Chapter 2

Building Technologies

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CHAPTER 2

Building Technologies

2.1. Green Building Rating System

There have been numerous international initiatives with the purpose of enhancing or improving energy security and lowering greenhouse gas (GHG) emissions to mitigate the negative environmental impacts of energy consumption. The United Nations Environment Programme Sustainable Buildings & Climate Initiative (UNEP-SBCI 2009) in its report states that the building sector's environmental footprint includes 40 percent of energy use, 30 percent raw materials use, 25 percent of solid waste, 25 percent water use, and 12 percent of land use. The report goes on to state that almost 90 percent of the energy used by buildings is consumed during its operational phase for heating, cooling, ventilation, lighting, and so on, while the remaining amount is consumed during the extraction and processing of raw materials, manufacturing of products, construction, and demolition. Furthermore, significant energy is used in transporting occupants, goods, and services to and from buildings.

Many countries have turned to developing and adopting a green building rating system to address the needs for sustainable utilisation of natural resources and mitigation of negative environmental impacts. A green building rating system provides a holistic approach through a systematic and comprehensive framework for assessing the overall environmental performance of new and existing buildings and townships to promote sustainable design, construction, and operating practices. In the ASEAN region, Singapore and Malaysia have embarked successfully on their green building rating systems since 2005 and 2009, respectively. The two countries have successfully promoted and implemented sustainability in the built environment and raised environmental awareness among developers, building owners, designers and builders, as well as communities. The benefits of green buildings are reduction in water and energy bills, improved indoor environmental quality, improved connectivity and community living, reduced environmental impact, meaningful differentiation of buildings in the real estate market, and improved corporate image. It has been recognised to be a game changer in the construction industry. If implemented properly, it can lead to continual improvement in the built environment and economic growth in the construction sector as well as the goods and services sector.

The green building rating systems in Singapore and Malaysia have a similar approach in terms of assessment criteria with emphasis on energy efficiency but with differing priorities to suit the needs of the respective countries. The similarities are due to the fact that both countries are located in a hot and humid climatic zone. The difference between Singapore's Building and Construction Authority (BCA) Green Mark rating system and Malaysia's Green Building Index (GBI) rating system, however, is in the implementation. Malaysia's GBI was developed and implemented by professional bodies and adoption is on a voluntary basis, which is supported by the Government of Malaysia through green building incentives upon award of green building certification. The implementation of Singapore's Green Mark is mandatory under the BCA through the Building Control (Environmental Sustainability) Regulations (under the Building Control Act), which apply to:

- all new building works with gross floor area of 2,000 square metres (m^2) or more
- additions or extensions to existing buildings which involve increasing gross floor area of the existing buildings by 2,000 m^2 or more
- building works which involve major retrofitting to existing buildings with gross floor area of 2,000 m^2 or more.

Brunei Darussalam is in the same climatic zone, so the green building rating systems from these two countries can be adopted in Brunei, especially for the development of an eco town. Brunei recently launched and unveiled its rating system version called the Brunei Accredited Green Unified Seal (BAGUS). During the launch, three government buildings were awarded with the BAGUS. Buildings awarded with the seal must have reduced their electricity consumption by more than 15 percent per year and meet the government-mandated energy efficiency index (EEI) of 175 kWh/m^2 per year. At this stage, information about the rating system is not readily available for public use and will not be compared in this report. However, in the development of the rating tool, both Green Mark and GBI were used as main references.

Table 1 below provides a brief comparison of the two green building rating systems for non-residential buildings. Table 2 provides the qualifying marks for the various rating classifications. Both rating systems cover a wide range of building types, for example non-residential buildings, residential buildings, healthcare facilities, retail buildings, hotels and resorts (for GBI), interiors, data centres, townships (for GBI), district projects (for Green Mark), restaurants (for Green Mark), supermarkets (for Green Mark), parks (for Green Mark), and industrial buildings (for GBI).

Table 1: Comparison of Green Building Rating Tools

Name of Green Building Rating System	Building and Construction Authority (BCA) Green Mark* Singapore		Green Building Index (GBI) Malaysia	
	Non-residential Building	**Maximum Points**	**Non-residential New Construction**	**Maximum Points**
Assessment Criteria	1. Energy Efficiency	116	1. Energy Efficiency	35
	2. Water Efficiency	17	2. Indoor Environmental Quality	21
	3. Environmental Protection	42	3. Sustainable Site Planning & Management	16
	4. Indoor Environmental Quality	8	4. Materials & Resources	11
	5. Other Green Features & Innovation	7	5. Water Efficiency	10
			6. Innovation	7
Total Score		190**		100

Notes:

* Based on BCA Green Mark for non-residential buildings, version NRB/4.1.

** To achieve the Green Mark Award, buildings must comply with a prerequisite of a minimum of 30 points from the energy-related requirements and 20 points from other green requirements.

Source: Building and Construction Authority, Singapore (2013), and Green Building Index Sdn Bhd, Malaysia (2009).

Table 2: Green Mark and GBI Rating Classification

	Green Mark		Green Building Index (GBI)	
Points & Rating	90 and above	Platinum	86+ points	Platinum
	85 to <90	Gold Plus	76 to 85	Gold
	75 to <85	Gold	66 to 75	Silver
	50 to <75	Certified	50 to 65	Certified

Source: Building and Construction Authority, Singapore (2013), and Green Building Index Sdn Bhd, Malaysia (2009).

2.2. Building Policy and Regulations

Green, sustainable, and energy-efficient buildings hold particular importance in most cities as buildings are the largest energy-consuming sector worldwide, accounting for more than 40 percent of the global energy use and responsible for an estimated 30 percent of CO_2 emissions. Buildings, therefore, have an immense potential for global energy savings. A recent report from the International Energy Agency (2012) has mentioned that the world's built stock accounts for up to 41 percent of the global energy saving potential by 2035. This is primarily due to green buildings using approximately 40 percent less energy and 30 percent less water than standard buildings of the same size.

The rapid growth of energy use worldwide has also raised concerns over problems of energy supply and exhaustion of energy resources. Most of the developed countries, and to some extent developing countries, are implementing building energy regulations such as energy standards, codes, and so on to reduce building energy consumption.

