HONG KONG 2050 IS NOW

DECARBONISING HONG KONG BUILDINGS

POLICY RECOMMENDATIONS AND NEXT STEPS

December 2020

思匯 CIVIC EXCHANGE

HKGFA 香港綠色金融協會 Hong Kong Green Finance Association

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Lawrence Iu	Civic Exchange
Ir Dr Cary Chan	Hong Kong Green Building Council Limited (HKGBC)
Dr Ma Jun	Hong Kong Green Finance Association (HKGFA)

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ABOUT CIVIC EXCHANGE

Civic Exchange is an independent Hong Kong public-policy think tank established in 2000 with a vision to shape a liveable and sustainable Hong Kong. Its mission is to engage society and influence public policy through in-depth research, dialogue, and the development of practical solutions. With research covering four areas — environmental, economic, social, and governance — Civic Exchange has been ranked among the top 50 environmental think tanks in the world by the Lauder Institute at the University of Pennsylvania since 2011.

ABOUT THE HONG KONG GREEN FINANCE ASSOCIATION

Founded in September 2018, the Hong Kong Green Finance Association (HKGFA) is a platform that offers channels and opportunities to facilitate the development of green finance and sustainable investments in Hong Kong and beyond. It aims to mobilise public- and private-sector resources and talents in developing green finance policies, to promote business and product innovation within financial institutions. HKGFA's main goal is to position Hong Kong as a leading international green finance hub by providing greater access and opportunities for Hong Kong's financial institutions to participate in green financing transactions locally, in mainland China, and in markets along the Belt & Road Initiative. This is in line with the global trend of implementing the UN sustainable development goals and the Paris Agreement. Currently, the Association has members of over 100 financial institutions, companies, service providers and other key stakeholders.

ABOUT THE GREATER BAY AREA GREEN FINANCE ALLIANCE

The Greater Bay Area Green Finance Alliance (GBA-GFA) is a collaboration between the Hong Kong Green Finance Association (HKGFA), the Green Finance Committee of the Guangdong Society for Finance and Banking (GDGFC), the Green Finance Committee of the Financial Society of the Shenzhen Special Economic Zone (SZGFC), and the Macau Association of Banks. The Alliance aims to promote research and to incubate green investments that will benefit the GBA by leveraging the vast green investment demand in Guangdong and green finance capacities in Hong Kong and Macau.

ABOUT HONG KONG 2050 IS NOW

Hong Kong 2050 Is Now galvanises collective action in science, media, business and policy, in efforts towards a carbon-neutral Hong Kong by 2050. This initiative by Civic Exchange, the World Resources Institute, and the ADM Capital Foundation aims to build a broad-based collective platform for driving action in Hong Kong in response to the 2018 Intergovernmental Panel on Climate Change (IPCC) report on "Global Warming of 1.5°C". According to that report, without urgent, large-scale action, global warming is likely to reach 1.5 degrees Celsius above pre-industrial levels, with potentially significant and dangerous consequences for the world. We believe that a decarbonised city is people-centric, more liveable, healthier and successful. That's what we want for Hong Kong.

ABOUT ARUP

Sustainability is at the heart of Arup's work. The firm has made a commitment to be a net zero organisation by 2030 and will achieve this by pursuing an ambitious 1.5 degrees Celsius-aligned science-based target for its full value chain emissions and compensating residual hard-to-decarbonise emissions with certified greenhouse gas removal. Arup is experienced in delivering exemplar sustainable projects worldwide, and its influence can be felt throughout Hong Kong's world-class infrastructure. It has always aimed to deliver innovative, feasible and comprehensive sustainable design strategies and solutions to achieve environmental integrity, economic viability, social welfare and efficient resource utilisation. With vast project experience in integrating environmental, economic and social factors, Arup's multidisciplinary team provides innovative, data-driven and sustainable solutions to clients, contributing to the United Nations Sustainable Development Goals.

ABOUT THE AUTHORS

Tracy Wong Harris is a consultant with Civic Exchange and the Deputy Secretary General of the Hong Kong Green Finance Association (HKGFA).
Contact: tracy.wong.harris@esg-partner.com

Ir Dr Vincent Cheng is an Arup Fellow and Director of Sustainability. Contact: vincent.cheng@arup.com

Ir Dr Bruce Chong is a Director of Urban Sustainability at Arup. Contact: bruce.chong@arup.com

Ir Samantha Kong is a Senior Engineer in the Sustainability Group at Arup. Contact: samantha.kong@arup.com

Ir Justin Cheung is a Consultant of Policy and Sustainability at Arup. Contact: justin.cheung@arup.com

Ariel Mak is an Assistant Consultant of Planning at Arup. Contact: ariel.mak@arup.com

David Lickfold is an Engineer in the Sustainability Group at Arup. Contact: david.lickfold@arup.com

Olivia Ku is a Research Assistant in the Sustainability Group at Arup. Contact: olivia.ku@arup.com

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EXECUTIVE SUMMARY

Background

China pledged to become carbon neutral by 2060 at the United Nations General Assembly in September 2020, followed by Hong Kong announcing the net-zero target by 2050 soon after. Hong Kong is taking the lead in setting a more ambitious target than China's latest National Determined Contribution (NDC) agreed in the Paris Agreement.

In Hong Kong's unique, high-density built environment, activities in buildings account for more than 90% of electricity consumption and 60% of greenhouse gas emissions, which means reducing energy consumption in buildings is critical. Civic Exchange therefore commissioned this report on decarbonising the building sector as part of a wider effort to decarbonise Hong Kong under the banner 'Hong Kong 2050 is Now', in collaboration with the Greater Bay Area Green Finance Alliance (GBA-GFA). Through an analysis of the current policy environment including building energy codes, incentives and subsidies and an evaluation of the approach taken in other jurisdictions – Singapore, mainland China, the United Kingdom, Australia and the European Union – we identified steps that Hong Kong's buildings sector must take.

To live up to the title of Asia's "World City", Hong Kong needs to take the lead in this area and show what is possible with effective collaboration and ambition. Our recommendations are structured around establishing a policy priority and introducing a range of effective policy instruments through a new institutional arrangement.

Policy Priority: Decarbonisation Roadmap

A building-sector specific roadmap must be developed which outlines the steps that will be required to achieve net-zero by 2050. This must cover both operational and embodied carbon emissions from new and existing buildings. A detailed study, using a recognised framework such as Science Based Targets, will be required to establish the necessary timelines and mechanisms for ensuring progress. This study should be completed with urgency. This process will require cross-government collaboration, as well as advice from industry, in line with Hong Kong's latest net-zero target by 2050.

Policy Instruments

STEP 1: IMPROVE REGULATORY TOOLS

Upgrade the Building Energy Code (BEC) and the Mandatory Energy Efficiency Labelling Scheme (MEELS)

The review of international building energy codes in this report has shown that there is significant potential, outlined in the steps below, to raise the regulatory floor and tighten regulations. Aligning Hong Kong with global best practice and adopting timelines for the introduction of new technologies, allowing the market time to adapt, will ensure that the minimum standard for Hong Kong's buildings remains high enough to close the gap to net-zero carbon in time. There are several measures that can be implemented immediately:

1	Improve Lighting Power Density requirements to the minimum international value for each space type.
2	Implement a timeline for the introduction of International Efficiency Class 4 for motors, in line with the EU's approach.
3	Expand the MEELS appliance rating scheme, ban the import of inefficient equipment, and introduce regular reviews of the grading standards. For example, it took 11 years for Grade 1 COP requirements to be updated by 50% from 3 to 4.5 for Single Package Type Room Air Conditioners.
4	Implement VDI[1] or ISO[2] international testing and classification standard for lifts to more effectively assess energy consumption, and then mandate a minimum efficiency standard.
5	Update Coefficient of Performance requirements for air conditioning equipment in line with global best practice.
6	Add sections to the BEC to cover external lighting and medium- and large-scale water heating systems.
7	Add more detailed sub-metering requirements to improve data quality on actual energy use within buildings.

Upgrade the Energy Audit Code (EAC)

Expand the scope of the EAC to include all buildings under Schedule 1 of the Hong Kong Building Energy Efficiency Ordinance (BEEO), the same as the BEC. Reduce the current 10-year period between audits to drive progress and address deficiencies in each building's performance – for example, Singapore Energy Audits for cooling systems are conducted on a three-year cycle. It is essential that existing buildings are regularly audited.

1. VDI: Verein Deutscher Ingenieure (Association of German Engineers)
2. ISO: International Organisation for Standardisation

Regulate and incentivise the implementation of Energy Management Opportunities (EMOs) – with a reasonable carbon payback period and positive cost-benefit analysis – identified during the Energy Audit process. Currently, there are no requirements for the implementation of any EMOs – even Category 1 EMOs, which require little to no cost. A full and effective policy should be established to ensure that the EAC effectively addresses operational emissions of existing buildings and that building owners are supported during implementation of EMOs.

Evaluate Building Envelope Requirements

Consistently review the Overall Thermal Transfer Value (OTTV) code to ensure that the requirements are in line with the decarbonisation strategy. This should include evaluating the regulations around external shading.

Require Public Disclosure

At the building level, mandate the public disclosure and rating of energy consumption and emissions data to enable benchmarking and comparisons between properties. The public disclosure of data submitted to Hong Kong's Electrical and Mechanical Services Department (EMSD), through a grading system similar to the Hong Kong Green Building Council's BEST tool or the NABERS system in Australia, will help to ensure that building owners are held accountable for the carbon emissions of their properties, incentivising energy-efficiency.

STEP 2: INCENTIVISE THE MARKET

Update the Gross Floor Area Concession Scheme

Realign this incentive to focus purely on energy efficiency requirements to make a more significant contribution to decarbonisation. Linking GFA concessions with verified post-occupancy improvements in performance is essential because GFA concessions are currently granted to buildings achieving an 'unclassified' rating, indicating they have met only the minimum standards for BEAM Plus certification. There are several options to improve this scheme, including linking BEAM Plus with IFC EDGE (a performance based green building certification), with the existing BEAM Plus Energy Use credits or the approach used by the Super Low Energy Building programme in Singapore.

Introduce Public-Private Partnerships for Existing Buildings

Implement public-private partnerships in order to address some of the issues around improving the energy efficiency of existing buildings. These include a lack of capacity to undertake widespread retro-commissioning and the regular implementation of the proposed EAC, as well as the long payback periods associated with large retrofits. Public-private partnerships allow the government to utilise external expertise, capital, and manpower, while attracting private companies to participate with incentives and mitigated risks. Requirements for regular retro-commissioning of all buildings should be introduced once these partnerships are established.

Participate in Emissions Trading

Creating an urban cap-and-trade system for Hong Kong would be a major incentive towards capturing the price of excessive carbon emissions in the building sector; however, there are significant challenges for the city to develop its own emissions trading scheme (ETS). Alternatively, there is an opportunity for Hong Kong to tap into China's national ETS after its launch.

Another opportunity will be through the Carbon Connect initiative launched by the Greater Bay Area Green Finance Alliance, which aims to establish a cross-border carbon trading market. A regional ETS that covers the commercial sector would be highly beneficial to Hong Kong's building industry.

Mandate Corporate Disclosures

Incorporating climate risk standards such as the Task Force on Climate-related Financial Disclosures (TCFD) and emissions reporting such as the Carbon Disclosure Project (CDP) into disclosure regimes can greatly incentivise a company to properly prepare for and contribute to decarbonisation. Instead of the current 'comply-or-explain' requirements for environmental aspects under the ESG Guide, the operator of Hong Kong's stock and futures markets (HKEX) can explore opportunities for the incorporation of ESG strategy and reporting into the Corporate Governance Code and consider making emissions disclosures mandatory for the building sector.

HKEX has aligned the environmental disclosures with the TCFD to cover the physical risks of climate change and the transition risk of decarbonisation. This could be made mandatory, to be in line with the objective of Mark Carney, the United Nations Special Envoy for Climate Action and Finance. To facilitate TCFD disclosures, the government should consider developing scenarios for companies to use in their TCFD reporting. This makes the task of reporting against TCFD much easier and makes the report more valuable, as they are done on a common basis and thus provide more valid comparisons.

STEP 3: INFLUENCING BEHAVIOUR CHANGE

Increase Renewable Energy Generation

The introduction of the Feed-in Tariff (FiT) Scheme has certainly incentivised investment into renewable energy generation. However, revision of the FiT rates and structure is needed to refocus investment for the city's next stage of renewable energy development. For example, large-scale renewable installations should be explored through public-private partnerships, such as utilising public housing rooftops or along public infrastructure. These pilot installations could be supported by subsidies on the capital cost or new FiT rates for large capacity systems in order to demonstrate not only the technical feasibility but also financial feasibility.

Implement Carbon Tax and Tariffs

A direct tax on fossil fuels could also be explored. This tax would be levied on fossil fuel suppliers or processors upstream, but the cost would likely be passed along to consumers. This would give consumers a monetary incentive to reduce emissions. Tiered subsidies could be established to keep electricity costs stable for small households or companies. Alternative electricity tariff rate structures should be explored to influence behavioural change on the way consumers use electricity.

STEP 4: PUBLIC SECTOR PROCUREMENT

Capacity and expertise should be built by first implementing potential decarbonisation strategies on public projects. Once the practise has been established and is suitable for widespread adoption, they can be introduced to the private sector through regulations or incentives, similar to the approach taken to introduce BEAM Plus. This approach can be applied to:

1	Undertake widespread retro-commissioning and retrofit on existing government buildings	4	Improve the design standards of government offices and public housing
2	Require a Life Cycle Assessment for all new projects	5	Set energy-efficiency requirements, in line with the proposed building rating system, for government leases
3	Follow the Construction Industry Council (CIC) carbon labelling scheme for construction materials		

Institutional Arrangement: Dedicated Cross-Agency Body

To implement this decarbonisation roadmap, a dedicated cross-agency body should be formed with members from relevant bureaus including, but not limited to, the Environment Bureau, the Development Bureau, the Transport and Housing Bureau, and the Financial Services and the Treasury Bureau. This body should be responsible for coordinating all incentives and regulations necessary for the buildings sector to achieve net-zero by 2050. This body is essential to ensure that any steps taken are not siloed and that effective decarbonisation across the whole sector is the sole priority.

Conclusion

It is important to emphasise that these policies will not immediately decarbonise Hong Kong's building industry, but instead be a positive step to advancing net-zero. All stakeholders within the building industry will need to contribute a significant amount of effort and resources to achieve net-zero by 2050. Steps must be taken now to keep this target within reach.

1 INTRODUCTION

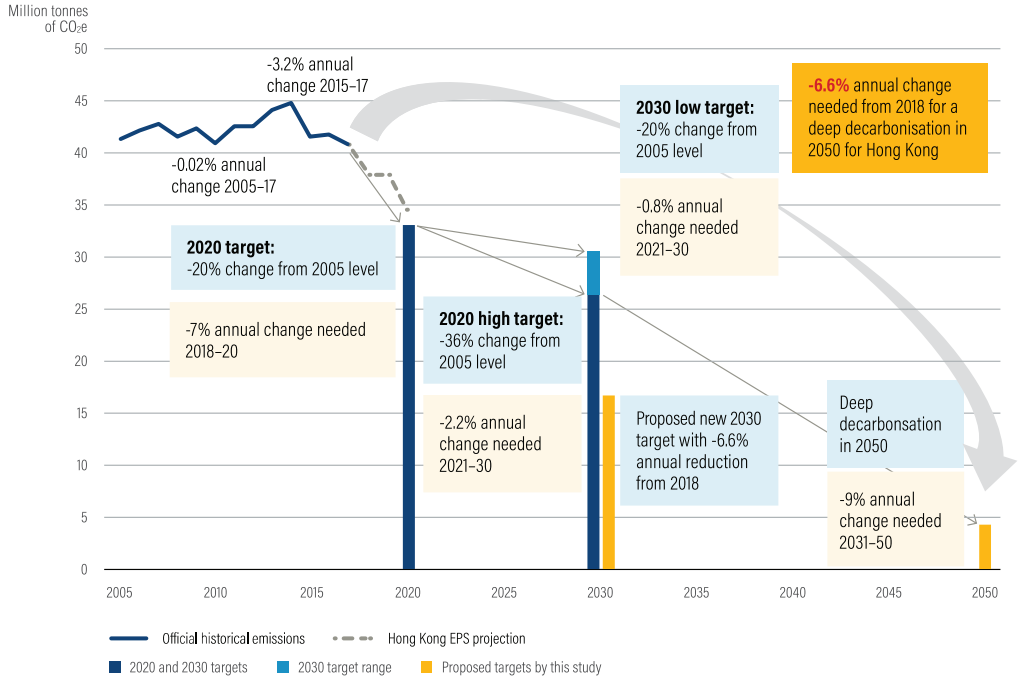
1.1 Decarbonising Hong Kong by 2050

The Paris Agreement came into force on 4 November 2016, with its central goal to strengthen the global response to the threat of climate change by pursuing efforts to limit global temperature increase to 1.5 °C. As decided by the Central People's Government, the Paris Agreement applies to the Hong Kong Special Administrative Region.

In response to the Paris Agreement, in January 2017, the Government of Hong Kong published Hong Kong's Climate Action Plan 2030+ report, setting a carbon emission-reduction target for 2030 and outlining the city's action plans. In September 2020, the Central Government announced the target of reaching peak carbon dioxide emissions before 2030 and net-zero by 2060. This announcement was soon followed in November 2020 by the Council for Sustainable Development, the Hong Kong Government's official environmental advisory body, recommending an updated 2050 net-zero target.

FIGURE 1 **Emission Gap from now to Deep Carbonisation in 2050**

source: Civic Exchange: Pathways to Net-zero Carbon Emissions by 2050



The goal to limit the temperature rise within 1.5°C above pre-industrial levels will only be achieved if Hong Kong net emissions (along with the rest of the globe) are reduced to zero by around 2050. As Asia's World City, Hong Kong should take the initiative to devise its own strategy and play its part by developing a concrete plan to transform the city into a net-zero emissions economy and society by 2050.

In 2020, Civic Exchange published the research report "*Towards a Better Hong Kong: Pathways to Net-zero Carbon Emissions by 2050*". The study, which is outlined below, highlights where action is needed through 2050 and provides context for landmark decisions that must be made under current policy plans until 2030.

1.2 Study Scope

The scope of this study involves reviewing building decarbonisation policy within Hong Kong and on the international stage. This report contains a comprehensive review of the regulations and incentives surrounding buildings in Hong Kong, Singapore, Shenzhen and the UK as well as innovative policy approaches from the EU and Australia. It also makes policy recommendations based on the effectiveness of those international policies reviewed and their applicability in Hong Kong. Both operational and embodied carbon emissions are addressed; however, the current policy environment for embodied emissions remains limited.

Often compared to Hong Kong, Singapore has a highly-developed and wealthy economy. Importantly, it has a similar sub-tropical climate and population density, which has a significant impact on building design and operation. The Singapore government has also made significant, coordinated progress regarding Green Buildings and the overall decarbonisation of the building sector with developments around Energy Codes and incentive schemes. Shenzhen has also been selected for the international review. As the neighbouring city to Hong Kong in the Greater Bay Area, Shenzhen is at a similar level of development and faces the same climate issues. The strong historical links with Hong Kong render the UK another suitable choice for comparison. Engineering institutions such as the Chartered Institute for Building Services Engineers (CIBSE) and the Institution of Mechanical Engineers (IMechE) have strong local chapters and links with the Hong Kong Institution of Engineers. This influences the Hong Kong approach to the built environment. British Standards – formal codes, regulations and procedures – are also used internationally, and frequently referenced in Hong Kong.

Analysing innovative policies at the city, municipal and country levels in the EU and Australia also provides an opportunity to evaluate a wide range of different approaches. Amsterdam is a pioneer in the Circular Economy, which has a large impact on buildings, especially embodied carbon. Finland has taken steps to introduce embodied carbon into regulations, while the EU as a whole has implemented some stringent efficiency standards. This section will analyse these specific approaches to determine if any ideas can be translated and applied to Hong Kong.

This study will also review the impact other sectors, such as green finance, sustainability linked loans and supply side innovations, including renewable energy credits, carbon tax and tariffs and corporate disclosure, can have on decarbonisation of the building sector.

Finally, policy recommendations will be formulated based on international best practise to drive the transition towards net-zero for the building sector. Where gaps exist, both in Hong Kong and internationally, this study will highlight those gaps in addition to making recommendations for mitigating steps that can be taken in Hong Kong.

1.3 Aims and Objectives

The goals of this study are to evaluate current policies and other measures implemented in the building sector in Hong Kong to reduce carbon emissions, consider frameworks in place in other cities and countries and ultimately make recommendations and propose policies for the building sector in Hong Kong that can drive the achievement of net-zero carbon emissions by 2050.

2 DECARBONISING THE BUILDING SECTOR

2.1 Sources of Carbon in the Building Cycle

Understanding the sources of carbon in the building sector is critical to achieving net-zero by 2050. This report will address whole life carbon, which can be divided into two main components: operational and embodied. The diagram in Figure 2 shows in detail the different sources of carbon emissions. Although there is some overlap, operational emissions generally occur while the building is occupied, represented by B1-3 and B6-7 in Figure 2 Sources of Carbon in the Whole Building Lifecycle (LETI, 2020), while embodied emissions occur during the design and construction stage and again post-occupancy.

The scope to reduce emissions at each stage varies significantly based on a vast range of factors including current available technologies, materials selected, cost, and the type, size and design of the building.

FIGURE 2 **Sources of Carbon in the Whole Building Lifecycle**

source: LETI, 2020

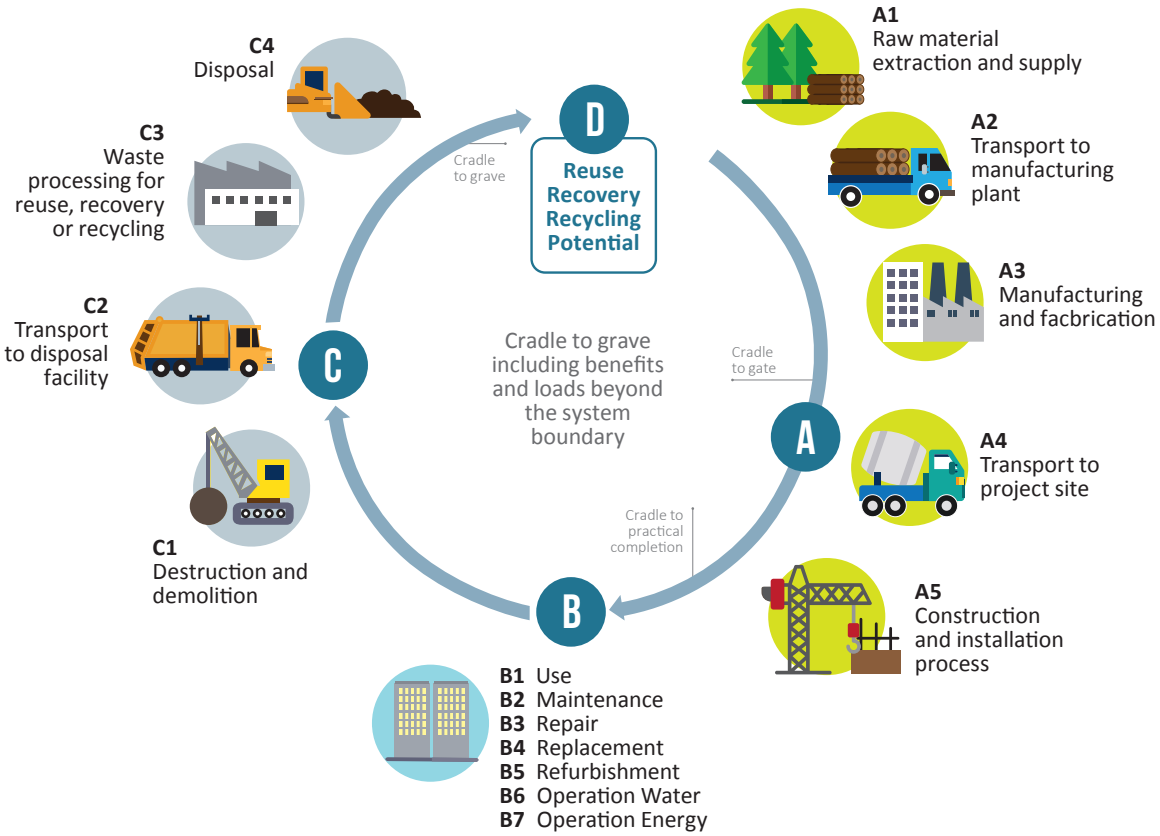


FIGURE 3 Embodied and Operational carbon emissions timeline

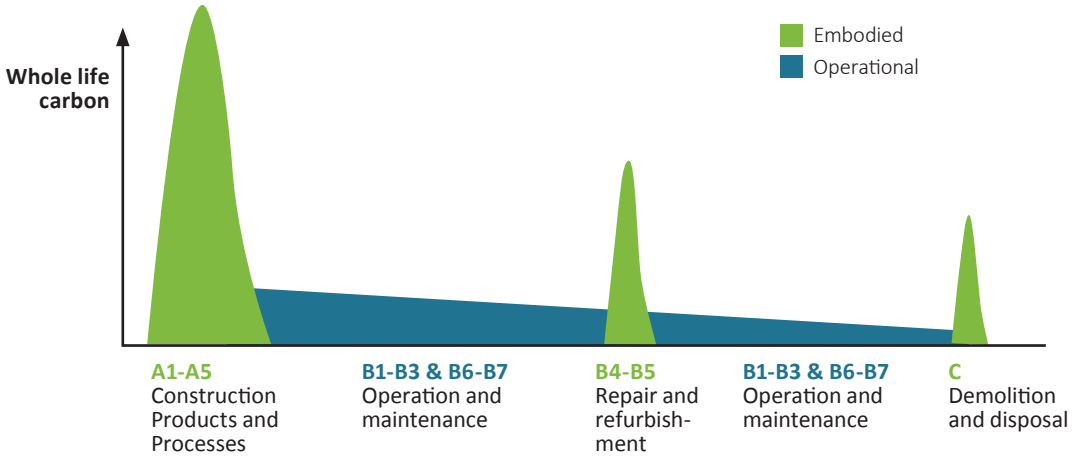
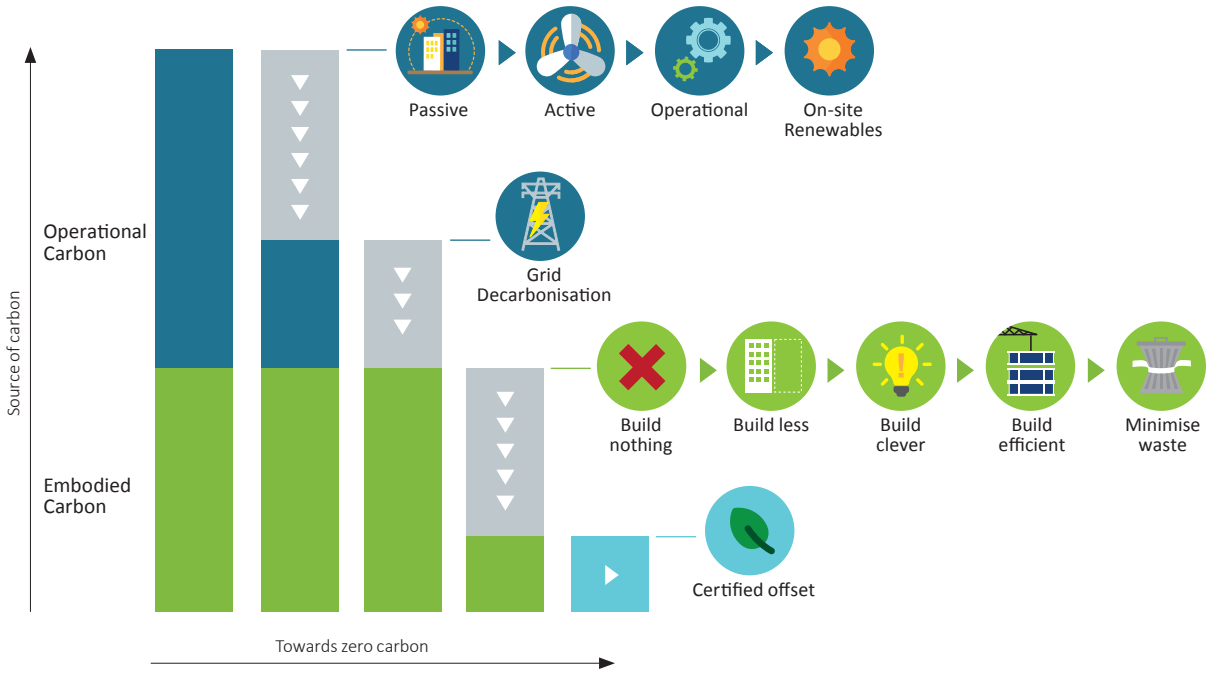


Figure 3 shows that embodied carbon contributes to the life cycle in three distinct phases, labelled A1-A5, B4-B5 and C, with the largest contribution during the design and construction phase. Mid-life refurbishment and repair also have an associated carbon cost, as well as demolition and disposal of the building at the end of its lifecycle.

Operational emissions begin to contribute when the building is first occupied and begins to use energy. It is possible for operational carbon emissions to be net negative; this occurs when on-site renewable energy generation is greater than the building's energy consumption. Special projects, such as the Zero Carbon Building in Kowloon Bay, which uses PV panels on the roof in conjunction with biodiesel tri-generation, solar thermal hot water heating and adsorption chillers to generate on-site energy show that this is possible. At present, however, this remains a one-off demonstration project with technologies that are not feasible for regular buildings due to space and costs constraints.

FIGURE 4 **Route to Zero Carbon**



As shown in Figure 4, a "whole-life net-zero carbon building" is a building that produces onsite or procures off-site enough energy from renewable resources to offset the carbon emissions related to the energy used in all phases of its lifetime, both operational and embodied. Carbon offsets can include several strategies such as power purchasing agreements for off-site renewable energy generation and green electricity tariffs. They allow buildings that cannot produce enough on-site energy to achieve net-zero by ensuring an equivalent amount of renewable energy is generated off-site.

2.1.1 Embodied

Embodied carbon is the carbon "stored" inside the materials of a building, or phrased another way, the total greenhouse gas (GHG) emissions (often simplified to "carbon") generated to produce a built asset. Carbon is emitted during the extraction, formation and construction of building materials. Attaching these emissions to the building materials enables an assessment of the environmental impact of a building. To aid understanding and to help analyse the sources and potential for improvement, embodied carbon can be divided into further sub-categories, described below in Sections 2.1.1 (i) to 2.1.1 (iv).

With respect to various building types in Hong Kong, estimates for the percent of total carbon that is embodied vary significantly, as shown in Table 1. This is due to the difficulty in measuring and estimating emissions at different stages in the production process, as well as variations on the estimated lifespan of the building. The longer the lifespan of a building, the less embodied emissions contribute to the overall percentage because they are concentrated at the initial stages of the

building's lifecycle. Building type also has a large influence on the embodied carbon percentage because this significantly influences the total energy consumption, and therefore operational emissions, for the duration of its lifecycle.

TABLE 1 **Estimated Embodied Carbon for Different Building Types**

Building Types	Estimated Embodied Carbon	Source
Hong Kong		
High-Rise Residential	38% (Housing Authority, 2013)	Kai Tak Public Housing
All Buildings	35% (CIC, 2014)	CIC Carbon Assessment Tool
Zero-Carbon Building	25% (Li, 2013)	Zero-Carbon Building
Singapore		
All Buildings	30%, 40% due to regular urban renewal (Singapore GBC, 2019)	Singapore

The project team for a building bears the responsibility for embodied carbon during the design and construction stages. Design decisions have the largest influence on both the type and quantity of material selected with cost, safety, buildability, and convention all influencing material and design selection.

i) A1-A4: Product

Product carbon applies directly to the extraction and processing of building materials.

Examples of extraction include iron ore for steel and limestone for cement. These materials must then be turned into useful construction materials in facilities such as furnaces and cement mills. These production facilities use large amounts of energy from electrical grids that run mostly on fossil fuels. The materials must also be transported from the place of extraction via road, rail and water, often internationally, which also has an associated carbon cost.

As the major sub-category of embodied carbon, the party responsible for this carbon is also the design team. The design of the building and the specified materials drive this source of carbon.

It is important to note that product carbon can vary widely between materials. Construction materials commonly used in Hong Kong such as concrete, steel, and glass typically have very high embodied carbon. However, it is possible for the contractor to select lower carbon sources of materials. Examples include selecting lower-carbon concrete that uses 'cement replacements' or steel from Electric Arc Furnaces (EAF) (IStructE, 2020). Although an extreme example, the use of 80% recycled steel can reduce product embodied carbon by up to 60%, showing the possibilities if a truly circular approach is utilised (Gan, et al., 2017).

ii) A5: Construction

Construction carbon is the emissions during the construction phase of the building. The transport of people – workers, contractors and consultants - to and from the site, as well as the use of construction equipment all contribute to this section.

The contractor bears the majority of responsibility for this source of carbon, although the developer and other members of the design team can specify more locally sourced and produced materials, if available.

iii) B4-B5: Use

In-use embodied carbon concerns the repair, refurbishment, and replacement of materials and equipment used to keep the building functioning. This includes the replacement of systems that have a shorter lifecycle than a typical building, such as building services equipment and interior furnishings (e.g. carpets).

Although not strictly carbon emissions, refrigerants often have global warming potentials measured in CO_2-equivalent units, which are often far higher than CO_2 itself. A common refrigerant, R-410a has a global warming potential of 2088 CO_2eq. Refrigerant leakage therefore also falls under this sub-category because of its global warming contribution.

This has implications regarding sourcing and upgrading equipment during mid-life upgrades and the careful disposal of equipment, particularly those involving refrigerants. This is the responsibility of the building owner and tenants.

iv) C: End-of-Life

End-of-life embodied carbon emissions concern the processing of the materials of the building when it has been decommissioned. This includes carbon emitted during the on-site deconstruction process, including dismantling and demolition, the transport of the waste material away from the site to be processed, as well as the final processing of the waste material. Material that is recovered and repurposed does not count towards the carbon emissions of this section. This means the worst-case scenario for carbon emissions is the removal of all materials to a landfill, while the best-case scenario is the systematic disassembly of a building and the complete reuse of all building materials.

Globally, consideration of this source of carbon is currently limited. In Hong Kong, this is largely because of the limited ability to influence this source due to the high-rise nature of the buildings. The ability to influence this source of carbon is greatest at the design stage where the construction method, such as Modular Integrated Construction (MiC) and the type of materials – both of which influence how easily they can be repurposed – can be discussed. Contractors have some influence on this during site clearance.

2.1.2 Operational

The whole lifecycle carbon of a built asset is comprised of the sum of the operational and embodied carbon costs. Operational emissions contribute between 60% and 75% of a building's lifetime emissions. The emissions associated with the in-use operation of the building – powering the HVAC, water, lighting, electrical equipment and vertical transportation systems such as lifts and escalators all require energy from the grid. In Hong Kong, due to the hot and humid outdoor weather conditions, the energy used to run the cooling systems typically makes up a large portion of the energy consumption.

Operational emissions, in modules B1-B3 & B6-B7, have been the focus of building codes and energy certificates as the climate crisis has come to the fore. Significant research has gone into making different systems and pieces of equipment more energy efficient.

Operational emissions in Hong Kong are strongly correlated with electricity consumption. This is because buildings do not generally require heating, which is often supplied by gas. Consequently, the carbon intensity of the electrical grid and the energy efficiency of the buildings largely dictates the total operational emissions of buildings in Hong Kong. The carbon intensity of the grid is ultimately dependent on the two monopolies, which together provide electricity across the whole of Hong Kong.

FIGURE 5 Operational Energy in a building

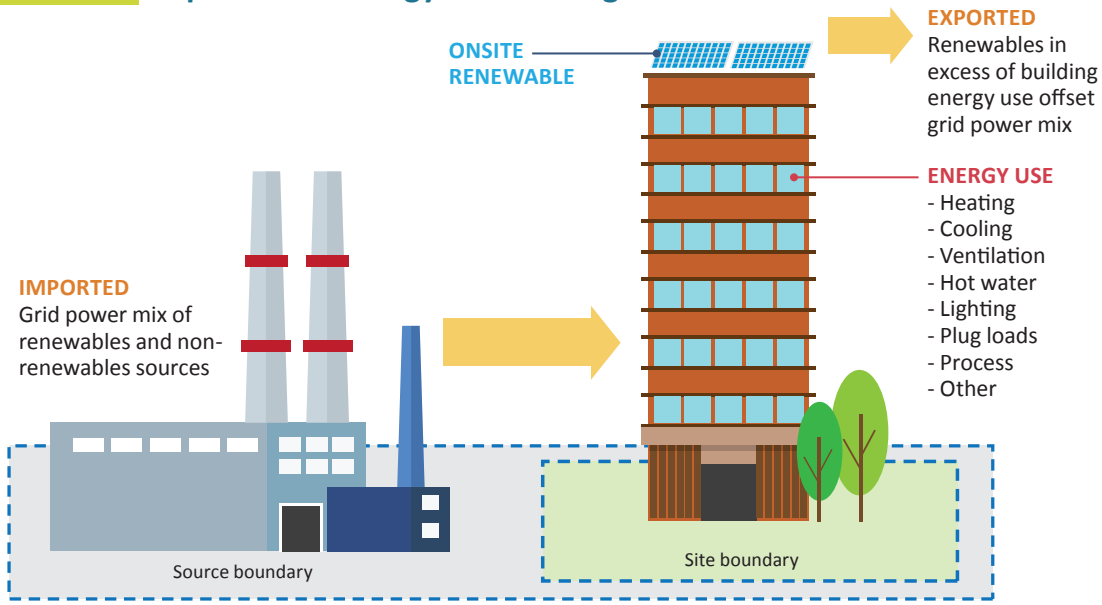


Figure 5 shows how operational energy use in a building is linked with carbon. In Hong Kong, achieving net-zero within the site boundary is only possible in specialist pilot projects such as the Zero Carbon Building. As the carbon intensity of the grid changes, as shown within the source boundary as 'imported', the carbon emissions of the applicable building will be reduced.

