table 6.4: Cash Flow on ROE (US$1,000)

Year	0	1	2	3	4	5	6	7	8	9	10
Profit after tax		-650	-362	-64	242	557	579	604	767	932	1,100
Depreciation		7,000	7,000	7,000	7,000	7,000	7,000	7,000	7,000	7,000	7,000
Equity	21,000										
Repayment (long)		4,900	4,900	4,900	4,900	4,900	4,900	4,900	4,900	4,900	4,900
Cash flow on ROE	-21,000	1,450	1,739	2,036	2,342	2,657	2,679	2,704	2,867	3,032	3,200
Accumulated cash flow	-21,000	-19,550	-17,812	-15,776	-13,434	-10,777	-8,098	-5,394	-2,528	504	3,705

ROE = return on equity.
Source: Author.

Both tables indicate that the accumulated cash flow becomes positive in the eighth year of ROI and the ninth year of ROE. The initial cost seems to be too large compared to the return.

3) Internal Rate of Return (IRR)

The IRR is a typical index to assess the economics of energy projects, calculated through the following formula, with the iteration method.

$$CC_0 = \sum_t \frac{CF_t}{(1+r)^t}$$

where,

CC_0: Initial capital cost at year *0*

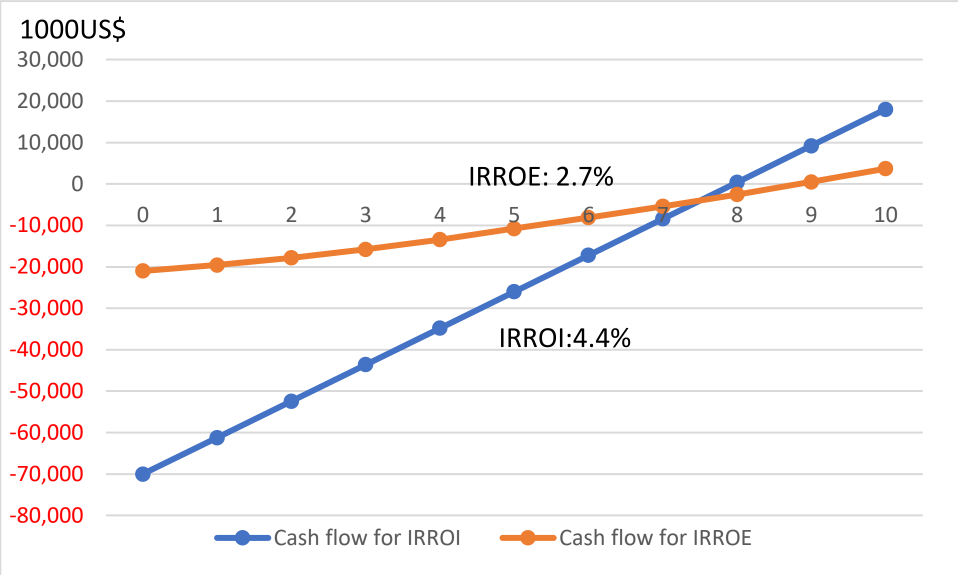
CFt: Annual benefit at year *i*

r: IRR

t: year from *1* to *n*

There are also two kinds of IRR: IRR on investment (IRROI) and IRR on equity (IRROE). Based on the cash flows in Tables 6.3 and 6.4, we can get 4.4% as IRROI and 2.7% as IRROE using the IRR numerical formula, one of the financial formulas installed in MS-Excel (refer to Table 6.5). Both the IRROI and IRROE of this sample project look unattractive. However, the savings on electricity consumption indeed reduce fossil fuel consumption, such as coal and gas for thermal power generation. As a result, CO2 emissions can be reduced. Suppose the owner could get financial incentives from the government for this investment: applicable soft loans, exemption from income tax, subsidies for capital costs, etc. This project should be implemented with appropriate government support.

Figure 6.1: Cash Flow for ROI and ROE



IRROE = internal rate of return on equity, IRROI = internal rate of return on investment.
Source: Author.