Typically, building policy and regulations include standards and codes that cover structural, construction, fire, earthworks and roads, water drainage and sewerage, and electrical installations. Building energy efficiency standards only arise when the concern for rising oil prices and climate change comes to the fore. Today, mandatory minimum energy efficiency requirements in the form of building codes or standards exist in nearly all developed and some developing countries.

However, substantial differences persist between legislation of states, regions, and cities. Regulations for energy efficiency in buildings in developing countries, especially in rapidly developing countries such as India and China with the economic capacity to install cooling or heating systems, seek to improve comfort and to reduce the dramatic increase in energy consumption in this sector.

Irrespective of the political and socioeconomic situation of the countries, having a robust and well-regulated building policy and regulations especially related to energy use in buildings has an impact on the reduction of CO_2 emissions and dependency on fossil fuels. Local and regional governments are uniquely positioned to implement policies that influence the commitments towards sustainability measures in the building sector and to encourage their corporate citizens to build green and their citizens to live green.

The present status of building energy regulations in selected countries internationally and regionally was reviewed and summarised in Table 3 to provide an understanding of how energy consumption and carbon emissions are reduced and tackled nationally.

Table 3: Building Policies and Regulations in Selected Countries in ASEAN and East Asia

Country	Policy and Regulation	Codes and Standards	Remarks
Brunei Darussalam	Building Control Order 2014 (Enforced-Nov 2015) Building Control Regulations	PBD 12: 2014 – Building Guidelines and Requirements (Mandatory) Energy Efficiency & Conservation Guidelines for Non-Residential Buildings (2015) Mandatory (Public Buildings only)	PBD 12 covers space, light and ventilation; structural, construction, and fire requirements; electrical installations; earthworks, road, and water; and drainage and sewerage
Indonesia	Building Energy Codes (Mandatory): ● Law No. 28/2002 (regarding buildings) ● National Energy Efficiency Standards (SNI) for Building	<u>Applicable Standards (Mandatory)</u> ● SNI 03-6389-2000: Energy Conservation for Building Envelope of Buildings ● SNI 03-6390-2000: Energy Conservation for Air Conditioning Systems in Buildings ● SNI 03-6197-2000: Energy Conservation for Lighting Systems	Applicable sectors: residential and commercial buildings

<table>
<tr><td></td><td></td><td>in Building Structures
● SNI 03-6196-2000: Energy Auditing Procedure for Buildings

<u>Building Rating Tool (Voluntary)</u>

GREENSHIP – Green Building Council of Indonesia (GBCI)</td><td></td></tr>
<tr><td>Japan</td><td>Two mandatory laws pertaining to building:
● Building Standard Law (BSL)
● Fire Standard Law (FSL)</td><td>BSL consists of three sections:
● General provisions
● Building codes
● Planning codes

Applicable Codes:
● JIS Q 50001: Energy Management System Requirements with Guidance for Use
● JIS Z 9204: General Rules for Energy Evaluation Method by Available Energy
● JIS A 1431: Method of Measurement of Air Quantity for Ventilation and Air Conditioning System
● JIS B 9908: Test Method of Air Filter Units for Ventilation and Electric Air Cleaners for Ventilation</td><td>● BSL is applicable to all types of buildings.
● The building codes section contains all codes pertaining to structural design, fire protection, and building equipment (HVAC, plumbing, and sanitation)
● Codes can be better described as laws in Japan. The codes are documented in the laws, and thus there are multiple codes.
Some of the standards have been converted into codes as codes are mandatory and standards may not be. Thus, codes are mandatory standards, while standards are not mandatory.</td></tr>
</table>

- JIS C 0364: Electrical Installations of Buildings
- JIS C 8105: Luminaires in Buildings
- JIS Z 9120 to 29: Lighting for Indoor Workplace, Outdoor Workplace, Sports Lighting, Tennis Court, Sport Stadiums, Swimming Pools, Etc.
- ISO 8995: Lighting for Work Place: Indoor, Security, and Outdoor
- Ministry of Energy's Design Code for Outdoor Light Pollution

There are no green building codes in Japan. Energy efficiency codes and indoor air quality codes have been included in the BSL.

<u>Building Rating Tool (Voluntary)</u>

Comprehensive Assessment System for Built Environment Efficiency (CASBEE) – Japan Green Building Council (JGBI)

Republic of Korea	The Building Act (2009)	Building Energy Conservation Code (BECC) The code specifies a set of mandatory design criteria for the four main building sections (building envelope, mechanical systems, electrical systems, and renewable energy systems) as well as an evaluation of the Energy Performance Index (EPI). Korean Standards (KS) are referenced in the ordinance of the Ministry of Land, Infrastructure and Transport (MOLIT). The ministry also allows equivalent codes and international standards to replace referenced KS, i.e. ASHRAE, IBC, IEC, IMC, and others. The green features that are mandatory in Korea include (selected): 1. Energy efficiency and construction waste recycling (under the Building Act's Energy Efficiency and Utilization of	Green features are introduced into the regulatory system through the Building Act. The act mandates energy efficiency, construction waste recycling and reuse, and water efficiency standards for buildings. The Building Act has included the certification of environmentally friendly buildings. It also has requirements for energy efficiency and construction waste management (including a certification for energy efficiency in buildings).

		Construction Waste section) 2. Energy saving building design criteria and a building certification system, under the Building Act 3. Protection of indoor air quality, under the Ministry of Environment's Indoor Air Quality Control <u>Building Rating Tool:</u> Mandatory: - 1. Building Energy Efficiency Certification System (BEECD) – Ministry of Trade, Industry, and Energy (MOTIE) and MOLIT 2. Green Standard for Energy and Environmental Design (G-SEED) – MOLIT and Ministry of Environment	1. BEECS administered by MOLIT and MOTIE. 2. Includes all building types (for public buildings only with total floor area of above 3,000 m^2)
Malaysia	• Uniform Building By-Laws (1984) • Building (Federal Territory of Kuala	Voluntary: • MS 5125: Code of Practice on Energy Efficiency and Use of Renewable Energy for Non-Residential Buildings	No mandatory regulation related to energy efficiency or green features (except Uniform Building By-Laws gazetted in Selangor)