2.2 Opportunities for Decarbonisation

There are over 42,000 private buildings and more than 8,000 government-owned buildings in Hong Kong (EMSD, 2018). With a current rate of construction of between 300 and 500 new buildings per year, between 60% and 80% of the buildings that will be in existence in 2050 have already been built. Addressing the total emissions of both new and existing buildings is therefore critical in the process of decarbonising the building sector. It is not enough to just focus on new buildings.

The ability to influence the sources of carbon in the building sector in Hong Kong depends on whether the building has already been built. As outlined in Section 2.1, embodied carbon makes up 30-40% of buildings' total lifecycle emissions, with the majority emitted during the construction process. For buildings that have not yet been built, all carbon emissions can be identified and possibly reduced. For existing buildings, the opportunity to significantly influence embodied carbon has been lost but the operational carbon emissions can still be minimised through retro-commissioning and retrofitting.

The large number of government-owned properties shows that the government has a large influence on the building sector, with the power to impose requirements on the buildings it controls. These include educational and health facilities, public housing, government offices, and other community buildings. Addressing carbon emissions from these buildings would make a significant contribution.

According to End-Use data, just over 60% of the energy consumption in buildings comes from the commercial sector, around 30% from the residential, and approximately 10% from industrial, although this includes processes such as manufacturing that are out of the scope of this report (EMSD, 2017). It is therefore extremely important to address both commercial and residential buildings on the path to net-zero.

3 HONG KONG REVIEW – EXISTING REGULATIONS AND SUBSIDIES

3.1 Building Energy Regulations

The five building energy regulations below control and monitor the energy efficiencies of the built environment. They can have exceptions or limits to their scope for a wide variety of reasons. Typical reasons include public or private ownership, access based on who owns the property, the size of the installations in that area and whether the building is open to the public.

TABLE 2 Scope of each Code in Hong Kong

Code	Private Dwellings	Common Areas of Industrial & Residential Buildings	Commercial Buildings	Other Building Types
Building Energy Code		•	•	• (with exceptions)
Energy Audit Code			•	
Mandatory Energy Efficiency Labelling Scheme	•	•	•	•
Overall Thermal Transfer Value			•	• (hotel only)
Residential Thermal Transfer Value	•	• (residential only)		

The Building Energy Code (BEC) regulates the energy efficiencies of four building services installations: air-conditioning, lighting, electrical installations, and lifts and escalators. The BEC provides standards such as minimum efficiencies and maximum power densities. It applies to all buildings except private dwellings because individual dwellings do not typically have large energy-consuming installations. Also, other measures are in place to address equipment at the consumer level. It does, however, apply to the common areas of residential buildings because building services such as lifts and lighting are present in communal areas.

The Energy Audit Code (EAC) provides standard practices for an energy auditing process. Energy audits are an inspection and survey procedure to examine the total energy consumption of major building services installations in a building. An analysis is then carried out to suggest appropriate recommendations for improvements. The code only applies to commercial buildings due to the absence of large equipment in households and private dwellings and the availability of other codes to address energy consumption in these areas. The feasibility of applying the EAC to other building types and common areas of industrial and residential buildings will be discussed in this report.

The Mandatory Energy Efficiency Labelling Scheme (MEELS) is an approach to involve the general public in the decarbonisation transformation process and encourages manufacturers to achieve higher gradings for their products' energy-efficiency. It facilitates the purchasing of energy efficient consumer products by displaying a label with efficiency gradings. The scheme covers eight products currently. It applies to all buildings, in the sense that small-scale electrical appliances are commonly used in all buildings.

The Overall Thermal Transfer Value (OTTV) and Residential Thermal Transfer Value (RTTV) are limits imposed to control the thermal performance of building envelopes. They are crucial, as they are factors affecting the cooling load in buildings in Hong Kong. The large differences in facade design for residential and commercial buildings leads to varied thermal performances and the need for two separate codes; OTTV covers the thermal performance of commercial buildings and hotels while RTTV covers the thermal performance of residential buildings.

Each code will be further elaborated in the relevant sections below.

3.1.1 Buildings Energy Efficiency Ordinance (BEEO)

The Buildings Energy Efficiency Ordinance is a law of Hong Kong which governs the energy efficiency of buildings with the goal of reducing carbon emissions. It focuses on the four major building components and services found in buildings in Hong Kong:

1. Air-Conditioning (AC)
2. Lighting
3. Electrical installations
4. Lifts and Escalators

First introduced as voluntary guidance named the Hong Kong Energy Efficiency Registration Scheme for Buildings in 1998, the BEEO became mandatory on 21 September 2012. It contains two major subsections: the Building Energy Code (BEC) and the Energy Audit Code (EAC). The BEC applies to the construction of new buildings as well as the retrofit of existing buildings. The EAC in contrast governs existing commercial buildings. The application of the BEC and EAC is described in more detail in Table 3 below.

TABLE 3 **Application scenarios of the Building Energy Efficiency Ordinance**

Scenarios	Responsible Party	Scope	Relevant Code	Legal Obligation
1. New Buildings	Developer	AC, Lighting, Electricals, Lifts and Escalators	BEC	Certificate of Compliance Registration
2. Retrofit of Existing Buildings	Owner of Installations	Major Retrofitting Works of Building Services	BEC	Form of Compliance
3. Energy Audit of Existing Buildings	Building Owner	Energy Audit	EAC	Energy Audit Form Energy Audit Report

FIGURE 6 **Central Building Services Installations definitions from EAC 2018**

	Building with designated common area	Building without designated common area
Lighting installation	located in common area	located anywhere in that building unless it is in an individual unit and is separately owned by the responsible person of the unit who is not the owner of that building
Air-conditioning installation	not separately owned by the responsible person of an individual unit	located anywhere in that building unless it is in an individual unit and is separately owned by the responsible person of the unit who is not the owner of that building
Electrical installation	on the incoming side of an electricity supplier's electricity meter for an individual unit	located anywhere in that building unless it is on the outgoing side of an electricity supplier's electricity meter for an individual unit with its responsible person not being the owner of that building
Lift and escalator installation	located in common area, unless solely serving an individual unit	located anywhere in that building unless it is solely serving an individual unit and is separately owned with the responsible person of that unit who is not the owner of that building

SCENARIO 1 – New Buildings

For new buildings, the process of compliance is completed in two stages, one before construction commences and then after the Occupation Permit has been issued for the building. For Stage One, the developer must engage a Registered Energy Assessor (REA) to submit a declaration to the EMSD stating that the design of the building services installations complies with the BEC. In order to make a declaration, the REA must check the building services installations design and equipment specifications. This occurs within two months of the developer obtaining consent to commence building works.

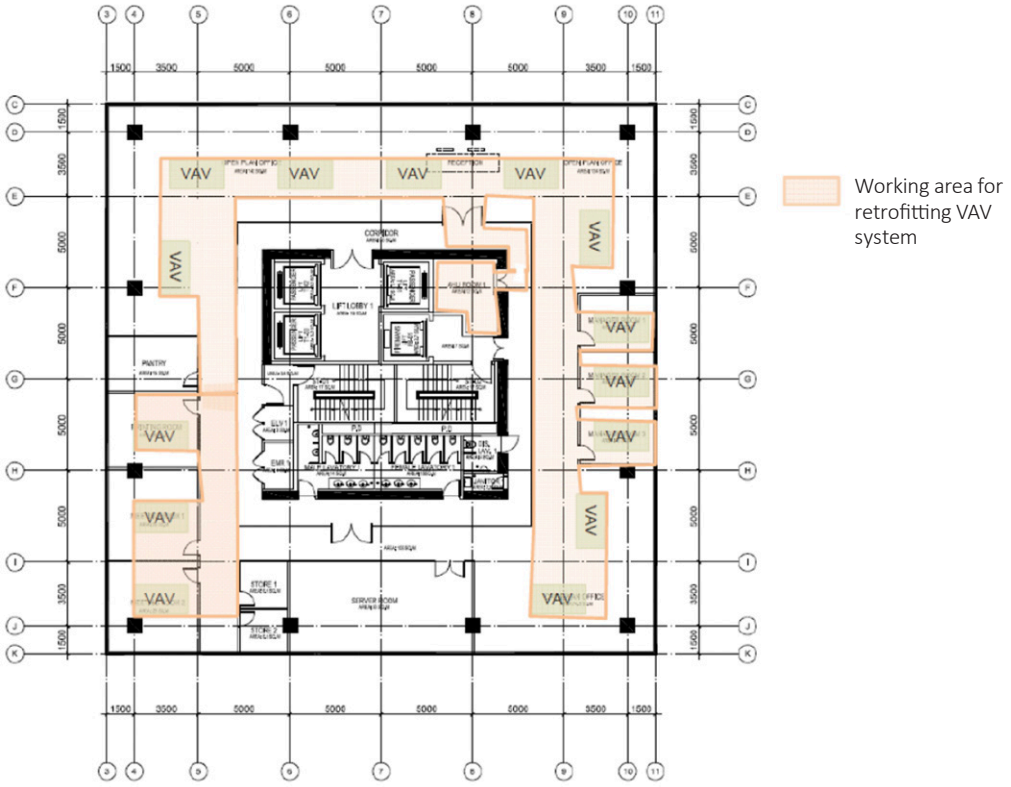
Stage Two requires the developer to engage an REA to submit a similar declaration within four months of the Occupation Permit being issued stating that the commissioned building services installations comply with the BEC. In order to make this declaration, the REA must personally inspect these installations.

SCENARIO 2 – Major Retrofit of Existing Buildings

In this scenario, it is important to understand the scope of retrofit works that are considered 'Major'. The criteria are as follows:

- Work area ≥500m² - made up of plant room area, cable/duct area etc. This is not equal to the GFA of the spaces served. Please see the example in Figure 7 Working Area Calculation Example
- Required size of addition/replacement of Central Building Services Installations (CBSI):
  - Electrical Circuit rated ≥400 A
  - Unitary AC, Chiller ≥350 kW
  - Lifts & Escalators – motor drive & mechanical drive

FIGURE 7 **Working Area Calculation Example**



If the retrofit is considered 'major', the responsible party – this could be the unit owner, the joint owners of a common area or the owner of a Central Building Services Installation – must follow a similar procedure to that outlined in Scenario 1 and comply with the latest edition of the BEC. A Form of Compliance (FOC) alongside other relevant documents must be submitted to the EMSD by a REA on behalf of the responsible party. Within two months of completion of the works, the REA must inspect the works, and make the declaration in the form of the FOC to the EMSD. As a side-note, non-major retrofits only need to meet the initial standard of the Certificate of Compliance Registration.

SCENARIO 3 – Energy Audit of Existing Buildings

In this scenario, an energy audit is required to be conducted every ten years to analyse the four key Building Services Installations and identify areas where energy-efficiency can be improved. The building owner can then make informed decisions about potential energy saving measures, both for economic and environmental reasons.

BEEO – Scope and Exceptions

The contents and scope of the BEC and EAC mean that the BEEO only addresses operational carbon in buildings (and primarily only commercial buildings). The purpose of the codes is to increase energy efficiency by setting the regulatory floor and ensuring a minimum standard is reached. At this stage, there is no consideration for embodied carbon.

The BEEO covers the buildings listed under 'Schedule 1' in the ordinance, as well as those listed below:

- Commercial buildings
- Commercial sections of mixed-use buildings
- Hotels
- Hospitals & Clinics
- Common Areas of Residential & Industrial buildings
- Railway Station
- Schools & Universities
- Municipal Services – Market, Library, Sports Hall
- Government Buildings
- Airport Passenger Terminal
- Community Halls & Social Service Centres

The BEEO does not apply to buildings if they are not included under Schedule 1, or fall under the following exclusion list:

- Electricity supply does exceed 100A (1- or 3-phase)
- 3 or fewer storeys or ≤8.23 m high
- Roof area ≤65 m^2
- A declared monument or historic buildings covered by the Antiquities and Monuments Ordinance Cap

These exceptions only apply to a small percentage of buildings in Hong Kong because most buildings are medium- or high-rise. For Building Services Installations (BSIs) in areas of buildings that are not covered by the BEC, such as individual residential flats, other regulatory initiatives are in place. These include, as an example, energy labelling schemes for individual AC units. These are discussed later in Section 3.2.

Owners and Writers of BEC and EAC

The two codes are the responsibility of the Electrical and Mechanical Services Department (EMSD), a department under the Development Bureau of the Hong Kong Government. A Technical Taskforce has been formed under the EMSD to periodically update and evaluate the two major codes. It is made up of a number of bodies, as listed below:

- Professional Institutes such as Hong Kong Institute of Engineers (HKIE) and the Chartered Institute of Building Services Engineers (CIBSE)
- A wide range of Trade Associations such as the Hong Kong Air Conditioning and Refrigeration Association and the Building Services Operation and Maintenance Executives Society
- University Academics
- HKE and CLP, the two electric companies in Hong Kong
- Members from ArchSD and the Housing Department

The wide representation ensures that all interested parties have a say in the direction of the energy use and the operational carbon emissions of buildings in Hong Kong.

i) BEC – Code of Practice for Energy Efficiency of Building Services Installation

The Building Energy Code has undergone constant revisions since its introduction in 1998, with five revisions completed in 2005, 2007, 2012, 2015 and 2018. A three-year update cycle began in 2012 and is expected to continue. The current version, BEC 2018, was released on 16 November 2018. It came into effect for new buildings on 16 May 2019 and from this date, the Certificate of Compliance Registration (COCR) during Stage One must declare the applicable new building reaches the new standard. For existing buildings, it came into effect on 16 August 2019, and requires any Form of Compliance (FOC) declaration signed on or after this date to declare compliance. The grace period of 6-9 months is typical for all new editions and is made available to give the industry time to adapt and ensure they can comply.

Each revision has expanded the scope to include new building design strategies and technologies, while also tightening the requirements. Between editions, several factors are considered when making updates. Firstly, manufacturers and suppliers of equipment such as chillers or escalators are contacted to evaluate energy-efficiency trends and establish reasonable requirements. Thirdly, an analysis of international guidelines is undertaken to ensure BEC is broadly in line with equivalent codes, particularly those in Mainland China and Singapore.

Performance-based Approach

As an alternative to following the prescriptive requirements outlined in the Appendix for the four separate BSIs, a building can instead follow a performance-based approach. The aim of this approach is to also reduce energy consumption in the designed building but doing so in a way that allows designers more flexibility.

It works by allowing trade-offs between the different requirements outlined for the four BSIs, as well as for the energy efficiency requirements for the building envelope:

TABLE 4 Performance-based Approach Sub-sections

Scenarios	Responsible Party
Lighting Installations	Lighting Power Density
	Automatic Lighting Control
AC Installations	Air distribution system fan power
	Pumping system variable flow
	Frictional loss of water piping system
	System control
	Air-conditioning equipment efficiency
Electrical Installations	Power distribution loss
	Motor installation
	Power quality
Lift & Escalator Installations	Electrical power
	Utilisation of power
	Total harmonic distortion
Energy Efficiency requirements for Building Envelope	OTTV requirements

There are several restrictions when performing a trade-off between requirements:

- The trade-off cannot be more than 15% lower compared to the initial requirement
- For LPD and Air Distribution System Fan Power, the maximum trade-off is 20% below the requirement.

The procedure to obtain compliance is outlined in Figure 8, below. In the figure, BEC section 9 refers to the above requirements in the 'Performance-based Approach' section while Sections 5 to 8 refer to the requirements for each of the four BSIs.

FIGURE 8 BEC Compliance options

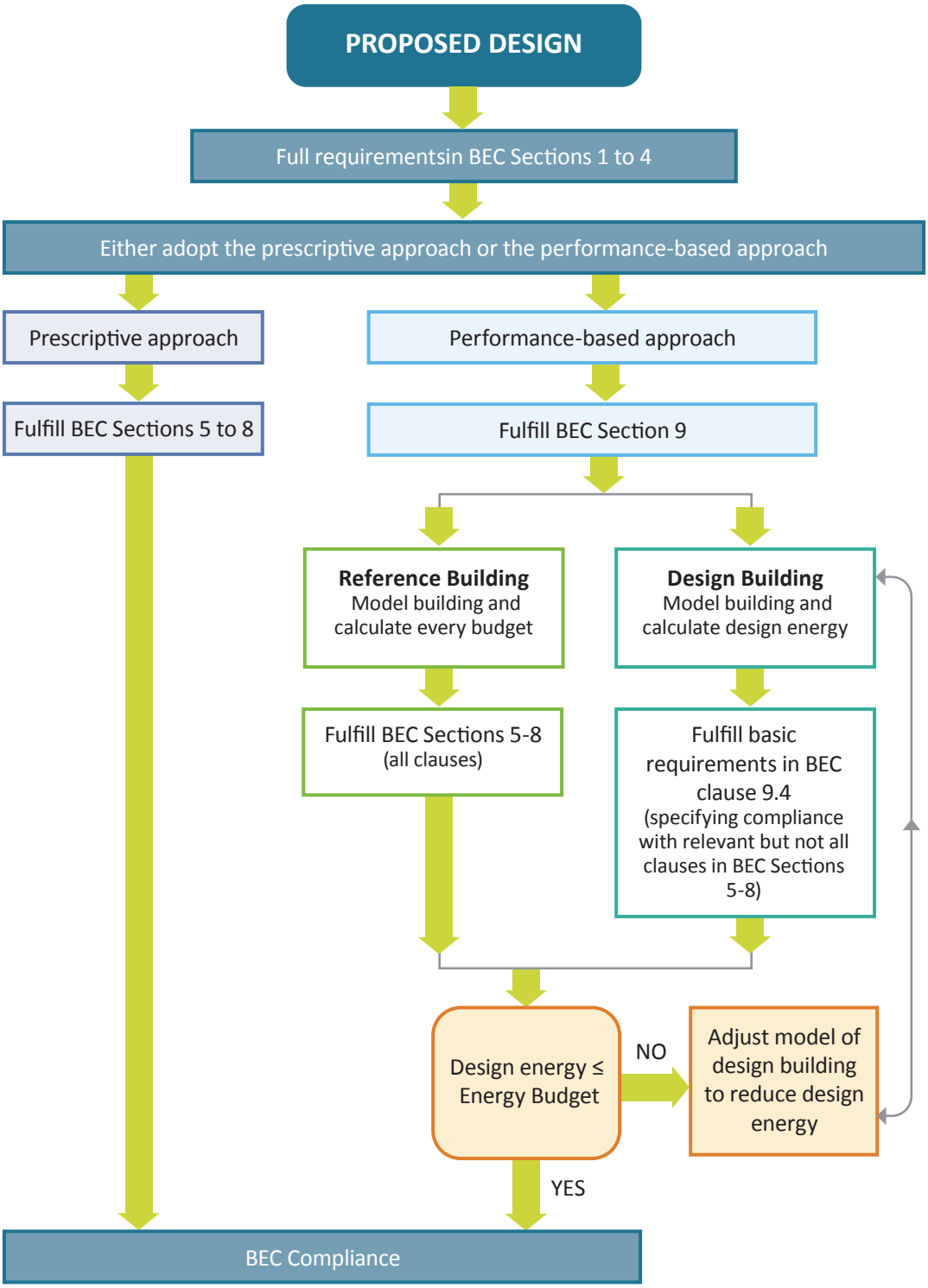
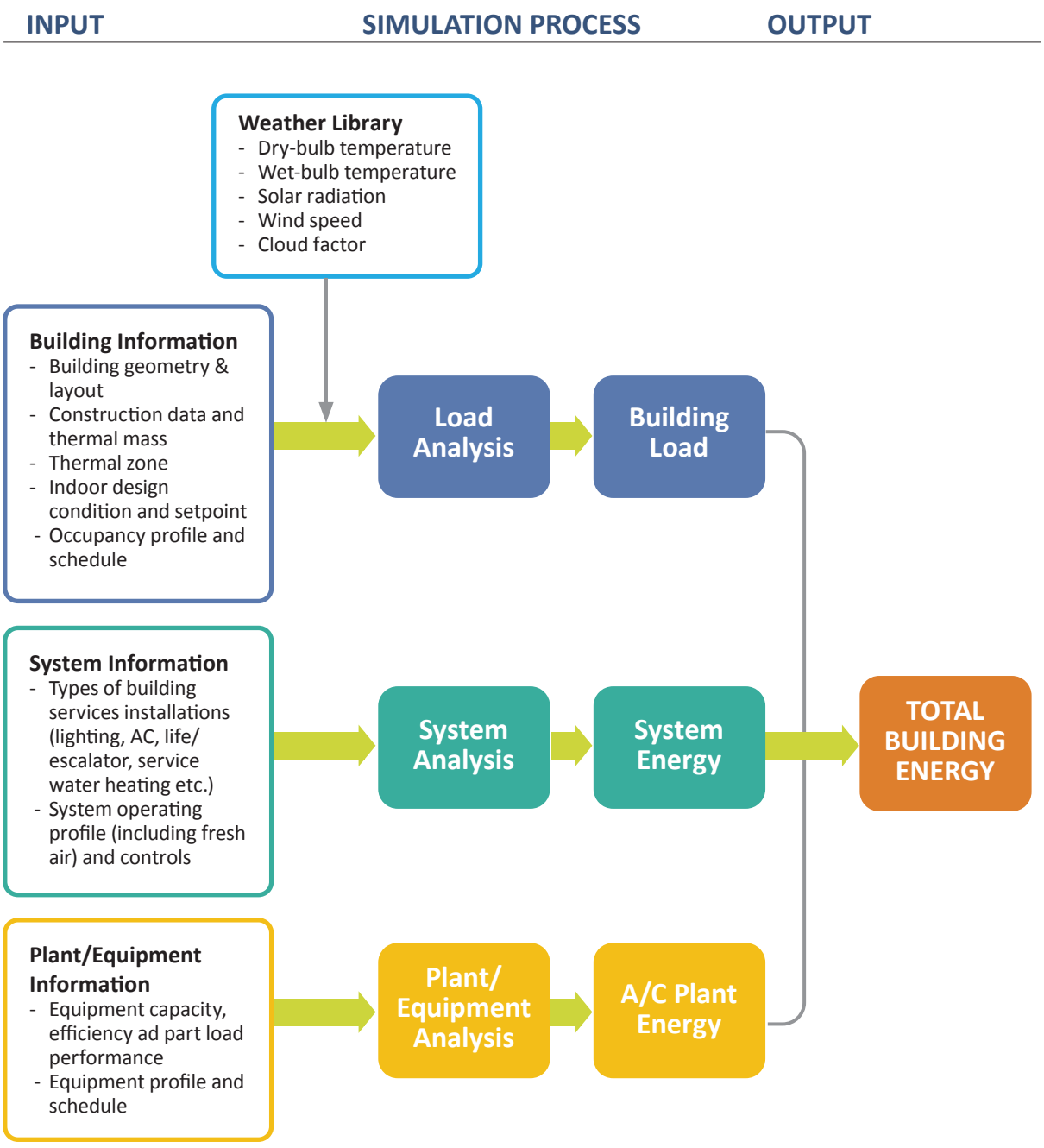


FIGURE 9 Performance-based Approach modelling process



The reference building must follow the prescriptive requirements for the four BSIs and is modelled with the intended size and shape of the proposed building. It includes information on the building envelope, BSIs and other energy-consuming equipment, such as small power equipment (computers, refrigerators, etc.). This establishes the energy budget and is outlined in Figure 9.

The designed building is the building which is aiming to comply with BEC via the performance-based approach. The model of the building is the same size and shape as the reference building but includes the proposed trade-offs. These two models are constructed to ensure the designed building does not consume more energy than the reference building. The addition of on-site renewable energy generation can also contribute to lowering the designed building's energy consumption, providing further flexibility.

This approach is not commonly used, however, because of the limited flexibility given to designers. In practice, 15% or 20% is not enough to encourage designers to regularly explore this approach.

Changes between BEC 2015 and 2018

The BEC is reviewed every 3 years by the EMSD to stay up to date. The update and review process involves evaluating the current regulatory environment:

- Contact equipment manufacturers to understand technological developments
- Consult with professional institutions and major stakeholders
- Survey international codes and standards

TABLE 5 Release and Compliance Dates for BEC 2018

Code	Date of Release	Date of Compliance	
		New Buildings	Existing Buildings
BEC 2015	11 December 2015	11 June 2016	11 September 2016
Update and review process			
BEC 2018	16 November 2018	16 May 2019	16 August 2019

Some of the major changes between the codes are summarised below:

TABLE 6 Major Changes in Version Update

Requirement		BEC 2015	BEC 2018
Lighting Installations			
Maximum LPD (W/m^2)	Added requirements for 12 new spaces	Changing Room: N/A Food Court: N/A Pantry: N/A	Changing Room: 10 Food Court: 14 Pantry: 12
	Tightened requirements for 11 different spaces by ~10%	Bar: 14 Gallery: 17 Retail: 17	Bar: 13 Gallery: 15 Retail: 16
Automatic Lighting Control	Added requirement to 5 new spaces	Changing Room: No Common Room: No Pantry: No	Changing Room: Yes Common Room: Yes Pantry: Yes
AC Installations			
Minimum COP of AC equipment	Increased the COP of some Air Cooled and Water Cool Chillers by 1-6%	VSD Screw <500kW: 6.1 @ 75% load	VSD Screw <500kW: 6.4 @ 75% load
	Added minimum COP for Heat Pump	None	COP added depending on type and capacity
	Added Cooling Tower Fan Speed Control	None	30% of design power at 50% of design flowrate
Electrical Installations			
Minimum Motor Efficiency	Increased requirements for <7.5kW motors	International Efficiency Class 2	International Efficiency Class 3 for motors >7.5kW
Metering intervals and storage	Added requirements	None	Every 15 minutes for 36 months (in-line with other installations)
Lifts & Escalators			
Maximum lift power	Reduced by 5% for all rated speeds and loads	Original requirements	Tightened requirements
Maximum lift decorative load	Reduced by 10% by adjusting equation	Original equation	Updated equation
Lift Car Automatic Lighting Control	Reduced time interval	15-minute activation time	10-minute activation time, 150W exception removed
Metering intervals and storage	Added requirements	None	Every 15 minutes for 36 months (in-line with other installations)
Performance-based Approach			
Metering	Metering provision for on-site recovered or renewable energy	None for on-site energy generation	Added requirement
Major Retrofitting Works			
VRF Systems and Heat Pumps	Expanded definition of major retrofitting -now included	Not specified	Added explicit requirement – now covered.
Lifts	Expanded requirements during the addition or total replacement of a lift car	Only lift decoration load requirement during total lift replacement	Added ventilation & AC, LPD, lighting control requirements to replace-ment works for lift cars

Although highly dependent on building size, shape, location, and function, these changes represent a modest tightening of requirements. The EMSD states that the difference between the 2012 version and 2018 version represents an 18% improvement in energy-efficiency standards. (HKSAR Government, 2018) It is reasonable to interpolate that 2015 to 2018 represents an improvement between 5 and 10%.

ii) Energy Audit Code – Code of Practice for Building Energy Audit

The EAC is the second section of the BEEO and sets out the guidance and details for conducting energy audits of the four main BSIs – MVAC, Lighting, Electrical and Lifts & Escalators - of commercial buildings, and the commercial portions of mixed-use buildings, as shown in Figure 10 below. Large installations covering non-commercial portions of buildings are recommended to be included. Notable exceptions include hotels, schools and universities, hospitals, airports, railway stations, and the common areas of industrial and residential buildings.

FIGURE 10 **BSIs covered under the EAC**

Commercial Building	Composite Building	
	Commercial portion	Non-commercial portion
Non-CBSI	CBSI	Non-CBSI
Carrying out of energy audit not mandatorily required	Mandatorily required to carry out energy audit complying with the EAC	Carrying out of energy audit not mandatorily required

To achieve compliance, the building owner is required to:

- Carry out an energy audit at least once every 10 years
- Engage a Registered Energy Assessor (REA) to conduct the energy audit
- Obtain an Energy Audit Form and Energy Audit Report from the REA and submit to the EMSD
- Publish the Form at the main entrance of the building

The objectives of the EAC are to review the energy-consuming systems in the building and identify energy-saving opportunities with the aim of implementing appropriate measures. EAC 2018, outlined below, was announced on 16 November 2018, with all audits conducted since 16 August 2019 subject to the latest requirements. An audit is required to be conducted by a REA with assistance from the building owner, Operation & Maintenance (O&M) personnel, and contractors.

An energy audit consists of the following steps:

1. Collection and analysis of energy consumption data in the building
2. Data review
3. Analysis of the condition and performance of equipment, systems and installation, as well as energy bills
4. Comparison of performance at different modes of operation
5. Identification of areas of improvement and possible Energy Management Opportunities (EMO), which are divided into three separate categories:
   - **Category 1:** very low-cost housekeeping measures that do not disrupt building operation
     - Closing doors/windows, reset AC supply temperature if it is too cold
   - **Category 2:** relatively low-cost operational changes
     - Add occupancy sensors for lighting, reset VAV static pressure control to reduce fan power
   - **Category 3:** relatively high capital investment required
     - Upgrade chillers to include variable speed drive chilled water pumps, replace 2-speed motor drive lift with Variable Voltage and Variable Frequency (VVVF) lifts to save power

Implementation of EMOs is not mandatory under the EAC. There are several energy consuming installations that are not audited under the EAC. They include safety-critical systems, specialist installations such as stage lighting, air traffic and railway control and safety systems, and specialist hospital equipment.

The full energy audit follows a comprehensive methodology, meaning it effectively captures the energy consumption of the building, as well as opportunities for improvement. However, there are significant issues. Firstly, the frequency of the audit – every 10 years – is far too low to effectively address the energy consumption of existing buildings. Between now and 2050, buildings will undergo a maximum of three energy audits which will make the 6.6% required annual reduction exceptionally difficult to achieve. Furthermore, for individual buildings, a 10-year period is enough time for significant operational, maintenance, and other energy-efficiency issues to manifest. Without consistent maintenance and upgrades, the efficiency of existing buildings is likely to deteriorate rather than improve.

Secondly, the optional nature of the EMOs means that the EAC does not ensure a reduction in carbon emissions. Without enforcement action, inefficient existing buildings will make net-zero impossible.

3.1.2 Code of Practice for Overall Thermal Transfer Value (OTTV)

Thermal transfer and solar heat gain through building envelopes leads to increased air-conditioning use to achieve thermal comfort, especially in the sub-tropical climate of Hong Kong. Hence, to limit the amount of heat transferred into buildings, the Buildings Department (BD) has developed a code on the design of building

envelopes. The Code of Practice for Overall Thermal Transfer Value (OTTV) is a document providing standards and calculation methods of OTTV. It was first published in 1995 and updated most recently in 2019.

The Code applies to non-residential buildings including all hotels and commercial buildings in Hong Kong. It excludes educational buildings and infrastructure.

An OTTV represents the heat transferred into buildings through the building envelope, accounting for both the thermal transfer and solar heat gains. Thermal transfer and solar heat gains are usually represented by the thermal transmittance (U-value) of walls and windows. Solar heat gain is represented by solar heat gain coefficient (SHGC) or shading coefficient (SC) of the windows. Solar heat gains are crucial in calculating heat transfer because fenestration and windows allow solar heat to transmit into the buildings. Both SHGC and SC have a positive correlation with the solar heat energy gained and they are related by the following equation:

$$\mathbf{SHGC = 0.87 \times SC}$$

To minimise the use of electricity in lighting, daylight is usually preferred and prioritised for the design. Window to wall ratio (WWR) is another factor which affects daylight transmittance and thermal performance. WWR is defined by the following equation:

$$\mathbf{WWR = \frac{Total\ Area\ of\ Windows}{Total\ Area\ of\ Walls}}$$

As transmittance of daylight leads to solar heat gain through fenestrations of the building envelope, a larger WWR means that the building is more susceptible to solar heat transfer. For this reason, the combination of U-values, WWR and SHGC should be optimised to balance the effects of daylighting and solar heat gains.

The OTTV is affected by various factors such as building façade materials, external shading for fenestration, and solar orientation. Since a higher OTTV represents a higher heat load for the cooling system in the building, OTTV is restricted to maximum limits. To comply with the code for non-residential buildings, the calculated OTTV of a building project should not exceed:

- In the case of a building tower: 21W/m^2
- In the case of a podium: 50W/m^2

A performance-based study commissioned by the BD found that residential buildings have the highest potential in energy saving by designing energy-efficient building envelopes and natural ventilation (Buildings Department, 2014). Given the Code of Practice for OTTV only applies to non-residential buildings, the BD developed the Guidelines on Design and Construction Requirements for Energy Efficiency of Residential Buildings in 2014, with reference to the OTTV code of practice. The OTTV equivalent in the residential guidelines is named Residential Thermal Transfer Value

(RTTV). The two values are similar, but the difference is that the RTTV calculation methodology has an assumption that residential units are not air conditioned from November to March, while the OTTV assumes commercial buildings or hotels require air conditioning during daytime throughout the year.

In residential buildings, RTTV is split into $RTTV_{wall}$ and $RTTV_{roof}$, which follow different calculation methods and have separate requirements.

- $RTTV_{wall}$ should not exceed 14 W/m^2
- $RTTV_{roof}$ should not exceed 4 W/m^2

By careful design of the building envelope, such as using insulation, external shading and appropriate shading coefficients of windows, the OTTV can be decreased to meet the above limits. However, an additional requirement is imposed such that beneficial external shading may be exempted in the GFA calculation, reviewed in Section 4.1.1, and so that developers would not build external features for unintended use, the current regulation Cap. 123 F controls shading projection length as follows:

- External shading with projection from external wall less than 1.5 m shall not be included in the GFA calculations
  - External shading with projection not more than 750 mm is considered as genuine shading
  - External shading with projection exceeding 750 mm should be justified with a quantitative assessment submitted to the BD

Research was conducted to compare baseline buildings with no external shading with energy-efficient buildings with overhangs and side fins in typical high-rise residential buildings in Hong Kong. The study found that electricity consumption was reduced by up to 5.3% with 750 mm overhangs, demonstrating external shading can significantly reduce the solar heat gain of buildings (Bojić, 2007). In order to achieve more energy-efficient buildings, the regulations on shading wider than 750mm must be re-examined to allow optimal external shading to be implemented without unnecessary regulatory burden. Furthermore, the maximum projection of 1.5m should be further studied and GFA regulations adjusted to allow external shading of appropriate size where it can provide maximum benefits.

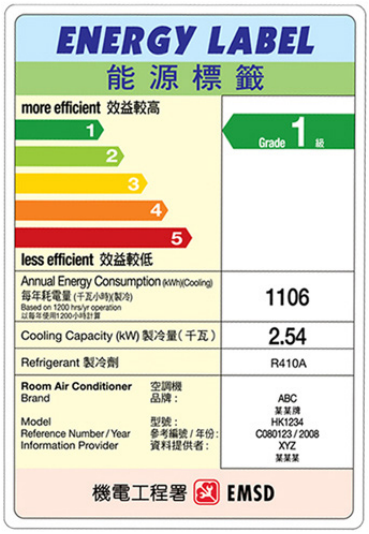
3.2 Energy Efficiency (Labelling of Products) Ordinance

The equipment used within a building contributes to its overall operational carbon emissions. This equipment is sometimes referred to as ‘plug loads’ or ‘small equipment’ when referring to a buildings energy consumption. It represents equipment that is typically plugged into wall electricity outlets.

3.2.1 Mandatory Energy Efficiency Labelling Scheme

Aimed primarily at the public to encourage the purchase of energy efficient equipment, the Mandatory Energy Efficiency Labelling Scheme (MEELS) requires products within certain categories to be rated according to their energy efficiency with Grade 1 representing the most efficient category and Grade 5 representing the least efficient. Prominent labels are shown on the products so consumers can make an informed choice, as shown in Figure 11.

FIGURE 11 Sample Energy Label as required by MEELS



The rating assigned to a product must be assigned after tests have been conducted in testing laboratories accredited under the Hong Kong Laboratory Accreditation Scheme or equivalent. Labelling is carried out by the manufacturers or importers of products under the stipulated categories and follows a prescribed format for the size and location.

The categories of products included under the MEELS has expanded since its introduction in 2009. It initially covered:

- Air Conditioners
- Compact Fluorescent Lamps
- Refrigerators

In 2011, it was expanded to include:

- Dehumidifiers
- Washing machines

The most recent expansion, in 2019, extended the coverage to:

- Televisions
- Storage Electric Water heaters
- Induction Cookers
- Additional categories of Air Conditioners and Washing Machines

The requirements to achieve a specific Grade are published by the EMSD. For the initial set of products introduced in 2009 – room air conditioners, compact fluorescent lamps and refrigerators – the requirements have been upgraded and will take effect on 31 December 2020.

This scheme has the dual effect of encouraging consumers to purchase energy-efficient equipment by providing them with information while deciding which model to purchase, while also encouraging manufacturers to increase the energy-efficiency of their product range to achieve a better grade. Consumers can compare the electricity consumption of similar products and the subsequent financial savings.