4) Payback Period

The IRROI payback period is on the eighth year after the start of operations; that of IRROE is on the ninth year (refer to the accumulated cash flow in Tables 6.3 and 6.4 and Figure 6.1). Generally, the payback period should be less than 5 years so that these results are also not attractive for private company owners. But for the same reason mentioned above, this project should be implemented.

6.2. Exercises of Economic Assessment of Energy-Saving Projects

1) Exercise 1

Building A currently uses 20,000 incandescent bulbs for lighting, and its owner wants to replace the incandescent bulbs with LED. Based on the conditions below, analyse the economic feasibility of this energy-saving project:

Assumed conditions:
Power rating of incandescent bulb: 60 W each
Power rating of LED: 10 W per each but same lumen of 60 W incandescent bulb
Duration period of LED: 5 years
Operating hours of building A: 10 hours/day
Price of LED: US$50 each
Electricity price: 11 cents/kWh
Share capital: 100%

Assessment Results:

The difference between the power rating of an incandescent bulb and a LED is assumed to be 50 W. This difference is significant even though the initial cost to install 20,000 LED at US$50 per unit is US$1 million. Thus, this project has profited from the first year and has never had a money shortage (refer to Tables 6.5 and 6.6).

Table 6.5: Income Statement of Exercise 1 (US$1,000)

Year	0	1	2	3	4	5	6	7	8	9	10
Benefits from energy saving		287	287	287	287	287	287	287	287	287	287
Operation cost		0	0	0	0	0	0	0	0	0	0
Depreciation		200	200	200	200	200	200	200	200	200	200
Interest payment (long term)		0	0	0	0	0	0	0	0	0	0
Interest payment (short term)			0	0	0	0	0	0	0	0	0
Interest received			7	15	22	30	38	45	53	62	70
Profit before tax		87	94	101	109	117	124	132	140	148	157
Income tax		43	47	51	55	58	62	66	70	74	78
Profit after tax		43	47	51	55	58	62	66	70	74	78

Source: Author.

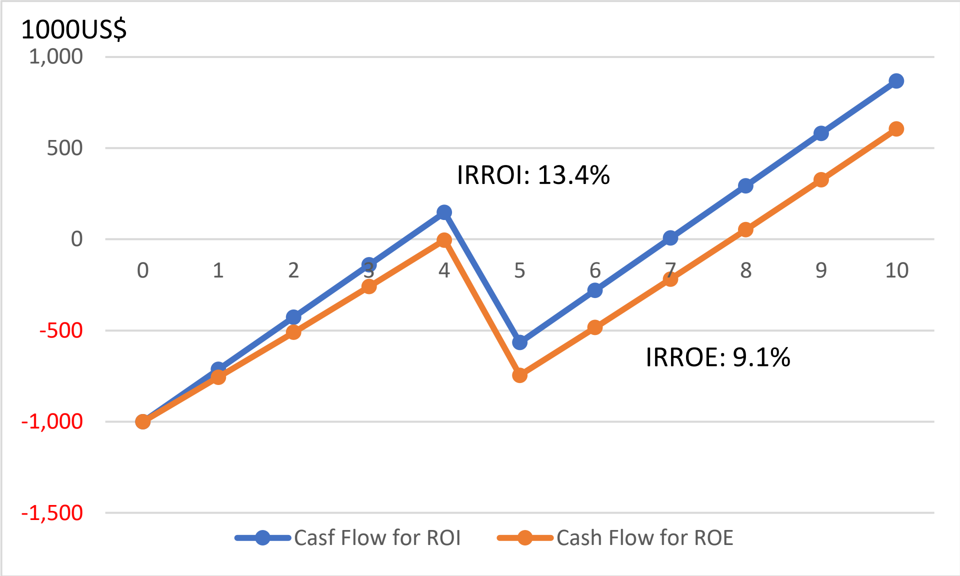
Table 6.6: Cash Balance Statement of Exercise 1 (US$1,000)