	Lumpur) By-Laws Street, Drainage and Building Act (1974)	● Building Energy Efficiency Technical Guideline for Passive Design, Building Sector Energy Efficiency Project (BSEEP), Public Works Department, Malaysia ● ASHRAE 90.1: Energy Standards for Buildings Except Low-Rise Residential Buildings <u>Building Rating Tool (Voluntary)</u> ● Green Building Index (GBI) – Greenbuildingindex Sdn Bhd GreenRE – Real Estate & Housing Developers' Association, Malaysia (RHEDA)	
Singapore	Building Control (Environmentally Sustainability) Regulations, 2008	Mandatory: ● Code for Environmental Sustainability of Buildings ● SS 530: Code of Practice for Energy Efficiency Standard for Building Services and Equipment ● SS 531: Code of Practice for Lighting of Work Places ● SS 553: Code of Practice for Air-conditioning and	Requirements: ● New building works with gross floor area of 2,000 m^2 or more ● Increasing the gross floor area of an existing building by 2,000 m^2 or more ● Building works to an existing building which involve a gross floor area of 2,000 m^2 or more ● Achieved a minimum Green Mark certified

		Mechanical Ventilation in Buildings ● SS 554: Code of Practice for Indoor Air Quality in Air-conditioned Buildings ● BCA Code on Envelope Thermal Performance for Buildings ● ASHRAE 90.1: Energy Standards for Buildings Except Low-Rise Residential Buildings ● AHRI 550/590: Performance Rating of Water Chilling Packages Using Vapour Compression Cycle ● ASHRAE Guidelines 22: Instrumentation for Monitoring Central Chilled Water Plant Efficiency <u>Building Rating Tool (Mandatory)</u> Green Mark – Building and Construction Authority (BCA)	rating or higher rating as mandated by the Government Land Sales Programmes
Thailand	Energy Conservation Promotion (ENCON) Act	Mandatory: ● The Building Energy Code of Thailand (1995, 2009)	● Applicable to new and retrofitted building only ● Buildings larger than 2,000 m^2 ● Building type: hospital, academic institute,

	(1992, 2003 – 1st Revision, 2007 – 2nd Revision)	● Energy Efficiency Standard of Equipment and Machinery Required to meet standards for six green criteria: building envelope-OTTV, RTTV, lighting, hot water generating system, air conditioning, renewable energy, and overall performance <u>Building Rating Tool (Voluntary)</u> ● Thailand Rating Energy and Environment System (TREES) – Thai Green Building Institute (TGBI) ● Thailand Energy & Environment Assessment Method (TEEAM) –Ministry of Energy ● Adaptation of German Sustainable Business Council (DGNB) by Thai Association of Sustainable Construction (TASC)	office, condominium, hotel, department store, entertainment service, theatre, and exhibition building
Viet Nam	The Building Control Decree Building Code of Vietnam (BCV)	Mandatory: Energy efficiency under Building Code through Decree No. 102/2003/ND-CP on	Building type: Hotel, high-grade office, foreign affairs office, retail, high-grade condominium, dwelling house, public

	Thrifty and Efficient Use of Energy <u>Building Rating Tool (Voluntary)</u> LOTUS – Vietnam Green Building Council	building (education building, cultural building, medical building, sports building, commercial building, and office building)

ASEAN = Association of Southeast Asian Nations, AHRI = Air-Conditioning, Heating, and Refrigeration Institute, ASHRAE = American Society of Heating, Refrigerating and Air-Conditioning Engineers, BCA = Building and Construction Authority, HVAC = heating, ventilation and air conditioning, IBC = International Building Code, IEC = International Electrotechnical Commission, IMC = International Mechanical Code, OTTV = overall thermal transfer value, RTTF = roof thermal transfer value.

Source: Author's compilation.

2.3. Current and Potential Energy-Efficient Building Technologies

The consideration of energy-efficient building technologies for Brunei should be based on the understanding of local climatic conditions. In view of the fact that Brunei lies in a region of hot and humid climate, the demand for thermal comfort will take up the largest share of energy consumption in buildings. Therefore, a substantial energy saving potential can be expected to come from the cooling requirements in buildings. In view of this, the focus area for current energy-efficient building technologies should be the minimisation of energy use and efficient utilisation of energy for the cooling requirements in buildings.

In a hot and humid climate, all buildings have a primary function of providing an internal environment which is conducive and provides thermal comfort desirable for the purpose of occupancy in buildings. For a holistic approach to energy efficiency in buildings, it is important to firstly adopt a *passive design strategy* before considering an *active design strategy*. Energy efficiency in buildings can be optimised with a combined effort in architecture, engineering, site planning, and landscaping; in other words, a multidisciplinary approach to designing an energy-efficient building when passive and active devices are employed. The passive and active design strategies are being practised in green building design.

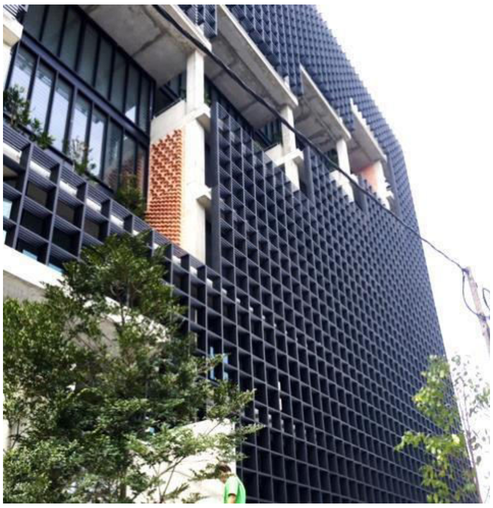
2.3.1. Passive Design Strategy

The primary objective in a passive design strategy is to minimise solar thermal heat gains so that the cooling requirements in a building can be reduced. Hence, its energy consumption will be reduced accordingly alongside the reduction in the cooling capacity of the air-conditioning equipment. Some examples of the key elements to be considered in this strategy are given as follows:

a) ***Building orientation*** that has the longer building axis facing North–South so that the narrow ends of the building would face East–West.

b) ***Building facades*** that provide shading to windows. Egg-crate louvres design (Figure 1) can provide effective shading to windows compared with horizontal projections (Figure 2).

Figure 1: Egg-Crate Louvres Design



Source: Ir. Leong Siew Meng. Photograph of the façade of Pertubuhan Arkitek Malaysia (PAM) Centre in Bangsar, Kuala Lumpur.