It is important to note that this scheme applies to smaller equipment capacities; the coverage of appliances typically has a maximum power rating, weight or volume, above which a label is not required. Despite this limitation, virtually all consumer-targeted capacities of appliances are covered. This type of regulatory approach is extremely common and is generally found to be very effective (European Commission, 2015). It provides a ready-made mechanism to eliminate the use of inefficient equipment by banning the sale of equipment that does not meet a specific energy-efficiency grade. Furthermore, the requirements for grade 1 can be periodically increased to motivate manufacturers to continually improve the efficiency of their equipment.

4 HONG KONG REVIEW – POLICIES AND INCENTIVES

4.1 Major Incentives

4.1.1 GFA Concession Scheme

To drive the green building movement in Hong Kong, the Government has launched several incentives to promote the green building construction industry. The Gross Floor Area (GFA) concession scheme is an incentive that has significant impact in encouraging private new green building developments.

The Building (Planning) Regulations (B(P)R) stipulates that gross floor area (GFA) is the area contained within the outer surface of external walls of a building measured at each floor level. Generally, the Buildings Department awards a specific GFA to a developer and the building is designed accordingly. GFA is a limit and may not be exceeded unless exemptions apply or bonus GFA is awarded. The Buildings Department introduced the GFA concession scheme in 2010 to promote a sustainable built environment and it is awarded to developers if they meet green building requirements described in the following section.

Current Framework

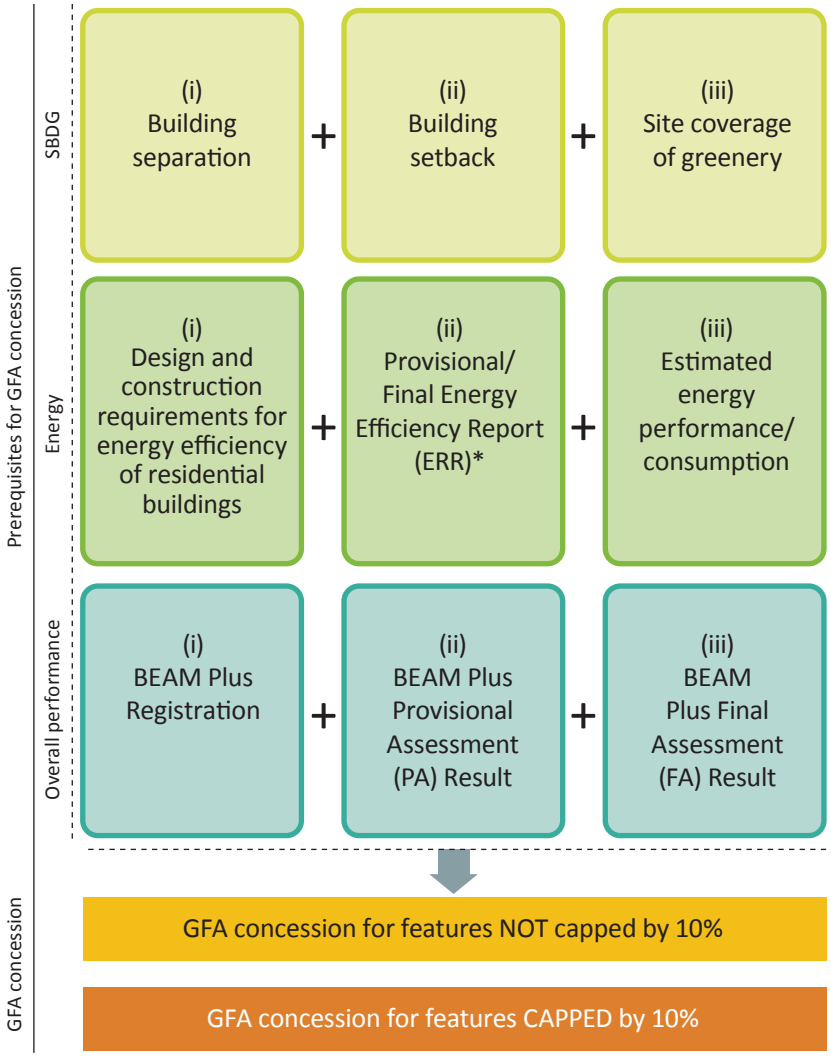
1. Prerequisites

Under the current framework, bonus GFA will be granted to projects that comply with the Sustainable Building Design Guidelines (SBDG), submit relevant energy efficiency data, and complete the Building Environmental Assessment Method Plus assessment (BEAM Plus).

The BEAM Plus prerequisite requires submission of the results of the Provisional and Final Assessments (PA and FA), regardless of the grading. Thus, projects achieving gradings from “Unclassified” to “Platinum” are qualified to apply for GFA concessions (Buildings Department, 2019).

FIGURE 12 **GFA Concession Requirements**

source: Buildings Department, 2019



2. Capped GFA Concession

To prevent bulk building while allowing flexible design for the incorporation of green/amenity features, the bonus GFA is capped at 10% of the total GFA of the development except for the following features (The Buildings Department, 2020):

(a) Mandatory features and essential plant rooms such as refuse storage chamber, telecommunications and broadcasting rooms;
(b) Communal podium gardens and sky gardens that improve permeability of a development to its neighbourhood;
(c) Floor space used solely for parking motor vehicles and loading and unloading of motor vehicles which is separately controlled given its significant impact on building bulk and height and the relevant transport, planning and environmental policies;
(d) Voids in front of cinemas or in shopping arcades, etc. with operational needs in non-domestic developments;

(e) Bonus GFA and / or GFA exemptions relating to dedication for public passage or surrender for road widening and building set back in accordance with the SBD Guidelines; and
(f) Hotel concessions granted under regulation 23A of the Building (Planning) Regulations.

3. International Green Building Assessment Schemes

TABLE 7 Schemes related to GFA Concession/ Bonus

	Hong Kong	Singapore
Accreditation Body	HKGBC	BCA
Certification	BEAM Plus	Green Mark
Application of GFA Concession	Yes	Yes

The Singapore Building and Construction Authority (BCA) issued the Green Mark Gross Floor Area Incentive Scheme (GM GFA) in 2009. Key differences between the Singapore and Hong Kong GFA concession schemes include:

1. Buildings need to have a minimum Green Mark rating of $Gold_{Plus}$ to be eligible for the GFA concession scheme for Singapore. For Hong Kong, minimum requirement is only to receive an "Unclassified" result.

2. Singapore's scheme requires building energy performance verification while Hong Kong's scheme does not.

3. The calculation for GM GFA takes the land value into account, to reduce the chance of overcrowding. While Hong Kong's GFA is not sensitive to land value.

4. The Singapore system has a fixed overall cap for bonus GFA, while various features are not subjected to the overall cap for the Hong Kong system.

5. The GM GFA scheme recognises exemplary performance by awarding more GFA to higher GM ratings, while Hong Kong GFA scheme awards the same GFA percentage to projects regardless of ratings.

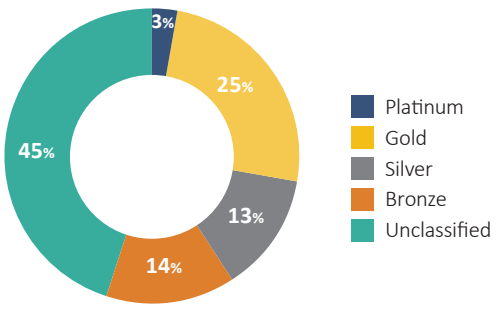
TABLE 8 Comparison between current Hong Kong and Singapore GFA Concession Schemes

	Hong Kong Gross Floor Area Concession	Singapore Green Mark Gross Floor Area Incentive Scheme
Objective	To attract developers to adhere to the sustainable building design guidelines and having a benchmarking tool to review the green building performance	To encourage private sector to develop buildings that achieves higher Green Mark ratings
Prerequisites	• Compliance with SBDG • Achieve minimum 'Unclassified' result	Green Mark Gold^{Plus}
Overall cap	10% (exemptions available to several features)	• 1% or 2,500 sqm for Gold^{Plus} • 2% or 5,000 sqm for Platinum Whichever the lower
Exemplary performance recognition	No	• 1% for Gold^{Plus} • 2% for Platinum
Post-occupancy Performance Verification	No	Security deposit to guarantee the building has reached the committed GM rating
Items apparent to users	Wider lift lobbies, corridors, lift shafts, clubhouse	Public areas, artwork, useable GFA

4. Projects awarded GFA

In accordance with the HKGBC and BD, in 2018, 69 private development projects were awarded bonus GFA through being assessed at provisional and final stages by BEAM Plus. Out of the 69 projects, 31 (or 44.9%) of these assessed developments have only managed to obtain an unclassified rating (Buildings Department, 2020). Therefore, although one-third of projects have only met the prerequisites which also leads to a better environmental performance, there is room for improvements for further policies to encourage a higher energy efficiency performance and BEAM Plus ratings to be met.

FIGURE 13 Distribution of BEAM Plus ratings of the 69 bonus GFA awarded projects in 2018



5. Comments and advice for further investigations

The GFA Concession Scheme has delivered benefits such as energy and water savings and the awareness of the green building movement.

To developers, benefits of BEAM Plus assessment and GFA concessions are as follows:

- Good reputation and branding
- Increases the competitiveness of the private sector
- Contribution to environmental and health benefits
- Increases job opportunities
- Incremental increase in property price of green buildings

Although the GFA Concession Scheme can bring the abovementioned benefits to the developers, it is a voluntary scheme, where the individual developers decide whether to participate in the scheme in accordance with their desire or need. According to Building Department's Practice Note for Authorised Persons (PNAP APP-151), the scheme is designed to address issues regarding bulk and height, air ventilation, greening, and energy efficiency in buildings, while allowing flexibility in the design to promote a quality and sustainable development.

Figure 13 indicates that more than one-third of the projects have gained the GFA concession benefits with a minimum of green features, even if they are technically feasible. Such practice undermines the original purpose of the GFA concession incentive, as the developers may not be using the space primarily in a sustainable manner and promotes bulk building to a certain extent.

Since one of the aims of the GFA concession scheme is to increase energy efficiency of buildings, the potential of the scheme should be maximised in order to decarbonise. Currently, the same bonus GFA concession is granted to buildings of any BEAM Plus rating, and performance verification is not currently required. Hence, individual developers may have limited motivation to pursue higher tier ratings and subsequently to increase energy performance. Also, the HK GFA concession scheme does not directly benefit designers and engineers and only targets the developers. Therefore, the drive of incorporating green features in a project relies wholly on the desire or commercial interest of the developer.

The Singapore GM GFA system may be referenced when providing solutions to these drawbacks, as it has more stringent requirements. An ongoing Review of the Mechanism for Encouraging a Quality Built Environment through Gross Floor Area Concession is being conducted by the Buildings Department. This review should include an investigation of the balance between costs and benefits of stakeholders to establish improvements on the incentive scheme.

4.1.2 Energy Efficiency Registration Scheme for Buildings

Introduced on 1 January 2018, the Energy Efficiency Registration Scheme for Buildings (EERSB) aims to promote buildings that achieve energy performance beyond the minimum requirements laid out in the BEC. This scheme is heavily linked with Green Building certificates, especially BEAM Plus, which is administered by the Hong Kong Green Building Council. This scheme links financial incentives with action to reduce carbon emissions.

The incentive provided under this scheme relates to tax. From the 2018-2019 financial year, the capital expenditures during the construction of energy efficient building installations registered under the EERSB can be fully deducted in the first year of purchase. Previously, this deduction was spread over five years.

To be eligible for registration, a building must achieve one of the following basic requirements:

1. Bronze award overall in BEAM Plus v1.2, the lowest level of achievement
2. Bronze level in the Energy Use (EU) category of BEAM Plus
3. Equivalent international standards such as LEED

A Bronze award, either overall or in the EU category, requires 40% of the relevant credits to be achieved. As of October 2020, of the 305 projects that have completed a Final Assessment under BEAM Plus v1.2, 230, 75% achieved a rating of Bronze or higher. This shows that the scheme is rewarding a large majority of buildings, not just the top performers.

Achieving this grade does not ensure that best practise design guidelines have been employed; only 14 of the possible 35 EU credits are required. Seven credits are available for fully implementing a Testing & Commissioning plan and an Operation & Maintenance plan. Although these documents help to ensure that the installed equipment is running efficiently after installation, they do not ensure that the required energy-saving design strategies have been employed or high-efficiency equipment has been selected. It is possible for buildings to achieve registration under this scheme that are not of the required standard to contribute to a net-zero future.

4.1.3 Urban Renewal Authority Green Item Subsidy

The Green Item Subsidy falls under Urban Renewal Authority (URA)'s Common Area Repair Works Subsidy to provide support to Incorporated Owners / Owners' Corporation / Representatives to carry out maintenance works in building common areas. The subsidy is applicable to private residential or composite buildings of more than 30 years with an average annual rateable value of less than HK$162,000 in urban areas or HK$124,000 in New Territories. Application for this subsidy requires the applicant to concurrently join the "Smart Tender" Building Rehabilitation Services subsidised by the Government (Hong Kong Building Rehabilitation Facilitation Services Limited, 2020).

The Subsidy provides monetary support to encourage the use of environmentally-friendly building products and installation of energy saving facilities when completing building maintenance and repair works. This included the use of durable paint materials to prolong wall finishing and installation of energy saving lighting systems to reduce operation costs.

TABLE 9 **Monetary Support for Building Maintenance**

Number of Units in Building / Application	Ceiling Amount of Subsidy within 5 Years
20 or less	30% of the approved cost of green items and related consultancy fee, capped at HK$75,000
21 – 49	20% of the approved cost of green items and related consultancy fee, capped at HK$75,000
50 or more	20% of the approved cost of green items and related consultancy fee; or not more than HK$1,500 per unit, capped at HK$600,000

Since its introduction in 2015, there has been a steady increase in the number of building blocks applying for the Green Item Subsidy. Up to end of June 2019, the URA had approved applications from owners of around 290 building blocks (approximately 10,800 units) amounting to a total of around HK$15 million in subsidies (Urban Renewal Authority, 2019).

TABLE 10 **Green Item Subsidy Distribution**

Reporting Year	No. of Building Blocks	Total subsidy amount (HK$ million)	Total no. of IBMAS case in progress in reporting year
2016/17	30	1.5	750
2017/18	200	10.5	790
2018/19	290	15	720

4.2 Voluntary Recognition Schemes

4.2.1 BEC Low Carbon Charter

Launched in March 2019, this charter encourages companies and businesses within the property and construction value chain to contribute towards long-term decarbonisation in Hong Kong through pledging to achieve set reduction targets. Companies have been invited to pledge commitment to one of two pathways, where Pathway 1 invites companies to acknowledge the goals of Paris Agreement and implement actions towards decarbonisation targets, and Pathway 2 commits to work towards the targets and submission of a commitment letter to the Science Based Targets initiative (Business Environment Council, 2020).

The charter provides a platform for the industry to share their knowledge, expertise and experience on reducing carbon and setting carbon reduction targets. As this is a voluntary programme, signatories are required to self-report their progress and achievements on an annual basis. To date, 64 businesses spanning developers, service providers, logistics, construction and engineering, and property owners have signed up. By signing up to the charter, not only are businesses acknowledging the need for carbon reduction, they are also committing to achieve targets and making conscious and actionable decisions to cut emissions. For example, property owners can reflect on building operation while construction and engineering firms can take on a proactive approach to change works process and switch to new equipment that minimises emissions.

4.2.2 Charter on External Lighting

Launched by the Environment Bureau in April 2016, this Charter invites participation from those responsible for external lighting installations during the night. It is important to note that this Charter is a strictly voluntary scheme. The two major objectives of this Charter are:

1. Reduce light pollution with the aim of creating a darker environment during sleeping hours.
2. Minimise energy consumption and save electricity.

The Charter targets 'decorative, promotional and advertising' lighting installations, particularly those outside hotels, shopping malls and restaurants. Importantly, the Charter is broad in scope, with a few exceptions such as shop-front signs on the ground floor if the shop is still open, festive lighting and safety and security lighting. In order to qualify under the Charter, the external lighting installation must be switched off between midnight and 7am to achieve a Gold award and between 11pm and 7am to achieve Platinum.

The major reason for joining the Charter is positive CSR and the associated PR opportunities. Between its launch in April 2016 and June 2018, 4,800 awards have been distributed by the Government. By reducing the time these external lighting installations are switched on, the operational carbon emissions of the building are reduced. The Charter also includes guidelines around best-practises regarding external lighting installations.

Operating Hours

- Reduce the length of time external lights need to be switched on, beyond the accreditation section of this Charter.
- Reduce the amount of lighting deemed 'essential' and ensure luminance levels are not unnecessarily high.

Energy Efficiency

- Similar to the control strategies outlined in the BEC, incorporating timers or daylighting sensors to ensure lighting installations are switched on for the minimum possible time.
- Select more energy-efficient lighting equipment, replacing outdated technology like fluorescent lighting with LEDs.
- Adding lighting control points so individual sections can be controlled.
- Avoid over-illumination – this applies especially to advertising signs and shopfronts.

It is extremely difficult to quantify the decarbonisation effects of this charter. There is no data available for external lights on buildings but to give some context, the Environment Bureau has estimated that in 2012 street lighting under the control of the Highways Department was responsible for 100 million kWh, or 0.25%, of Hong Kong's electricity consumption. (Environment Bureau, 2012) To achieve net-zero however, addressing unnecessary energy consumption should be amongst the first measures implemented.

The Charter provides minimal additional incentives to companies and building owners to switch off their external lighting. It only provides recognition for an energy saving strategy that already provides a financial incentive through saving electricity costs.

4.2.3 HKGBC Benchmarking and Energy Saving Tool (HK BEST)

The objective of this tool is to promote greater energy-efficiency in commercial buildings using a similar grading system to MEELS. Building owners have access to an online tool which measures and compares energy consumption with equivalent buildings and awards a grade based on energy performance, with outstanding performers given special recognition. Furthermore, potential improvement measures are identified to help owners upgrade their buildings and achieve higher rankings. These arrangements are split into two separate offerings:

1. Free Benchmarking Tool

Designed as a general tool, this uses the minimum of data including

- Total energy consumption over previous 12 months
- Internal and Gross Floor Area
- % area of different space types
- Biweekly Office operation schedule
- Type of air conditioning system
- % of building entity as common area

Inputting this information provides an advisory general energy performance rating and comparison with buildings that have similar characteristics.

2. Recognition Scheme

The Recognition Scheme is significantly more in-depth; it provides a detailed assessment of building energy performance by a registered assessor. This option provides specific recommendations for energy-efficiency improvements once the assessment has been complete, as well as quantified estimations for cost savings as a result of implementing these improvements. This stage also provides an official certificate of the grading level, which is verified by the assessor.

The scheme is currently available to commercial buildings served by a centralised AC system and office buildings served by a decentralised AC system. There are several other criteria for eligibility to ensure that buildings can be directly compared, such as not sharing the chilled water plant with other buildings and having occupancy of less than 80% (unoccupied areas would give an advantage by reducing consumption). The assessment follows a similar evaluation procedure to other energy audit processes by collecting data from relevant sources and evaluating performance.

Once the assessment is completed, the grades are awarded according to the following criteria:

Calculated Percentile of Operational Energy Performance	Free Benchmarking Tool Rating	Certificate & Label Rating obtainted after the Verified Assessment
Top 10th percentile	Good	Platinum
Top 20th percentile		Gold
Top 30th percentile		Silver
Top 40th percentile	Average	Bronze
Top 50th percentile		Green
Bottom 50th percentile	Below Average	No Rating

This rating has several effects on decarbonisation. It provides an opportunity for building owners to promote energy-efficient buildings by using an easily recognisable grade to demonstrate their credentials. For tenants, this system allows them to set minimum requirements for energy-efficiency of their potential new offices, helping them make informed decisions. As climate change and decarbonisation become increasingly important from the public's point of view, a grading system encourages competition between building owners to ensure that their building does not achieve an unsatisfactory rating and potential reputational damage.

4.2.4 Voluntary Energy Efficiency Labelling Scheme

Released in 2020 as an extension of MEELS, the Voluntary Energy Efficiency Labelling Scheme (VEELS) covers a broader range of products, for both the home and office (as well as motor vehicles). The basic aims of the scheme are very similar to those of MEELS:

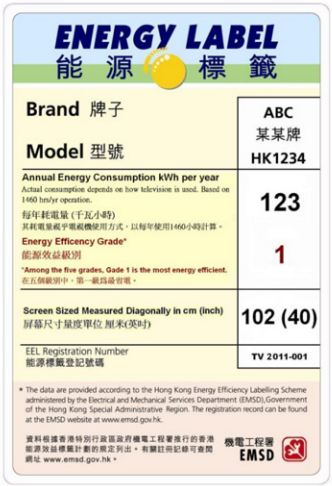
1. to promote public awareness of energy conservation
2. to help consumers make informed decisions; and
3. to encourage manufacturers to produce energy-efficient products.

VEELS takes this further by covering a wider range of appliances including office equipment such as photocopiers and computers. The EMSD also hopes that the market will phase out lower-performance appliances.

Where an equipment category is already covered under MEELS, VEELS extends the labelling scheme to products that fall out of the range specified under MEELS. For example, dehumidifiers with capacities greater than 35 litres/day are excluded under MEELS but are now covered by VEELS, up to a capacity of 87 litres/day. In total, the two schemes cover 13 household appliances, seven types of office equipment and two gas appliances.

VEELS incorporates two types of energy labelling schemes. The 'Grading Type' is the same as that used in MEELS, categorising equipment on a scale of energy-efficiency and assigning the relevant energy label. The 'Recognition Type' does not follow a grading scheme; instead, appliances eligible for this scheme only need to meet the minimum standards of performance and energy-efficiency for which they are awarded the only available type of label. The 'Grading Type' is therefore more comprehensive and allows consumers to make informed decisions. The 'Recognition Type' only shows that the minimum standards have been met.

FIGURE 14 'Grading Type' energy label and 'Recognition Type' energy label



Grading Type

Recognition Type

VEELS covers the following range of products under the 'Grading Type' energy label:

- Electric Clothes Dryers
- Household Refrigeration Appliances (extended)
- Room Coolers
- Washing Machines
- Household Electric Storage Water Heaters
- Televisions
- LED Lamps

VEELS covers the following range of products under the 'Recognition Type' energy label:

- Electric Rice-Cookers
- Electronic Ballasts (Lighting)
- Dehumidifiers
- Photocopiers
- Hot/Cold Bottled Water Dispensers
- Multifunction Devices
- Laser Printers
- LCD Monitors
- Fax Machines
- Computers
- Domestic Gas Instantaneous Water Heater
- Gas Cookers
- Induction Cookers
- Non-integrated Type Compact Fluorescent Lamps
- Microwave Ovens

VEELS contributes to the decarbonisation of the building sector by reducing the energy consumption of the building by improving the energy efficiency of equipment located inside. This applies to both new and existing buildings, as well as commercial and residential.

4.2.5 Corporate Disclosures

Under the Hong Kong Exchange (HKEx) Listing Rules, Environmental, Social and Governance (ESG) Reporting comprises two levels of disclosure obligations: mandatory disclosure requirements and "comply or explain" provisions (Hong Kong Exchange, 2020).

The mandatory disclosure requires companies to issue a high-level statement addressing the board's oversight of ESG issues; approach, strategy, and monitoring of ESG-related issues and goals; and reporting principles including the selection of ESG factors, adopted standards and methodology.

More specific environmental and social metrics, however, are required to be reported on a "comply or explain" basis, in which companies can choose to disclose the requested information or explain the reasoning for the lack of disclosure. In particular, disclosures on the types of emissions, emissions intensity, and emissions targets (KPI A1.1, A1.2, A1.5) fall under this category, allowing companies to choose to provide this information, if available. The full list of Environmental disclosures is extracted below:

FIGURE 15 HKEx ESG Reporting Guideline: "Comply or explain" provisions

source: Environmental Aspect

Emissions	KPI A1.1	The types of emissions and respective emissions data
	KPI A1.2	Scope 1 and Scope 2 GHG emissions and intensity
	KPI A1.3	Total hazardous waste produced and intensity
	KPI A1.4	Total non-hazardous waste produced and intensity
	KPI A1.5	Description of emissions target(s) set and steps taken to achieve them
	KPI A1.6	Description of how hazardous & non-hazardous waste are handled, description of reduction target(s) and steps taken to achieve them
Use of Resources	KPI A2.1	Direct and/or indirect energy consumption by type and intensity
	KPI A2.2	Water consumption in total and intensity
	KPI A2.3	Description of energy use efficiency target(s) set and steps taken to achieve them
	KPI A2.4	Description of whether there is any issue in sourcing water that is fit for purpose, water efficiency target(s) set and steps taken to achieve them
	KPI A2.5	Total packaging material used for finished products (in tonnes) and, if applicable, with reference to per unit produced
The Environment and Natural Resources	KPI A3.1	Description of the significant impacts of activities on the environment and natural resources and the actions taken to manage them
Climate Change	KPI A4.1	Description of the significant climate-related issues which have impacted, and those which may impact, the issuer, and the actions taken to manage them

In July 2020, the HKEx ESG guidelines introduced the Climate Change Aspect (KPI A4.1), which aligns with the Recommendations by the Task Force on Climate-related Financial Disclosures (TCFD) to address physical and transitional risks associated with climate change. While the physical risks of climate change are particularly applicable to the building sector with long-life assets vulnerable to weather events, companies need to also consider adapting to, preparing for, and investing in the transition to a zero-carbon economy.

While the TCFD Recommendations advocate scenario analysis as an important and useful tool for assessing climate risks, there are no standard climate scenario tools provided for Hong Kong, or region-specific transition pathways provided for companies to reference. This differs from other publicly available resources developed in other regions, such as US flood hazard maps provided by FEMA that contain climate and risk projections to help guide mitigation actions. The lack of such tools creates added difficulties for smaller companies to conduct climate assessments and subsequent ESG reporting.

4.3 Embodied Carbon Measures

4.3.1 Carbon Assessment Tool (CAT)

The Carbon Assessment Tool (CAT) is an online tool that was designed by the Construction Industry Council (CIC) to develop a database of embodied carbon in construction materials, measure the embodied carbon of materials and site activities, analyse the carbon performance of construction projects and establish carbon reduction targets for the industry (Construction Industry Council, 2019). The scope of coverage embraces the whole Cradle-to-Site process, including material production (e.g. from mines and factories), transportation (e.g. from port to warehouse) and on-site installation. Temporary works are also covered by the assessment tool, including hoardings, formwork, and scaffolding. The aim is to cover the core and shell elements of a construction project, capturing at least 80% of the overall embodied carbon of construction materials in both the design and construction phase.

The CIC has been promoting the tool and it is now integrated into BEAM Plus NB to encourage carbon reduction through embracing low-carbon designs and construction. One credit is awarded for demonstrating use of CAT or similar assessment tool on permanent works during design, with a bonus credit awarded for demonstrating that the structure has achieved low embodied carbon in construction through assessment of as-built design.

The CAT has the capacity to develop carbon emissions factors for over 300 construction materials and has been adopted by 100 pilot projects in public and private sectors.

4.3.2 Green Product Certification (GPC)

The GPC scheme, which is managed and administered by the HKGBC and CIC, is designed to classify and certify construction products and materials used in buildings, phasing out the previously separate “Carbon Labelling Scheme” (ex-CLS) and “HK G-PASS” (ex-HK G-PASS). While the schemes will be referred to under the umbrella term of “Green Product Certification”, it will still consist of two streams: “CIC Green Product Certification – Carbon Labelling Scheme” (GPC-CLS) and “CIC Green Product Certification HK G-PASS” (GPC-HK G-PASS) (Construction Industry Council, 2020).

Despite the labelling schemes enabling better decision making by communicating the embedded carbon and sustainability-related issues of materials and products, the choice for adopting the product is still heavily affected by the product’s cost and quality. Building developers could take lead to specify the use of such products within their contracts. Government departments can take lead in adopting the use of certified green products, such as those with Green Product Certification, though adoption by industry may be hindered unless the range of products covered can adequately address materials required.

i) Green Product Certification – Carbon Labelling Scheme

This scheme promotes sustainable development and green building practices by publishing and categorising carbon footprint information (CO_2, CH4, N20, HFCs, PFCs and SF6) for carbon-intensive construction materials. The assessment spans across all phases of the products' lifecycle (i.e. raw material acquisition, transportation, production, storage / packaging, distribution) and requires product manufacturers to conduct carbon audits on the product for verification and certification in accordance with ISO14064-1:2006 "Greenhouse gases – Part 1: Specification with Guidance at the Organisation Level for Quantification and Reporting of Greenhouse Gas Emissions and Removals"[3] or ISO/TS 14067:2013 "Greenhouse gases – Carbon footprint of products – Requirements and guidelines for quantification and communication".[4] The scheme will then grade the performance of products using a five-tiered rating category (Platinum, Gold, Silver, Bronze and Green).

Currently, the scheme covers three product categories: cement, ready-mixed concrete and structural steel / reinforcing bars. While the scheme is available for anyone to apply and use, it is not compulsory for building developers, designers, or works contractors to use the rated products unless specified under a contract requirement. Similarly, suppliers intending to sell their products in Hong Kong do not have to gain certification under this scheme, though the scheme may provide one possible route of entry into the local sustainable material market. Suppliers and manufacturers may choose to adopt other alternative schemes or certification processes to confirm their products' sustainability (e.g. Hong Kong Green Label Scheme). To date, approximately 300 types of ready-mix concrete have obtained labelling and are supplied by only two suppliers. No products under the cement or structural steel / reinforcement bars have obtained labelling (Construction Industry Council, 2020).

While these actions are designed to reduce carbon, the adoption of labelling and use of labelled products are not pre-requisites for building development. Developers, designers and contractors are therefore not incentivised to demand the use of carbon labelled products unless aiming for a specific classification under green building certification such as BEAM Plus.

Even though the use of labelled products is voluntary, it is ultimately the cost of the products and incentives that are the primary factors to drive potential demand, along with possible legislative mandates in the future. The following are the main considerations on the general perception and beliefs to adopting carbon labelled products: (Ng, et al., 2018)

3. ISO14064-1:2006 specifies principles and requirements at organisation levels for the design, development, management, reporting and verification of GHG inventory
4. ISO14067:2013 specifies principles and guidelines for quantification and reporting of carbon footprint of a product within its lifecycle

- Private developers would consider lowering environmental impacts of projects if there are incentives (e.g. GFA concession or subsidies)
- It is believed that if developers could play a role in promoting and demanding the use of low carbon materials, the entire supply chain would follow, making it worthwhile for suppliers to certify their products
- Contractors are bound by the contract requirements, though some contractors may still opt to use and procure green construction materials even without specifications in the contract or green building certification scheme requirements
- Other than price, contractors will also have to consider and justify quality, performance and safety of the product (e.g. containing hazardous materials)
- Engineering consultants design the equipment and components based on energy efficiency and performance; it may be up to the contractor to select the appropriate equipment and submit specifications for consultants to review

While there are overall positive reviews and industry feedback for having a recognised carbon labelling system, the scheme is not yet widely adopted, and the existing list of labelled products is limited. The cost of certification and demand for labelled products remains a barrier. Without a clear incentive to drive demand for these labelled products, manufacturers are unlikely to prepare certifications and labelling of their products. Additionally, the scope of products should be expanded to cover other construction materials and components commonly used in civil, structural and mechanical projects, such as copper for cable, polyvinylchloride conduit, stone tile, and dry wall panels.

ii) Green Product Certification – HK G-PASS

This scheme aims to certify environmentally friendly building material, products and components. The G-PASS currently covers 25 product categories[5] including pavement blocks, cooling towers, furniture, cabling, paints, etc. The building products are assessed on a similar five-tiered rating based on core criterions, such as harmful and toxic substances, raw materials efficiency, availability of product information, and non-core criterions such as packaging, carcinogenic substances, innovative features, and management process (Construction Industry Council, 2020).

The HK G-PASS is related to overall sustainability rather than focusing on carbon emissions. The scheme includes the wider environmental impacts such as toxicity levels, end-of-life considerations, and ecosystem impacts. While some products assess the resource consumption or energy management of producers, this may not be one of the core assessment criteria, nor is it assessed for all products.

Developers are incentivised to make use of products listed under the certification as it is linked to BEAM Plus EB V2.0, as extracted below. Additionally, the HK G-PASS is referenced in the URA Green Item Subsidy to support the scheme in the repair or retrofitting works of old buildings.

5. Full list of the 25 product categories can be found on the G-PASS website: http://cicgpc.hkgbc.org.hk/hkgpass/textdisplay.php?serial=10

TABLE 11 G-PASS Summary

BEAM Plus EB V2.0 Comprehensive Scheme Materials and Waste Aspects – use of Certified Green Product	BEAM Plus EB V2.0 Selective Scheme Materials and Waste Aspects – Materials Purchasing Practices
1 Bonus credit of having 5% of the sustainable products in any one of the product categories as specified in CIC Green Product Certification – HK G-PASS 2 Bonus credits for having 5% of certified sustainable products for at least 3 product categories (each category should have at least 5%) as specified in CIC Green Product Certification – HK G-PASS	Maximum 5 credits for purchasing environmentally friendly product during refurbishment including product certified under CIC Green Product Certification – HK G-PASS

4.3.3 Hong Kong Green Label Scheme

This independent and voluntary scheme is run by the Hong Kong Green Council, an environmental stewardship charity established in 2000 to encourage the industrial and commercial sectors to prioritise environmental protection. This scheme certifies environmentally preferable products, awarding a "Green Label" to products that are qualified in terms of environmental attribute and/or performance. It aims to encourage manufacturers to supply products with good environmental performance and involves third-party certification of the product's lifecycle impact. With criterions reviewed every three years, the product criteria are updated regularly to reflect advancement in environmental technology, concerns and expectations. It currently covers eleven categories including construction materials and consumables. Of the construction material, it covers building material made with fly ash, flooring materials, wall coverings, windows, carpeting modular, fibre reinforced home décor product, ceramic tile, adhesive, building products using recycled materials, paint, building products using natural minerals, and thermal building insulation (Green Council, 2020).

Declaration of a product under this Scheme requires proof of compliance according to specification (e.g. testing reports from accredited laboratory and declaration such as those issued by HOKLAS), documents demonstrating the factory does not violate any Environmental Laws or ISO14001 Certificate or Environmental Impact Assessment Report, product material safety data sheet, product catalogue, and other supporting documents (e.g. other certifications).

TABLE 12 **Product Categories**

source: Hong Kong Green Label Scheme – List of Certified Products (https://www.greencouncil.org/hkgls4)

Product Category	# listed
Industrial Cleaner	2
Printed Matter	2
Ink & Toner Cartridges	1
Printed paper	1
Oxo-biodegradable Plastic Non Food / Drink-	5
Oxo-biodegradable Plastic Food / Drink-	5
Flooring Materials	2
Fibre Reinforced Home Décor Product	1
Adhesive	5
Building Products using Recycled Materials	7
Paint	66
Building Products using Natural Minerals	9

Although the Scheme has specified it covers a large selection of construction materials and consumables, there is little indication that it has been widely adopted by the manufacturers. This Scheme faces similar changes to the CIC Green Product Certification, and also has linkages with third party certification schemes, including BEAM Plus Existing Building V2.0 Comprehensive Scheme and Selective Scheme, and URA's Green Item Subsidy.

4.3.4 Embodied Carbon of Construction Materials (ECO-CM) Database Study

The Hong Kong University of Science & Technology (HKUST) is developing a localised carbon inventory that examines the embodied carbon covering "Cradle-to-Gate" (material production) and "Cradle-to-Site" (production and transport to site) of construction materials (Lo & Cheng, 2013). The database, currently in V1.1, focuses on materials produced locally and in nearby areas, and covers a much wider range of construction materials than the CIC's Carbon Labelling Scheme, including aluminium, cement, ceramics, clay, glass, lead, lime, stone, timber, and steel. It aims to promote a low carbon construction industry by providing information on green materials and a database for the estimation of a building's embodied carbon.

While the database does not directly contribute towards the reduction of carbon from buildings, it assists in the assessment of carbon by providing Hong Kong-specific data that can lead to more accurate carbon estimations, and a local benchmark for construction material green labelling.

4.4 Other Schemes

4.4.1 Retro-commissioning

The 2030+ Climate Action Plan of Hong Kong plan proposes retro-commissioning as a key initiative to improve the energy efficiency of existing buildings, especially in high density cities like Hong Kong. Retro-commissioning (RCx) is a process to inspect the energy performance of buildings periodically, and to identify improvements and carry out fine-tuning of systems in the buildings. The building systems require these checks due to changes in building equipment set points, control points and occupancy status, which deviate from the designed range over time. RCx addresses such issues and delivers benefits such as cheaper energy bills and O&M costs, extended equipment lifespans and optimum equipment efficiency.

The process of RCx and energy auditing may be similar, but their goals are distinct. While energy auditing focuses on capital intensive installations and replacements, RCx aims to point out equipment that are not operating under optimum conditions and simple repairs or adjusts to them, instead of complete equipment replacement. Besides, energy audits do not demand implementation of the EMOs, while RCx emphasises implementation as it is one of the stages of the procedure. Therefore, if the RCx process is made compulsory, the addressing of the identified issues will be made mandatory as well.

The first draft version of the technical guidance on retro-commissioning was issued in 2016 by the EMSD. The Government has taken the lead to conduct six pilot projects with government buildings, utilising the draft technical guidance. The impacts of conducting retro-commissioning were studied, and an average annual saving in electricity consumption was found to be 5%. Subsequently, revised versions of the technical guidance were published in 2017 and 2018.