Year	0	1	2	3	4	5	6	7	8	9	10
Cash Inflow	1,000	243	247	251	255	1,258	262	266	270	274	278
Shared capital	1,000					1,000					
Borrowed money (long term)	0					0					
Borrowed money (short term)											
Profit after tax		43	47	51	55	58	62	66	70	74	78
Depreciation		200	200	200	200	200	200	200	200	200	200
Cash outflow	1,000	0	0	0	0	1,000	0	0	0	0	0
Capital cost	1,000					1,000					
Repayment of borrowed money (long)		0	0	0	0	0	0	0	0	0	0
Repayment of borrowed money (short)											
Cash balance	0	243	247	251	255	258	262	266	270	274	278
Accumulation of cash balance	0	243	490	741	996	1,254	1,516	1,782	2,052	2,327	2,605

Source: Author.

The IRRs of this project are also reasonable, 13.4% ROI and 9.1% ROE. Therefore, this financial feasibility study surely greenlights the implementation of this EEC project.

Figure 6.2: Cash Flow for ROI and ROE of Exercise 1



IRROE = internal rate of return on equity, IRROI = internal rate of return on investment.
Source: Author.

2) Exercise 2

Hotel A uses an old chiller system to supply cool air to guest rooms and other areas. It plans to replace the old one with a new one. Therefore, based on the conditions below, we analyse the economic feasibility of this energy-saving project:

Assumed conditions:

Capital cost of a new chiller system: US$1.25 million
Saved electricity amount: 2,171,224 kWh/year
Duration period of the chiller system: 10 years
Electricity price: 16 cents/kWh
Produce cash flow on ROI and seek IRROI and payback period

Assessment Results:

The expected electricity saving (2.2 GWh/year) is significant compared to the initial cost (US$1.24 million) to install a new chiller system. Both financial statements indicate that Hotel A has profited from the first year of operation and has had no money shortage in 10 years due to the significant electricity savings and relatively higher electricity price at 16 cents/kWh. In addition, a remarkable reduction of CO2 emissions is expected every year if a coal power plant generates electricity.

Table 6.7: Income Statement of Exercise 2 (US$1,000)

Year	0	1	2	3	4	5	6	7	8	9	10
Benefits from energy saving		347	347	347	347	347	347	347	347	347	347
Operation cost		0	0	0	0	0	0	0	0	0	0
Depreciation		125	125	125	125	125	125	125	125	125	125
Interest payment (long term)		44	39	35	31	26	22	18	13	9	4
Interest payment (short term)			0	0	0	0	0	0	0	0	0
Interest received			4	8	12	16	20	25	29	34	39
Profit before tax		179	187	195	204	212	221	230	239	248	257
Income tax		89	93	98	102	106	110	115	119	124	128
Profit after tax		89	93	98	102	106	110	115	119	124	128

Source: Author.

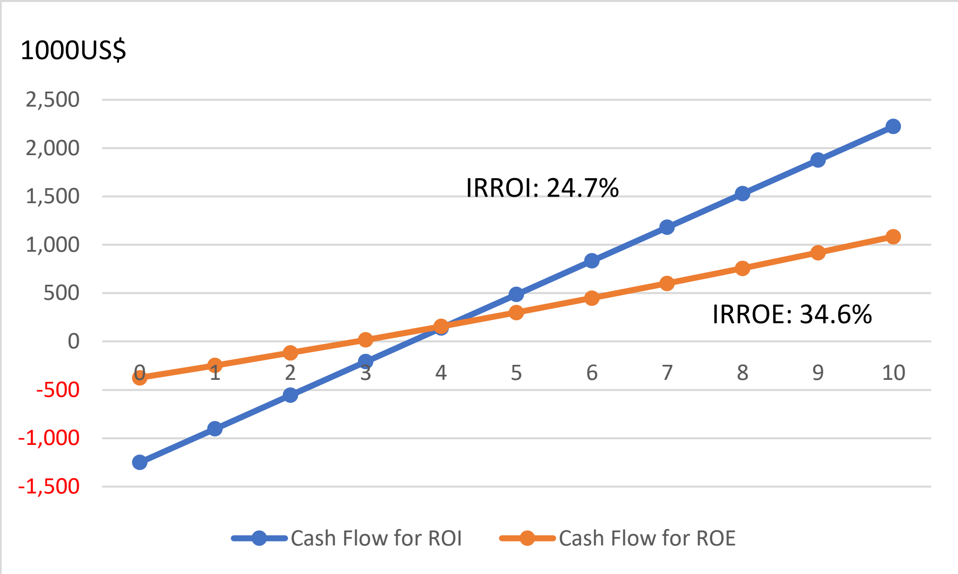
Table 6.8: Cash Balance Statement of Exercise 2 (US$1,000)