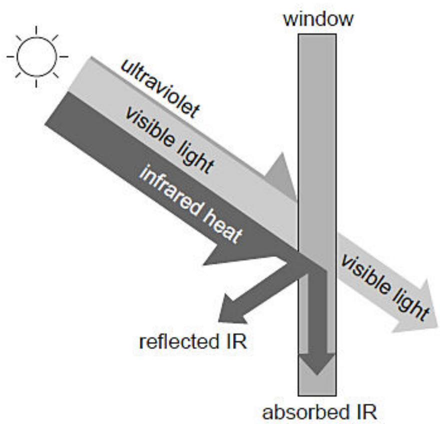
Figure 2: Horizontal Projections

Source: Leong (2013).

c) ***Fenestrations (windows)*** that provide low thermal transmittance and an effective shading coefficient of the glazing used in the fenestration system. Glazing selection is critical as solar radiation heat transfer through glazing can be as much as 80 percent. Glazing should be selected to minimise solar heat gain in order to minimise energy use while maximising daylight effectiveness and meeting architectural objectives. The solar heat gain coefficient (SHGC) or shading coefficient (SC) is the ratio of total transmitted solar heat to incident solar energy, typically ranging from 0.1 to 0.9, where lower values indicate lower heat gain. Another consideration is the selection of the U-value (thermal transmittance in watts per square metre, per degree kelvin, W/m^2K), which is a measure of heat transfer through the glazing. This glazing property is important for the estimation of the overall thermal transfer value (OTTV) when designing an appropriate building envelope.

Another property in glazing is spectral selectivity, which refers to the ability of a glazing material to respond differently to different wavelengths of solar energy. In other words, visible light is admitted while the unwanted invisible infrared heat is rejected. Glazing with relatively high visible transmittance and a low solar heat gain coefficient indicates that it is selective, as illustrated in Figure 3. For greater effectiveness in fenestration design, double glazing is recommended for consideration, but economic justification for the selection of double glazing should be worked out.

Figure 3: Spectrally Selective Glazing

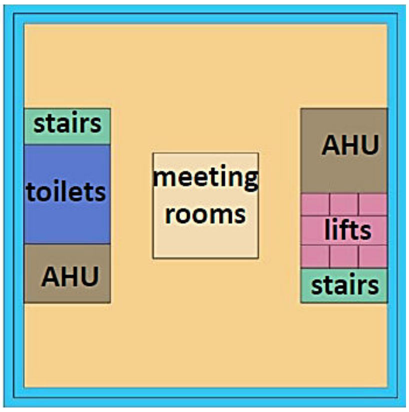


IR = Infrared.
Note: Spectrally selective glazing admits only the part of sun's energy that is useful for daylighting
Source: University of California (1997).

d) ***Building and insulating materials*** that provide low thermal transmittance of the opaque walls and roofs. Suitable building materials including insulating materials that have lower U-values are recommended to be used in roofs and walls. Such selection will improve the OTTV, which will result in lower heat transfer into a building through the building envelope.

e) ***Location of service cores***, such as lifts, staircases, air handling units (AHUs), and toilets, at the sides of a building especially facing East and West will help minimise solar heat gain through the building envelope as illustrated below in Figure 4. The overall thermal transfer for such a design will be reduced.

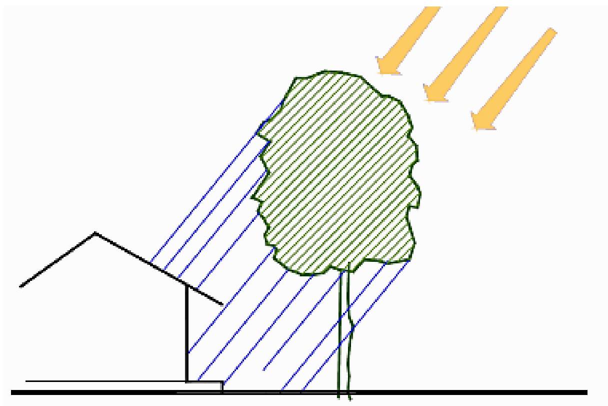
Figure 4: Service Cores at the Sides of a Building



Source: Leong (2013).

f) ***Strategic landscaping*** that provides shading from the sun, shielding from heat reflection, and use of paving materials with a high solar reflective index in the surrounding spaces will help create a cooler microclimate environment around the building (Figure 5).

Figure 5: Benefits of Strategic Landscaping to Improve Microclimate at Building Surrounding



Source: Nayak and Prajapati (2006).

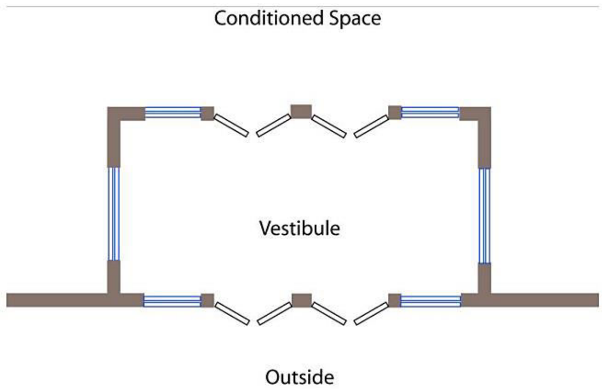
g) ***Daylighting*** design that captures the natural daylighting to reduce the need for artificial lighting.

h) ***Natural ventilation*** that makes use of the natural forces of wind and buoyancy to deliver sufficient fresh air and air change to ventilate enclosed spaces without the needs of relying on air conditioning. There are two basic methods for providing natural ventilation:

  - cross ventilation (wind-driven)
  - stack ventilation (buoyancy-driven)

i) ***Measures to prevent air leakage*** as uncontrolled mixing of outside air with air-conditioned spaces requires more energy to remove moisture and heat gain contributed by air leakage. Air infiltration is commonly done through an entrance door that separates air-conditioned spaces from the exterior. Vestibules should be installed on primary entrance doors to reduce the infiltration of outside air for commercial buildings or buildings with large floor areas. The diagram in Figure 6 illustrates the design of a vestibule which will have interior and exterior doors not necessarily opened at the same time so that infiltration losses will be minimised.

Figure 6: Example of Vestibule Design



Source: US Department of Energy (2009).