The current Technical Guidance on Retro-commissioning was published in 2018, by a collaboration between EMSD and HKGBC. It provides a clear procedure for conducting RCx. An RCx process consists of four stages:

1. **Planning**
    a. Setting out an RCx plan covering measurement and analysis required for identified systems
    b. Operational data is collected either by O&M reports or on-site measurement

2. **Investigation**
    a. Analysis is conducted with the collected data to point out operational issues
    b. Energy saving opportunities are determined accordingly

3. **Implementation**
    a. Changes ranging from quick finetuning to system upgrades should be made to address the ESOs. For example:
        i. Flow rate of chilled water
        ii. Set point of room temperature
        iii. Operation schedule of lighting and AC
        iv. Automation algorithm for controls

4. **Ongoing commissioning**
    a. Measurement and verifications should be carried out and documented in order to ensure that systems are maintained at optimum performance

Currently, there is no definite timeframe for RCx, but the Retro-Commissioning Resources Centre suggests conducting RCx once every 3 to 5 years. Building owners can define the scope of the process according to budgets, but the technical guideline covers all energy consuming systems of a typical building. RCx is a cost-effective method to improve energy efficiency, as specific qualifications are not required for people who conduct RCx. Thus, building owners may review the capability of their O&M team who are familiar with the building's design, operation and maintenance procedures and to determine their suitability of conducting RCx. Voluntary further training events and seminars are provided by EMSD. If the O&M team do not possess the capacity to conduct RCx, owners may consider involving external RCx service providers.

The six government pilot project buildings ranged from 10 to over 30 years in age. After conducting RCx, the estimated annual electricity savings was up to 490,000 kWh across the six buildings, which is equivalent to 7% of electricity consumption being saved by the buildings annually. A total of HK$2,300,000 was saved across the six projects by 2018. Another pilot project at Kowloon Tong Education Service Centre has an annual estimated saving of 350,000 kWh (9.4%) (Environmental Bureau HKSAR, 2018). Most energy is saved by adjustments to the operating points of the HVAC systems of the building, but energy saving measures were also implemented in lighting and lifts/escalators. Seven ESOs have been identified through this project, most of them involving minor adjustments. Two of the ESOs were determined to be more costly but resulted in higher energy savings. The two more expensive ESOs are reviewing and adjusting the AHU static pressure setting and upgrading the chiller plant automation system (CPA). Compared to major repairs and reinstallations, these changes are straightforward and economical to implement, as payback times of the six pilot projects were between two to six years (Environmental Bureau HKSAR, 2018). The accumulated energy savings that could be achieved across all buildings in Hong Kong would be significant in return. Therefore, this initiative could be a huge contributor in reducing carbon emissions in Hong Kong and more incentives should be put in place to promote this initiative in the private sector.

Since 2018, several private buildings have conducted retro-commissioning projects. Notable results were achieved by V city, a shopping mall in Tuen Mun. Across the MVAC division, retro-commissioning identified 16 separate Energy Saving Opportunities which were funded by the CLP Eco Building fund. An accumulated total energy saving of 1,777,000 kWh was obtained in the two-year period, which is equivalent to 16% of the annual electricity consumption in 2017. Another retro-commissioning project was conducted by Gateway II Harbour City, which claims to save 5,000,000 kWh or 5% of electricity annually. The project was awarded the Outstanding RCx (Proposal) Award by the Environmental Bureau. Cloud-based Building Management Systems are used by these two projects. These systems simplify data interpretation and visualization for the facilities management team. This helps to facilitate the retro-commissioning process by making the identification of ESOs simpler and cheaper.

4.4.2 Green Finance – Green Bonds & Sustainability-Linked Loans

Green financial instruments available include green bonds – funds that generally come from investors that are committed to environmental or climate projects; green loans – for financing or re-financing green projects (LMA, APLMA, LSTA, 2018); and sustainability-linked loans – funding based on borrower's sustainability performance (LMA, APLMA, LSTA, 2020). Recent trends lean towards sustainability linked loans as there is no restriction on the purpose / use of proceeds while green loans are exclusively for green projects (e.g. recycling).

In 2019, the issuance of green bonds in Hong Kong reached US$10 billion, 61% of which was allocated to low-carbon building projects (Lau, et al., 2020). In addition to the local green deals, the green bonds from Greater Bay Area (GBA)-domiciled issuers also increased by 54%.

In the 2020-2021 Budget plan, the Hong Kong Government announced its plans to issue green bonds with a total value of HK$66 billion in the next five years (HKSAR Government, 2020). The proceeds will be used exclusively to fund projects that support sustainable development in Hong Kong. Eligible project categories include renewable energy, energy efficiency and conservation, pollution prevention and control, waste management and resource recovery, water and wastewater management, nature conservation / biodiversity, clean transportation, and green buildings (HKSAR Government, 2020).

Following its Strategic Framework for Green Finance in 2018, the Hong Kong Monetary Authority (HKMA) established a Centre for Green Finance in 2019 to facilitate the financing of sustainable infrastructure and green developments. A year later, HKMA initiated the establishment of the Green and Sustainable Finance Cross-Agency Steering Group to foster the development of green finance in Hong Kong (HKSAR Government, 2020). The vision of the steering group is to accelerate the sustainable finance growth in Hong Kong by providing green finance policy direction and facilitating regional coordination to support the region's green finance strategy. The Hong Kong Green Finance Association has announced the launch of the Greater Bay Area Green Finance Alliance (GBA-GFA) to promote green finance in the Greater

Bay Area. The Alliance will support five green finance-related projects, three of which are led by Hong Kong: the Green Building Project, which targets to facilitate the establishment of green finance platforms for the building industry; Blockchain Solar Project, which offers innovative funding structures and new digital investment classes to promote solar energy projects; and Carbon Connect, which aims to establish a cross-border carbon trading market.

Under the Green Finance Certification Scheme, Swire Properties Limited launched the first certified green bond in Hong Kong in 2018. Hang Lung Properties, Landsea Green have also contributed to green building development through their respective green bond programmes. These green bonds finance (or refinance) green building development for projects which have or are expected to receive LEED, BREEAM, or other equivalent certifications, as well as other projects related to energy efficiency, water efficiency, waste reduction, and climate adaptations. In 2019, Swire Properties Limited converted an existing five-year revolving credit facility of HK$500 million into a sustainability-linked loan, with the interest rate being indexed against the Company's ESG performance – the first in Hong Kong to launch such a financing mechanism against its year-on-year ESG performance (Swire Properties Limited, 2020).

Sustainability-linked loans are a new thematic sustainable debt mechanism in addition to green bonds and green loans. Sustainability-linked loans generally seek to provide incentives for businesses to boost their sustainability performance, with interest rates specifically tied to environmental, social and/or governance (ESG) targets of the underlying companies (LMA, 2019). Therefore, the proceeds of sustainability-linked loans can be used either to fund specific green projects or for general ESG purposes. The global issuance of sustainability-linked loans has seen a remarkable annual growth rate of 164% in 2018-2019 (Bloomberg Finance L.P., 2020). Hong Kong has a 2% share of the global issuance, accounting for half of the sustainability-linked loan issuance in the APEC region (Our Hong Kong Foundation, 2020).

4.4.3 Renewable Energy Certificates (RECs) and Feed-in-Tariffs (FiTs)

The Renewable Energy Certificates Scheme was introduced under the Scheme of Control Agreements (SCA), signed between the Hong Kong Government and the power companies China Light and Power (CLP) and Hong Kong Electric (HKE) in 2018 and 2019 respectively. Under this scheme, the certificates are sold by the individual power companies based on units of electricity.

CLP offers RECs to all its consumers at a minimum volume of 100 units of electricity (in kWh) such that a 0.49kg/kWh emission offset could be claimed per unit (CLP Power Hong Kong Limited, 2020). HKE also issues RECs to all registered customers in blocks of 100 units on a first-come-first-served basis, while the REC inventory lasts (HK Electric Investments Limited, 2020). On top of the normal price of a unit of electricity, CLP and HKE set the price of RECs at HK$0.50, which will be reviewed annually to reflect the market demand. For CLP and HKE, RECs covering total green electricity of approximately 3 million kWh[6] and 2 million kWh[7] of renewable energy were subscribed by customers respectively for the reporting year of 2018-2019.

It is estimated that Hong Kong has around 3-4% of realisable renewable energy (RE) potential from wind, solar, and waste-to-energy. The Feed-in Tariff (FiT) scheme has pushed the growth of local renewable energy generation. Launched under the SCA in 2017, FiT allowed properties that have installed solar PV or wind systems on premise to sell RE generated to power companies at a rate of approximately five times the normal electricity tariff rate. Currently, the FiT mechanism allows owners to recover the cost of installation, operation and maintenance in approximately ten years, favouring small-scale systems (EMSD, 2019). Installations with a generating capacity of up to 1MW are eligible for prescribed FiT rates provided it has been connected to the power company's electricity grid. Systems with a capacity above 1MW are considered on a case-by-case basis.

RE Production	FiT Rate
≤10kW	$5
10kW to ≤200kW	$4
200kW to ≤1MW	$3

The number of FiT applications has seen a steady increase since its launch. FiT encourages property owners to actively support RE through installation of RE generation systems that not only provides a nominal financial return but contributes electricity into the wider community, therefore reducing the amount of energy needed to be generated through conventional coal-fired means and reducing overall emissions on a wider scale.

	Year	CLP	HKE	Total
Feed-in-Tariff (applications)	2018	1,400	70	1,470
	2019	6,900	130	7,030

4.4.4 CLP subsidies

CLP offers free energy audits to commercial and industrial customers to conduct energy system performance analysis for raising awareness of energy consumption within the applicable building and offers recommendations on opportunities to improve energy efficiency. Having identified areas for improvement, CLP provides a number of funds and schemes to retrofit buildings to become more energy efficient. Three major schemes / subsidies applicable to buildings as a whole include the Eco Building Fund, the Electrical Equipment Upgrade Fund (part of the CLP Community Energy Saving Fund[8]), and the Energy Saving Loan Scheme.

The Eco Building Fund, established in 2017, is applicable to business customers of residential, commercial, industrial and composite buildings, where CLP subsidises energy-saving improvement projects in a building's communal areas. It includes

6. From CLP 2019 Annual Report. In the same year, total reported electricity sales to be 34.3 million of kWh
7. From HKE 2019 Annual Report. In the same year, total reported electricity sales to be 10.5 million of kWh
8. CLP Community Energy Saving Fund also includes CLP Power Connect, which is directed to residential customers of CLP with the aim of encouraging energy saving behaviour through a rewards scheme, and Support for Subdivided Units Household Scheme, which gives direct assistance to people living in subdivided households.

replacement / retrofitting projects, use of smart technology to increase efficiency, and replacing old and less efficient equipment such as air conditioning and lighting. The subsidised amount depends on the building type, project nature, energy saved, and project duration. While there are no lower limits to the application, ceiling amount per application ranges from HK$250,000 - $500,000 or HK$1 million whichever the lowest amount, and each applicant is limited to 5% of annual total available funding from the Fund. Subsidies are disbursed on a reimbursement basis for project expenditures. For retro-commissioning projects or implementation of smart /IT technologies, subsidies are based around the amount of energy saved by the project for one year (as reported by applicant). In 2019, subsidies for installation of energy efficient equipment for more than 600 residential and commercial buildings was provided by the Eco Building Fund, saving approximately 50GWh of electricity.

	2019	2018
Subsidy Applications	600+	130

The Electrical Equipment Upgrade Scheme targets industrial and commercial customers within the period of January 2019 to December 2023, in particular targeting SMEs, to replace or upgrade existing equipment to be more energy efficient. These energy efficient measures include replacement of LED lighting (e.g. light bulbs, light tubes, etc.), upgrade of air-conditioning units to Grade 1 energy label registered under the Record of Listed Models of the Mandatory Energy Efficiency Labelling Scheme, and other highly energy efficient air-conditioning systems such as Variable Refrigerant Flow Systems, Air-cooled Chillers and Water-cooled Chillers. The subsidised amount is based on item type or energy saved, with a capped amount within the scheme period. This scheme targets small projects and individual organisations rather than single buildings. Therefore, the subsidised amount is relatively low and based on a per installation basis. For bulk tariff / large power tariff, the ceiling amount is HK$150,000 while for non-residential tariff is HK$10,000.

The Energy Saving Loan Scheme offers interest-free loans for implementation of savings opportunities identified through the energy audit. It is applicable for eligible energy efficient projects, such as retrofitting systems and equipment. While this does not directly subsidise the installation or implementation of enhancement features, it provides building and property owners with some financial relief when looking to implement energy saving projects. In 2019, the Energy Audit service helped over 600 commercial and industrial customers of CLP to save around 55GWh of electricity potentially (CLP Power Hong Kong Limited, 2019).

TABLE 13 CLP Subsidies

	Eco Building Fund	Electrical Equipment Upgrade Scheme	Energy Saving Loan Scheme
Eligibility^	• Business customers • Owner Corporation (registered under Building Management Ordinance Cap 344) • Owners organisation / committee • Residents' organisation	• Commercial customers • Industrial customers • SMEs	• Commercial customers • Industrial Customers • Non-government organisations • Projects under CLP Eco Building Fund • Energy savings programmes supported by CLP Community Energy Saving Fund
Building type	• Residential • Commercial • Industrial • Composite	• Not specified	
Project type	• Retrofitting project with higher energy efficiency (e.g. lighting, air conditioning) • Retrofitting projects with lower energy efficiency (e.g. lift, escalator, pump, etc.) • Retro-commissioning / implementation of smart / IT technology	• Replacement or upgrade of: • LED light bulbs and tubes • Air-conditioners with Grade 1 energy label • Other high energy efficient air-conditioning systems (e.g. air-cooled / water cooled chillers, variable refrigerant flow systems)	
Subsidised amount	• Retrofitting projects: 10%-50% project expenditure dependent on account type, building type, whole project duration • Retro-commissioning / smart technologies implementation—HK$0.7 – HK$0.9 per kilowatt hour energy saving (one year), dependent on account type, building type, whole project duration	• LED light bulb / downlight: HK$20 each or 80% of net purchase price per unit (whichever lowest) • LED Tube / light strip / panel light: HK$60 or 80% of net purchase price per unit (whichever lowest) • Air-conditioner (Grade 1 energy label): HK$1000 or 80% of net purchase price per unit (whichever lowest) • High energy efficient air-conditioning system: HK$0.5/ kWh based on energy saving (one-off payment)	• Loan application amount up to 100% of project cost capped at HK$5 million (not exceeding cumulative total loan of HK$10 million) and repayment period of 5 years (depending on type of system / equipment)
Limitations and Conditions	• The funding will be disbursed to applicants in the form of reimbursement • Whole project must be completed within 24 months • Funding amount is at a percentage of the project expenditure (energy efficiency parts only plus cost of Qualified Service Provider, if engaged), plus the funding to the service charge of Energy Saving Facilitator (if applicable) • Each applicant entitled to an annual ceiling of 5% annual total available funding from the Fund • Funding ceiling under non-residential tariff accounts or residential buildings of applicant organisations registered under Section 88 of Inland Revenue Ordinance between HK$300,000# for standard arrangement • Funding ceiling under bulk tariff / large power tariff accounts HK$250,000# for standard arrangement • For chiller arrangement, ceiling of HK$350,000#-HK$500,000#, dependent on building type, customer account, project completion and coefficient of performance of new chiller • Full subsidy will be provided to the cost of engaging Qualified Service Provider for retrofitting projects with expenditure less than HK$100,000 subject to ceiling of HK$10,000 and approval	• Equipment must be listed on "record of Listed models in The Mandatory Energy Efficiency Labelling Scheme" by EMSD • Equipment must be purchased between 1 Jan 2019 and 31 Dec 2023 • Applicants are required to self-report estimated annual energy consumption of equipment • Subsidy ceiling price per electricity account for non-residential tariff: HK$10,000 • Subsidy ceiling price per electricity account for bulk tariff/ large power tariff: HK$150,000	• Limited to projects that generate energy savings through retrofitting of existing system with more efficient designs • Applicants are required to self-report estimated annual energy consumption of existing equipment of a full year to date or nearest 12-month period

Note
^: Must be buildings located inside CLP's supply area
#: per building per year or HK$1 million per application, whichever is lower

4.4.5 HKE subsidies

HKE also launched a number of funds and schemes under "Smart Power Services" in response to the Government's energy and environmental policy, of which the "Smart Power Building Fund" and "Smart Power Loan Fund" are most applicable on a building scale.

HKE offers free inspection of business premises to analyse energy efficiency performance and identify energy saving opportunities to non-residential customers, raising awareness to energy consumption and building performance. Improvement projects resulting from this energy audit may apply for the Smart Power Loan Fund, in which HKE collaborated with local banks to provide subsidises on the loan interest of completed projects.

Applicable to non-residential customers, the Smart Power Building Fund provides subsidies for enhancing energy efficiency of communal building services installations such as retrofitting service installations (e.g. lighting, air-conditioning, lift, escalators, electrical installations), retro-commissioning, and installation of building-based smart technologies to monitor, track, and optimise energy consumption. The subsidised amount is based on the types of buildings and actual project expenditures and is disbursed on a reimbursement basis. A subsidy cap is applicable for the projects based on the number of buildings per application, except applications for enhancement on a single premise, with ancillary facilities buildings considered as one building itself. In 2019, HKE received 59 applications covering 83 buildings for Smart Power Building Fund (HK Electric Investments Limited, 2019).

Subsidies from energy companies are generally based around upgrading existing equipment to enhance energy efficiency of existing buildings rather than targeting new buildings. They provide additional support for optimising building operations and reducing carbon emissions through improving energy efficiency.

TABLE 14 HKE Subsidies

	Smart Power Building Fund	Smart Power Loan Fund
Eligibility^	• Non-residential customers (except HKSAR Government)	• Non-residential customers
Building type	• Residential • Composite • Buildings / property operated by non-profit-making NGOs for education / welfare • Commercial • Industrial	• Projects approved under Building Fund • Projects identified through Energy Audit
Project type	• Retrofitting communal building services installations (i.e. lighting, air-conditioning, lift and escalator, electrical installations) • Enhancing communal building services (e.g. building-based smart technologies	
Subsidised amount	• Category 1 Multi-owned residential / composite buildings (for residential use): 50% for buildings with ancillary facilities, 25% for others • Category 2 Buildings owned / operated by NGOs for education, community or welfare services: 80% for whole buildings / premises • Category 3 Other buildings, not belonging to Category 1 or 2: 50% for multi-owned buildings without central air conditioning facilities, 25% for others	• Cost of materials, installation, testing and commission that contributes to energy efficiency are covered, maximum of HK$3 million or 80% of Eligible Project Cost (whichever lowest)
Limitations and Conditions	• Subsidised as a percentage of the Net Eligible Project Cost (cost of materials, installation, testing and commissioning, and service fee of Qualified Service Provider less Project Subsidy and/or Revenue) less Project Subsidy / Revenue (estimated revenue gained from project and / or subsidies of similar nature from other sources) • For eligible projects involving chiller plants, only cost of item relating to the portion for communal use can be considered • Maximum subsidy for each category of building is subject to the number of buildings per application • Category 1 cap HK$500,000# - HK$1,500,000* for buildings for residential use, and HK$250,000# - HK$400,000* for others • Category 2 cap HK$500,000# - HK$1,500,000* for whole buildings, and $250,000 (applicable for single premise only) • Category 3 cap HK$500,000# - HK$1,500,000* for multi-owned buildings without central air-conditioning, and HK$250,000# - HK$400,000* for others • If same building/premise have received subsidy within the 5-year period prior to the date of submission under different project, the cap amount will be reduced by the aggregate of such subsidy amount • Full subsidy will be provided to the cost of engaging Qualified Service Provider for retrofitting projects with Eligible Project Cost of less than HK$100,000 subject to ceiling of HK$10,000 and approval	• Eligible Project Costs include the net of any contributions, grants, loans or rebates from other funding sources including subsidy under Smart Power Building Fund • Cumulative amount of loans from multiple applications by the same applicant within each 5-year period (Jan 2019 – Dec 2023, Jan 2024 – Dec 2028, Jan 2029-Dec 2033) must not exceed HK$6 million and cover different energy efficiency projects • Technical assessment carried out by HKE upon submission to determine Eligible Project Cost and estimated payback period as these technologies mature • Disbursement of Interest Subsidies on a reimbursement basis

Note
^: Must be buildings located inside HKE's supply area and not owned or operated directly by Government
#: Single building
*: 6 or more buildings

4.4.6 Electricity Tariff

Tariff setting is determined by the Scheme of Control Agreement (SCA) between the Government and the electricity company. The tariff charged is based on the "Basic Tariff", which reflects the cost of service, and "Fuel Cost Adjustment", the cost of rebate or surcharge on consumers that takes into account the difference between actual fuel price and forecasted fuel price. Low-energy consumers are charged based on consumption, with an inclining block structure for domestic tariffs where higher consumption is charged at a progressively higher unit rate. A demand charge is added on top of the energy charge to cover cost of facilities to support non-residential consumers with high demand for electricity.

For bulk and large power tariff customers, CLP's Peak Demand Management program aim to encourage reduction in electricity consumption during peak demand hours. CLP notifies customers of the specific hours that is anticipated to have extremely high electricity demand. Financial incentives are paid according (HK$10 – HK$15) to each kWh of electricity demand reduction realised and are offset against billing charges (CLP Power Hong Kong Limited, 2020). Similarly, a one-year pilot scheme for 26,000 CLP residential customers for both public and private housing with smart electricity meters was previously launched in 2017, in which during peak demand periods of 6pm-10pm the tariff was set at HK$0.60 more while off-peak periods from 10pm-9am was set HK$0.18 lower than normal (CLP Power Hong Kong Limited, 2017). The residential scheme was met with mixed views as residents who return home late will be forced to pay higher rates for electricity (SCMP, 2017).

CLP has identified Carbon Capture and Storage (CCS) and hydrogen as potential technologies to aid the journey towards decarbonisation. Current CCS projects tend to be very costly and energy-intensive and the use of hydrogen is still considered to be as at an early stage for Hong Kong. While this may not affect the design and construction of buildings, it may have implications on the buildings' operation in terms of cost of electricity as these technologies mature.

5 INTERNATIONAL REVIEW

5.1 Singapore

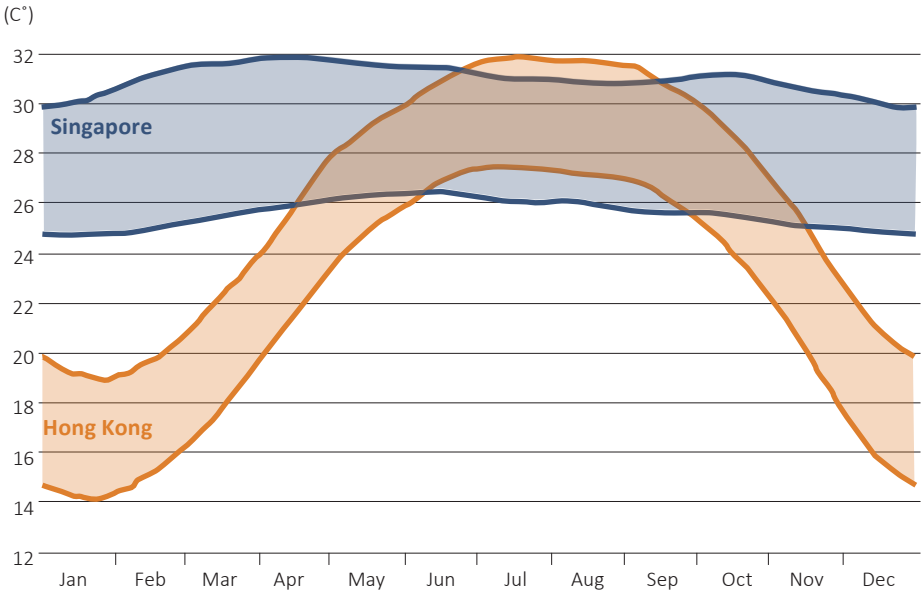
Hong Kong and Singapore are similar in several aspects. They are both high-rise and densely populated cities with sub-tropical and tropical climates, respectively.

TABLE 15 Population and Humidity Data for Hong Kong and Singapore

	Hong Kong	Singapore
Population Density	Very High	High
Relative Humidity	77%	84%

FIGURE 16 Yearly Temperature Profile for Hong Kong and Singapore

source: Weather Spark, n.d.



The daily average high and low air temperatue at 2 metres above the ground

Buildings in Hong Kong consume up to 90% of total electricity generated in Hong Kong, while buildings in Singapore consume up to half of the nation's generated electricity (Environmental Bureau, 2017) (Nanyang Technological University, Singapore, n.d.). The Singapore Government is committed to achieve at least 80% of buildings with green features in Singapore by 2030. Therefore, when establishing environmental sustainability regulations and incentives for Hong Kong, policies of the Singapore Government can be referenced.

The 3rd Green Building Masterplan developed by Singapore BCA provides an overarching framework for the goals and incentives of the Singapore building sector. BCA aims to advance three aspects:

1. Continued Leadership
Singapore aims to become "A global leader in green buildings with special expertise in the tropics and sub-tropics, enabling sustainable development and quality living."

2. Wider collaboration
It is important for all stakeholders to be involved in the green building movement, therefore, a change in behaviour will be needed to succeed in driving sustainability.

3. Proven Sustainability Performance
To assess the sustainability performance of a building, BCA encourages the monitoring and sharing of information across the projects' whole life.

5.1.1 Code for Environmental Sustainability of Buildings (CESB)

Singapore's Building Sustainability regulations are structured differently as compared to Hong Kong's regulations. The top-level code is based on Green Mark, the Green Building certification programme of the Building and Construction Authority of Singapore (BCA), and covers not only energy efficiency, but also 'Water Efficiency', 'Environmental Protection', 'Indoor Environmental Quality' and 'Other Green Features'. This high-level code is called the 'Code for Environmental Sustainability of Buildings' and is similar to the minimum standards for BEAM Plus accreditation. Green Mark is the key driver of energy efficiency, and therefore operational carbon emissions in Singapore. This Code ensures that, outside prescribed exceptions, all buildings in Singapore meet the minimum requirements for this certification programme.

The energy efficiency section is covered by a set of standards called the 'Code of practice for energy efficiency standards for building services' and is analysed below. This is equivalent to the BEC and lists out the baseline requirements for the major BSIs.

Exceptions to the Code for Environmental Sustainability of Buildings are similar to those in Hong Kong in that they exclude smaller works that are likely to consume less energy, as shown in Table 16.

TABLE 16 Exceptions to Hong Kong and Singapore's Energy Codes

Hong Kong	Singapore
Electricity supply does exceed 100A (1- or 3-phase)	New building works with GFA > 2000m²
3 or fewer storeys or ≤8.23 m high	Existing Buildings: • Additions or extensions that will increase GFA by > 2000m² • With GFA > 2000m², all Major retrofitting works
Roof area ≤65 m²	
A declared monument or historic buildings covered by the Antiquities and Monuments Ordinance Cap	

Achieving Compliance

Like Hong Kong, the compliance process in Singapore requires a Qualified Person (QP) to ensure that building works comply with the Code. This includes the design as well as the methods and materials selected by the project team. The QP has overall responsibility, alongside professional mechanical and electrical engineers to assess and score the relevant building works.

The two major Green Mark schemes are applicable to residential and non-residential buildings, with other schemes available for certain special-use buildings such as schools and transit stations. To comply with this Code, buildings must achieve a minimum score of 50 over the whole certification process. In the Energy Efficiency section, a minimum of 30 points is required, shown in Figure 17 and Figure 18. The other four sections must contribute a minimum of 20 points. The allocation of points available for the energy efficient section for residential and non-residential buildings are shown below:

FIGURE 17 Singapore Green Mark (Residential) points allocation for Energy Efficient features

Catergory		Point Allocations
Energy related requirements		
Min. 30 points	**Part 1: Energy efficiency**	
	RB1-1 Thermal performance of building envelope - RETV	15
	RB1-2 Naturally ventilated design and air-condition system	22
	RB1-3 Daylighting	6
	RB1-4 Artificial lighting	10
	RB1-5 Ventilation in carparks	6
	RB1-6 Lifts	1
	RB1-7 Energy efficient features	7
	RB1-8 Renewable energy	20
	Category score for Part 1: Energy efficiency	**87 (max)**

FIGURE 18 Singapore Green Mark (Non-residential) points allocation for Energy Efficient features

Catergory			Point Allcations
Energy related requirements			
Min. 30 points	**Part 1: Energy efficiency**		
	NRB1-1 Thermal performance of building envelope - EETV	Section (A) applicable to air-con areas	12
	NRB1-2 Air-conditioning system		30
	Sub-total (A): NRB 1-1 to 1-2		42
	NRB1-3 Building envelope - design/thermal parameters	Section (B) applicable to non air-con areas excluding carparks and common areas	35
	NRB1-4 Natural ventilation/ Mechanical ventilation		20
	Sub-total (B): NRB 1-3 to 1-4		55
	NRB1-5 Daylighting	Section (C) generally applicable to all areas	6
	NRB1-6 Artificial lighting		12
	NRB1-7 Ventilation in carparks		4
	NRB1-8 Ventilation in common areas		5
	NRB1-9 Lifts and escalators		2
	NRB1-10 Energy efficient practices and features		12
	NRB1-11 Renewable energy		20
	Sub-total (C): NRB 1-5 to 1-11		61
	Category score for Part 1: Energy efficiency **Prorate subtotal (A) + Prorate subtotal (B) + Prorate subtotal (C)**		**116 (max)**

This approach is different from that in Hong Kong because points must be earned beyond the minimum requirements in order to satisfy the higher-level code. There is also flexibility in achieving compliance. A designer, once the baseline has been met across all categories, must target different points in order to achieve the 30-point requirement. There are restrictions to ensure that the selected measures make a meaningful contribution to the energy efficiency of the building:

- Points for the AC system are only counted if the conditioned area is > 500m²
- Points for non-conditioned areas are only counted if the non-conditioned area is >10% of the total GFA, excluding car parks and common areas.

This Code therefore works in tandem with the minimum requirements listed in the 'Code of practice for energy efficiency standard for building services and equipment' by mandating energy-efficiency improvements beyond the baseline.

i) SS 530: 2014 – 'Code of practice for energy efficiency standard for building services and equipment'

This Code, referred to as SS530 for clarity, provides specific technical requirements on BSIs. The latest edition, released in 2014 and updated from the 2006 version based on improvements in international standards, covers the BSIs shown in Table 17 below. There are differences in the application and design of the code compared to BEC although these differences do not necessarily affect the operational carbon emissions.

SS 553: 2016 'Code of practice for air-conditioning and mechanical ventilation in buildings' sets out several design conditions and control requirements related to AC equipment that also affect energy-efficiency and are applied in a similar way to BEC so are included in the comparison table for completeness.

There are two major additional sections in SS530 covering the energy-efficiency of Water Heaters and provision of Exterior Lighting. The 'Electrical Installations' section in BEC covers the equivalent of the 'Electric Motors' and 'Distribution Transformers' section of SS530.

TABLE 17 **Hong Kong and Singapore Energy Code section comparison**

Hong Kong – BEC 2018	Singapore – SS 530
AC Equipment	AC equipment
Lighting Installations	Lighting Installations Additional section: Exterior Lighting
Electrical Installations	Electric Motors Distribution Transformers
Lifts & Escalators	Lifts & Escalators
-	Additional section: Water Heaters

When analysing the codes, the reader should note that the COPs for the maximum and minimum AC equipment sizes have been included from the equivalent Hong Kong code, and the closest equivalent has been included from the relevant Singapore code.

AC Equipment

TABLE 18 Hong Kong and Singapore Energy Code section comparison

Requirement	Hong Kong – BEC 2018			Singapore – SS 530: 2014 & SS 553: 2016		
System Load Calculation	Summer	Min Dry Bulb Temp	22-23°C (Space dependent)	Whole Year	Min Dry Bulb Temp	23-25°C
		Min Relative Humidity	50%		Max Relative Humidity	65%
	Winter	Min Dry Bulb Temp	22-24°C (Space dependent)			
		Min Relative Humidity	50%			
Separate Air Distribution System for Process Zone	Special process or temperature/humidity requirement. Exceptions: • SA ≤ 25% of Comfort Zone flowrate • Served Comfort Zone < 100m²					
Air Distribution Ductwork Leakage Limit	If the Operating Static Pressure >750Pa, at least 25% of duct area tested in accordance with DW143.			If the Operating Static Pressure >750 Pa, at least 25% of duct area tested in accordance with industry accepted test procedures.		
Air Distribution System Fan Power	If system fan power >2.5kW or if AHUs system, for each AHU, the motor power of fan is > 1kW: • Constant Air Volume: 1.6 W/L/s • Variable Air Volume: 2.1 W/L/s			If AHU system fan power > 4kW: • Constant Air Volume: 0.47 • Variable Air Volume: 0.67		
	If system fan motor power ≥ 1 kW: Mechanical Fan: 1.1 W/L/s			If system fan power > 4 kW: Mechanical Fan: 1.26 W/L/s		
	Fan motor > 1 kW should be able to vary the flowrate as a function of the load					
Pumping System Variable Flow	Variable Flow Control and ability to reduce to ≤ 50% of design flowrate. Exceptions: • > 3 Control Valves • If Supply Water Temperature Reset Control is included • Chiller Plant design capacity ≤ 350 kW			• Chilled water system pump power < 349 kW/m³/s • Condensing water system pump power < 301 kW/m³/s		
	If Motor Output Power > 3.7 kW, controls included so no more than 30% of Design Input Power required at 50% of Design Flow			If Motor Output Power > 3.7 kW, controls included so no more than 30% of Design Input Power required at 50% of Design Flow		
Frictional Loss of Water Piping System	When Diameter ≤ 50 mm, Water Velocity ≤ 1.2 m/s When Diameter > 50 mm, Friction Loss ≤ 400 Pa/m, and for: • Constant Flow - velocity ≤ 2.5 m/s • Variable Flow - velocity ≤ 3 m/s					
SYSTEM CONTROL						
Temperature	1 x Automatic Temperature control device per AC system For cooling, adjustable to ≥ 29 °C For heating, adjustable to ≤ 16 °C Temperature control for comfort cooling/heating, deadband of 2°C Exception: • Unitary AC with integrated control device			Room Temperature Control should be within ± 1 °C in actual operation		
Humidity	1 x Automatic humidity control device per AC system • For humidification, adjustable up to 60% • For dehumidification, adjustable down to 30%					
Zone	Separate temperature control device for each zone, not usually across different floors Some exceptions, but no heating and cooling at the same time			Enough number of zones should be provided when the AC system serves area with different cooling requirements.		
Off-Hours	Each AC system must have automatic controls to reduce energy use during periods of zero occupancy through equipment shutdown; • Occupancy sensor and 7-day customised schedule or setback; • Cooling: > 5°C above setpoint • Heating: > 6°C below setpoint			AC systems must have automatic control of at least one of the following to enable them to shutdown automatically; • 7-day customised schedule • Occupancy sensor • Interlock to a security system Hotel guestrooms, space demanding continuous operation and systems with cooling capacity less than 4.4 kW with manual control are exempted. Air handling units with a supply of > 5 m³/s should have an optimum start control		
	When system ≥ 10 kW, each hotel guest room should have a single master control device to reduce energy use when unoccupied.					

