Chapter 2

Fundamentals of Energy Efficiency in Buildings

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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.

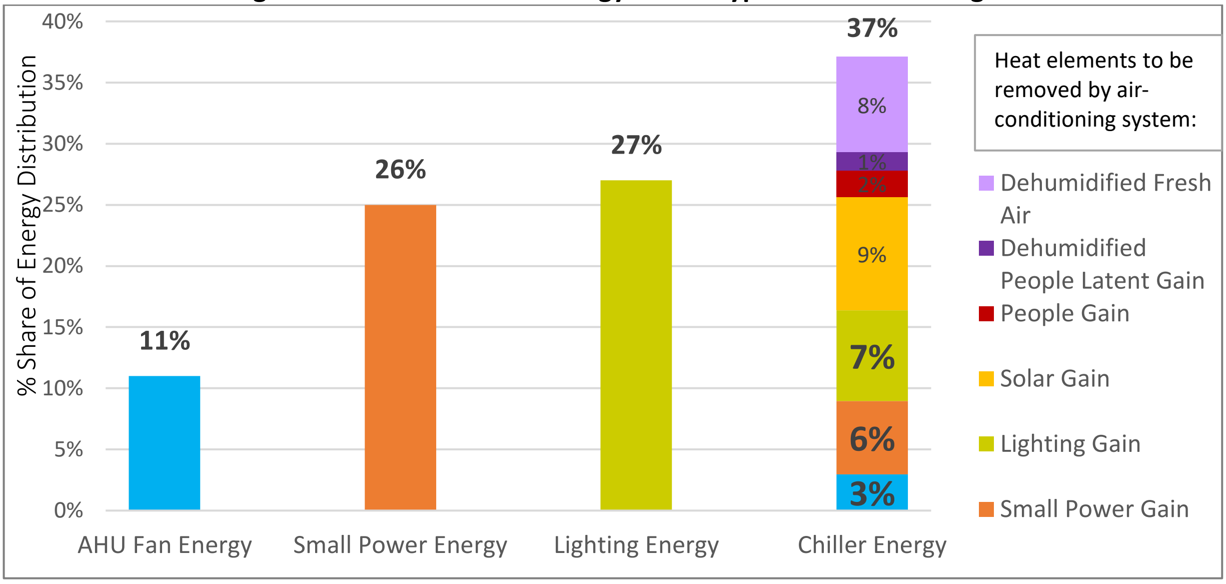
2.2 Energy-use Breakdowns in Commercial Buildings

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**

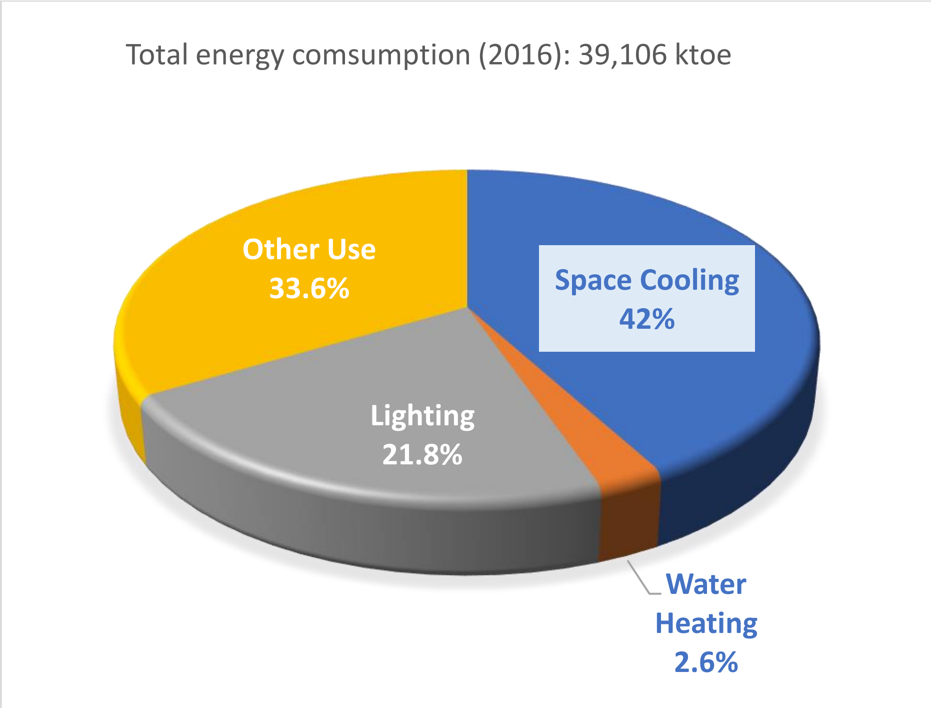
Public Administration	2,946.31	262.71	1,418.34	2,267.82	**6,895.18**
Education	1,339.60	–	673.90	1,139.99	**3,153.49**
Human Health and Social Activities	2,120.27	200.57	1,103.11	1,516.59	**4,940.04**
Arts, Entertainment, and Recreation	343.17	40.51	223.79	284.82	**892.29**
Other Service Activities	1,860.37	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.