2.3.2. Active Design Strategy

Having minimised the solar heat gain and maximised the capture of daylighting and natural ventilation, an active design strategy will play a key role to complete the achievement of energy efficiency in buildings. The extent of energy efficiency in active systems often depends on budget allocations. If budget permits, a sophisticated energy management system and lighting control system may be considered. The minimum approach in an active design strategy is to cover systems that consume higher shares of energy use, i.e. air-conditioning systems and lighting.

2.3.2.1 Air-Conditioning System

The design of an energy-efficient air-conditioning system requires a clear understanding of the building's functional requirements and consideration of many aspects, which may begin with accurate estimates of cooling load requirements, correct sizing, and configuration and selection of chillers or air-conditioning equipment, pumps, fans, motors, variable speed drives, and so on. Other considerations are appropriate zoning, effective air distribution and type of control, energy loss minimisation in ducting and piping systems, air leakage minimisation, and energy recovery system. The setting of air-conditioned space temperature during building occupancy will have a significant influence on the energy consumption of a building. The lower the temperature setting, the higher the energy consumption will be.

The adoption of a low-energy cooling system especially for space cooling, i.e. air distribution, should also be encouraged where possible. Technologies such as radiant ceiling panels, chilled beams, a displacement ventilation system (or underfloor air distribution), demand control ventilation, or a dedicated outdoor air-conditioning system (for latent heat removal) are among those that have the potential to save between 20 and 30 percent energy use as compared with a conventional system using a forced convection air handling unit (AHU) or fan coil unit (FCU). However, the minimum air movement requirement needs to be considered for thermal comfort in a hot and humid environment if design methods using radiant cooling and chilled beams are adopted.

2.3.2.2 Lighting

Lighting must provide a suitable level of illuminance for the performance of a range of tasks and provision of a desired appearance. In general, lighting for infrequently used areas should be designed with lower illuminance (e.g. 100 lux for corridors, car parks, etc.); lighting for working interiors should be designed with higher illuminance (e.g. 300–400 lux for general offices, reading and writing areas, 500 lux for proofreading, etc.). In addition, there should be guidelines for the design of lighting load, which should not exceed a maximum allowable power, for example 5 W/m^2 for hotel bedrooms, 8 W/m^2 for restaurants, 11 W/m^2 for museums and galleries, 14 W/m^2 for offices, 18 W/m^2 for classrooms and libraries, 24 W/m^2 for supermarkets and department stores, and so on. It should be noted that these are typical maximum values. For a higher energy efficiency standard, these values should be set lower. It is possible to achieve such design objectives by using high efficiency lamps with high efficacy (e.g. light fittings of more than 80 lumens per watt).

Further savings in lighting can be achieved by employing passive design methods as discussed earlier to capture daylighting in order to reduce artificial lighting, provision of lighting zone controls for energy saving, use of task lights, and use of lighting controls with timer, motion, and photoelectric sensors.

2.3.2.3 Lifts and Escalators

Traditionally, the focus in the design and installation of lifts and escalators has been on issues such as reliability, safety, riding comfort, and space restrictions. However, in line with the eco town concept, energy-efficient technologies should be considered and incorporated in lifts and escalators to help save energy and costs in the daily operation of lifts and escalators.

The following measures and criteria are recommended to be included in the design and specification of energy-efficient lifts and escalators:

- The design team should conduct an analysis of the transportation demand and usage patterns by the estimated building occupants and determine the optimum number and size of lifts, escalators, and/or moving walks. In addition, appropriate computerised control should be incorporated in the operation of lifts in order to optimise the operation of lifts for greater energy efficiency.
- The lift, escalator, and/or moving walk system with lowest energy consumption should be specified.
- For lifts, the following energy-efficient features should be considered:
    - The lifts operate in a standby condition during off-peak periods. The power side of the lift controller and other operating equipment such as lift car lighting, user displays, and ventilation fans switch off when the lift has been idle for a prescribed length of time. However, such lift car lighting being switched off shall not affect any lift emergency lighting requirement, which will switch on automatically in the event of any loss of power.
    - The lift car uses energy-efficient lighting and display lighting, i.e. an average lamp efficacy of >55 lamp lumens/circuit watt and lighting switches off after the lift has been idle for a prescribed length of time.
    - The lift uses a drive controller capable of variable-speed, variable-voltage, and variable-frequency (VVVF) control of the drive motor.
    - The lift has a regenerative drive unit so that any energy generated by a traction lift or by a hydraulic lift (due to running down) is used in the lift system or elsewhere in the building.
- For escalators and/or moving walks, each escalator and/or moving walk is required to comply with either of the following:
    - A load sensing device that synchronises motor output to passenger demand through a variable speed drive is fitted; or
    - A passenger sensing device for automated operation (auto walk) is fitted so that the escalator operates in standby mode when there is no passenger.

For a holistic approach, energy efficiency guidelines need to be established to ensure their proper and uniform adoption in professional design practices and construction practices. Such guidelines need to be supported by building codes for consistency and enforcement purposes.

2.3.3. Potential Energy-Efficient Technologies

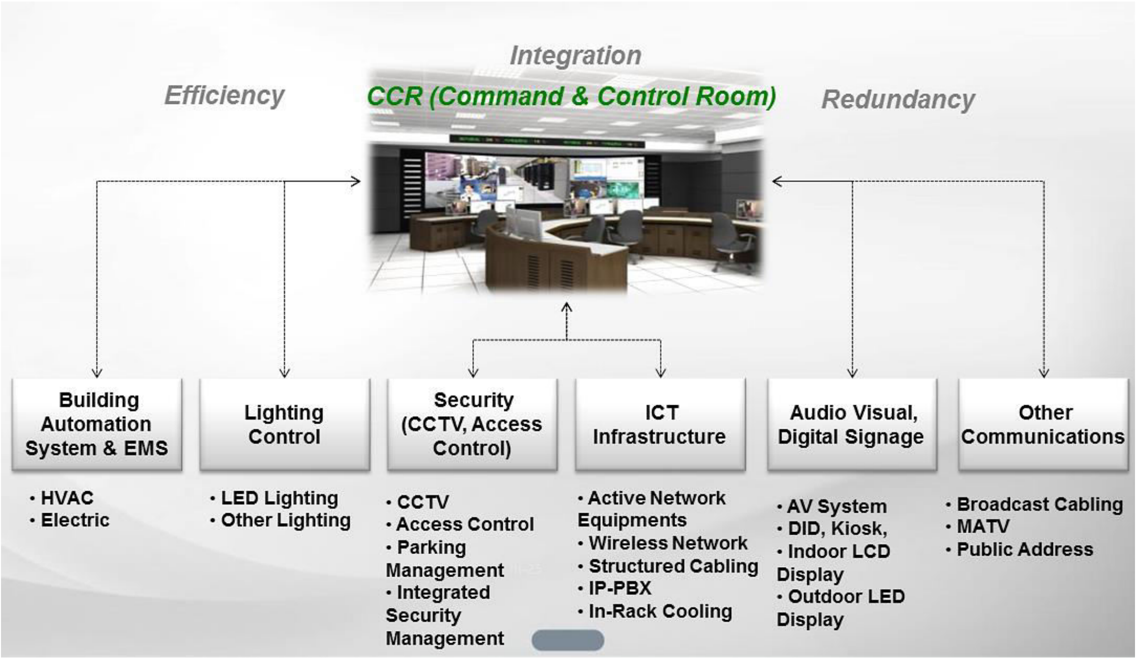
The demand for energy-efficient technologies is on the rise and so is the development and advancement of such technologies. For advanced technologies, the applications depend on the needs, economic viability, and competent operation and service support. One such area that can be explored is to make use of advancements in information and communications technology (ICT), which are wide-ranging and cover any communication application and integration of telecommunications, satellites, and computers, as well as software and storage.