Requirement	Hong Kong – BEC 2018		Singapore – SS 530: 2014 & SS 553: 2016	
SYSTEM CONTROL				
Isolation of Zones	Zone occupied non-simultaneously should be isolated when the area > 2300 m² and then equipped with controls to shutoff supply, fresh and exhaust air. Central systems equipped with control to serve smallest isolation area. Exceptions: • Exhaust air and fresh air systems ≤ 2400 L/s • Isolation areas operated 24/7		Zones occupied non-simultaneously should be isolated when the area > 2300 m² and then equipped with controls to shutoff supply, fresh and exhaust air. Central systems equipped with control to serve smallest isolation area. Exceptions: • Exhaust air and fresh air systems ≤ 2400 L/s • Isolation areas operated 24/7 • Exhaust airflow from a single isolation zone of less than 10% of the design airflow	
VAV Distribution	Controller set point ≤ 300 Pa and placed along major branches as required.		Static pressure sensors shall be placed in a location where controller set point ≤ 1/3 of the total design fan static pressure.	
	Set Point reset based on actual demand of conditioned space.		Set point shall be reset based on the zone requiring the most pressure.	
DCV	In Car Parks, for systems with power ≥ 11 kW, ability to modulate or stage down to ≤ 50% of design capacity based on contaminant level.			
	For an AC system with Fresh Air flowrate ≥ 1400 L/s, DCV required according to CO_2 level. Exceptions: • System has Exhaust air energy recovery			
THERMAL INSULATION				
	Thickness requirements applied to Chilled Water and Refrigerant pipework, ductwork and AHU Casing.		Thickness and R-values requirements applied to Chilled Water and Refrigerant pipework, ductwork and AHU Casing.	
AIR CONDITIONING EQUIPMENT EFFICIENCY				
	Air-Cooled Min. COP	Water-Cooled Min. COP	Air-Cooled Min. COP	Water-Cooled Min. COP
Unitary	≤ 7.5kW: 2.3 ≥ 200 kW: 3.1	3.3	≤ 8.8kW: 2.9 (NEA Singapore, 2018) ≥ 223 kW: 2.84	≤ 19kW: 3.54 ≥ 223 kW: 3.57
VRF System	≤ 20kW: 3.6 ≥ 200 kW: 3.3	4.5	≤ 17.6kW: 3.78 ≥ 70 kW: 3.28	< 19kW: 3.52 ≥ 40 kW: 2.93
Reciprocating & Scroll Chiller	≤ 400kW: 2.8 ≥ 400 kW: 2.9	≤ 500kW: 4.2 ≥ 1000kW: 5.3	≤ 528kW: 2.985 ≥ 528kW: 2.985 Integrated Part Load Value also provided based on AHRI 551/591. Equivalent of a weighted COP value that provides a measure of relative part load performance comparison.	≤ 263kW: 4.694 ≥ 1055kW: 5.771 IPLV also provided based on AHRI 551/591
Screw & VSD Screw Chiller	≤ 400kW: 3.0 ≥ 400 kW: 3.1	≤ 500kW: 4.8 ≥ 1000kW: 5.5	≤ 528kW: 2.985 ≥ 528kW: 2.985 IPLV also provided based on AHRI 551/591	≤ 263kW: 4.694 ≥ 1055kW: 5.771 IPLV also provided based on AHRI 551/591
Centrifugal & VSD Centrifugal Chiller	3.2	≤ 1000kW: 5.4/5.3 ≥ 1000kW: 5.8	≤ 528kW: 2.985 ≥ 528kW: 2.985 IPLV also provided based on AHRI 551/591	≤ 528kW: 5.771 ≥ 1055 kW: 6.286 IPLV also provided based on AHRI 551/591
Heat Pump	Air-to-Water: ≤ 100kW: 2.8 ≥ 500kW: 3.1	Water-to-Water: ≤ 500kW: 4.4 ≥ 500kW: 4.5		
Open Circuit Cooling Tower	• Centrifugal Fans: 1.7L/s/kW • Propeller/Axial Fans: 3.4 L/s/kW NB: Rating Conditions slightly different If Motor Output Power ≥ 3.7kW, variable flow control so power consumption is < 30% of design input power at 50% of design flowrate.		• Centrifugal Fans: 1.7 L/s/kW • Propeller/Axial Fans: 3.23 L/s/kW NB: Rating Conditions slightly different – references Cooling Tower Institute procedure Also applies to Closed Circuit Cooling Towers	

Requirement	Hong Kong – BEC 2018	Singapore – SS 530: 2014 & SS 553: 2016
Energy Metering	• Chiller, Heat Pump, Unitary AC or Chilled/Heated water plant with ≥ 350 kW of cooling/heating capacity, must be equipped with continuous monitoring facilities to measure its power (kW) & energy (kWh) input and output and coefficient of performance. • AHUs with motor(s) with a power rating ≥ 5 kW inside a plant room, metering devices or the provision of measurement should measure the power (kW) consumption	Main meter thresholds: • Electricity: > 200 kW • On-site renewable energy: >1 kW • Gas and steam service: > 300 kW
Direct Digital Control	Required for: • Chilled/Heated water plants with capacity ≥ 350 kW serving more than 3 zones • Air Distribution System for a conditioned space with system fan motor power ≥ 7.45 kW	

Lighting Installations

SS530 contains a table of LPD requirements covering common space types. Examples of common space types are provided in Table 19. The list of spaces is not as extensive as that provided in BEC 2018, but there are other options provided in SS530 for calculating LPD requirements based on room shape and illuminance requirements. This means the approach to LPD is different which makes direct comparison more difficult and conclusions difficult to draw. Nevertheless, of the 24 spaces that are shared by both SS530 and BEC, SS530 had stricter maximum LPDs for fifteen of these spaces and the same requirements for a further five.

TABLE 19 SS530 and BEC LPD Requirements Sample

Space Type	Hong Kong – BEC 2018 (W/m²)	Singapore – SS 530: 2014 (W/m²)
Entrance Lobby	13	10
Office (according to Floor Area)	Area ≤ 15m²: 12 15m² < Area ≤ 200m²: 10 Area > 200 m²: 9	12
Plant Room	10	10
Washroom	11	12

As outlined previously, lighting control is an important part of controlling the energy-efficiency of lighting installations. Singapore takes a different approach for interior lighting control, which is summarised and compared with BEC in Table 20.

TABLE 20 BEC and SS 530 Interior Lighting Control approach

Hong Kong – BEC 2018	Singapore – SS 530: 2014
Lighting Control Points: • Control ≤70W of lighting power per point • Equation to determine number of points required according to floor area	General Control requirements: • Lighting control points should be readily accessible or be automated. • Maximum control area of <1000m², 250m² if the enclosed space is <1000m² • Separate control of general, display and ornamental lighting
Automatic Lighting Control: • Installations <150W do not require control • Able to reduce or shut off power consumption by at least 50%. • If the space is exposed to exterior light, Daylighting controls are required when automatic lighting controls are required • Maximum 2000m² covered • BEC lists the types of spaces that require Automatic Lighting Control	Automatic Lighting Control: • All luminaires providing general lighting in a daylighted zone need to be controlled independently from luminaires in other zones. • Common areas receiving >150% of designed illuminance (usually on rainy/overcast days), daylight control is required via daylight sensor or timers. Unless daylight area is <20m² or the total luminaire power consumption is <120W
	Light Control Allowances gives a space an overall reduction in LPD if the space has a certain type of control strategy applied to it according to a multiplier called a 'Power Adjustment Factor' (between 0.01 and 0.3). Mandatory daylighting is excluded. Ten control strategies available, based around occupancy and automatic dimming requiring manual override.

The Power Adjustment Factor gives designers flexibility. BEC is prescriptive when assigning requirements for Automatic Lighting Control to a space, even if in some cases it might be appropriate, or if a space could be categorised under different BEC labels, with different requirements.

BEC 2018 specifically excludes all types of external lighting, apart from a single LPD requirement for car parks. It excludes building façade and architectural lighting and outdoor lamps whereas SS530 comprehensively addresses lighting for the building exterior and outdoor spaces such as driveways, pavements, cycle paths, plazas and 'other improved areas.' Timers and daylight sensors are required to control the lights in these spaces during the following conditions:

- when there is enough daylight
- for building façade and landscape lighting; during non-business hours (after 12am)

Exterior Lighting requirements are split up according to the building location, divided from Zone 1, with the most stringent requirements, to Zone 4, with the loosest requirements.

- Zone 1 covers National Parks, forest land rural areas.
- Zone 2 consists of residential areas, neighbourhood business districts and light industrial area.
- Zone 3 consists of 'all other areas' i.e. areas not covered by Zones 1, 2 and 4.
- Zone 4 is the high activity central business district area.

Table 21 shows the type of spaces, the regulations and the way in which the requirements are adjusted according to the zones. Zone 4, where the local environment is already brightly lit allows a higher LPD compared to more rural areas where additional lights will have a greater impact.

TABLE 21 SS 530 Maximum Exterior Lighting Power Density - Hardscape

Hardscape Lighting for uncovered Areas	BEC 2018	Zone 1	Zone 2	Zone 3	Zone 4
Linear Wattage allowance (W/m) Walkways	-	1.5	2	2.5	3
Area wattage allowance (W/m²) Plazas, pedestrian tunnels	-	1.5	1.6	1.8	2.2
Area wattage allowance (W/m²) Uncovered parking, walkways, cycle paths	Car Park: 5	0.5	0.7	1.2	1.5

Table 22 contains examples of the application of the zonal thinking to different types of spaces. In total, 17 types of outdoor zones have associated requirements. The Charter for External Lighting is the closest Hong Kong policy equivalent, but this does not provide specific numbers or requirements. As outlined previously, it is purely voluntary and requires only that certain external lights be turned off between midnight and 8am.

TABLE 22 530 Maximum Exterior Lighting Power Requirements - Specific Applications

Building Exterior Lighting	Zone 1	Zone 2	Zone 3	Zone 4
Total Watts: Building Entrances/Exits, within 7m	30	60	90	90
W/m: Outdoor Sales Frontage, shopfront	N/A	75	120	150
W/m²: Building Facades	N/A	1.1	1.6	2.2

Electric Motors

TABLE 23 SS 530 Electric Motors Requirement

Requirement	Hong Kong – BEC 2018	Singapore – SS 530: 2014 & SS 553: 2016
Power Distribution Loss	Maximum copper loss: • Main circuit: < 0.5% • Feeder circuit: < 2.5% • Sub-main circuit, <100m length: < 1.5% • Sub-main circuit, >100m length: < 2.5%	
Motor Efficiency	Minimum nominal full-load efficiencies are 80.7% to 96% for three-phase totally enclosed induction motors of 0.75 kW to 200 kW	Nominal full-load efficiency requirements provided for general purpose single-speed polyphaser squirrel-cage induction of 0.75 kW to 185 kW. Minimum Energy Performance Standards (MEPS) International Energy Efficiency Class 3 for all continuously operated single-speed motors.
Power Quality	Total power factor for a circuit at or above 400A at designed circuit current should not be less than 0.85	
Metering and monitoring facilities	Main circuit and feeder/sub-main circuits > 400 A: Metering devices for voltage, current, total power factor, total energy consumption, maximum demand and total harmonic distortion. Feeder/ sub-main circuit >200A and <400A: Metering devices for measuring currents and total energy consumption.	

Distribution Transformers

TABLE 24 SS 530 Distribution Transformers Requirements

Requirement	BEC 2018	SS 530: 2014
Transformer Efficiency	At 100% load: < 1000kVA: 98% ≥ 1000kVA: 99%	Applies to: Single-phase >10kVA up to 50kVA Three-phase >25kVA up to 3150 kVA Efficiency at 50% load for Three-phase, 1000 kVA: 98.87% to 99.37% depending on application

Lifts & Escalators

SS530 simply references VDI 4707, a lift energy-efficiency classification guideline established by the Association of German engineers for planning. For installed equipment, it suggests the use of ISO 25745 (Energy performance of lifts, escalators and moving walkways), an international standard.

VDI 4707 measures and classifies lifts according to their energy performance. A rating is assigned, from A to G, in addition to a figure for yearly nominal energy demand. This rating measures both standby and travel energy and depends on variables such as travel height, speed, load and frequency of use.

FIGURE 19 **VDI 4707 testing steps**

Schindler NZ, n.d

Measurements
- Measured energy demand
- Classified into A-G ratings

Mathematical model
- Elevator/customer data
- Given specifications influence the weighing of travel and stand-by energy demand
- Influence the total classification

Classification
- Rating given according to individual unit specification and usage
- Total energy-efficiency classes from A-G, whereby A is “best in class”

BEC 2018 contains two tables that state maximum power requirements for lifts at certain rated load capacities and rated speeds for (1) new buildings and (2) major retrofitting works.

TABLE 25 BEC 2018 and SS 530 Lift and Escalators Requirements comparison

Lifts	BEC 2018	SS 530: 2014
Lift Maximum Allowable Power	Maximum Power (kW) specified according to Rated Load (kg) and Rated Speed (m/s) and the location of the lift in a new building or as part of major retrofitting works.	Suggests the use of VDI 4707 & ISO 25745 international testing standards. Energy Efficiency Class (A-G) based on energy consumption over a unit of time (typically a year). No minimum standard set
Total Power Factor	≥0.85	
Lift Decoration Load	Lift load < 1800 kg: Decoration < 0.45L or 490 kg Lift load ≥ 1800 kg: Decoration < 1015 or 0.308L-0.0000211L^2	
Lift Parking Mode	Under normal operation, at least 1 lift should be under parking mode during times with low demand.	
Lift MVAC	Ventilation should be turned off automatically after the lift has idled for 2 minutes. Air-conditioning should be turned off automatically after the lift has idled for 10 minutes and should turn on no earlier than 5 minutes after the shut off.	
Lift Regenerative Braking	Regenerative braking should be provided if: • Rated speed > 2.5 m/s • Rated load > 1000 kg	
Lift Car Lighting	• LPD < 11 W/m^2 Lift car lighting should be reduced to 50% automatically after idling for 10 minutes.	
Escalator Maximum Allowable Power	Maximum power should not exceed maximum values in the code, depending on the nominal width, rise and rated speed.	
Escalator Automatic Speed Reduction	Escalator should be able to operate with reduced speed when demand is low.	

There are several advantages to relying on international testing standards for lifts and escalators:

1. Reduce trade barriers – remove the regulatory barrier to entry to the Hong Kong market
2. Positively influence investment in innovation and energy-efficiency
3. Can lead to improved product functionality (European Commission, 2015)

Although there are barriers to overcome to implementation, aligning Hong Kong's regulations with international regulations will, in the long-term, reduce the burden on the EMSD to develop local regulations, as well as that on manufacturers who must adhere to a Hong Kong-specific compliance process. The grading systems of international standards also provide a mechanism to easily tighten regulations and incentivise the deployment of more energy-efficient equipment.

Envelope Thermal Transfer Value (ETTV)

Singapore regulates the thermal transfer into the building envelope with the code on envelope thermal performance for buildings. The code covers envelope and roof thermal transfer for air-conditioned non-residential buildings and the overall transmittance for residential buildings.

The code provides maximum values for Envelope Thermal Transfer Value (ETTV), Roof Thermal Transfer Value (RTTV) and Residential Envelope Transmittance Value (RETV), which correspond to OTTV of wall, OTTV of roof and RTTV in Hong Kong codes respectively.

Since the calculation methodologies of ETTV and OTTV are different, a comparison cannot be made without a detailed study. However, an additional section about roof insulation for air-conditioned non-residential (without skylight) and residential buildings is built on the RTTV in the Singapore code but not in codes of Hong Kong. Since an uninsulated roof will lead to a high heat gain in the building, and in Singapore, intensity of radiation on a horizontal surface is three times of that on a vertical surface (Building and Construction Authority, 2008). Therefore, insulation plays a crucial role in decreasing the cooling load of the building and the regulation requires the roof to meet U-value limits shown in Table 26.

TABLE 26 **Maximum Allowable Thermal Transmittance Values of Rood of Air-conditioned Buildings**

Weight Group	Weight Range (kg/m^2)	Maximum Thermal Transmittance (W/m^{2}K)
Light	Under 50	0.5
Medium	50-230	0.8
Heavy	Over 230	1.2

Water Heaters

This section does not have an equivalent in BEC 2018 because there are no requirements surrounding hot-water systems under Hong Kong regulations, except control for AC systems that require hot water input. In SS 530, boilers and other types of water-heating equipment are given minimum efficiency ratings according to specified testing procedures. The first section covers gas- and oil-fired boilers, producing hot water and steam, with minimum efficiencies from 77% to 84% depending on the type and size.

Despite being outside of the BEC, parts of this regulation covering lower capacity gas-fired heaters overlap with Voluntary Energy Efficiency Labelling Scheme in Hong Kong because they are typically used in non-commercial settings such as residential dwellings. The ‘Recognition Type’ label that does not grade equipment is awarded to equipment that is voluntarily submitted for testing and meets minimum requirements. These requirements are referenced from English and Japanese

standards, and correspond to energy-efficiencies of approximately 82%, up to a maximum heat input of 70 kW.

It also covers electric, gas and oil water heaters, with requirements given in Thermal Efficiencies, Energy Factors and Standby Losses. While a majority of these do not have equivalent requirements in Hong Kong, storage-type electric water heaters are covered under the Mandatory Energy Efficiency Labelling Scheme (MEELS), which requires all equipment be graded between 1 and 5. MEELS and SS530 use completely different testing procedures making comparison very difficult, with SS530 following US testing standards. It should be emphasised that SS530 is comprehensive, covering virtually all types of water heater types and sizes.

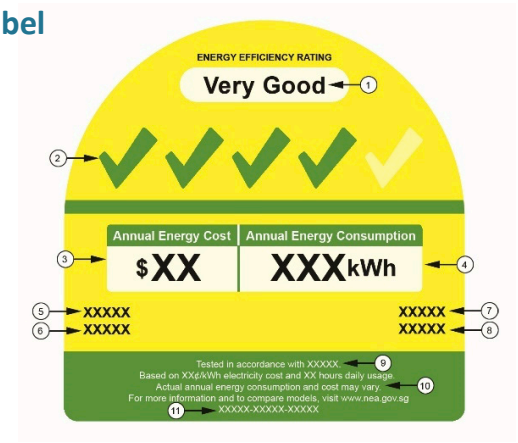
A separate sub-section for high-capacity systems requires a minimum thermal efficiency of 90% and it applies to new buildings with gas service hot-water systems with a total capacity of 293 kW or greater. This would therefore apply to buildings with large hot water requirements such as hotels. This section has the following exceptions:

- where ≥25% of the annual service water-heating requirement is provided on-site by solar hot water installations or from site-recovered energy
- Water heaters inside individual residential units
- Individual Gas Water Heaters with input capacity ≤29 kW (this therefore excludes types typically used in bathrooms in Hong Kong)

5.1.2 Mandatory Energy Labelling Scheme (MELS) and Minimum Energy Performance Standards (MEPS)

Mandatory Energy Labelling Scheme has a direct comparison in MEELS and VEELS in Hong Kong, with a similar application and objectives. MELS designed to help consumer compare energy efficiency and make informed decisions while MEPS works to raise the average energy efficiency of covered equipment provided by the market. These Schemes are enforceable under the Energy Conversation Act and require suppliers to register with the National Environment Agency (NEA) of Singapore.

FIGURE 20 MELS Label



It covers the following consumer goods, most of which are aimed at the consumer level:

- AC Units <17.6kW
- Household Refrigeration Appliances
- Clothes Dryers
- Televisions
- Lamps

Notably, it also covers single-speed, three-phase induction motors across a full range of rated power, 0.75kW to 375kW. The requirement is to achieve International Energy Efficiency Class 3 (IEC 3) against an international testing standard. Guidance is also provided for achieving International Energy Efficiency Class 4 (IEC 4).

The energy efficiencies are represented by the number of ticks shown on the energy label displayed on the products. Five ticks represent the most efficient and one tick represents the least. A comparison of the most efficient gradings of Singapore and Hong Kong is shown in Table 27.

TABLE 27 Comparison between MEELS and MELS

Device	Parameter	HK MEELS	SG MELS
Split type non-inverter Air conditioners	SEER (W/W)	> 4.5	>5.5
Televisions	Energy Efficiency Index (EEI)	< 0.13	< 0.16
Compact Fluorescent Lamps	Luminous Efficacy (Lumen/W)	> 110	> 135

Devices with comparable energy efficiency grades were compared and the better performing standards are shown in Table 27. It is seen that two out of three equipment from Singapore outperform those of Hong Kong. Thus, it is suggested that the energy efficiency gradings in Hong Kong should be reviewed and revised regularly in order to keep up with the latest technology.

To add on MELS, the Minimum Energy Performance Standards (MEPS) set threshold energy efficiencies for the devices. This means that devices with energy efficiency lower than those that are set in MEPS are not allowed to enter Singapore's market. This would have an expected effect of improving the average efficiency of the regulated devices in the market. Hong Kong may also adopt MEPS to ban new inefficient goods to be sold.

5.1.3 Existing Buildings

i) Code for Environmental Sustainability Measures for Existing Buildings

The Code for Environmental Sustainability Measures for Existing Buildings sets out the minimum environmental sustainability requirements for existing buildings. It acts in a similar way to the previous code covering New Buildings – it follows the Green Mark Green Building certification scheme and covers a range of Green Building topics including:

- Energy consumption monitoring
- Air-conditioning system minimum operating efficiency
- Energy improvement on lighting system
- Water consumption monitoring
- Chiller plant measurement and verification (M&V) instrumentation
- Indoor temperature
- Indoor air quality (IAQ) surveillance audit

It should be highlighted that this code combines the Energy Audit Code with the BEC Major Retrofitting Works section. It therefore contains guidance on reviewing existing buildings, as well as technical requirements on the systems to be replaced. The requirements in Table 28 show that it focusses on larger buildings that are likely to consume more energy.

To comply with the code, the building owner must appoint a Professional Mechanical Engineer to assess the design of the retrofitting works and prepare a design submission that meets the standards below. The design submission must approve by the Building and Construction Authority before the commencement of the retrofitting works. Once the works have been completed, an assessment must be undertaken to show compliance and a declaration signed by the Professional Engineer. This declaration, plus other relevant documents, must then be submitted to the BCA.

TABLE 28 Scope comparison between Hong Kong and Singapore Existing Buildings Energy requirements

Device	Hong Kong – Major Retrofitting Works	Singapore – Existing Building Code
Area	Works area ≥500m² - made up of plant room area, cable/duct area etc.	Building GFA >5000m²
Systems	Required size of addition/replacement of Central Building Services Installations (CBSI): • Electrical Circuit rated ≥400 A • Unitary AC, Chiller ≥350kW • Lifts & Escalators – motor drive & mechanical drive	Install or replace building cooling system
Exceptions	• Electricity supply does exceed 100A (1- or 3-phase) • 3 or fewer storeys or ≤8.23 m high • Roof area ≤65 m² • A declared monument or historic buildings covered by the Antiquities and Monuments Ordinance Cap	• Industrial buildings • Railway premises, port services and facilities or airport services and facilities • Religious buildings • Data centres • Utility buildings • Residential building, excluding serviced apartments

The requirements for compliance are as follows:

Energy Consumption Monitoring

The Energy Use Intensity (EUI) (kWh/m²), a measure for the building's total energy consumption per unit gross floor area, should be calculated for the previous three years, based on actual utility bills. Any abnormal trends or increases in EUI should be investigated and any necessary corrective actions undertaken. The Building's Energy Efficiency Improvement Plan should also be reviewed.

TABLE 29 Example EUI Submission Table, referencing submitted electricity bills

	2015	2016	2017
Total (kWh/yr)	11,104,395.15	10,766,680.34	10,443,841.48
GFA (m²)	31540	34540	31540
EUI (kWh/yr/m²)	352.07	341.37	33.13
Deviation (%)	-	-3.04%	-3%

AC System Minimum Operating Efficiency
This section addresses the total system performance through energy efficient and appropriately sized AC systems. This applies to buildings where the total conditioned area is greater than 500m². The requirements in this section are set according to the level of Green Mark accreditation of the building.

TABLE 30 Hong Kong Chiller and Singapore Chilled Water Plant Retrofit compliance

	Hong Kong BEC 2018	Singapore Existing Building Code
Air-Cooled Chiller Minimum COP	Chillers: ≤ 400kW: 2.8 – 3.2 ≥ 400 kW: 2.9 – 3.2	Chilled Water Plants <1750kW: Certified: 3.2 Gold: 3.5 Gold^{PLUS}: 4.1
Water – Cooled Chiller Minimum COP	≤ 500kW: 4.2 - 5.3 ≥ 1000kW: 5.3 - 5.8	1750kW: Certified: 4.4 Gold: 4.7 Gold^{PLUS}: 5 Platinum: 5.2

It is important to note that the figures in this table are not directly comparable because the original Singapore requirements are in kilowatt per refrigerant ton, a unit that depends on operating conditions and is applied to much larger installations. Generally, Hong Kong regulations have tighter requirements for large Water-Cooled Chillers, while Singapore has tighter requirements for large Air-Cooled Chillers.

An Energy Audit is conducted prior to the retrofit with the results submitted to the BCA as part of the submission process. The Energy Audit allows a load profile to be developed – information which allows the Professional Engineer to design an updated system. The energy efficiencies of the pumps, cooling towers and chillers are all identified based on catalogues. From this, the system efficiency is calculated based on prescribed formulas to ensure compliance with the figures in Table 30.

Lighting Installations Energy Improvement
Buildings are required to demonstrate at least 20% improvement in the lighting power budget for common areas beyond the baseline.

TABLE 31 Hong Kong and Singapore Lighting Requirements Comparison

Space Type	Hong Kong – BEC 2018 (W/m²)	Singapore – SS 530: 2014 (W/m²)
Entrance Lobby	13	80% of 10 = 8
Office (according to Floor Area)	Area ≤ 15m²: 12 15m² < Area ≤ 200m²: 10 Area > 200 m²: 9	80% of 12 = 9.6
Plant Room	10	80% of 10 = 8
Washroom	11	80% of 12 = 9.6

These figures are used as reference values to ensure the updated lighting design is of sufficient quality. Compliance is achieved if the total power consumption is 20% less than the baseline values. This is shown through the submission of luminaire product catalogues and engineering layouts to prove the calculated LPDs are accurate.

Chiller Plant Measurement and Verification Instrumentation

To detect abnormalities during operation and to track the usage patterns for further analysis to optimise the performance of the system, suitable instruments should be installed to ensure the operating performance of all chilled-water AC systems is measured continuously. The instrumentation should have an accuracy of 5% when calculating the operating system efficiency and should include sensors, any necessary signal conditioning, the data acquisition system and wiring connecting these components.

To comply with the standard, the permanent measurement instrument should consist of data logger, flow meters and sensors with accuracy requirements stated in the standard. A calculation of the total uncertainty of the whole operating system efficiency is also required along with detailed schematic drawings of monitoring strategies. This ensures that updates to the chiller settings and control systems are using reliable data.

Indoor Temperature

To avoid overcooling, the indoor temperature should be regulated and maintained at a normal dry-bulb temperature of 23 °C or above for all air-conditioned spaces. This is the same as the System Load Calculation in BEC 2018. An IAQ surveillance audit report signed by an accredited laboratory should be submitted. Currently, Hong Kong only publishes voluntary guidance on Indoor Air Quality, although the System Load Design Conditions in BEC 2018 have the same temperature requirements.

ii) Code on Periodic Energy Audit of Building Cooling System

The purpose of this code is to ensure that the chilled water plant operates efficiently throughout its lifecycle. Hong Kong has equivalent regulations in the Energy Audit Code as well as the detailed Technical Guidelines on Retro-commissioning. The Singapore code is different in that it focuses purely on the efficiency of the chilled water plant; the chillers and associated ancillary equipment such as pumps and cooling towers that typically makes up a large percentage of a building's energy consumption.

The scope of the Code is similar to that of Hong Kong's EAC, as shown below:

Hong Kong – EAC	Singapore – EAC
Commercial Buildings and the commercial portion of mixed-use buildings • AC • Lighting • Electrical • Lifts & Escalators	Existing Buildings that have undergone a major energy use change and New Buildings (after 2010): • Chilled Water Plant
	EXCLUDES: • Data Centres • Religious Buildings • Residential (excluding serviced apartments) • Utility and Industrial Buildings • Railway, Port and Airport buildings

The frequency and requirements of the audit are significantly different:

	Hong Kong – EAC	Singapore – EAC
Frequency	10 years	3 years (upon receiving notice from the authority which will not be less than 3 years)
Requirements	No	Meet minimum Operating System Efficiency (OSE) requirements

The audit is undertaken by a Professional Mechanical Engineer or registered Energy Auditor to ensure that the requirements are followed, and regulations met. The auditor is responsible for ensuring the plant meets the minimum Operating System Energy-efficiency (OSE) standard stipulated in the Code, and if it is not met, undertaking further measures within the specified timeframe to ensure compliance with the standard. The Building Owner submits the result of the report from the auditor to the BCA.

Ensuring Compliance

The minimum OSE for the chilled water plant depends on the regulations the building falls under, as shown below:

Buildings with major energy-use change that are subject to the Code on Environmental Sustainability Measures for Existing Buildings		
	Building Cooling Load <500RT	Building Cooling Load ≥500RT
Water-Cooled Minimum OSE (kW/RT)	0.80	0.75
Air-Cooled/Unitary Minimum OSE (kW/RT)	1.1	1.0
Buildings subject to the Building Control (Environmental Sustainability) Regulations 2008 and where planning permission was granted after 2010		
	Building Cooling Load <500RT	Building Cooling Load ≥500RT
Water-Cooled Minimum OSE (kW/RT)	Gold^{PLUS}: 0.7 Platinum: 0.7	Gold^{PLUS}: 0.65 Platinum: 0.65
Air-Cooled/Unitary Minimum OSE (kW/RT)	Gold^{PLUS}: 0.85 Platinum: 0.78	N/A
All other Buildings		
	Building Cooling Load <500RT	Building Cooling Load ≥500RT
Water-Cooled Minimum OSE (kW/RT)	0.8	0.7
Air-Cooled/Unitary Minimum OSE (kW/RT)	0.9	0.8

Once the minimum standard for a building has been established, a specific methodology outlined in the Code is followed. The data is taken from instruments installed as part of compliance with the version Code for Environmental Sustainability of Buildings or the Code on Environmental Sustainability Measures for Existing Buildings that was in force at the time of installation. The auditor checks the accuracy of the permanent temperature sensors with a calibrated temperature sensor before extracting data for analysis. The maximum deviation allowed between two sensors is 0.07°C. A heat balance substantiating test is undertaken for water-cooled systems to check the quality of the measurements and ensure the accuracy and precisions of the tests is within prescribed tolerances.

To check the operating conditions for indoor spaces, ten spot measurements are taken, measuring the dry-bulb temperature, relative humidity and carbon dioxide concentration.

When the full energy audit is complete and the audit form has been filled out, it is submitted online to the BCA via an e-submission system. Supporting documents are similar to those required in the Hong Kong EAC and include raw data from meters, engineering drawings, calibration certificates, input parameters and relevant calculations.

This system is significantly more effective than Hong Kong's current arrangement because it sets minimum, enforceable standards for efficiency. This ensures that existing buildings are as energy efficient as possible and are regularly checked to ensure compliance. This means that inefficient buildings do not continue to waste energy.

5.1.4 Programs & Incentives

i) Public Sector Taking the Lead in Environmental Sustainability (PSTLES) programme

Introduced in 2006, the Public Sector Taking the Lead in Environmental Sustainability (PSTLES) initiative aims to encourage the public sector to take the lead in environmental sustainability and strengthen organisational processes to manage resource use. Measures such as energy efficiency, water efficiency and waste minimisation are included by the public sector agencies as part of the sustainability outcomes to be undertaken.

In 2014, enhancements were made to the PSTLES initiative, requiring each Ministry to appoint a Sustainability Manager to set sustainability targets for FY2020, and also to develop a resource plan to meet the targets. The public sector is required to share its progress through a Public Sector Sustainability Report every 3 years.

The current initiatives relate to a wide range of sustainability metrics with a significant portion addressing the building sector:

Public sector-owned Buildings

New and existing buildings

All new public sector buildings with >5000m² air-conditioned space that are partly- or fully funded by the public sector must achieve Green Mark Platinum rating.

All existing public sector buildings with >10000m² air-conditioned space must achieve Green Mark GoldPlus by FY2020.

All existing public sector buildings with <10000m² air-conditioned space but with Gross Floor Area >5000m² must achieve Green Mark Gold by FY2020.

Office Premises

All new public sector offices or those that undergo major retrofitting programmes must achieve Green Mark Gold for Office Interiors

Energy Efficiency

The premises of public sector agencies must have indoor setpoints of 24°C or higher for air-conditioned spaces.

Data centres with GFA >1,000 m² must install separate meters and monitor and report their energy use.

Green Procurement
Public sector agencies must select the most cost-effective appliances, including consideration for life cycle costs. Office equipment must meet the latest Energy Star standards. For electrical appliances that are under NEA's Mandatory Energy Labelling Scheme, the equipment must be rated to the higher tick ratings (e.g. lamps and air-conditioning are to be rated at least three ticks).

Public sector using private buildings
Tenanted Office Premises
Public sector agencies must lease from buildings with a minimum Green Mark $Gold_{Plus}$ rating.

Events and Functions
Events organised by public sector agencies must be hosted in venues that have been Green Mark certified.

These initiatives are directly applicable to Hong Kong and would act as a major decarbonisation driver. By implementing these programmes, the Singapore Government is ensuring that higher Green Mark ratings than the minimum are required if building owners, developers and equipment manufacturers want the public sector as a client. This framework also provides scope to periodically improve these requirements, steadily improving all the buildings the public sector occupies and building capacity and expertise which can then be applied to the private sector.

ii) Super Low Energy and Zero Energy Programme

Launched in September 2018, the Super Low Energy (SLE) Programme is an accreditation under the Green Mark scheme aimed at non-residential buildings. This programme contains two separate awards for which projects can apply: Super Low Energy building and Zero Energy building. A building that achieves Green Mark Platinum and Green Mark Super Low Energy would be awarded Green Mark Platinum (Super Low energy). To achieve one of these accreditations, the building must meet a minimum of Green Mark Gold award standards. The definition of a SLE building is: "The best-in-class energy performing Green Mark Building that achieves at least 40% energy saving based on prevailing code [SS 530:2014]" which is equivalent to a 60% energy saving compared with Singapore's 2005 building codes (Building & Construction Authority, 2018). The definition of a Zero Energy Building is: "The best-in-class energy performing Green Mark Building with all of its energy consumption, including plug load, supplied from renewable sources (both on-site and off-site)" (Building & Construction Authority, 2018).

As with other Green Mark awards, this saving must be verified. The initial prediction of the energy performance of the building must follow the established methodology for building energy simulations, which compares the performance of the designed building to a reference model. The quantity of on-site (and off-site for the Zero Energy programme) renewable energy generated is predicted using technical

product information. The results of these models are verified post-occupation by demonstrating the implementation of strategies outlined during the design stage and supported by both actual building energy performance and renewable energy generation data over the preceding 12 months. For the Super Low Energy programme, the savings are required to be within 5% of those predicted by the initial models. For the Zero Energy programme, the building must demonstrate compliance with the 100% net energy replacement requirements.

To kickstart implementation, the Minister for National Development issued a SLE challenge in 2018 for developers to voluntarily complete one SLE project within five years. No extra Green Mark assessment fees are charged on accreditation. So far, more than ten developers and building owners, covering more than twenty projects, have signed up including the Defence Science and Technology Agency which retrofitted a number of buildings on a military base that are on track to achieve ZEB. Notably, one of these facilities used Mass Engineered Timber as a sustainable construction material.

Green Buildings Innovation Cluster (GBIC) & SLE Smart Hub
To address the difficulties building owners and developers have in acquiring information on new energy-efficiency technologies and products, the BCA established the SLE Smart Hub under the GBIC. The Smart Hub provides actionable insights into these technologies and predicts the costs and benefits of applying them to their buildings. It also helps owners and developers source and adopt these technologies.

SLE Buildings Technology Roadmap
These programmes do not have an equivalent in Hong Kong and could serve as a framework for an incentive scheme to encourage deep energy-efficiency savings. The BCA has declared that achieving SLE with a 60% improvement in energy efficiency compared to Singapore's 2005 codes is technically feasible, but an 80% reduction requires further R&D for it to be cost-effective. Keppel Land, a large developer in Singapore, agreed to pilot several technologies at Keppel Tower, a platinum rated development, supported by SGD 1.28 million fund from the BCA.

This programme is particularly suitable to Hong Kong because it addresses the often weak links between decarbonisation and Green Building ratings. This programme ensures that buildings awarded high ratings implement energy-efficient design strategies and equipment. It also provides an example for integrating special additional requirements into current frameworks.

iii) Green Mark Portfolio Programme

The Green Mark Portfolio Programme was launched by Building and Construction Authority (BCA) to meet tenants' needs of a streamlined approach to certify similar spaces across a portfolio of projects. Due to the large number of building tenants and their growing awareness of environmental sustainability, there is demand from

the industry to provide a more efficient and cost-effective approach to certifying tenanted area. This Programme aims to encourage adoption of energy efficient design, technologies, and good environmental management system among tenants.

This Programme is applicable to companies that are committed to certify at least 20 projects within three years. However, it is only applicable for projects pursuing occupant-centric Green Mark schemes, such as supermarkets, retail, restaurants and office interior. Compared to the traditional individual project certification, this Programme streamlines the process and enables applicants to achieve the certification within a shorter time period and at a lower cost due to the reduced repetitive auditing procedure.

The certification has two phases, namely (i) Prototype Pre-certification and (ii) Project Certification. The first phase aims to develop a set of common criteria, i.e. Green Mark prerequisites and other common features, in consultation with a Green Mark assessor. Upon achieving the precertification, the applicant can move on to the second phase. In the Project Certification phase, each individual project under the portfolio is assessed based on the prototype and individual project special features.

iv) Green Lease Toolkit

Launched in 2014, BCA published a Green Lease Toolkit, which included a "Office Green Schedule 2014" and a "Retail Green Schedule 2014". These schedules provide recommendations on standards to monitor and improve energy efficiency, water efficiency, outdoor and indoor air quality, sustainable material and waste management through a target-based approach.

The green lease incentive aims to enable landlords and tenants to work together on increasing energy efficiency, water efficiency and other measures that will make a more sustainable building. In addition, it will enhance transparency and accountability between building owners and tenants.

The Green Lease is an agreement between the landlord and the tenant. It basically includes and sets out all the environmental objectives on improving the building and manage it in a sustainable manner. Green leases play a critical role in aligning incentives to shift buildings from a linear economic model and into a renewable and circular economy throughout their life cycle, including the occupation stage.

v) Green Mark Pearl Award

This Green Mark Pearl Award is a prestigious award that recognises strong commitment of building owners/landlords who meet the threshold number of tenants/occupants or threshold net lettable area occupied tenants who are GM certified under the GM occupant-centric schemes within a base building which is GM $Gold_{PLUS}$ or higher.

The purpose of the Award aims to emphasise the importance of total building performance of building, covering both the building core and shell and its interior tenanted spaces. Building types such as commercial offices, retails malls and business park developments are eligible for the Award.

vi) Greenovate Challenge Programme

Back in 2013, BCA introduced the Greenovate Challenge Programme, aiming to engage secondary school students in greening their schools. The objectives are to generate students' interest and nurture them to become green building advocates, eventually helping schools to build on their green building journeys.

Since 2016, enhancements have been made to transform this competition into an educational programme to better engage schools. It also aims to build a bridge to encourage industry collaborations and opportunities, which ultimately provide a chance for students to play a part in greening their schools. In addition, the Programme aims to aspire the students to becoming green building professionals in the future.