Year	0	1	2	3	4	5	6	7	8	9	10
Cash Inflow	1,250	214	218	223	227	231	235	240	244	249	253
Shared capital	375										
Borrowed money (long term)	875										
Borrowed money (short term)											
Profit after tax		89	93	98	102	106	110	115	119	124	128
Depreciation		125	125	125	125	125	125	125	125	125	125
Cash outflow	1,250	88	88	88	88	88	88	88	88	88	88
Capital cost	1,250										
Repayment of borrowed money (long)		88	88	88	88	88	88	88	88	88	88
Repayment of borrowed money (short)											
Cash balance	0	127	131	135	139	144	148	152	157	161	166
Accumulation of cash balance	0	127	258	393	532	676	824	976	1,133	1,294	1,460

Source: Author.

Both IRRs are significant, 24.7% ROI and 34.6% ROE. Thus, the financial indicators of this EEC project give the green light to proceed.

Figure 6.3 Cash Flow for ROI and ROE of Exercise 2



IRROE = internal rate of return on equity, IRROI = internal rate of return on investment.
Source: Author.

3) Exercise 3

The owners of Building A plan to install a solar photovoltaic (PV) system to utilise auto-generated electricity for its internal use and reduce electricity procurement from a power utility company. Based on the conditions below, we analyse the economic feasibility of this energy-saving project:

Assumed conditions:

Capacity of solar/PV system to be installed: 1 MW
Unit price of solar/PV system: US$3,000/kW
Duration period of solar/PV system: 10 years
Electricity price: 12 cents/kWh
Share capital: 30%

Assessment results:

The installation of a 1 MW solar PV system seems to be profitable for Building A. The initial cost is US$3 million, but the annual saving from electricity payments to a power utility is around US$0.5 million. So, 6 years is enough to recover the initial cost according to a simple calculation. In addition, both financial statements reflect good conditions of a profit–loss (positive profit from the first year of operation) and cash balance (no money shortage in 10 years).

Table 6.9: Income Statement of Exercise 3 (US$1,000)

Year	0	1	2	3	4	5	6	7	8	9	10
Benefits from energy saving		473	473	473	473	473	473	473	473	473	473
Operation cost		30	30	30	30	30	30	30	30	30	30
Depreciation		300	300	300	300	300	300	300	300	300	300
Interest payment (long term)		105	95	84	74	63	53	42	32	21	11
Interest payment (short term)			0	0	0	0	0	0	0	0	0
Interest received			3	7	10	14	18	23	27	32	37
Profit before tax		38	52	66	80	94	109	124	139	154	170
Income tax		19	26	33	40	47	54	62	69	77	85
Profit after tax		19	26	33	40	47	54	62	69	77	85

Source: Author.