2.3.3.1 ICT for Energy Efficiency

This report does not intend to explore the full capabilities of ICT. For eco towns, one suggestion is to narrow down the focus to two areas such as the following:

- Provide ICT infrastructures that will support more energy-efficient business models, work practices and lifestyles (e.g. e-commerce, e-banking, teleconferencing, online learning, e-government, etc.) to facilitate efficient work, business development and transactions, and lifestyles without having to travel long distances, which translates to energy savings as well as time savings.
- Provide integrated facility management of both public and corporate facilities and infrastructures so that all public facilities and amenities such as street lighting, parks, transportation hubs, and so on, as well as the security systems and building management systems of institutional and corporate buildings can be monitored and maintained using real-time tracking and control of energy usage in accordance with the needs and benchmarking standards such as building energy intensities (BEI). Energy efficiency in buildings can be enhanced using ICT for on-site or off-site control and monitoring capabilities for air-conditioning and ventilation systems, lighting, pumping systems, and other building services against predetermined industry practices and standards, which can be set lower or higher when desired. The diagram in Figure 7 illustrates the concept of integration of extra low voltage (ELV) systems, which includes building an automation system and energy management system (EMS) and provides streamlining in efficient operational control and monitoring. It should be noted that the diagram below does not depict the full capabilities of ICT.

Figure 7: Integration of ELV Systems



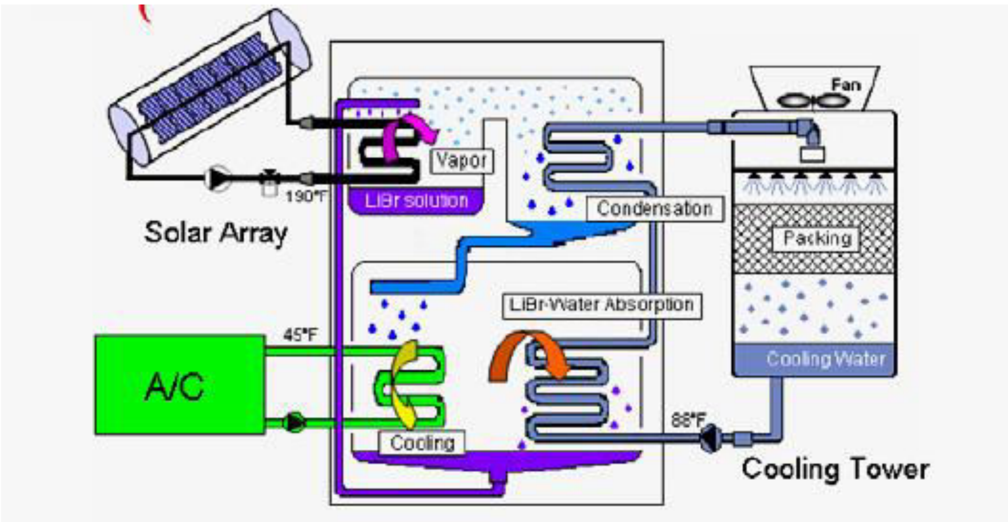
AV = audiovisual, HVAC = heating, ventilation, and air conditioning, CCTV = closed circuit television, EMS = energy management system, ICT = information and communications technology, IP-PBX = internet protocol–private branch exchange, LCD = liquid crystal display, LED = light-emitting diode, MATV = master antenna television.
Source: Quek (2016).

2.3.3.2 Solar Thermal Cooling

There is an abundance of solar energy in varying degrees in a hot and humid climate. Harnessing solar thermal energy to meet the cooling requirements in buildings in the ASEAN region will be an ideal situation. Solar thermal energy is harnessed through solar collectors for the production of hot water, which provides the driving heat source for the generation of chilled water through absorption chillers for air-conditioning purposes. Solar thermal cooling is based on the application of an absorption cycle instead of the conventional compression cycle in refrigeration. The conventional refrigeration system has four basic functions (evaporation, compression, condensing, and throttling-expansion cycles), whereas the basic solar thermal cooling system or solar thermal absorption refrigeration technology is based on a single-effect absorption cycle, which has the following four basic functions: evaporation, absorption, generation, and condensing.

The diagrams in Figures 8 and 9 illustrate the basic solar thermal cooling system and equipment.

Figure 8: Flow Diagram of a Solar Assisted Single-Effect LiBr-H_2O Absorption Cycle



Source: Kong (2013).

Figure 9: Absorption Chiller and High-Efficiency Evacuated Tube Solar Collectors

Source: Kong (2013).

The main components of a solar thermal cooling system are the absorption chiller and high-efficiency evacuated tube solar collectors as illustrated above. Solar thermal cooling systems will provide the energy saving potential to be harnessed in commercial and office buildings, where the demand for air conditioning coincides with the greatest availability of solar radiation in a hot and humid climate and cooling is required the most during the day. In a hot and humid climate, air conditioning takes up the largest share of energy use in buildings. In addition, solar air-conditioning facilities can reduce the peak load demand for electricity and this certainly reduces considerably the infrastructure costs; otherwise, the transmission and distribution assets need to be sized to cater for the greater peak electricity demand. This will also result in a significant reduction in GHG emissions.