5.2 Shenzhen

China's economy has grown rapidly over the past decades, with urbanisation transforming rural areas into modern cities. Energy consumed by buildings in China accounts for nearly half of the total energy, including embodied energy in construction (Energy Foundation, n.d.). China began to address energy efficiency issues in 2005, including the development of buildings design standards and green building evaluation standards.

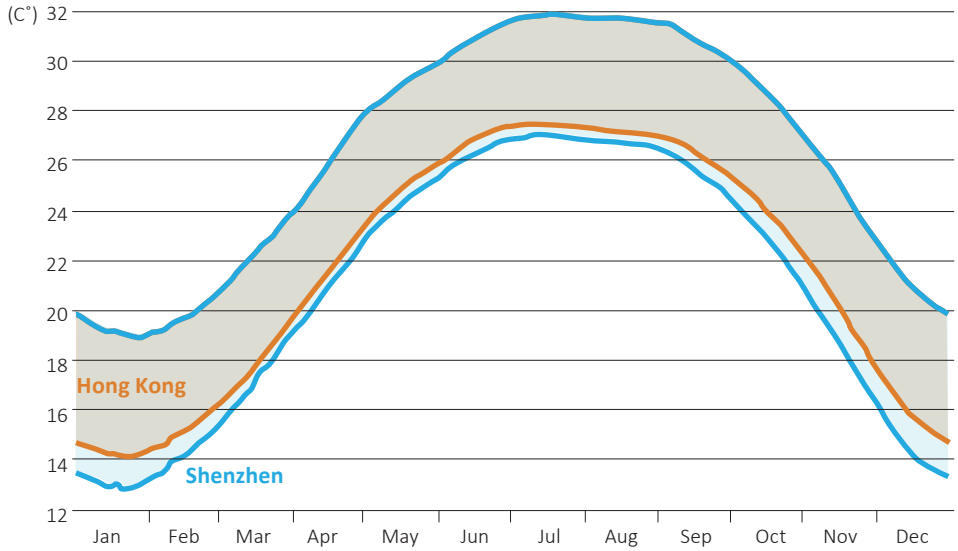
Among the cities in China, Shenzhen is a close neighbour of Hong Kong and a megacity that has undergone a massive economic transformation. Hong Kong and Shenzhen not only have a similar population density and economic status, but their climate is also identical given their proximity. Since Shenzhen has been one of the pioneers of the development of green buildings in China, a study of the standards in Shenzhen will provide guidance for Hong Kong's own policies in decarbonisation.

TABLE 32 **Population and Humidity Data for Hong Kong and Shenzhen**

	Hong Kong	Shenzhen
Population Density	Very High	High
Relative Humidity	77%	79%

FIGURE 21 **Yearly Temperature Profile for Hong Kong and Shenzhen**

source: Weather Spark, n.d.



The daily average high and low air temperatue at 2 metres above the ground

In addition to following the national Green Building Action Plan as a roadmap for green building development by 2020, the Shenzhen Housing and Construction Bureau has also set goals for the city. The objectives cover four main aspects:

1. **Regulations**
Different departments work closely to improve standards and regulations to buildings
2. **Research and development**
Support research and commit to be the showcase of sustainable design
3. **Industry**
Establish association and training framework to promote innovation in the industry
4. **Collaboration**
Participate in international and domestic conferences to raise awareness

5.2.1 SJG 44 and SJG 45

China has developed national and local building codes since 1980s. The national building codes are known as GuoBiao (GB) standards and the National Design Standard for Energy Efficiency of Public Buildings, GB 50189 was developed to regulate the design of BSIs like BEC and the current version was published in 2015. This code acts as a baseline for provinces and cities to develop more stringent codes based on their local climate conditions. In 2018, the Shenzhen Housing and Construction Bureau provided the most recent version of the two codes for energy efficiency of buildings:

- SJG 44-2018 – Design Code for Energy Efficiency of Public Building
- SJG 45-2018 – Design Code for Energy Efficiency of Residential Buildings

These two codes were derived from the National Design Standard for Energy Efficiency of Public Buildings (GB 50189-2015) and were modified to suit the local climate of Shenzhen. To provide supplementary information, SJG 44 and SJG 45 reference other building services specific codes and standards and the following will be discussed in this report:

- GB 21455-2019 – Minimum Allowable Values of Energy Efficiency and Energy Efficiency Grades for Decentralised Air Conditioners
- GB 50034-2013 – Standard for Lighting Design of Buildings
- JGJ/T 163-2008 – Code for Lighting Design of Urban Nightscape
- GB 20052-2013 – Minimum Allowable Values of Energy Efficiency and Energy Efficiency Grades for 3-Phase Distribution Transformers
- GB 20665-2015 – Minimum Allowable Values of Energy Efficiency and Energy Efficiency Grades for Domestic Gas Instantaneous Water Heaters and Gas Fired Heating and Hot Water Combi-Boilers

SJG 44 is applicable to newly built, renovated, expanded public buildings in Shenzhen. Public buildings include office, commercial buildings, hotels, clinics and other non-residential buildings. Renovation of existing buildings should comply with this code, except for small-scale public building projects with limited government fund and renovation of buildings with GFA less than 5,000 m^2 that does not involve renovation of building envelope.

SJG 45 applies to newly built, renovated, expanded residential buildings. Unlike BEC 2018, SJG 45 applies to both communal and private spaces. When the building consists of both public and residential components, the respective code should be followed for each component. The sections in both SJG 44 and SJG 45 are shown in Table 33.

TABLE 33 Scope of Hong Kong and Shenzhen Building Energy Codes

Hong Kong – BEC 2018	Shenzhen – SJG 44-2018	Shenzhen – SJG 45-2018
AC Equipment	AC equipment	AC equipment
Lighting Installations	Lighting Installations Additional section: Exterior Lighting	Lighting Installations
Electrical Installations	Electric Installations	Electric Installations
Lifts & Escalators	-	-
-	Additional section: Water Heaters	Additional section: Water Heaters
COP of OTTV	Additional: Heat Transfer in Building Envelopes	Additional: Heat Transfer in Building Envelopes

Although most sections provide requirements against the local conditions of Shenzhen, some sections require fulfilment of other national GuoBiao standards. The associated codes will be stated in the following sections.

AC Equipment

TABLE 34 Hong Kong and Shenzhen AC Equipment Code Comparison

Requirement	Hong Kong – BEC 2018			SJG 44		
System Load Calculation	Summer	Min Dry Bulb Temp	22-23°C (Space dependent)	Summer	Min Dry Bulb Temp	24-26°C
		Min Relative Humidity	50%		Min Relative Humidity	40-60%
	Winter	Min Dry Bulb Temp	22-24°C (Space dependent)	Winter	Min Dry Bulb Temp	22-24°C
		Min Relative Humidity	50%		Min Relative Humidity	30%
Separate Air Distribution System for Process Zone	Special process or temperature/humidity requirement. Exceptions: • SA ≤ 25% of Comfort Zone flowrate • Served Comfort Zone < 100m²					
Air Distribution Ductwork Leakage Limit	If the Operating Static Pressure >750Pa, at least 25% of duct area tested in accordance with DW143.					
Air Distribution System Fan Power	If system fan power >2.5kW or if AHUs system, for each AHU, the motor power of fan is > 1kW: • Constant Air Volume: 1.6 W/L/s • Variable Air Volume: 2.1 W/L/s			When air volume > 10,000 m3/h, the power consumption per unit air volume of the air duct system should not exceed the limits: • Mechanical ventilation system: 0.93 W/L/s • Fresh air system: 0.86 W/L/s • Office building constant air volume system: 0.93 W/L/s • Office building variable air volume system: 1.04 W/L/s • Commercial and hotel building air system: 1.08 W/L/s		
	If system fan motor power ≥ 1 kW: Mechanical Fan: 1.1 W/L/s					
	Fan motor > 1 kW should be able to vary the flowrate as a function of the load					
Pumping System Variable Flow	Variable Flow Control and ability to reduce to ≤ 50% of design flowrate. Exceptions: • 3 Control Valves • If Supply Water Temperature Reset Control is included • Chiller Plant design capacity ≤ 350 kW			For small to medium scaled projects: • The variable flow single stage pump system should be adopted For large scaled projects: • The variable flow two stage pump system should be adopted		
	If Motor Output Power > 3.7 kW, controls included so no more than 30% of Design Input Power required at 50% of Design Flow					
Frictional Loss of Water Piping System	When Diameter ≤ 50 mm, Water Velocity ≤ 1.2 m/s When Diameter > 50 mm, Friction Loss ≤ 400 Pa/m, and for: • Constant Flow - velocity ≤ 2.5 m/s • Variable Flow - velocity ≤ 3 m/s			When relative difference of pressure loss between parallel loops exceeds 15%, hydraulic balance measures should be taken.		
SYSTEM CONTROL						
Temperature	1 x Automatic Temperature control device per AC system For cooling, adjustable to ≥ 29 °C For heating, adjustable to ≤ 16 °C Temperature control for comfort cooling/heating, deadband of 2°C Exception: • Unitary AC with integrated control device			Sensors should be able to measure up to 1.2 to 1.5 times the temperature range of the measuring point. Allowable fluctuation range of room temperature is less than or equal to ±1°C.		
Humidity	1 x Automatic humidity control device per AC system • For humidification, adjustable up to 60% • For dehumidification, adjustable down to 30%			Sensors should be able to measure up to 1.2 to 1.5 times the temperature range of the measuring point. Allowable fluctuation range of relative humidity is less than or equal to ±5%.		
Zone	Separate temperature control device for each zone, not usually across different floors Some exceptions, but no heating and cooling at the same time			CO_2 concentration measurement control to adjust fresh air flow.		
Off-Hours	Each AC system must have automatic controls to reduce energy use during periods of zero occupancy through equipment shutdown; • Occupancy sensor and 7-day customised schedule or setback; • Cooling: > 5°C above setpoint • Heating: > 6°C below setpoint			The AC system should be able to start and stop according to a customised schedule		
	When system ≥ 10 kW, each hotel guest room should have a single master control device to reduce energy use when unoccupied.					

Requirement	Hong Kong – BEC 2018		SJG 44	
SYSTEM CONTROL				
Isolation of Zones	Zone occupied non-simultaneously should be isolated when the area > 2300 m² and then equipped with controls to shutoff supply, fresh and exhaust air. Central systems equipped with control to serve smallest isolation area. Exceptions: • Exhaust air and fresh air systems ≤ 2400 L/s • Isolation areas operated 24/7			
VAV Distribution	• Controller set point ≤ 300 Pa and placed along major branches as required. • Set Point reset based on actual demand of conditioned space.		The following zones should adopt VAV distribution: • If the difference and fluctuation of the cold and heat load of each air-conditioning zone is large, and the low-load operation time is long; • If the temperature of each air-conditioning zone needs to be controlled separately; • If the inner area of the building needs to send cold air throughout the year.	
DCV	In Car Parks, for systems with power ≥ 11 kW, ability to modulate or stage down to ≤ 50% of design capacity based on contaminant level. For an AC system with Fresh Air flowrate ≥ 1400 L/s, DCV required according to CO_2 level. Exceptions: • System has Exhaust air energy recovery			
THERMAL INSULATION				
	Thickness requirements applied to Chilled Water and Refrigerant pipework, ductwork and AHU Casing.		Thickness requirement should be calculated by the method in GB/T 8175 "Guidelines for Design of Thermal Insulation of Equipment and Pipes"	
AIR CONDITIONING EQUIPMENT EFFICIENCY				
	Air-Cooled Min. COP	Water-Cooled Min. COP	Air-Cooled Min. COP	Water-Cooled Min. COP
Unitary	≤ 7.5kW: 2.3 ≥ 200 kW: 3.1	3.3	≤14.0 kW: 2.85 > 14.0 kW: 2.75	≤14.0 kW: 3.55 > 14.0 kW: 3.45
VRF System	≤ 20kW: 3.6 ≥ 200 kW: 3.3	4.5		
Reciprocating & Scroll Chiller	≤ 400kW: 2.8 ≥ 400 kW: 2.9	≤ 500kW: 4.2 ≥ 1000kW: 5.3	≤ 50 kW: 3.8 > 50 kW: 2.9 IPLV: ≤ 50 kW: 3.2 > 50 kW: 3.45	≤ 528 kW: 4.4 IPLV: ≤ 528 kW: 5.25
Screw & VSD Screw Chiller	≤ 400kW: 3.0 ≥ 400 kW: 3.1	≤ 500kW: 4.8 ≥ 1000kW: 5.5	≤ 50 kW: 2.9 > 50 kW: 3.0 IPLV: ≤ 50 kW: 3.10 > 50 kW: 3.20	≤ 528 kW: 4.9 > 1163 kW: 5.6 IPLV: ≤ 528 kW: 5.65 > 1163 kW: 6.3
Centrifugal & VSD Centrifugal Chiller	3.2	≤ 1000kW: 5.4/5.3 ≥ 1000kW: 5.8	-	≤ 1163 kW: 5.4 > 2110 kW: 5.9 IPLV: ≤ 1163 kW: 5.55 > 2110 kW: 6.20
Heat Pump	Air-to-Water: ≤ 100kW: 2.8 ≥ 500kW: 3.1	Water-to-Water: ≤ 500kW: 4.4 ≥ 500kW: 4.5		
Energy Metering	Chiller, Heat Pump, Unitary AC or Chilled/Heated water plant with ≥ 350 kW of cooling/heating capacity, must be equipped with continuous monitoring facilities to measure its power (kW) & energy (kWh) input and output and coefficient of performance. AHUs with motor(s) with a power rating ≥ 5 kW inside a plant room, metering devices or the provision of measurement should measure the power (kW) consumption		Energy metering should include: • Fuel consumption • Power consumption • Heat supply of the central heating system • Make-up water • Cooling capacity of the cold source • Power consumption of the circulating water pump When the zones belong to different users, the cooling capacity metering devices shall be installed separately.	
Direct Digital Control	Required for: • Chilled/Heated water plants with capacity ≥ 350 kW serving more than 3 zones • Air Distribution System for a conditioned space with system fan motor power ≥ 7.45 kW			

For residential buildings utilising central cooling systems, temperature controls and cooling metering should be installed for each separate household. The energy efficiency ratio and integrated part load values of the cooling equipment should follow the national standard GB 50189.

For decentralised AC systems in residential buildings, SJG 45 requires the fulfilment of Grade 2 or above, in the China Energy Labelling Scheme, which will be further explained in the Energy Efficiency Grading and Limits section below.

Lighting Installations

SJG 44 requires fulfilment to the Guobiao (GB) Standard for Lighting Design for Buildings GB 50034 and therefore SJG 44 has no provision for requirements of LPD. The most recent version of this GB 50034 was published in 2013 and was established by the Ministry of Housing and Urban-Rural Development of the People's Republic of China. The code gives suggestions on lighting quantity, illuminance and controls and mandatory standards of maximum allowable LPD.

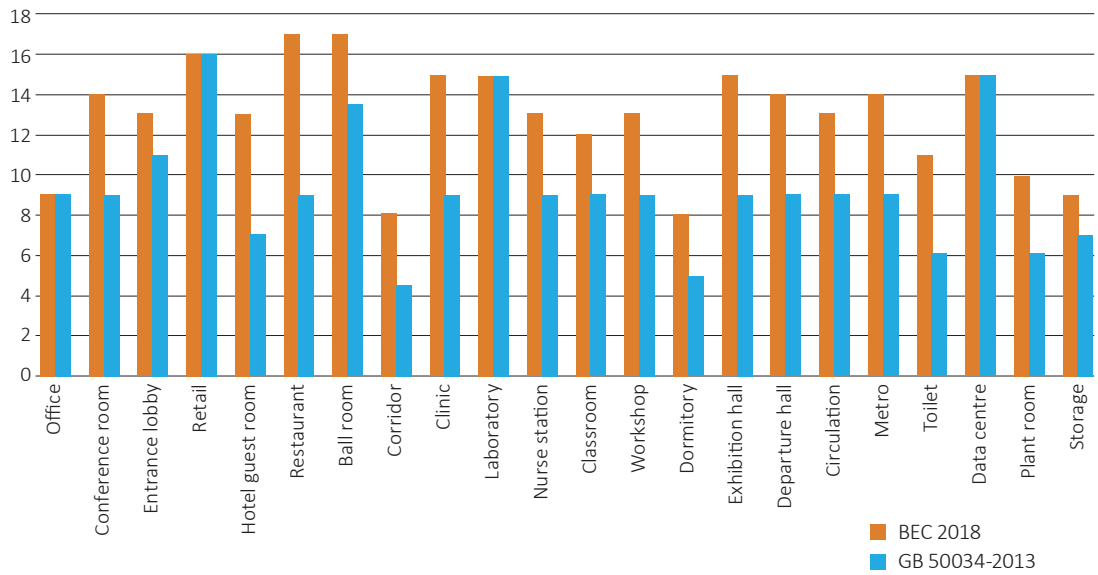
GB 50034 applies to newly built, renovated, expanded or fitted out residential, public and industrial buildings.

GB 50034 has mandatory LPD requirements covering space types in several building types: Office buildings, shopping malls, hotels, hospitals, institutions, exhibition buildings, transportation terminals and industrial buildings. Suggested LPD values are also mentioned for residential buildings, galleries and libraries but are not mandatory requirements. Table 35 shows the comparison of example LPD requirements for six space types and Figure 22 shows the comprehensive comparison of LPD.

TABLE 35 Comparison between LPD of selected space types in BEC and GB 50034

Space Type	Hong Kong – BEC 2018 (W/m²)	China – GB 50034-2013 (W/m²)
Office (according to Floor Area)	Area ≤ 15m²: 12 15m² < Area ≤ 200m²: 10 Area > 200 m²: 9	9
Restaurant	17	9
Clinic	15	9
Classroom	12	9
Toilet	11	6
Plant Room	10	4

FIGURE 22 LPD comparison for space types in BEC 2018 and GB 50034-2013



For rooms with room index smaller than or equal to one, which in practical terms describes very small rooms, the LPD limits should be increased accordingly by at most 20%. This is a similar provision to that in BEC which states that LPD requirements are not required if the installation is <70W.

For residential buildings, SJG 45 provides a table of LPD requirements of common spaces of apartment buildings. Examples of residential communal space types in BEC 2018 are extracted and compared to the equivalents in SJG 45, as shown in Table 36.

TABLE 36 LPD requirements comparison for elements in residential buildings

Space Type	Hong Kong – BEC 2018 (W/m²)	Shenzhen – SJG 45-2018 (W/m²)
Lobby	13	11
Parking	5	2
Pump room	10	3.5

The mandatory requirements of the 22 comparable space types in GB 50034 are tighter than those in BEC 2018 by up to 47%, with a median of 33%. It can also be seen from Figure 25 that all requirements in GB are either equal or less than the standards of BEC 2018. For elements in residential buildings, LPD requirements from BEC 2018 are also less stringent than those of SJG 45.

The standards in China demonstrate the possibility of lowering LPD requirements for certain space types in BEC so they are in line with these standards. This should be further investigated by EMSD.

It is also recommended that the LPD requirements may be split into different building types, in order to cater for specific applications for LPD. For example, in GB 50034, corridors in industrial buildings and hotels have LPD requirements of 2.5 W/m^2 and 4 W/m^2 respectively. By setting different limits, it provides opportunities to restrict the maximum LPD by providing a different set of requirements specific to the building type.

External Lighting

Regarding external lighting, design criteria can be found in the Code for Lighting Design of Urban Nightscape, JGJ/T 163. It was established by the China Academy of Building Research in 2008.

The code applies to external lighting of buildings, structures, landscapes, commercial pedestrian streets, squares, parks, and advertisements that are newly built, renovated, or expanded.

LPD Requirements are set based on the external façade colour and material, city size and city type. For example, Table 37 shows the LPD requirements of a high-brightness environment area, such as urban and commercial areas.

TABLE 37 External lighting LPD requirements depending on city size, type and building facade

Façade type	Small-scaled city (W/m^2)	Medium-scaled city (W/m^2)	Large-scaled city (W/m^2)
Light coloured façade	3.3	4.5	6.7
Silvery or grey coloured facade	4.5	6.7	8.9
Dark coloured façade	8.9	11.2	13.3

Hong Kong only launched the Charter on External Lighting in 2016 as a voluntary scheme to improve light pollution and reduce energy consumption by external and decorative lighting. Corporates and organisations join the charter and pledge to switch off external lighting during a pre-set time, which can contribute to minimising lighting nuisance and energy wastage. The participants may receive certificates and awards for their contribution.

However, there are currently no legal requirements targeting the reduction of energy consumption for external lighting in Hong Kong. Therefore, it is advised that Hong Kong should develop a code on external lighting to control the LPD and

the lighting equipment to achieve a higher energy efficiency of external lighting. The JGJ/T 163 may be referred when developing the code as LPD requirements are provided and various factors have been taken into account, such as the surface of the exterior wall, the size of the city, and the surrounding area type.

Electric Installations

Distribution Transformers

Regarding efficiency of transformers, SJG 44 and SJG 45 state that transformers should comply with the national standards of Minimum Allowable Values of Energy Efficiency and Energy Efficiency Grades for 3-Phase Distribution GB 20052, which is requirements for the energy label for transformers. The principle of the two labelling schemes is the same, but unlike MEELS, CEL of transformers is targeted towards engineers for the design selection.

Distribution transformers are classified into three energy efficiency grades in GB 20052. Grade 1 represents the most efficient and Grade 3 represents the least. Tables are provided in the standard, listing the maximum no load losses and load losses of a certain transformer capacity, for both oil immersed transformers and dry type transformers. Examples of loss limits of a dry type transformer are shown in Table 38 and minimum efficiencies of the respective transformers are calculated for comparison between the Hong Kong and China standards.

TABLE 38 **Comparison of Dry Type Transformer Minimum Efficiencies between Hong Kong and Shenzhen**

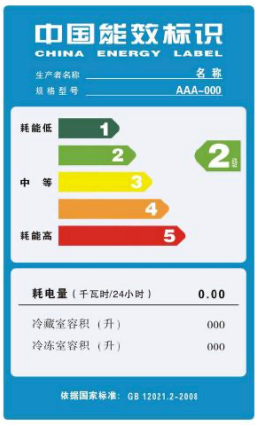
	BEC 2018	GB 20052-2013 – Grade 3
Transformer Capacity (kVA)	Efficiency	Efficiency
800	98%	98.8%
1000	99%	98.8%

The GB efficiency standards are around 99% for the three transformer capacities, while BEC also requires efficiency of transformers to be at least 98%. The comparison implies that the transformer efficiency requirements set by BEC are comparable to those of the lowest grade of the national standards in China. Therefore, it is deemed that the requirements of BEC 2018 are suitable and adequate to regulate energy consumption.

Energy Efficiency Grading and Limits

China has implemented China Energy Labelling (CEL) Scheme since 2005. Like MEELS, electrical appliances should present their energy labels to indicate their energy efficiency grades. Initially, the scheme only included refrigerators and air conditioners that are imported or sold in China. Over 11 years, the list has expanded to cover 37 key energy-consuming products to the labelling scheme, including washing machines, lamps, electric motors, printers, TV and more. Figure 23 China Energy Label shows an example of CEL.

FIGURE 23 China Energy Label



Same as MEELS in Hong Kong, energy efficiency levels range from Grade 1 to Grade 5, with Grade 1 being the most efficient. Equipment is required to meet Grade 5 in order to be registered for the energy label, and the requirements to achieve each grade are provided in separate GB standards. It entails that China bans equipment with efficiencies lower than the Grade 5 or equivalent to enter its market.

Unitary air conditioner is an example of a product which requires CEL. GB 21455 – Minimum Allowable Values of Energy Efficiency and Energy Efficiency Grades for Decentralised Air Conditioners regulates the energy efficiency ratings, limits and test methods of decentralised air conditioners which are those typically found in private dwellings. It applies to air conditioners that consists of air-cooled condensers, fully enclosed electric compressors with a rated cooling capacity less than 14kW. Mobile air conditioners, multi-connected air conditioners and ducted air conditioners are not under the scope of this standard.

The standard provides Seasonal Energy Efficiency Ratio (SEER) gradings for unitary air conditioners, which represents the heat removed from the air by the amount of energy required for the air conditioners. It is similar to COP but also takes into account the weather conditions during the cooling seasons. The grading is divided into five grades, with Grade 1 as the most efficient and Grade 5 the least. In accordance with SJG 45, unitary AC in dwellings should meet Grade 2 of CEL.

TABLE 39 SEER standards for Residential Air Conditioners

	SEER / CSPF (W/W)	
	HK MEELS (Rev 4)	GB 21455 – 2019
Grade 1	≥ 4.50	≥ 5.20-5.80
Grade 2	3.50 - 4.50	≥ 4.70-5.40
Grade 5	< 2.80	≥ 3.50-3.70

In MEELS, the CSPF limits are equivalent to SEER in GB 21455. From the comparison in Table 39 SEER standards for Residential Air Conditioners, all limits are lower in MEELS than those in GB 21455. Although improvements will be made in MEELS to increase minimum standards by at least up to 50% in 2020, they are yet insufficient to act as a leading standard.

Besides, since Grade 5 of GB 21455 is equivalent to Grade 2 in MEELS, lower gradings in MEELS represent equipment with low efficiency that are not allowed in China's market. A minimum threshold CSPF is also absent in MEELS because any equipment with CSPF less than 2.8 is still allowed to register for the energy label. Another example is the labelling of the fluorescent lamps. Grade 5 in CEL is equivalent to Grade 3 in MEELS, and equipment which is less efficient than Grade 5 would not be allowed to enter China's market. Hence, it is suggested to ban the import and manufacture of equipment lower than the lowest allowable efficiencies in GB standards.

Although eight major energy consuming appliances are included in MEELS, the list of appliances included in GB is more extensive than that of MEELS. Hong Kong should refer to CEL and select other energy consuming appliances to expand the range of equipment that requires registration.

Besides, it is suggested that equipment of low efficiencies should be banned from being imported into Hong Kong, or the gradings in MEELS should be tightened to reflect the true potential of recent technology.

Heat Transfer in Building Envelopes

Requirements for thermal transfer in building envelopes are included in SJG 44 and SJG 45. Unlike the Code of Practice for OTTV in Hong Kong, the requirements in SJG 44 and SJG 45 are split into two separate sections – thermal transfer and solar heat gains. Both factors contribute to the thermal performance of the building envelope.

The first section, thermal transfer, is dependent on the heat transfer coefficient (U-value) of the building envelope elements. Table 40 contains the maximum limits in SJG 44 of mean U-values for each element in the building envelope provided.

TABLE 40 Maximum limits of U-values in commercial and residential buildings in Shenzhen

Envelope Structure	SJG 44 - Mean Heat Transfer Coefficient (W/m^2K)	SJG 45 – Mean Heat Transfer Coefficient (W/m^2K)
Roof	≤ 0.8 (depending on thermal inertia values)	≤0.9 (depending on thermal inertia values)
External Wall	≤ 1.5 (depending on thermal inertia values)	≤2.5 (depending on thermal inertia values)
Overhead	≤ 1.5	≤1.5
Fenestration	≤ 5.2 (depending on WWR)	≤4.7

U-values are provided for both commercial and residential buildings in Shenzhen, but Hong Kong uses OTTV as a comprehensive limit. Since OTTV is a project specific value, which can vary greatly from high-end to low-end buildings, a general calculation for the respective U-values may not be obtained. For this reason, a direct comparison between limits in Hong Kong and Shenzhen requires further study. Even though OTTV can restrict thermal transfer at the design stage, the effect of workmanship during the construction stage has a significant impact and is extremely challenging to verify results once the building is complete. Therefore, a comprehensive study should be conducted by the Buildings Department to examine the benefits of further tightening OTTV requirements, in order to make continuous improvements.

The second section suggests that an optimised combination of Solar Heat Gain Coefficient (SHGC) and Window to Wall Ratio (WWR) may effectively reduce the solar heat gain of a building envelope. The maximum allowable WWR of residential and public buildings of both Hong Kong and Shenzhen codes are shown in Table 41. SHGC measures the amount of solar heat transferred to the building envelope through windows. The maximum limits of SHGC values are shown in Table 42.

TABLE 41 Comparison of maximum allowable WWR

Building Type	Shenzhen Maximum WWR	Hong Kong Maximum WWR
Public Buildings	0.7 (all orientations)	n/a
Residential Buildings	0.4 (South and North-facing) 0.3 (East and West-facing)	0.2-0.7 (depending on shading coefficients and orientation)

TABLE 42 Comparison of maximum SHGC limits

Envelope Structure	Shenzhen Maximum SHGC	Hong Kong Maximum SHGC
Windows	0.18 – 0.52 (depending on WWR and orientation)	0.2-0.99
Roof skylights	0.27	

The limits in Table 42 depend on the window to wall ratio of the building envelope and the window's orientation. If the window to wall ratio is higher, a window with lower SHGC values should be adopted to reduce heat load. In this code, North-facing windows may have a slightly higher SHGC value than the other orientations because less heat is received from the sun when facing North.

The restrictions on WWR are imposed in Shenzhen because a building envelope with higher WWR will be more susceptible to solar heat gains than a lower WWR building. Although WWR is accounted for in the process of calculating the OTTV, the fact that the Hong Kong OTTV Code of Practice does not include a requirement for WWR may imply that the architectural and façade design of non-residential buildings are prioritised over better thermal insulation. Therefore, it may be challenging for Hong Kong to implement WWR limits and innovative solutions providing suitable glazing and shade will be needed to mitigate effects of solar heat gain.

Water Heaters

SJG 44 provides guidance on the efficiency of the water heating systems with a heating capacity greater or equal to 10 kW. The efficiency and COP values stated below are not mandatory requirements, but the code suggests that they should be followed.

It is stated in SJG 44 that when gas or oil is used as the heat source, minimum thermal efficiencies of the boilers should lie between 86% to 90%, depending on operating conditions and heating capacity. Since BEC 2018 does not regulate the efficiencies of water heaters, VEELS in Hong Kong is compared to SJG 44. Minimum efficiencies for water heaters suggested by SJG 44 are at least 4% higher than 82% from VEELS. Hence, it is suggested to review the efficiency gradings in VEELS to match the leading standards in Shenzhen.

Existing Buildings

The Ministry of Housing and Urban-Rural Development of the People's Republic of China approved the Technical Code for the Retrofitting of Public Building on Energy Efficiency in 2009. It is a code for the energy analysis of current building before formulating an energy-saving design for retrofitting of the building. The code addresses thermal performance of façade, HVAC systems, power supply, lighting, and monitoring and control. A report should be generated after testing to present results, testing methods and suggestions for modifications for each subsystem. It is currently a voluntary process which applies to all public buildings.

In 2017, the China Academy of Building Research developed the Technical Standard for Green Retrofitting of Existing Residential Buildings in Shenzhen SJG40-2017. It quotes GB standards which were aforementioned for new buildings including aspects of façade, plumbing and drainage, electrical, structural safety, application of renewable energy, and green construction and waste.

The standard does not provide explicit procedures and timeline for retrofitting, but an additional section about green construction requires construction units to establish a construction waste reduction and treatment plan, achieve 80% of recyclable construction waste and prohibits construction waste to be mixed with domestic refuse.

The idea of an energy-saving analysis may be considered before retrofitting buildings in Hong Kong. The energy audit may be used as the analysis and qualified specialists should propose suitable and specific recommendations to each individual project.

5.2.2 Programs & Incentives

Shenzhen Building Energy Efficiency Development Funding

Since the city is undergoing rapid development in the building energy conservation sector, funding plays an important role in promoting and supporting the enhancement of energy efficiency and emission reduction. In 2013, the Shenzhen Municipal Housing and Construction Bureau and the Shenzhen Municipal Finance Committee formulated the "Measures for the Management of Funds for the Building Energy Conservation Development in Shenzhen" as an updated plan for allocation of its funding. Key areas that are supported by the funds are (1) Showcase projects with emission reduction and green innovation development in the construction sector; (2) Energy conservation capacity development in the construction sector, including research, trainings and promotion activities; (3) Utilisation of recyclable construction waste products. Projects may apply if they comply with the national, Guangdong and Shenzhen industrial policies and the outcome of the project should be able to promote the green building movement (Shenzhen Housing and Construction Bureau, 2018).

Green Building Subsidy Scheme

Starting from 2013, to promote the adoption of green building evaluation schemes in Shenzhen, projects which apply for the Chinese Green Building Evaluation Label and achieve a rating level of 3-star may obtain a full refund of the evaluation fee from the municipal building energy conservation development fund. Projects achieving 1-star, 2-star and 3-star ratings from the Evaluation Label will be subsidised with ¥10, ¥20, ¥50 per square metre building area. In addition, if certified by the Shenzhen Municipal Government's separate rating scheme with Bronze, Silver, Gold and Platinum gradings, the building project may receive a subsidy of ¥5, ¥15, ¥30 and ¥60 per square metre building area. Buildings which applied for the subsidy but fail to reach the targeted ratings or requirements should inform the Municipal Government as soon as possible, else, a fine up to 3 million yuan will be imposed. The same applies to buildings which refuse to provide building energy consumption statistics for carbon emission verification (Jungreen, 2017).

Green Building and Construction Technology Innovation Award

The Shenzhen municipal established the Green Building and Construction Technology Innovation Award, which is awarded every three years to building projects which demonstrate green building technology innovation. Bonus funding will be awarded to the project from the municipal building energy conservation development fund (Shenzhen Government, 2020).

Building Energy Monitoring Platform
As a leader in the nation, Shenzhen built the country's first building energy consumption monitoring platform, which issues standards and collects government and large-scale public buildings' energy usage information. The Shenzhen Municipal Housing and Construction Bureau will perform analysis on the data collected and generate yearly reports to the general public. In 2019, 599 buildings were connected to the energy monitoring platform, the buildings' power consumption over the years are compared and analysed. The report will finally suggest measures on improving energy management of buildings and refining guidelines and standards when necessary (Shenzhen Housing and Construction Bureau, 2020).

Thirteenth Five-Year Plan
In 2016, the Shenzhen Municipal Bureau of Housing and Urban-Rural Development and the National Development and Reform Commission jointly issued the "Thirteenth Five-Year Plan" for the Shenzhen construction and development industry. The plan aims to increase the green building area by 37 million square metres, save 430,000 tonnes of coal in the construction and operation of new buildings, and strive to achieve an annual processing capacity of recycled construction materials of 10 million tonnes or above by the end of 2020. Shenzhen plans to achieve the above goals by promoting green building construction methods and upgrading green building evaluation specifications. Meanwhile, enterprises are encouraged to research building information technologies such as BIM, networking platforms, intelligent operating or monitoring technologies, virtual simulation technologies and management systems (Green Ranking, 2018).

5.3 United Kingdom

Although Hong Kong and the UK are very different in terms of climate, population and local conditions, the UK is one of the leaders in driving sustainability in buildings. In 2002, the first "zero-carbon" development was completed in the UK. Since then, policies and codes have been published to guide buildings towards net-zero. In line with the Paris Climate Change Agreement, in 2019, the UK Government announced a commitment addressing climate change by legislating for net-zero emissions by 2050. In the UK, building operational carbon emissions account for approximately 30% of total emissions (UK Green Building Council, 2019).

The UK Green Building Council introduced a framework for the UK construction and property industry to transition new and existing buildings into net-zero carbon buildings by 2050. The framework acts as a guideline which focuses on five key approaches for developers, owners and occupiers to achieve net-zero carbon buildings:

1. Establish net-zero Carbon Scope
Redefine the scope of net-zero carbon to include construction, operation and whole life carbon.

2. Reduce Construction Impacts
Develop modelled assessment of the impact of construction stage.
3. Reduce Operational Energy Use
Prioritise reduction of energy consumption and increase transparency of energy data.
4. Increase Renewable Energy Supply
Encourage the installation of on-site renewable energy.
5. Offset any Remaining Carbon
Residual carbon may be offset by procurement.

5.3.1 Building Energy Regulations

The UK's Ministry of Housing, Communities and Local Government publishes a list of approved documents designed to provide guidance on complying with building regulations. The building regulations contain functional requirements covering all aspects of building including fire safety and structural stability, which are drafted in broad terms, making it difficult to guarantee compliance. There are therefore fifteen approved documents, labelled Parts A through R (skipping Parts I and O), covering a wide range of regulations, from fire safety and electrical safety to equal access. Part L is based around the 'Conservation of fuel and power' and provides energy-efficiency guidance. Part L is divided into four documents:

- L1A: New Residential
- L1B: Existing Residential
- L2A: New Non-Residential
- L2B: Existing Non-Residential

It should be noted that there are other ways to comply with the regulations, but this is the exception rather than the rule, and guidance provided in the approved documents is typically followed. The assumption is that if the approved documents have been followed, the building complies with the Building Regulations.

Part L1A: New Residential Buildings

The process for demonstrating compliance is similar to that in the BEEO. An output report is produced via a compliance report, to a Building Control Body (BCB). BCBs perform a similar role to Hong Kong's Registered Energy Assessors; they are either a member of Local Authority's Building Control department or an independent Approved Inspector responsible for checking building work to ensure it complies with the regulations. Part L1A has five separate criteria that must be satisfied.

TABLE 43 Hong Kong and UK Scope Comparison

Hong Kong	UK
Electricity supply does exceed 100A (1- or 3-phase)	New building works with GFA > 2000m²
3 or fewer storeys or ≤8.23 m high	Existing Buildings: Additions or extensions that will increase GFA by > 2000m²
Roof area ≤65 m²	Existing Buildings: With GFA > 2000m², all Major retrofitting works
A declared monument or historic buildings covered by the Antiquities and Monuments Ordinance Cap	

The approved documents are supported by the Domestic and Non-Domestic Building Services Compliance Guides which form a sub-section of Part L.