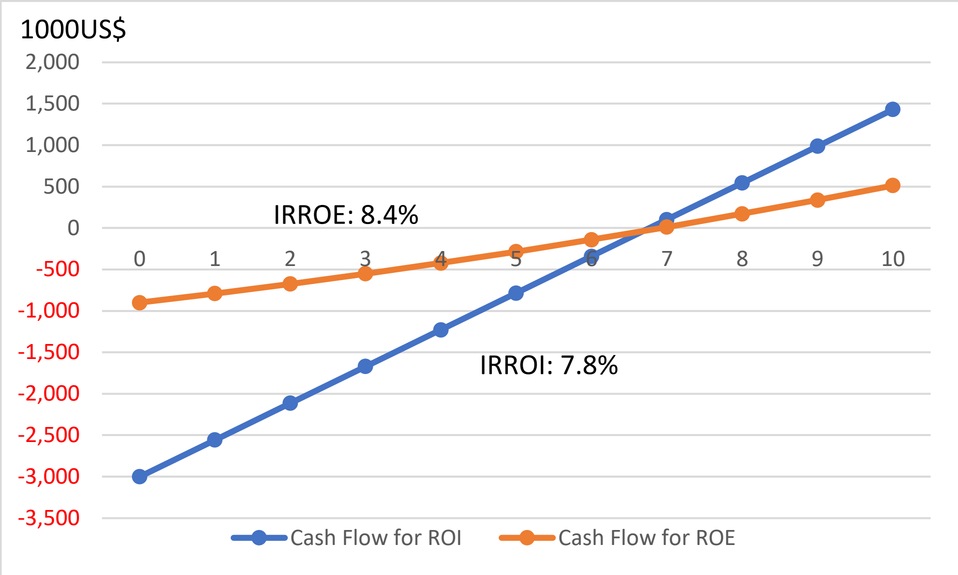
Table 6.10: Cash Balance Statement (US$1,000)

Year	0	1	2	3	4	5	6	7	8	9	10
Cash Inflow	3.000	319	326	333	340	347	354	362	369	377	385
Shared capital	900										
Borrowed money (long term)	2.100										
Borrowed money (short term)											
Profit after tax		19	26	33	40	47	54	62	69	77	85
Depreciation		300	300	300	300	300	300	300	300	300	300
Cash outflow	3.000	210	210	210	210	210	210	210	210	210	210
Capital cost	3.000										
Repayment of borrowed money (long)		210	210	210	210	210	210	210	210	210	210
Repayment of borrowed money (short)											
Cash balance	0	109	116	123	130	137	144	152	159	167	175
Accumulation of cash balance	0	109	225	348	478	615	759	911	1.071	1.238	1.413

Source: Author.

The actual payback period is on the seventh year, which is more than 5 years, the expected longest payback period. In addition, the IRRs look better, 7.8% ROI and 8.4% ROE. As a result, this solar PV installation project is recommended to proceed due to a better financial situation, a reasonable rate of return, and an increase of low carbon energy and CO_2 emission reduction. But this project also needs to pay attention to the electricity price of 12 cents/kWh. If it is lower than this price, the financial situation and the rate of return will be worse.

Figure 6.4: Cash Flow for ROI and ROE of Exercise 3



IRROE = internal rate of return on equity, IRROI = internal rate of return on investment.
Source: Author.

6.3. Energy Service Companies (ESCOs)

Energy service companies (ESCOs) consult with factories and commercial buildings to save the latter's energy costs by proposing to replace lower energy-efficient equipment and facilities with higher ones. A factory can save US$5,000 of electricity cost per month. Thus, a certain share (usually 30%–50%) of the energy costs saved goes to the ESCO as revenue or consultation fee. Energy managers who belong to ESCOs should understand the economic analysis of EEC projects mentioned in Sections 6.1 and 6.2. Suppose factories and commercial buildings want to reduce energy costs, such as electricity payment to a utility company. In that case, they can ask an ESCO to prepare energy-saving measures after a survey on their energy consumption, expected energy-saving amount in physical and monetary units, and initial costs. The ESCO produces the financial statements – income statement and cash balance statement, cash flow tables, IRR, and payback period – to assess the economic feasibility of the EEC project.

Consequently, the ESCO should be familiar with the technical and economic aspects of EEC. The ESCO should also know EEC regulations in countries, especially the EEC financial incentives provided by the government, the minimum energy performance standards, standard and labelling system, and others. Thus, the ESCO contributes to energy saving and CO2 emission reduction on a business basis. Some ESCOs can arrange to finance the initial cost (capital costs) from commercial and public development banks.

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