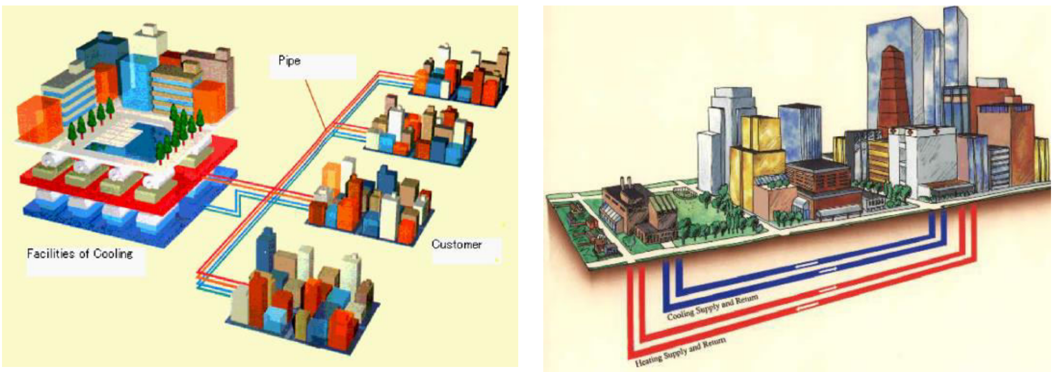
However, under the current technology development for this technology, there are limitations in this system such as the generation capacity fluctuation due to weather conditions, capacity constraints (not suitable for small cooling load), inflexible operation, installation space requirements, demanding operational and maintenance skills, and high capital costs. These limitations may be overcome with greater research and development as well as advancement in this technology.

2.3.3.3 District Cooling System for an Eco Town

A district cooling system (DCS) refers to a system that generates cooling energy at a central plant and distributes chilled water through a network of supply and return piping interconnected with multiple buildings within the eco town via an energy transfer station (Figure 10). It is ideal for a township where there is mixed development of residential homes, offices, shopping centres, commercial centres, hotels, convention centres, hospitals, schools, and other institutional buildings.

It should be noted that DCS is not new, having started in 1930 in Denver, Colorado, United States, and in the 1960s the first two European systems in La Défense, France and Hamburg, Germany. It is, however, suggested that the eco town plant configuration of DCS incorporate a solar hybrid cooling system, which will comprise a solar thermal cooling system, electric centrifugal chillers, and thermal energy storage. This type of DCS configuration will capitalise on the free solar energy, while the electric chillers address the shortcomings of the solar thermal cooling system. The solar hybrid cooling system combined with thermal energy storage will be able to manage the cooling load demand profile including day and night load requirements of the eco town. With the proper planning, sizing, design, selection, and incorporation of the suitable control technology, the DCS will be able to provide energy savings and GHG emissions reductions.

Figure 10: Illustration of District Cooling System



Source: Ong (2016).

2.4. Energy Saving Potential

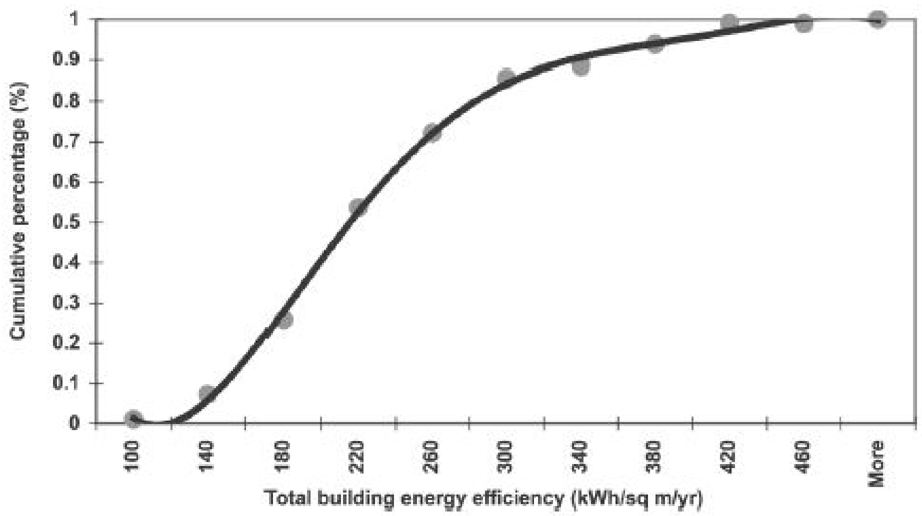
In order to assess the potential energy efficiency improvements through the adoption of energy-efficient building technologies, an energy use index is normally used to determine and compare building energy efficiencies. This is expressed typically in kilowatt-hours per square meter, per year (kWh/m^2/year). There is no standard term to express this value and different countries have different names to describe this indicator.

Malaysia under its GBI rating system, for example, uses the term Building Energy Intensity (BEI), while Singapore uses the term Energy Utilisation Intensity (EUI). In both cases, the definition is similar which is the total energy consumed in a building in a year expressed as kilowatt-hours (kWh) per gross floor area (m^2). For new buildings, the approach to determine this value is mainly through energy modelling or simulation exercises in consultation with project team members, i.e. mechanical and electrical engineers, building technologies manufacturers, and system vendors.

2.4.1. Building Energy Use Benchmarking

Before the energy saving potential can be determined, an energy use benchmark at the building level in the unit of kWh/m^2/year needs to be established first. Most countries within the region, especially Malaysia, Singapore, and Thailand, have developed their own benchmarks for different building types through rigorous study and research work jointly undertaken by the local building authority and institutions of higher learning. These are done mainly through continuous data collection and survey work to develop the building energy efficiency curve as in the example shown in Figure 11.

Figure 11: Total Building Energy Efficiency Curve for Singapore



Source: Sapar and Lee (2005).

From the curve, a performance target may be set for a short-, medium-, or long-term performance of the building. If the services' system energy data are available, a building can also determine the savings achievable from each of the systems from the benchmarking curves.

For new buildings, the minimum requirement in terms of the EUI or BEI value is specified typically in the green building rating tool. Examples of minimum EUI or BEI values are shown in Table 4 for three common building types for both GBI and Green Mark rating system, respectively.