Domestic Building Services Compliance Guide
This guidance applies to the installations of BSIs in both new and existing residential buildings. This guide sets out recommended minimum energy efficiency standards for BSIs. For new buildings, the standards are minimum requirements. For existing buildings, the standards outlines can be treated as reasonable provision for complying with Building Regulations. Further supplementary information is included that identifies good design practice. There is also scope to provide new, innovative solutions, that, if it has undergone a recognised testing procedure or modelled with justifications, may be used to prove it is suitably efficient.

It should be emphasised that due to the different climate and arrangement of residential properties in the UK, a large portion of this guide is not relevant to Hong Kong. Relevant sections are compared below.

TABLE 44 Hong Kong and UK Codes Sections Comparison

Hong Kong	Domestic Building Services Compliance Guide
Parts covered by Hong Kong's energy-efficiency labelling scheme: MEELs: Electric Water Heaters VEELs: Gas Instantaneous Water Heaters	Heating: Gas-fired space and water heating Oil-fired space and water heating Electric heating Solid fuel heating Community heating Underfloor heating System Circulators
BEC 2018 AC Equipment	Mechanical Ventilation
BEC 2018 AC Equipment	Heat Pumps
BEC 2018 AC Equipment	Comfort Cooling
Incentive Scheme	Solar Water heating
BEC 2018 Lighting Installations VEELS: LED Lamps	Lighting
	Micro-combined heat and power

Part L1B: Existing Residential Buildings

This section of Part L covers existing dwellings – self-contained units such as flats and houses that are designed to be used separately. It provides guidance in the following scenarios:

- Construction of an extension
- Change of use or energy status e.g. garage or loft conversion
- Provision or extension of a water, waste or energy-related system or piece of equipment
- Replacement or renovation of the wall, floor or roof
- Major renovation of a building

Part L2A: New Non-domestic Buildings

Demonstrating Compliance

For new buildings of both residential and non-residential buildings, compliance of the Part L1A and L2A codes can be demonstrated by meeting five criteria summarised as follows:

1. The calculated CO_2 emission rate should not be greater than the target CO_2 emission rate and residential buildings should meet an additional requirement of the target fabric energy efficiency rate
2. The performance of individual building envelope elements and the building services should achieve the standards of energy efficiency provided by the document
3. The buildings should contain suitable passive control measures to limit solar heat gains in summer
4. The actual performance of the as-built building should be consistent with the calculated CO_2 emission rate, where builders can provide evidence of quality assurance
5. The necessary provisions for enabling energy-efficient operation of the buildings should be put in place

The following paragraphs describe the procedures to meet the above criteria. Compliance reports may be generated by compliance software, which would aid the checking by the Building Control Bodies (BCB).

Target CO_2 Emission Rate and Target Fabric Energy Efficiency Rate

This process of evaluating the target and actual CO_2 emissions is similar to the performance-based verification in BEC of Hong Kong. Both procedures require a comparison to a reference building with the as designed parameters of the building services.

The Target CO_2 Emission Rate (TER) is a measurement for the minimum energy performance requirement for all new buildings. The Target Fabric Energy Efficiency Rate (TFEE) is an additional minimum energy performance requirement for residential buildings only. TER is given in terms of the mass of CO_2 emitted as by the

BSIs per year per m^2 of the total useful floor area. The requirement is calculated by a tool included in the SAP 2012 methodology which is approved for use by the Government.

TER is calculated based on a reference residential or non-residential building of the same size and shape as the actual building. It is constructed with the reference building envelope properties stated in the code as the baseline. The calculated TER reflects the total CO_2 emissions arising from the provision of space heating and hot water (CH), the use of pumps and fans (CPF), and the use of internal lighting (CL). A fuel factor (FF) is applied to the calculation to account for the type of fuel used to provide space heating and hot water. The equation below shows the calculation of TER and examples of fuel factors are stated in Table 45.

$$\mathbf{TER = CH \times FF + CPF + CL}$$

TABLE 45 Fuel Factor for TER calculation

Type of Fuel	Fuel Factor (FF)
Mains gas	1.00
LPG	1.06
Oil	1.17
Grid electricity for direct acting and storage systems	1.55
Grid electricity for heat pumps	1.55

To show compliance to the requirement for non-residential buildings, the builder must calculate the actual Building CO_2 Emission Rate (BER) of the designed building before work commences and show that the BER must not exceed the TER using the same calculation tool.

Target Fabric Energy Efficiency (TFEE) rate is contained in Part L1A for residential buildings. TFEE rate expresses the target amount of energy demand per unit floor area per year. The TFEE rate is obtained by calculating the fabric energy efficiency (FEE) from a notional residential building of the same size and shape, which is constructed according to the reference baseline values in the code.

Dwelling CO_2 Emission Rate (DER) and Dwelling Fabric Energy Efficiency (DFEE) are calculated to achieve TER and TFEE respectively, where TER and TFEE should not be exceeded. The builder is required to calculate DER and DFEE rate of the design before work starts to demonstrate compliance. The final DER and DFEE rates should be based on the final constructed building design, incorporating any changes to the design and the assessed air permeability.

Both TER and TFEE are obtained by the modelling in the compliance software, using reference values provided in the code and a notional building with the same shape, size and orientation as the designed building. The obtained values should be reported to BCB to show compliance.

The two verification procedures require the same information for the building services except Part L does not require systems like lift/escalator and does not account for the occupancy profile. Thus, it is found that the BEC requires a more comprehensive set of information than TER and TFEE.

Cooling

Residential buildings should always be designed to avoid mechanical cooling by providing sufficient ventilation, limit thermal transfer and solar heat gain. The systems should be controlled so that space heating and cooling do not occur simultaneously. The COP standards of air conditioner units of residential buildings stated in the domestic compliance guide are compared to the MEELS gradings of cooling seasonal performance factors in Table 46. Cooling seasonal performance factor is an average COP throughout the full cooling season.

TABLE 46 Hong Kong and UK small AC unit requirements comparison

Air Conditioners	HK MEELS – CSPF	UK – COP
Air-cooled air conditioners	-	> 2.4
Water-cooled air conditioners	Grade 1: ≥ 4.5 Grade 5: < 2.8	> 2.5

The energy efficiency of mechanical ventilation systems of residential buildings should also be regulated by following the guidance in the DCLG Domestic Ventilation Compliance Guide and meet minimum standards for specific fan power, stated in Table 47.

TABLE 47 Hong Kong and UK Fan Power requirements comparison

	HK	UK – Minimum Standards
Fan Power	BEC 2018 does not apply to residential units.	• Intermittent extract ventilation systems: 0.5 W/L/s • Continuous extract ventilation systems: 0.7 W/L/s • Continuous supply ventilation systems: 0.5 W/L/s • Continuous supply and extract with heat recovery ventilation systems: 1.5 W/L/s
Heat recovery efficiency	Heat recovery is not relevant to Hong Kong as space heating is not usually adopted.	The heat recovery efficiency of balanced mechanical ventilation systems should be higher than 70%.
Controls	No regulations on controls of residential air conditioning.	Manual or automatic controls should be installed.

Lighting Installations

The provisions of lighting installations in the Non-Domestic Building Services Compliance Guide apply to general interior lighting and display lighting of non-domestic buildings. The Lighting Energy Numeric Indicator (LENI) method should be followed to comply with the lighting standards. A lighting energy limit is provided for a given illuminance level and hours run instead of depending on the space type like BEC 2018. The limit is in energy per square metres per year and examples of lighting energy limits are shown in Table 48. The lux levels and operation hours are assumed with reference of commonly used values and the limits are converted to units of W/m^2 for easy comparison.

TABLE 48 **Hong Kong and UK Energy Codes LPD sample requirements**

Space Type	Hong Kong – BEC 2018 (W/m^2)	UK – Non-Domestic Building Services Compliance Guide (W/m^2)
Entrance Lobby	13	3.6
Office (according to Floor Area)	Area ≤ 15m^2: 12 15m^2 < Area ≤ 200m^2: 10 Area > 200 m^2: 9	8.4
Plant Room	10	3.8
Washroom	11	3.6

According to the above comparisons, the lighting power density limits of the UK are 52.1% more stringent than Hong Kong. This implies that Hong Kong is also capable of tightening the LPD requirements by around 50% to reduce energy consumption.

For residential buildings, minimum standards for efficacy and controls are provided for internal and external lighting in the Table 49.

TABLE 49 Comparison of Minimum Standards for Efficacy and Controls for Internal and External Lighting in Hong Kong and UK

Internal/ External Lighting	HK	UK Minimum Standard
Fixed Internal Lighting	In MEELS, the lowest grade: <50 lumens/W Highest grade: ≥ 110 lumens/W.	Lamps with a luminous efficacy greater than 45 lamp lumens per circuit-watt and a total output greater than 400 lamp lumens should be installed in low energy light fittings.
	HK does not have regulations on incandescent lamps.	Light fittings with GLS tungsten filament lamps or tungsten halogen lamps should not be used as they would not meet the standards.
	BEC 2018 doesn't apply to residential buildings.	A single switch should not operate more than 6 light fittings with a total maximum load of 100 circuit-watts.
Fixed External Lighting	BEC 2018 excludes external lighting and does not apply to residential buildings. Hong Kong may consider not regulating external lighting on residential buildings as exterior lighting are mainly on commercial buildings.	Either 1 of the following light fittings should be provided when fixed external lighting is installed: Lamp capacity lower than 100 lamp-watts per light fitting, all lamps are automatically controlled and could be switched off when space is unoccupied, or daylight is sufficient. Lamp efficacy greater than 45 lumens per circuit-watt, all lamps are automatically controlled and can be switched off when daylight is sufficient, and light fittings may be manually controllable by occupants

EU - Electric Motors

Electric motors consume up to 50% of electricity generated in the EU. To ensure that electric motors are designed to be energy efficient, the EU has implemented rules for the electric motors sold in the EU. The current version of Regulation on Ecodesign for Electric Motors set standards for single speed, three-phase 50Hz or 50/60Hz, induction motors with features as follows:

- 2 to 6 poles
- rated output between 0.75kW and 375kW
- rated voltage up to 1000V
- rated on the basis of continuous duty operation

However, in July 2021, the scope of the regulation will be expanded to further include the followings:

- smaller motors between 120W and 750W
- larger motors between 375kW and 1000kW
- 60Hz motors, 8 poles motors and single-phase motors (the latter only as of July 2023)

The energy efficiencies of the motors are determined and used to classify the motors into four International Energy (IE) classes. The class with highest efficiency is IE4 while IE1 is the lowest. The current regulation requires motors to meet IE3, or for those with variable speed drive, IE2. Starting from July 2021, the requirement will be expanded such that motors range from 750W to 1000kW must meet IE3 while motors range from 75kW to 200kW should meet IE4.

Under the expansion of the scope, it is expected that the annual energy saving will double from 57 TWh to 110 TWh by 2030 in the EU. This will lead to a significant reduction in CO_2 emissions and cost of operations.

In Hong Kong, the requirements in BEC 2018 corresponds to IE3 of the EU classifications. To achieve further energy savings, it is suggested that the threshold may be increased to correspond with IE4 for motors ranging from 75 kW to 200 kW.

Building Fabric Insulation and Solar Heat Gain

Unlike the OTTV code of practice provided by Hong Kong, requirements in Part L2A are broken down into the aspects of thermal transfer and solar heat gain. Limiting values provided by the two codes are different. For heat transfer, the limiting heat transfer coefficient – U-values of each fabric element instead of OTTV of the whole building envelope are used in the UK.

U-values represent the amount of thermal energy transferred across an individual fabric element per unit area such as windows, walls and roofs. They are affected by the thickness and material combination of the units. U-values of buildings should be calculated using conventions in BR 443 Conventions for U-value calculations and should not exceed the limits in Part L1A and Part L2A.

TABLE 50 **Maximum limits of U-values in non-residential and residential buildings in the UK**

Fabric Element	Part L2A – U-value in non-residential buildings (W/m²K)	Part L1A – U-value in residential buildings (W/m²K)
Roof	0.25	0.20
Wall	0.35	0.30
Floor	0.25	0.25
Windows	2.20	2.00
High-usage entrance doors	3.50	2.00

Since Hong Kong does not provide limits on U-values, valid comparison between the two codes could not be made at this stage. Therefore, further investigation would be needed to review the provision of regulations in Hong Kong.

In terms of limiting solar heat gains in summer, Part L2A requires demonstration for each building space that demand mechanical cooling, a suitable solar energy transmittance (g-value) should be no greater than the limits which range from 0.46 to 0.68 depending on façade orientation and design conditions. The default g-value provided by BEAM Plus v1.2 is 0.57, which agrees with the range in Part L2A. Part L1A for residential buildings does not provide a limit but advises that appropriate amount of daylighting should be considered as well.

Due to the contrasting climate, Hong Kong uses an overall thermal transfer value which accounts for the effects of both heat and solar heat gains, while UK separates them. In Hong Kong, heat transfer and solar heat gain are both not desirable for most months because of the sub-tropical climate. As for the UK, solar heat gain is beneficial for winter months, and heat should be kept inside the building. However, for summertime, overheating due to solar heat gains should be avoided. Therefore, a balance of the two effects of solar heat gains should be obtained and an OTTV is not appropriate for regulating the building design in the UK.

Hot Water Supply
The Non-Domestic Building Services Compliance guide provides a table of recommended minimum thermal efficiencies for domestic hot water systems. Direct, indirect-fired and electrically heated systems with fuel types of natural gas, LPG and oil are included. Regarding the direct-fired systems in new buildings and existing buildings, thermal efficiencies lie in the range of 73%-92%, while boiler seasonal efficiency ranges from 80%-82% for indirect-fired systems in new and existing buildings. For electrically heated systems in new and existing buildings, it is assumed that the thermal efficiency reaches 100%.

In residential buildings, gas-fired boiler efficiency should not be less than 88%. BEC 2018 does not include a section on domestic hot water heating, but VEELS covers Domestic Gas Instantaneous Water Heaters as they are typically used in residential units. The minimum requirements to achieve the 'Recognition Type' label are referenced from English and Japanese standards and correspond to energy efficiencies of approximately 82%, which may be increased to match efficiencies in the UK.

Part L2B: Existing Non-Residential Buildings

This section of Part L covers existing non-dwellings. It provides guidance in the following scenarios:

- Construction of an extension
- Change of use or energy status e.g. building is used as an institution, where it was not previously
- Provision or extension of a water, waste or energy-related system or piece of equipment
- Replacement or renovation of the wall, floor or roof
- Major renovation of a building

In most scenarios mentioned above, thermal element requirements such as U-values, insulation and airtightness are provided.

5.3.2 Energy Performance Certificates

The Energy Performance of Buildings (England and Wales Regulations 2012) directive introduced Energy Performance Certificates (EPCs). It is a scheme to increase transparency of the energy performance information of residential and commercial properties. Energy performance certificates should be obtained whenever a flat or

a house is built, rented, or sold. The general public, such as buyers and tenants may access this information and comparison may be made with similar properties to aid their selection when buying or renting a property.

An Energy Performance Certificate (EPC) classifies the energy efficiency performance of a property into grades from A to G, with grade A being the most energy efficient. The certificate is valid for 10 years once acquired and it provides information on energy consumption. An EPC also provides suggestions for ways to improve the energy performance of the properties, along with an estimated cost.

Coming into force in April 2018, the Minimum Energy Efficiency Standard (MEES) Regulation sets a minimum energy efficiency standard of Energy Performance Rating E for domestic private rented properties in the UK. It applies to all domestic private rented sector properties that are legally required to have an Energy Performance Certificate (EPC) and are let on a relevant tenancy type.

It targets this type of building because landlords are not responsible for the energy bills of their buildings and therefore have little incentive to invest capital to upgrade their efficiency while they are being renting out. Meanwhile, the tenants cannot make significant changes to a property they are renting. This regulation was designed to address this gap and ensure that landlords upgrade their properties.

From April 2020 onwards, the Scheme entered Phase 2, where the regulations are applied to all privately rented properties that are required to have an EPC.

Buildings that do not require an EPC include:

- Places of worship
- Temporary buildings that will be used for less than 2 years
- Stand-alone buildings with total useful floor space of less than 50 square metres
- Industrial sites, workshops and non-residential agricultural buildings that do not use a lot of energy
- Buildings that are due to be demolished
- Holiday accommodation that is rented out for less than 4 months a year or is let under a licence to occupy
- Listed buildings (cultural or historic importance) - advice from your local authority conservation officer if the work would alter the building's character
- Residential buildings intended to be used less than 4 months a year

The certification requires a qualified assessor to perform a physical examination for the property. Features such as the wall, roof, window, heating, and hot water supply and lighting are assessed and the final grade determined. Properties that do not meet a minimum requirement of grade E cannot be rented or sold until the property is renovated according to the recommended works. The recommended works should cost under £3,500 per property, but failure to improve the rating to reach grade E may be exempted with the reason "All Improvements Made". Owners can either apply for funding from a third-party, or self-fund. For instance, the Energy

Company Obligation (ECO), Green Deal Finance and the Renewable Heat Tariff will financially support the enhancement of energy efficiency of houses in the UK.

In 2019, the UK Government has proposed to raise the minimum EPC rating requirement for non-domestic privately rented buildings from E to B by 2030. This would require an investment of approximately £5 billion and an average payback time of 4 to 5 years. An alternative proposal is to raise the minimum EPC rating of non-domestic privately rented buildings to C by 2030. This will require a reduced cost of £1.5 billion and the average payback time will be three years. This ongoing study will consult different stakeholders for their views on the proposal (Headrige, 2019).

If the authority believes and confirms that a property does not comply with the regulations and recommended works are not carried out when being rented or sold, the owner of the property will be financially penalised for at least 12 months and up to 18 months. A maximum fine of £5,000 can be levied per property.

The EPC acts as another example of public disclosure of energy usage data. The general public can take the energy efficiency of the operations of the building into consideration before buying or renting the property. This will enable lower energy bills and improved indoor environment. Additionally, direct EMOs with reasonable cost and benefits of energy auditing may be made mandatory like the compulsory recommended works for EPC.

5.3.3 Programs & Incentives

i) Energy Company Obligation (ECO)

Launched in 2013, following the passing of the Energy Act, the Energy Company obligation (ECO) became the UK's flagship energy efficiency initiative, replacing the Carbon Emission Reduction Target (CERT) and Warm Front Scheme. The Energy Company ECO requires energy suppliers to provide funds to support lower income, vulnerable and fuel poor households to install energy efficiency and heating measures improvements to homes. This allows households to keep their homes warmer, reduce energy bills and associated carbon emissions. Up to 2018, it has delivered over 2.4 million improvements in around 1.9m homes.

The ECO Scheme started off slow in the first year; it contained a flaw that allowed energy suppliers to prioritise cheaper and easier measures that are not as energy efficient. Also, only 7.5% of all properties receiving measures were rural (i.e. very little activity in rural areas), which deviated from its original aim of supporting lower income households. In addition, the reporting requirements for ECO are relatively complex, time-consuming and bureaucratic compared to previous schemes, leading to an increase in delivery costs and a slow deployment.

It is recommended to develop a quality and standards framework to avoid negative consumer experiences, undermining the uptake of energy efficiency. It is worthwhile to revisit the Scheme as the role of suppliers has not created demand but maintained a market and supply chain through subsidy instead.

ii) Smart Energy GB

Smart Energy GB is a UK government campaign which has rolled out a smart meter campaign to establish a smarter and greener Britain. Smart meters are the new generation of gas and electricity meters, placed inside private homes, that shows the financial cost of energy being consumed in real-time. It is designed to help individuals visualise the amount of energy being consumed and encourages consumers to reduce their consumption.

Results found that more than 85% of people with smart meters have found ways to reduce their energy consumption. The rollout will be completed by 2024.

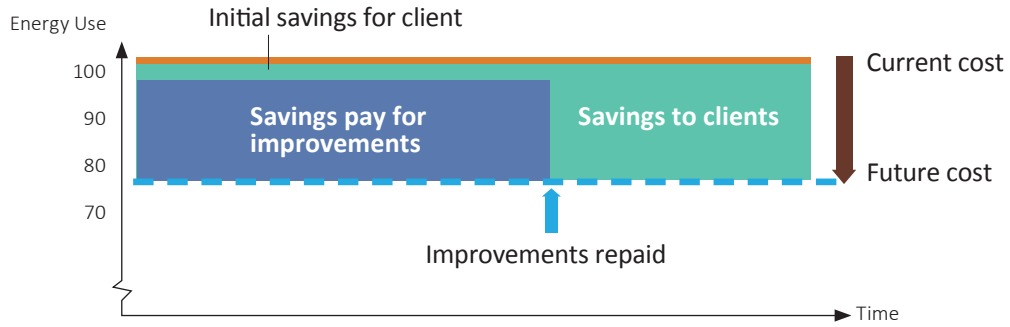
iii) Regulatory Fitness and Performance (RE:FIT) Framework

The RE:FIT programme provides a commercial model to public bodies to address the difficulties around financing of retrofit of existing buildings. Energy-efficiency improvements and financial savings are achieved by appointing an energy service company (ESCo) to undertake the building works.

RE:FIT implements Energy Performance Contracting; the ESCo is contractually obliged to deliver a certain level of energy savings which is verified throughout the length of the contract period. The ESCos is paid according to the energy efficiency improvement or other criteria such as energy generated, if renewable energy is installed. The risks associated with the delivery of the energy savings is held with the ESCo rather than the building owner. Figure 24 shows how the financial rewards are distributed. The procurement process is streamlined by providing pre-negotiated, EU-regulation compliant framework contracts that prequalified ESCos can use to complete the design and implementation of retrofit measures. By having a standard framework model, bidding costs and time are reduced for both parties - the public sector bodies and suppliers. The model can also be applied to groups of buildings to enable economies of scales. A diverse selection of projects have successfully used the framework, from standard retrofit measures such as optimising current equipment to installing solar PV.

FIGURE 24 **Business case for RE:FIT projects**

source: Local Partnerships UK, 2016



It has gone through several iterations. First introduced by the Greater London Authority in 2008, 42 public sector buildings were used as pilot projects; GBP 7 million was spent with a payback period of 7 years. The framework was officially established in 2010 with several updates in 2012 and 2016. Sixteen ESCos are currently approved to bid for contracts under the framework. There are also two expert teams, one for London and one for the rest of England and Wales, that provide end-to-end support. These teams, known as the Programme Delivery Units, provide a free service to other public sector organisations and help them set-up and implement retrofit projects. They provide information on best practise as well as case studies and data on potential costs, savings and carbon reductions. They also provide training on measurement & verification, technical reviews and opportunity assessments.

Within London, 200 public sector organisations have participated in RE:FIT including 31 of 33 London boroughs and 31 NHS (National Health Service) organisations. With an investment of 102 million GBP, an estimated 32000 tonnes of CO_2 are being saved per year, equivalent to 90 GWh of energy savings. The savings are estimated as the equivalent consumption of 40000 UK homes.

This approach has been shown to be effective once the regulatory framework has been put in place. Hong Kong must develop its own framework appropriate to local context and then apply it to address the challenge of existing buildings. However, there are significant issues with a lack of capacity to undertake retrofit programmes in Hong Kong and this must be addressed in order to fully implement these measures. This capacity can be built with an effective training programme delivered by an equivalent PDU and a range of contract opportunities from public sector bodies.

iv) Energy Performance Certificates

To provide energy performance information of residential and commercial properties to buyers and tenants, energy performance certificates should be obtained whenever a flat or a house is built, rented or sold. The general public may access this information and comparison may be made with similar properties to aid their selection when buying or renting a property.
Buildings that do not require an EPC include:

- Places of worship
- Temporary buildings that will be used for less than 2 years
- Stand-alone buildings with total useful floor space of less than 50 square metres
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- Buildings that are due to be demolished
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- Residential buildings intended to be used less than 4 months a year

An Energy Performance Certificate (EPC) classifies the energy efficiency performance of a property into grades from A to G, with grade A being the most energy efficient. The certificate is valid for 10 years once acquired and it provides information on energy consumption and cost of a property. An EPC also provides suggestions for ways to improve the energy performance of the properties, along with an estimated cost.

The certification requires a qualified assessor to perform a physical examination for the property. Features such as the wall, roof, window, heating and hot water supply and lighting are assessed and determine the final grade. Properties that do not meet a minimum requirement of grade E cannot be rented or sold until the property is renovated according to the recommended works. The recommended works will cost under £3,500 per property and owner can either apply for funding from a third-party, or self-fund. For instance, the Energy Company Obligation (ECO), Green Deal Finance and the Renewable Heat Tariff are able to support the enhancement of energy efficiency of houses in the UK.

In 2019, the UK Government has proposed to raise the minimum EPC rating requirement for non-domestic privately rented buildings from E to B by 2030, this would require an investment of approximately £5 billion and an average payback time of 4 to 5 years. An alternative proposal is to raise the minimum EPC rating of non-domestic privately rented buildings to C by 2030. This will require a reduced cost of £1.5 billion and the average payback time will be 3 years. This ongoing study will consult different stakeholders for their views on the proposal. (Headrige, 2019)

If the authority believes and confirms that a property does not comply with the regulations and recommended works are not carried out when being rented or sold, the owner of the property will be financially penalised for up to 18 months and for at least 12 months. A maximum fine of £5,000 can be levied per property.

The EPC acts as another example of public disclosure of energy usage data. The general public can take the energy efficiency of the operations of the building into consideration before buying or renting the property. This will enable lower energy bills and improved indoor environment. Additionally, direct EMOs with reasonable cost and benefits of energy auditing may be made mandatory like the compulsory recommended works for EPC.

5.4 European Union

Innovative approaches and strategies from across the EU are analysed here to provide insight into forward-looking policies that address factors such as the circular economy and embodied carbon.

The EU targets to be climate neutral by 2050. The European Green Deal is an action plan developed in 2019 by the European Commission to mitigate climate and environmental challenges. It includes various areas such as Clean Energy,

Sustainable Mobility, and Building and Renovating. The plan provides a framework of investments needed and available financing tools to aid the transition. Since buildings in the EU account for 40% of the total energy consumed, the building and construction industry plays a crucial role in reaching the target (European Commission, 2019). In the Building and Renovating aspect of the Green Deal, it is proposed to start a 'renovation wave', which involves doubling the current rates of renovation of buildings.

Building and Renovating

Currently, some of the projects are being funded by the European Investment Bank and guaranteed by the European Fund for Strategic Investments. Examples are (European Commission, 2020):

- The European Investment Bank lent €12.5 million to the Lithuanian Public Investment Development Agency to support its development of the first national energy efficiency investment platform in Lithuania. The financing will be used to promote and fund the energy efficiency enhancement projects across Lithuania, focusing on installation of PV panels in private homes, renovation of apartment buildings and installation of efficient lighting. This aids lowering of electricity bills and reduction in CO_2 emissions.

- The European Investment Bank supported social housing by building 524 affordable and energy efficient social housing units in Spain. Equivalent apartments in buildings that are 30 years and older require €785 a year to heat while buildings on this scheme cost an average of €75 a year to heat. Except enhancing energy efficiency, it also provided 700 jobs during the construction phase.

5.4.1 Netherlands

In accordance to the Paris Agreement from 2015, the Dutch Government has set a goal to be both fossil fuel free and carbon neutral in order to contribute to carbon reduction. However, prior to the Paris Agreement, the Dutch Government has been working on initiatives to mitigate carbon emissions since 2009, focusing on the sustainable procurement aspect of the construction industry. (Kadefors, et al., 2019) Firstly, the government developed a Sustainable Procurement Programme, followed by an Action Plan for Responsible and Sustainable Procurement (RSP) by governments in 2015-2020. In 2012, a Dutch national procurement law was established and required tenders to be assessed according to qualitative, technical and sustainable criteria in the Most Economically Advantageous Tender (MEAT). The principle of MEAT is similar to the Life Cycle Assessment (LCA), which will be further elaborated in Section 5.4.3.

In 2019, the Dutch Government introduced the most recent Climate Agreement, which contains measures formulated with consultation across the Dutch society. It has agreed to reduce carbon emissions by 49% compared to 1990 baseline by 2030 (Government of the Netherlands, n.d.). Regarding the built environment, the agreement aims to build sustainable and carbon free buildings. To reach the

2030 goal, around 1.5 million existing houses should be renovated and made more sustainable. Carbon emissions from non-residential buildings should be reduced by 1MT by 2030 (Baker McKenzie, 2019). Hence, the capacity of installing renewable energy and renewable heating should be increased and implemented to neighbourhoods. The government will legislate laws to accelerate the change in laws of electricity, heating, gas supply by 2021.

In addition, to boost the number of sustainable buildings, the government will grant funding of EUR 50-80 million to private house owners and house owner associations per year. House owners may apply for subsidy to install better insulation to reduce the amount of heat loss, which will reduce carbon emissions. The maximum subsidy amount provided to each house owner is EUR 25,000 per year. To transition from gas to sustainable heat, the government targets to make 30,000 to 50,000 existing houses to be natural gas-free per year from 2019. By the end of 2021, the percentage of gas free houses that are newly built in the Netherlands should reach 75% (Baker McKenzie, 2019).

Apart from the climate agreement, Green Deal GWW is another incentive programme which promotes sustainable economic growth by stimulating sustainable innovation. It covers nine themes, including construction. Example projects include transitioning circular cities, making schools more sustainable and developing district heating.

The Hong Kong Government has internal procurement regulations to require bureaux and departments to consider environmental impacts when purchasing products. The scope of this regulation covers 150 goods and over 20 services. The categories include building construction supplies, computer equipment and electrical and gas appliances. Each product has green specifications providing mandatory and desirable requirements. A tender assessment panel will evaluate and approve tenders with the mandatory requirements stated in green specifications. However, this regulation only currently applies to government departments in Hong Kong. It may be extended to the private sector of the construction industry. An evaluation criteria system like MEAT or Life Cycle Assessment may be developed and tenders should be chosen according to the criteria.

i) Amsterdam

The Amsterdam Circular Strategy 2020-2025, aims to halve the use of raw materials and achieve a fully circular economy by 2050 (City of Amsterdam, 2020). The ambitious strategy involves three value chains: food and organic waste streams, consumer goods and the built environment. They were selected based on the scale of their impact on the city, the affects they impose on the natural environment and the size of influence that Amsterdam can have. (City of Amsterdam, 2020).

The built environment value chain refers to the design, construction and renovation of any urban development. There are three pillars to the strategy:

1. The transition to circular development requires a joint effort.
The collaboration between stakeholders such as developers, public authorities, and the people of Amsterdam is needed to reach the target. The joint challenge depicted in this section is to reduce the use of primary raw materials in the built environment, as well as retaining the value of raw materials for as long as possible.

2. The City sets the right example by formulating circular criteria
The City will be the leader of implementing circular criteria in the development of built environments, starting with public housings, schools, and public spaces. Socially responsible criteria include procurement, management, end-of-life treatment and land allocation.

3. A circular approach to the existing city
Amsterdam aims to have 50% of renovations and building maintenance activities to follow the principles of circular construction by 2025. This targets at all public and private buildings.

Currently, this strategy is being implemented and the city monitors the progress by assessing the social and ecological impacts of the transition. Initial findings suggest that focusing on solely the input materials does not provide a comprehensive evaluation of the impact of the strategy. Output waste information will be needed to establish a conclusion of consumption of raw materials.

As Hong Kong only manufactures a small percentage of the construction materials it consumes within Hong Kong itself, it is challenging to implement circular economy. The recycling and reuse of construction waste plays an even more important role to offset the embodied carbon in the transportation of the materials. Therefore, the Government may focus on imposing regulations on construction waste generation in Hong Kong. Furthermore, the Government can introduce circular economy principles by placing requirements on the import of construction materials such as EPD certificates.

5.4.2 Sweden Fossil Free Roadmap

Sweden has been one of the international leaders in environmental politics since 1991 when it imposed a carbon dioxide tax on fossil fuels and introduced 15 environmental quality objectives including “Reduced Climate Impacts”. In 2014, The Royal Swedish Academy of Engineering Services and the Swedish Construction Federation published a report with findings of the impacts of the construction industry have on the climate. The report focuses on the life cycle and material use in the construction of buildings and found that the annual carbon emission from construction processes is of the same order of magnitude as the emissions from traffic. The report therefore suggested areas of improvement such as effective communication between industry representatives, establishing government research councils and formulating calculation methods for carbon emissions.

Subsequently, prior to the Paris COP 21 conference in 2015, the Sweden Government launched the Fossil Free Sweden initiative. Stakeholders from different sectors who declare to strive for a fossil free country worked together to build roadmaps for their own industry. Although this is not a compulsory roadmap to follow, to date, more than 400 organisations are taking part in the initiative.

In 2017, Sweden adopted the Climate Policy Framework, in line with the Paris Agreement. The framework consists of a goal of transforming Sweden into a net-zero country by 2045 and carbon negativity from 2045 onwards. The Fossil Free Initiative has encouraged business sectors to prepare roadmaps for a clear direction to achieve carbon neutrality. The roadmaps outline the technical developments, approaches and challenges of reaching the goal. The construction and civil engineering sector is one of 13 involved in the initiative and currently accounts for 20% of Sweden's carbon emissions. (Karlsson, et al., 2020) The sector's key objective is to halve carbon emissions by 2030 and meet carbon neutrality by 2045.

The Swedish Construction Federation is responsible for the implementation of the roadmap. The following goals, calculated from a 1990 emissions baseline, were established:

1. From 2020 to 2022, key players in the sector should have mapped their emissions and established carbon goals.
2. By 2025, carbon emissions should clearly show a declining trend.
3. By 2030, 50% reduction in emissions
4. By 2040, 75% reduction in emissions
5. By 2045, net-zero should be achieved.

The roadmap identifies the manufacture of construction materials and buildings energy usage are the major contributors to carbon emissions. Therefore, trends like digitalisation, circular resource usage and access to financial capital will aid reaching the goals along with the help of innovation, incentives and policies. By planning with a life-cycle perspective, the sector agreed on recommendations for the action plan for politicians, authorities and key players to work towards the goals. The recommended actions are summarised below:

1. Introduce ambitious and long-term legal requirements to enable investments that help maintaining or strengthening competitiveness of the key player so that their business models may be modified while remaining profitable.

2. Create conditions for the transformation of the base industry, to ensure cement and steel are manufactured in a carbon neutral manner through appropriate financing, risk-sharing and support for innovation.

3. Derive a strategy to provide information on sustainable building materials and fuels. An open database of generic carbon data should be established by an appointed organisation.

4. Introduce requirements for buildings and construction materials to declare for their own carbon impacts.

5. Tighten regulations of the classifications of waste, to promote the re-use and recycle of excavation materials.

6. Introduce incentives for green financing solutions and promotion for efficient use of energy and resources.

7. Appoint an appropriate organisation to develop a method to visualise the carbon emissions down the value chain, and to develop requirements for procurement of building materials.

8. Utilise public procurement to boost the carbon transition.

The roadmap and targets provide a clear framework for the Swedish Government to implement appropriate approaches to meet the desired goals. With consultation and support of the stakeholders, the construction and civil engineering sector is optimistic that carbon-smart solutions will be implemented, and net-zero will be reached by 2045.

5.4.3 Finland

The Ministry of Environment of Finland released a timeline in 2017 outlining the steps required in order to achieve low-emission buildings. One of them is to integrate by 2020 the use of Life Cycle Assessment (LCA) into building regulations by requiring the completion of at the design stage. (Kuittinen, 2019) LCA is a methodology that assesses the overall environmental impact of a building throughout its lifetime, including construction, operation and deconstruction phases. It is intended to influence design considerations at an early stage by computing the total reduction of carbon emissions if investing into more sustainable options.

Finland has built a first version of a standardised LCA framework based on the Level(s) framework of European Commission in 2019. (Kuittinen, 2019) The calculation of carbon footprint is divided into different life cycle stages of a building project: the product stage, construction process, use stage and end-of-life stage. Each stage is further divided into modules, as described in Section 2.1. Calculation of carbon footprint in each stage should follow the methods laid out in the framework. For instance, the LCA on materials use must be conducted by obtaining a database for materials' carbon footprint, gathering information and then estimating the available materials for reuse and recycle throughout the life cycle. Carbon handprint, the environmental benefits resulting from the building, are also accounted for in the LCA. This framework will be tested on pilot projects and will be reviewed to provide updates.

The LCA methodology allows designers and engineers to estimate the carbon footprint at the initial stage of design, so that modifications such as materials with lower embodied and operational carbon content and employing greener transportation may be selected. Therefore, incorporating LCA which includes both structural and operational aspects into building regulations will urge engineers and building owners to make more sustainable decisions.

In Hong Kong, the Housing Authority has studied and promoted the use of LCA of building materials and components since 2003. However, the use of LCA in buildings has been limited by the lack of an agreed upon methodology for LCA tools. Recently, an LCA credit has been added to BEAM Plus but the effects of this have yet to be evaluated. Hence, an LCA framework should be developed echoing the framework by Finland and should be implemented by all new building projects in Hong Kong to account for emissions from both embodied and operational carbon. To build on the framework of Finland, A central, standardised digital platform to facilitate the LCA procedure for designers would be beneficial.

5.5 Australia

5.5.1 NABERS and Commercial Building Disclosure

The National Australian Built Environment Rating System (NABERS) is a rating tool that measures the actual energy performance of a building. It was launched by the Australian Government in 1998 and is applied to buildings across residential and commercial sectors. Since then, the initiative has saved AUD 1 billion in energy bills, and 7 million tonnes of CO_2. NABERS is required for all new buildings over 2000 m^2 as well as those over 2000 m^2, which are intended to be sold or rented.