Table 4: Minimum Energy Efficiency Index for Different Building Types

	Rating System	
Building Type	**Green Building Index (BEI)**	**Green Mark (EUI)***
Office	150	172
Hotel	290**	242
Retail	350	269

* Based on top 25 percentile: applicable for those buildings targeting the highest rating, i.e. 'Platinum'.
** 4-star and above
Source: Building and Construction Authority, Singapore, and Green Building Index Sdn Bhd, Malaysia.

2.4.2. Energy Saving Forecasting Methodology

To analyse the energy saving potential through the adoption of energy-efficient building technologies, a target needs to be set making reference at least to the minimum energy efficiency index like those tabulated in Table 4, both for new and existing building. For the purpose of developing an eco town, the target index for the different building types should be set higher, i.e. lower than the BEI or EUI. A minimum target index with an energy efficiency improvement of not less than 30 percent should be considered. In the case of an office building in Malaysia for example, a BEI of around 100 kWh/m^2/year or less should be the target (energy efficiency improvement of more than 30%) as compared to the minimum threshold of 150 kWh/m^2/year.

The steps that are applicable for both new and existing buildings to determine the potential savings are as follows:

- Set good design/post-retrofit targets and approximate the total savings using the total building energy efficiency curve. Take two examples:

For a new building:

$$Potential\ Energy\ Savings\ (\%) = \left(\frac{Minimum\ Benchmark - Design\ Efficiency\ Target}{Minimum\ Benchmark}\right) x\ 100\%$$

For an existing building:

$$Potential\ Energy\ Savings\ (\%) = \left(\frac{Current\ Benchmark - Design\ Efficiency\ Target}{Current\ Benchmark}\right) x\ 100\%$$

- Match total savings target against system performance benchmark to determine realizable savings versus cost outlay.
- Rank energy saving measures in terms of savings–cost ratio, investment quantum, and ease of installation/retrofitting work for management decision.

2.4.3. Further Work

For the next phase of the work, a more detailed assessment of the energy saving potential is proposed. To simulate future buildings and to determine reasonable efficiency target values and energy saving potential, research and consultation (with academicians, researchers, industry experts, manufacturers, and practitioners) need to be conducted to determine the energy subsystem equipment and technology improvements that are expected to be standard practice in future buildings. For example, the best technology available on the market today can be expected to be standard practice in 2017 or beyond.

However, predicting standard practices say in the medium term, i.e. 2022, is more challenging because a plethora of technologies that are currently in the R&D phase may only achieve market adoption in 5–7 seven years' time. The level of complication is even more pronounced when trying to predict and simulate standard practices by 2030.

The assessment will be carried out using globally established and well-validated energy simulation software such as EnergyPlus, IES, DesignBuilder, Bentley, and so on. For the purpose of this assessment, building types that would typically be built under the eco town concept are selected, i.e. offices, schools, shopping centres, institutes of higher education, hospitals, and so on.

The energy saving potential determination is carried out for the short-term (by 2018), medium-term (2022), and long-term (2030) time frames. For each of these time frames, three scenarios are assessed. The definition of the three scenarios is briefly explained in Table 5.

Table 5: Definition of Modelling Scenarios

Scenario	Remarks
Conservative	Technology improves with conservative energy efficiency targets
Moderate	Technology improves with moderate energy efficiency targets
Aggressive	Technology improves with aggressive energy efficiency targets

Source: Building and Construction Authority, Singapore (2014).

2.5. Issues, Challenges, and Recommendations

Energy-efficient technologies for buildings are being adopted throughout the world to varying extents. The adoption of energy saving technologies is on the rise and so is the advancement in technologies. There are issues and challenges to be considered in the decision- making process in identifying and selecting technologies, whether current or potential technologies. However, the mere adoption of energy-efficient technologies is not an effective way of achieving energy efficiency in buildings for the eco town project because sole reliance on energy efficiency may not be sustainable. Further, the impact to achieving the objective of energy savings may not have been optimised, and consistency in implementation may be lacking.

2.5.1. Non-technology Issues

Fundamental issues in most mega projects are normally non-technology related, such as unclear and conflicting objectives, lack of direction and framework, weak project management organisation, changing requirements during the project period resulting in loss of focus areas and priorities, change of project management personnel resulting in lack of continuity, financial constraints, and unforeseen developments.

The challenge is to convince the project owner to allocate a budget to conduct advance planning, which is to analyse, plan, and find a comprehensive solution so that a project management framework and master plan can be formulated for the implementation of the eco town project. To address these non-technology issues, it is recommended to conduct an eco town foresight study, which is a critical thinking process that can be used to facilitate forward thinking and planning. In addition, it is recommended to establish a project management framework and master plan as well as owner’s project requirements (OPR).

2.5.2. Eco Town Planning and Design Issues

People may interpret differently the concept of a sustainable township. It is important to develop a master eco town plan for the whole project and to ensure that it is consistent with the concept of sustainability. It is a challenge to have consistently competent town planning, design, project management, and construction teams who can adhere to the same standards and requirements. The best way to go about it is to use the methodologies laid out in the green building rating system, which promotes a holistic and systematic approach to be implemented by a multidisciplinary professional team. Therefore, it is recommended to identify and establish a green building rating system for the eco town project. It is also equally important to have competent professionals, who are responsible for the town planning, design, project management, and construction in the eco town project and who are familiar with and dedicated to the practice of a sustainable township and the multidisciplinary approach. The use of advanced design software that has simulation capabilities is recommended to address unforeseen design issues.

2.5.3. Technology Issues

As discussed, achieving energy efficiency is not merely adopting advanced technologies. The consideration of technologies should begin with fundamental design strategies, which are based on the understanding of local climatic conditions. Such strategies include the passive and active design strategies outlined in Section 2.3. Incorporating innovative and advanced technologies addressing the following issues is encouraged:

- effectiveness and potential benefits
- economic justification
- suitability and reliability in terms of applications, climatic conditions, durability, etc.
- sustainability in terms of design lifespan and availability of technology updates
- capabilities of continuous monitoring and verification of energy performance
- ability to operate and maintain in terms of availability of competent operational and maintenance personnel, availability of training, long-term service support, etc.
- adherence to the criteria set out in green building tools

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