NABERS differentiates itself from other common sustainability rating systems as it does not assess the intended energy usage at the design stage, but the actual energy performance at the operational stage. Since this rating is valid for 12 months, building owners are required to continuously renew the buildings rating and perform retrofitting and retro-commissioning to ensure that performance is optimised under the latest operational circumstances. Therefore, NABERS ensures that the rating is easy and inexpensive to perform. It rates four specific areas in a building: Energy, Water, Waste and Indoor Environment. NABERS also certifies a net-zero building under the NABERS Energy category, to provide recognition for this accomplishment.

NABERS Energy has the greatest impact on achieving net-zero buildings. Under this category, four rating types are offered for office buildings and tenancies.

- **Base building NABERS Energy rating**
  - Rates central services
- **Tenancy NABERS Energy rating**
  - Standalone rating for business

- **NABERS Co-Assess for business**
  - Rates businesses alongside the base building
- **Carbon Neutral Certification**
  - Awards effort of carbon offsetting

The four rating types provide a comprehensive reflection of the energy performance of the whole building as it involves building owners and tenants. Both parties receive separate ratings, which aids understanding on how their operations contribute to emissions. Upon receiving the ratings, each party may develop their own strategies to drive sustainability and implement them as required.

NABERS, along with a tenancy lighting assessment, form a Building Energy Efficiency Certificate (BEEC), which is the certificate required by the Commercial Building Disclosure Program (CBD). The CBD program is an initiative under the Building Energy Efficiency Disclosure (BEED) Act rolled out in 2010. Building owners are required to obtain a NABERS rating and conduct the tenancy lighting assessment, in order to submit energy usage information in form of a BEEC. The information will be disclosed to prospective buyers and tenants and is accessible to the general public. The NABERS rating must also be presented on any promotional material for buildings that are for sale, lease or sublease.

In the current BEED 2016, BEEC is required by the CBD for office space greater than 1000 m^2 that are for sale or for lease. The following are exempted from the act:

- new buildings where a certificate of occupancy (or equivalent) has either not yet been issued or was issued less than two years earlier
- buildings which have completed a major refurbishment for which a certificate of occupancy (or equivalent) was issued less than two years earlier
- strata-titled buildings
- mixed use buildings where total office space comprises less than 75% of the building by net lettable area (or gross lettable area if net lettable area is unavailable)
- Properties may apply for an exemption with justifications.

The compulsory public disclosure of energy information allows businesses and owners to compare with their peers. With the help of NABERS, the technical side is translated into accessible information for the general public. As a result, it provides financial and reputational incentives for businesses and property owners to achieve a higher rating. This encourages retrofitting and retro-commissioning of operating systems, leading to a reduction in energy usage. Businesses and building owners may also access funding and tax reductions when conducting improvements.

The CBD program and the NABERS rating provides an idea of the implementation of public disclosure of energy consumption data in Hong Kong. This initiative must be adopted, taking ideas from NABERS as well as the HK BEST tool and the EERSB, which provides a mechanism for financial assistance. By allowing the public to

access energy use and emissions information, comparisons can be made before buying or renting a property. Property owners are also held accountable for their energy consumption and will be incentivised to improve their ratings and therefore competitiveness within the real estate market.

5.5.2 Australia Carbon Positive Roadmap

The Green Building Council Australia (GBCA) developed a roadmap in 2018 for achieving a decarbonised built environment by 2050. This is a first draft release and focuses on commercial, industrial and government buildings and fitout as the first stage, while the next release will be highlighting residential buildings. The roadmap is built on previous analysis conducted by advisory groups and recommendations provided by the government and the building industry. It will be continuously updated as new information and technology becomes available so that the timeline is adjusted accordingly.

The roadmap covers targets to reduce scope 1, 2 and 3 emissions and concludes that new buildings and fitouts must be net-zero energy by 2030, and operations of existing buildings and fitouts must be net-zero energy by 2050. To achieve this, the roadmap sets out detailed actions that can be taken, along with timelines for reaching the outcomes. The voluntary sustainability rating system in Australia, Green Star, is also employed to ensure progress of the actions. To take the lead in achieving the targets, Green Star is updated and tightened regularly according to the roadmap.

The roadmap is structured such that buildings that are aiming for different ratings in Green Star should be able to perform the action by a specified year. The timeline provides concrete actions needed and the respective outcome expected, which makes new and existing buildings aware of their responsibilities. Figure 26 shows that all buildings should undertake certain actions by 2030. For example, 6-star rated existing buildings should be fitted out with smart meters by 2020 and by 2023 the Green Star rating system shall be tightened such that 5-star rated existing buildings shall comply as well. Advocacy recommendations are made with specific timeframes for policy makers and the government to implement.

FIGURE 26 An Example Item in the Roadmap

source: Green Building Council of Australia, 2018

Outcome	Action	Green Star Buildings registering from this date will be encouraged to:	2020	2023	2026	2028	2030	2035	2040	2050	Advocacy
Commit to a permanent transition to buildings and fitouts with no greenhouse gas emissions	Adopt a vision for a zero emissions built environment	(All) work with tenants to disclose[1] energy information, seek operational fitout ratings[2], use renewables, and address other emission sources	All ratings		All ratings		All buildings				In consultation with industry, establish a national plan towards 2050 zero carbon buildings and establish responsibilities at the ministry level. Expand mandatory disclosure to new sectors, with a priority focus on tenancies & fitouts.
	Measure, disclose, collaborate on, and improve, the ongoing performance of building and fitouts	(Existing) be fitted out with smart meters.	6 star	5 star	4 star		All buildings				Improve access to energy consumption data requiring energy metering and sub-metering for all buildings by 2030. Introduce requirements in the NCC for all new buildings to be commissioned and tuned from 2025 onwards.
		(New) be commission and tuned	All ratings				All buildings				
		(New) continue to use Green Star – Performance[3].	All ratings				All buildings				
Switch to, install, or procure renewable energy, and support the decarbonisation of the grid	Power buildings and fitouts with 100% renewable electricity and switch away from fossil fuel use	(New) be fully powered by renewables once they are built	6 star	5 star	4 star					All buildings	Reform policy and markets as necessary to: increase the uptake of storage and renewable energy; facilitate district-based utilities; address energy market barriers; ensure and provide fair tariff structures and value for distributed solutions; and improve access to networks. National energy policy delivers long-term certainty, incentivises investment in storage and renewables, and provides clarity on the attributes of any certificates or tracking mechanism used for renewable energy distribution. Incentivise the replacement of non-electric appliances including natural gas, and avoid incentivising installation of non-electric appliances. Require on-site storage and on-site renewable energy as part of upgrades to the NCC in 2025.
		(New) be fossil fuel free[4]		6 star	5 star	4 star				All buildings	
		(Existing) be fully powered by renewables and have a plan to transition away from fossil fuels		6 star	5 star	4 star				All buildings	
	Increase the use of on-site, or near site, renewables, and measures to support the decarbonisation of the grid[5]	(All) have on-site, or access to near-site, renewables[5], install battery storage systems, or technologies that promote grid decarbonisation.	All ratings		All buildings					All buildings	
Build, operate, or occupy low energy intensive buildings and fitouts	Reduce building and fitout energy demand by prioritising passive design, demand control, and energy efficient systems	(New) have 40 to 50% reduction in total energy demand compared to the 2016 NCC[6]	6 star	5 star	4 star		All buildings				Support the upgrade of the National Construction Code's energy performance standards and trajectory consistent with ASBEC's proposal. Introduce ambitious targets and incentives to achieve energy demand reductions of 20 to 30% for all buildings by 2035.
		(Existing) have 40 to 50% reduction in energy consumption over an average building[6]			6 star		5 star	4 star		All buildings	
Adopt zero carbon materials, products, and services	Stimulate markets for carbon neutral products and services	(New) reduce by 10% their embodied carbon against a reference building[7]	6 star	5 star	4 star		All buildings				
		(New) reduce by 20% their embodied carbon against a reference building[7]		6 star	5 star	4 star		All buildings			Expand the reach of the National Carbon Offset Standard to cover a larger share of building products and materials In collaboration with industry lead a review of opportunities to reduce embodied carbon in building products and through the supply chain. Incentivise the phase-down of high-Global Warming Potential (GWP) refrigerants, e.g. in HVAC systems. Lead a review of the availability and market for domestic carbon offsets in Australia, and to identify opportunities to use offsets as part of an incentivise mechanism to encourage building upgrades.
		(All) select carbon neutral products and services	All ratings								
	Increase the use of low-GWP refrigerants	(All) phase down high-GWP refrigerants in existing buildings		6 star	5 star	4 star	All ratings	All buildings	All buildings		
	Support high quality offsets for remaining emissions as a transition strategy	(New) offset total remaining embodied carbon emissions from construction.		6 star	5 star	4 star				All buildings	
		(Existing) offset total remaining carbon emissions from building operations		6 star	5 star	4 star				All buildings	

New rated. Registration date · New all. DA Approval · Existing rated. Certification date · All buildings. Target met

As a result, more businesses and buildings will have to continually enhance their assets in the future as Green Star is tightened.

Currently, HK3030, a campaign developed by HKGBC outlines the targets and timeframe of the route to decarbonising the building sector in Hong Kong. It targets to bring down electricity consumption of buildings in Hong Kong by 30% by 2030 (Hong Kong Green Building Council Limited, 2014), compared with the baseline level in 2005. The campaign uses a Science Based Targets (SBT) approach, which follows the criteria established by the Science Based Targets Initiative (SBTI). This ensures that the targets will align with reaching the long-term IPCC 1.5-2 °C goal.

The provision of HK3030 highlights the key market drivers for the transformation, which aims to stimulate discussion and further study by the relevant stakeholders in Hong Kong. Positive impacts of this roadmap have been observed, such as a review of GFA Concession and the tightening of regulations in response. However, the campaign does not suggest clear and concrete actions with a specific timeline to meet the targets laid out in the report. Although businesses and building owners have the intention to cut down emissions, they do not have clear guidelines to follow and key deadlines to meet.

Hence, the Australia Carbon Positive Roadmap acts as an example for Hong Kong to develop practical timelines and performance verification methods. Green Star is being utilised to ensure progress of the roadmap and likewise, Hong Kong may integrate BEAM Plus or another specific energy-rating system into the roadmap. The SBTI methodology and a quantitative approach may be adopted for Hong Kong to determine science supported targets which should reflect outcomes that limits the warming temperature to at least 2 °C. A detailed framework must be built with urgency, so that immediate progress can be made while allowing continuous updates and revision to keep up with most recent technology.

5.6 Influence of Other Sectors

5.6.1 Renewable Energy

Physical and geographical constraints ultimately limit the total amount of electricity that can be generated by renewable technology within Hong Kong's border.

At a policy level, governments may set targets for renewables generation and / or percentage of renewables in the energy mix rather than consumption-based targets. Following the publication of the 13th Five Year Plan, various local and state governments in China set individual monitoring goals in response to the national target (which provides that by 2020, non-fossil fuel should achieve at least 15% of energy mix) (General Office of the State Council, 2014). China has also set targets to reach peak emissions by 2030 and carbon neutrality by 2060. Dependent on the nature and project sum, renewable energy projects in China may receive up to 100% subsidy for projects involving PV provision.

For locations such as Singapore, with limited land space, solar PV on rooftops has become the major source of renewable energy generated. Singapore's government-led programme SolarNova aggregates solar demand across government agencies and invites private energy company to install, own and operate the solar system on public housing sites and sell electricity back to agencies through a power purchase agreement. (Government of Singapore, 2020) An estimated 420GWh of solar energy is generated annually under this programme, approximating to 5% of Singapore's total energy consumption or equivalent to powering 88,000 flats. By 2019, solar installations in Singapore have achieved a capacity of 262.4MWp, with non-residential private-sector installations accounting 52% of generated capacity.[9] Singaporean government officials have stated the adoption of subsidies, such as FiT, distorts energy markets and increases costs for consumers (Energy Market Authority of Singapore, 2020). Instead solar energy produced by consumers are first offset from consumption and excess energy will be exported at a cost based on the prevailing low-tension electricity tariff minus grid charge, adjusted to the monthly electricity bill.

The support mechanisms in UK for solar is funded through the Levy Control Framework – Feed-in Tariffs (FiTs) that mainly support small scale generation and Renewables Obligation (RO) for large-scale renewable electricity projects. FiTs in UK covers a large selection of RE including solar PV, wind, micro combined heat and power (CHP), hydro, and anaerobic digestion. Payments are made by the supplier to applicants based on meter reading submitted on amount of electricity the installation has generated (dependent on system size, technology, when system is installed and energy efficiency) from each individual energy supplier and exported at a value of 5.24p per unit of electricity (Government of UK, 2020).

Implemented in 2001, Italy's PV incentive programme "Photovoltaic roofs" provided financial support of up to 75% of total capital cost to install a PV system. However, the cost of replacing or repairing broken equipment was costly, leading to PV systems being turned off after a few years as producers lack motivation to spend resources for maintaining their system. In 2005, the Italian Government implemented a Feed-in Tariffs scheme "Conto Energia" specifically to incentivise PV systems, which provided the possibility for PV owners of selling the electricity to the grid, providing the incentive and motivation for PV owners to keep the system running. The program gradually evolved to cover different system typologies (i.e. building integrated PV systems and advanced concentrating PV systems) and came to an end at its 5th iteration in 2013. Currently, there are three support schemes actively supporting RE generation: (1) Premium Tariff a simplified purchase/resale arrangement similar to the FiT in which producers can decide between selling the produced energy on a free market or sell back to GSE (Energy Service System Operator in Italy); (2) Net-Metering allowing prosumers to offset electricity produced and fed into the network; and (3) tax deductions (European Commission, 2019). These schemes have been effective, with Italy now the second-largest solar producer in Europe with a capacity of 20.7GWh in 2019 (International Energy Agency, 2020).

9. Base-Emissions: average emissions of three consecutive fiscal years between FY2002-FY2007 for facilities

i) New Technologies

Carbon Capture & Storage / Sequestration

Carbon Capture and Storage / Sequestration (CCS), sometimes also known as Carbon Capture Utilisation and Storage / Sequestration (CCUS), involves trapping carbon emissions at its source, transporting to a storage location and isolating it. Current projects tend to be very costly and energy-intensive, but real improvements are on the horizon as the technology continues to develop and becomes more practical.

Shenzhen

Since the 11th 5-Year Plan, there have been a number of CCS facilities that have been, or are being, constructed in China as both demonstration projects and large-scale facilities, though the lack of regulatory policies for size, operation and management of CCS makes it difficult to be implemented in China. Currently, CCS is being demonstrated in the industry of chemical production, power generation, natural gas processing, coal-to-liquids, and petrochemical production. CCS is also costly; the introduction of carbon capture may increase operating cost by 140 – 600 yuan/ton CO_2 (National Center for Climate Change Strategy and International Cooperation (NCSC), 2018).

Singapore

In July 2020, Keppel Data Centres, Chevron, Pan-United and Surbana Jurong, with the support of the National Research Foundation signed a Memorandum of Understanding (MOU) to explore, identify and develop mature carbon capture technologies. While there are currently no demonstration projects or facilities being built in or near Singapore, options in the nearby region and beyond can be explored to proceed with sequestration, such as in Thailand and Indonesia. It is estimated, depending on the transportation method and storage location, it may cost an additional SG$0.06/tonne/km for pipeline transportation (EDB Singapore, Energy Market Authority Singapore, NCCS, n.d.).

United Kingdom

As part of the UK's industrial decarbonisation action with CCUS, which includes decarbonising energy intensive industries including iron, steel, cement, chemicals and oil refining, the Industrial Energy Transformation Fund worth up to £315 million was launched for decarbonisation investments, including fuel switching and carbon capture. (Government of UK, 2018) In the 2020 budget, a £800 million Carbon Capture and Storage Infrastructure Fund was announced to establish at least 2 CCUS by mid-2020 and 2030. (Tiley, 2020) The plan is to facilitate the commercial operation of CCUS and it is anticipated that overall, CCUS could provide 37% abatement potential in energy intensive industries by 2050. The UK is currently reviewing barriers to deployment of industrial carbon capture for establishing options to a market-based framework. However, CCUS for energy production may still be considered as a more expensive options as it is estimated the first-of-kind CCUS at a gas-fired power station to cost about £80-160/tonne of CO_2, other industrial activities such as fertiliser production and natural gas processing costs around £23-33/tonne of CO_2 and £20-27/tonne of CO_2 respectively (UK Paliament, 2019).

European Union

In the EU there are two important financial support schemes for CCS – the Innovation Fund, which focuses on CCS and CCU, is estimated to accumulate EUR 10 billion for the period 2020–2030, and the Connecting Europe Facility (CEF), which supports cross-border energy infrastructure projects, is expected to amount approximately €1.1 billion per year for the period of 2012 to 2027 (Carbon Limits AS, THEMA Consulting Group, 2020). Northern Lights, a full-scale project in Norway supported by CEF, captures CO_2 from industrial sources in the Oslo-fjord region and transports it to an offshore subsea location in the North Sea for permanent storage. The Northern Lights builds a CCS network that enables European industries to decarbonise. The operation cost for ten years is expected to be in the range of 5.7 to 8 billon NOK and a total cost including investment to range between 18.6 and 25 billion NOK (Gassnova, 2020). It has been identified that there may be 11 projects located in other EU countries that do not have storage possibilities in the near term that plan to use Northern Lights for transport and storage (Carbon Limits AS, THEMA Consulting Group, 2020).

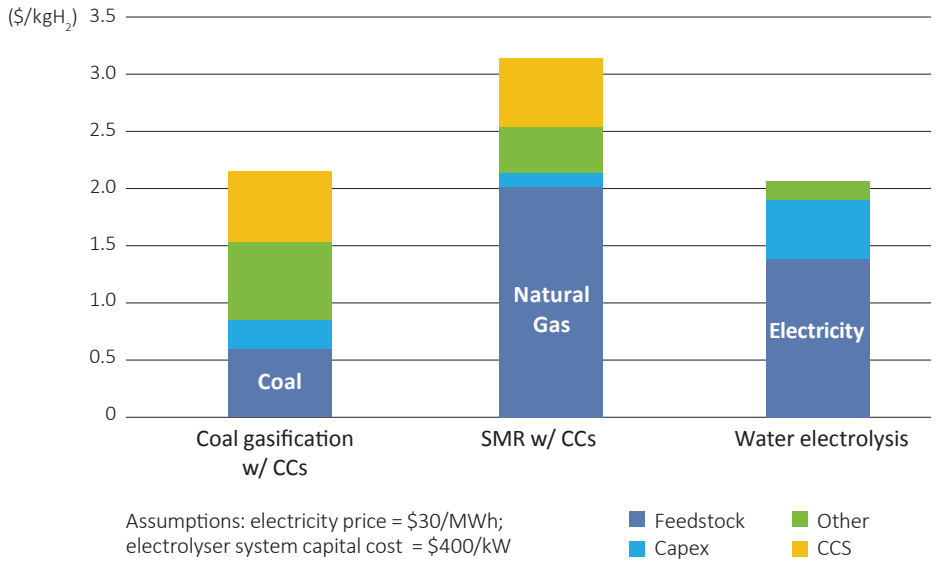
Hydrogen Economy

Hydrogen is considered as a clean fuel as the only by-product of its consumption is water and unlikely to exacerbate climate conditions. Hydrogen does not exist freely in nature, rather it is produced from other sources. Common processes include thermal process where steam is reacted with hydrocarbons to produce hydrogen, currently approximately 95% of hydrogen is created in this form using natural gas as fuel (US Department of Energy, 2020); electrolytic process using electricity to separate hydrogen from water; solar-driven process that uses light as an agent and may include photobiological (use of natural photosynthetic activity of algae and bacteria), photoelectrochemical (use of specialised semi-conductor to separate hydrogen from water), and solar thermochemical (use of concentrated solar power alongside metal oxides to separate hydrogen from water); and biological process that makes use of microbes to produce hydrogen from biological reactions.

It has also been identified that although the current cheapest form of hydrogen production is through coal gasification, the cost of electrolysis is anticipated to fall. At a US$30/MWh renewable electricity price, it is estimated that the cost of electrolysis would be lower than coal gasification with CCS, but still be more than coal gasification without CCS. Given this, using coal gasification for hydrogen production would still be contributing carbon emissions, in which it is estimated that with current technology would still contribute 2kg CO_2 per kg of hydrogen although there are indications that it may be reduced to 0.4 kg CO_2 per kg of hydrogen in the future, by using energy from off-peak hours or renewable sources to keep the carbon emissions at a minimum.

FIGURE 27 **Hydrogen Production Costs**

source: Rocky Mountain Institute analysis for ETC China



Shenzhen

The adoption of hydrogen is predominately focused in the transportation industry, but applications to building operation and construction are possible and numerous. China has been taking steps to develop fuel cell technologies and providing subsidies to encourage its uptake (Sanderson, 2019). In Shenzhen, the focus was placed on manufacturing fuel cell components and vehicle-based hydrogen technology (Energy Iceberg, 2019). While research has identified transportation may be a major direct consumer for hydrogen, direct consumption by buildings is possible although the majority may be in the cement, iron and steel production (Energy Transition Commission, 2019).

Singapore

The Energy Market Authority of Singapore has identified hydrogen as a potential low-carbon alternative for energy. (Energy Market Authority of Singapore, 2019) Under an MOU agreement between PSA Corp. Ltd., Jurong Port Pte. Ltd., City Gas Pte. Ltd., Sembcorp Industries, Singapore LNG Corp. Pte. Ltd., Chiyoda Corp. and Mitsubishi Corp., Singapore has begun to explore the use of hydrogen as a green source of energy. (Mohanty, et al., 2020) There are exploration in the use of hydrogen-powered tri-generation plant for use in data centres, examining commercial viability of establishing liquefied natural gas and hydrogen infrastructure for power and cooling plants (Straits Times, 2020).

United Kingdom

Recently, UK's Department for Business, Energy and Industrial Strategy has awarded £28 million to hydrogen production schemes to examine how to reduce carbon emissions from sectors such as industry and homes and includes development of low-carbon hydrogen production plants in Mersey and Aberdeen, the HyNet scheme that involved hydrogen production plant in Chester and the creation of CCUS infrastructure, and a project near Peterhead that involves the production of hydrogen from natural gas extracted from the North Sea. (Financial Times, 2020) It is estimated by 2035, 11.3TWh of hydrogen would be required to support end use in sectors such as heat, transport, power and industry, of which approximately 20% would be derived from green hydrogen (hydrogen produced by renewable sources of energy) while the remaining would come from blue hydrogen (hydrogen produced from low-carbon non-renewable energy sources e.g. nuclear). (edie newsroom, 2020) There are also cases where heating appliance manufacturers are developing hydrogen fuelled appliances for use in homes. Baxi Heating UK, for example, is developing a 100% hydrogen fuelled "hydrogen ready boiler" for demonstration testing during 2020 (Hydrogen Taskforce UK, 2020). These boilers can be initially installed to operate on natural gas then converted to hydrogen at a future date as it uses same outer case dimensions and pipe connection points as a natural gas boiler.

European Union

Hydrogen has been identified to play a large role in enabling decarbonisation in the EU. Hydrogen has been seen as having the potential to provide for a quarter of EU's energy demand in 2050; heat more than the equivalent of 52 million households; and provide as much as 10% of building power demand. The roadmap to ambitious hydrogen economy development should focus on prioritising the blending of hydrogen into the natural gas grid and use in commercial transportation fleets, larger passenger vehicles, heavy transport, material handling, and the decarbonisation of existing hydrogen production. For buildings, it is envisioned with an ambitious roadmap that hydrogen could replace an estimated 7% of natural gas (by volume) by 2030 (Hydrogen Europe, 2019). Strategically, in the first phase from 2020 to 2024, the objective is to install at least 6 GW of renewable hydrogen electrolysers in the EU and produce up to 1 million tonnes of renewable hydrogen (European Commission, 2020). During the second phase between 2024-2030, the target is the installation of at least 40 Gigawatt of renewable hydrogen electrolysers and production of up to ten million tonnes of renewable hydrogen in the EU. Beyond 2030, up to 2050, renewable hydrogen would be deemed mature and deployed at a large scale. However, hydrogen is currently not cost competitive. It is estimated that fossil fuel-based hydrogen costs around 1.5 €/kg for EU and is highly dependent on the price of natural gas, with CCS it would cost around 2 €/kg and renewable hydrogen between 2.5 and 5.5 €/kg (European Commission, 2020).

5.6.2 Carbon Tax & Carbon Pricing

To capture the external costs of carbon emissions, governments and corporates have developed several market instruments of putting a price on carbon. To date, there are two prominent types of carbon pricing: emission trading systems (ETS) and carbon taxes. A carbon tax explicitly levies a fee on the carbon content of fossil fuels, acting as a disincentive to drive the transition to a low carbon economy. Carbon tax adds costs upstream, putting a price on carbon emissions and driving up the cost of electricity to consumers. Sweden has the highest carbon tax in the world, with a price of US$119/$tCO_2$ in 2020 (Government Offices of Sweden, 2020).

An alternate approach to carbon price would be based around the emissions reduction generated through activities, converting these into carbon credits. These credits can be bought by companies either as obligations under an ETS or carbon tax or voluntary commitments to demonstrate corporate social responsibility. Emission reductions refer to both the sequestration of emissions and the avoidance of emissions. Some common crediting projects include afforestation, deployment of renewable energy, waste management, as well as carbon capture and storage (CCS). As of 2019, a total of 3.9 billion tCO_2e of carbon credits had been released. The price for carbon credits ranged from US$0.15-85/$tCO_2e$ in 2019 (World Bank Group, 2020).

A growing number of companies has seen internal carbon pricing as an important mechanism to inform business decisions and drive down greenhouse gas emissions. Businesses either apply carbon prices as a shadow price to monetise carbon emissions, or they charge business units for their greenhouse gas emissions and re-invest these funds in low-carbon and energy efficiency programmes. The United Nations Global Compact calls for businesses to establish an internal carbon price of at least US$100/$tCO_2e$ over time (UN Global compact, 2016).

It had been indicated that carbon tax has an impact in the proportion of energy generated from coal-fired plants, with the tax in Great Britain that had led to the proportion of coal-based electricity to drop to 3% from 40% between 2013 and 2019. (University College London, 2020) UK's Carbon Emissions Tax has been recently changed. Previously, the tax affected power generators, large industrial premises and manufacturers, public sector facilities, small emitters and hospitals, the 2020 provisions will also affect verifiers and advisers to such installations and ultra-low emitters. (Government of UK, 2020) This is a fall-back policy should UK cease its participation in the EU ETS. Emissions are also set to be taxed at a rate of £16 per tonne under the new revision.

The tax rate within EU differs between the various country, with Sweden placing the highest at more than €110 per tonne of carbon emissions and Poland and Estonia at the lowest at less than €1. (Tax Foundation, 2019) It has been identified, for Sweden, that the steadily increasing carbon tax on motor fuels have played a role in the increased use of biofuels in the transportation sector and have been helpful in reducing GHG emissions overall since its operation from 1991 (Åkerfeldt & Hammar, 2015) while GHG emissions associated with heating fuels have seen a drop from

85% of Sweden's total emissions in 1990 to the current 2% since the introduction of carbon tax (Government Offices of Sweden, 2020). Most EU partner states are also part of the EU ETS, with the exception of Switzerland that has its own emissions trading and Ukraine.

It is not apparent that there has been an explicit carbon tax present in China, though tax levies have been placed based on fuel / energy consumption. (OECD, 2018) The Refined Oil Excise Tax applies to gasoline, diesel, naphtha, solvent and lubricating oil at a uniform rate of CNY 1.52 per litre, and a uniform rate of CNY 1.2 per litre for fuel oil (OECD, 2019).

Singapore's Carbon Pricing Tax Act came into operation in January 2019 that required any facilities that emits direct GHG emissions equal to or above 25,000 tCO_2e annually to register itself as a taxable facility and pay the tax rate of SG$5 per tonne of GHG emissions (tCO_2e) from 2019 to 2023 (NEA Singapore, 2020).

5.6.3 Emissions Trading Scheme

In an emission trading system, governments determine the total cap on the number of emissions for a particular section of the economy such that emissions units are either auctioned off or allocated according to set criteria. A market price for carbon emissions is therefore established by creating supply and demand for emissions allowance. The European Union ETS, the biggest ETS in the world, priced carbon at approximately €25 per tCO_2e over 2019.

The Chinese Government announced the establishment of seven regional pilot ETS in 2011. The pilots started operation in 2013 and 2014, covering five cities (Beijing, Shanghai, Tianjin, Chongqing and Shenzhen) and two provinces (Guangdong and Hubei). In 2016, an eighth pilot ETS was launched in the province of Fujian. The Shenzhen ETS was the first city-wide ETS. During the first year of operation of the pilot study, it successfully achieved the reduction targets in both carbon intensity and carbon emissions. GHG emissions of regulated companies decreased at a rate of 11.5% in 2013 against the 2010 base-year and carbon intensity of regulated manufacturing companies declined by 33.2%, exceeding the goals set in Shenzhen's 12th Twelfth Five-year Plan (Shenzhen Research Center for Urban Development, China Emissions Exchange, 2015). As of 2019, carbon was priced at approximately CNY 17 per tCO_2e for the Shenzhen ETS (OECD, 2019).

In 2017, China announced the launched of a National ETS to be introduced gradually in three phases, with the first being the completion of the legal foundation, establishment of institutional arrangements, registry and trading platform in Hubei and Shanghai respectively. The ETS mainly targets heavy polluting industry, beginning with the power sector and gradually expand to cover other sectors including chemical industry, iron and steel, building materials, petrochemical industry, paper making, non-ferrous metals and civil aviation. A National ETS is anticipated to be aggressive in order for China to reach its net-zero goal by 2060. However, national level ETS are generally directly implemented by the national

government, in which the national government also sets the absolute cap-and-trade rules, and regional governments and authorities are responsible for implementation. Entrance into a national ETS by Hong Kong may not be ideal as Hong Kong would have no control over emissions goals and caps and may face difficulties when applying the ETS if Hong Kong's goal are delinked from China.

As a regional ETS, the GBA-GFA's Carbon Connect aims to establish a standardised carbon marketplace for cross-border trading covering the Greater Bay Area. Hong Kong may benefit more from entering into a regional ETS, which provides higher flexibility in terms of contributing towards goal and target setting when compared to a national ETS. A regional ETS that could cover the commercial building sector could also be highly beneficial to Hong Kong as demonstrated by Japan's urban cap-and-trade scheme. Japan's urban cap-and-trade, which began in 2010, covered 1,200 facilities that have an annual usage equivalent to 1,500kL or more of crude oil equivalent in commercial and industrial sectors, including office buildings and public buildings. Building owners are responsible for the reduction obligations as opposed to individual companies. It was reported that a 27% reduction from Base-Emission[10] of 16.5 million tCO_2 was achieved by 2018.

5.6.4 Electricity Tariff

The energy market in Singapore is regulated by Energy Market Authority. Consumers are able to buy electricity from a market support services company or directly in the open electricity market. The tariff comprises of two key components: Fuel Cost, taken using the average of daily natural gas prices in the first 2.5 month period in the preceding quarter; and Non-Fuel Cost covering the cost of power generation, network connectivity, market support services (e.g. billing, meter reading, data management, etc.) and power system operation and market administration fees. Residential tariff from October to December 2020 is at 22.93 cents per kWh GST inclusive (Energy Market Authority of Singapore, 2020).

The energy market in UK is regulated by Ofgem (Office of Gas and Electricity Markets). There are 14 electricity distribution network operators owned by six ownership groups. Tariff rates are based on consumers' tariff plans, though the average domestic electricity price for a medium user for the period of January to June 2020 approximates to 19.48 pence per kWh tax inclusive (OFGEM, 2020).

Price of electricity varies significantly between the different EU Member States depending on the market conditions, geopolitical situation, national energy mix, network costs, levels of excise and taxation, etc. In 2019, for household consumers with annual consumption between 2,500 kWh and 5,000 kWh, Denmark and Germany has the highest electricity prices of €0.2924 per kWh and €0.2873 per kWh respectively with taxes and levies accounting for more than half of the electricity cost. (Eurostat, 2020) In Denmark, levies and tax placed includes a fixed state electricity tax, a public obligations tariff that fluctuates quarterly and VAT. (Danish

10. Base-Emissions: average emissions of three consecutive fiscal years between FY2002-FY2007 for facilities

Energy Agency, n.d.) The price of electricity in Germany includes components such as electricity tax, VAT, and state-imposed surcharges (e.g. renewables surcharge for funding electricity from wind, solar and biomass, and offshore surcharge). (Federal Ministry for Economic Affairs and Energy, Germany, 2020) On average, cost of electricity in EU is around €0.216 per kWh and the levies and tax accounting for 41% of household electricity prices.

In 2011, following the National Development and Reform Commission for guidance on tiered electricity prices that aims to promote a resource-saving and environmentally friendly society, local municipalities directly under the Central Government introduced guidance notes to electricity pricing system for categorising levels of electricity use based on season and time of day. (NDRC, 2011) In Shenzhen, One-household-one-meter residents are free to choose whether to adopt the "Time-of-Use" tariff system or the multi-tiered tariff system based on the seasonal electricity use (Dongguan Development & Reform Bureau, 2012).

Hong Kong's electricity tariff is comparatively lower than overseas counterparts, which could be explained by the lack of service tax. Hong Kong does not have as many surcharges, as compared to the EU, that could drive up electricity costs.

Cities	Domestic Electricity Tariff (per kWh) (HK$ equivalent as of Nov 2020 exchange rate)		Taxes
Hong Kong	CLP	HK$1.218 (average net tariff in 2020)	-
	HKE	HK$1.264 (average net tariff in 2020)	
Shenzhen	Variable pricing system		-
Singapore	SG$0.2293 (approx. HK$1.31, 2020 price)		7% GST
UK	£0.1948 (approx. HK$1.96, 2020 price)		5% VAT
EU	Denmark	€0.2924 (approx. HK$2.66, 2019 price)	25% VAT
	Germany	€0.2873 (approx. HK$2.61, 2019 price)	19% VAT
	Average in EU	€0.216 (approx. HK$1.96, 2019 price)	41% (VAT/GST & levies)

5.7 Corporate Reporting Standards

5.7.1 Corporate Disclosure & Reputation

International disclosure standards offer insights into the company's performance. Often, these are linked with other reporting systems, such as Global Reporting Initiative (GRI), with sustainability indicators, such as United Nations Sustainable Development Goals (UN SDGs), or with other disclosure standards, such as Task Force on Climate-related Financial Disclosures (TCFD) recommendations. Rather than focusing on a singular building, disclosures are often linked to individual companies, organisations and businesses, such as property developers, real-estate management, material suppliers, etc.

i) Global Real Estate Sustainability Benchmark (GRESB)

The GRESB is an organisation issuing standards for Environmental, Social and Governance (ESG) performance disclosure, providing ESG benchmark for Real Assets and Infrastructure, with intended responders being real estate owners, asset managers and developers. It provides standardisation and validation to ESG data and are aligned with international reporting frameworks such as GRI, PRI (Principles for Responsible Investment), UN SDGs and TCFD recommendations. The assessments generate four benchmarks for the industry: Real Estate Benchmark, Real Estate Development Benchmark, Infrastructure Fund Benchmark, and Infrastructure Asset Benchmark; enabling companies to evaluate their sustainability and ESG performance against those within the industry. Using a survey issued to participating members, a number of aspects, such as water and energy consumption, waste diverted and GHG emissions, are assessed under four components of Management, Performance, Development, and Resilience (GRESB, 2020).

The GRESB benchmarks are one of the well-recognised measure worldwide. The 2020 ESG benchmark is reported to cover more than US$5.3 trillion assets under management (AuM), compared to 2019 amounting to US$4.5 trillion. 1,229 (2019: 1,005) property companies, REITs, private equity funds and real estate developers participated in the 2020 Real Estate Assessment, covering US$4.8 trillion (2019: 4.1 trillion) AuM for more than 96,000 assets across 64 countries. Infrastructure Assessment covered 544 (2019: 500) and represents US$576 billion (2019: 471 billion) AuM across 40 countries (GRESB, 2020).

The benchmarks and assessments enabled the industry to understand the value of sustainability. A research in 2018 identified a premium on total returns of up to 3% between the highest and lowest GRESB scores for non-listed European funds. (EVORA, 2018) Lenders are also seen to favour loans where assets are considered sustainable. A European REIT and lender have signed a €150 million sustainability performance-linked loan in 2018 with a margin partially determined by GRESB ratings. (GRESB, 2018) A Singapore real estate group obtained a 4-year SG$500 million sustainability-linked loan from bank explicitly linked to the company's achievements in GRESB (CapitaLand, 2020).

The GRESB provides a sustainability score and allows companies to compare themselves with their peers and those within the industry. This benchmark may be more suited to helping develop sustainability strategy.

ii) Carbon Disclosure Project (CDP)

This is a global disclosure system for investors, companies, cities, states and region to manage environmental impact. The CDP collects self-reported data from corporations around the world. It focuses on three main environmental issues climate change, water scarcity, forest degradation and provides a rating system for companies and countries to benchmark. (CDP, 2020) The CDP raises a company's

awareness of climate risks, assessing the company in terms of information disclosure, management and leadership. In 2019, over 8,400 companies and 920 cities have disclosed environmental information through the CDP.

Through the disclosure, companies and cities can understand best practices and their position and facilitates investors in assessing a company's carbon footprint and risk management. It has been reported that potentially US$1.2 million was saved annually by companies in interest payments with the disclosure of carbon emissions through CDP. (CDP, 2020) In 2019, it was also reported that suppliers reporting to CDP have seen a collective saving of around US$20.2 billion and has also seen an increase in request by supply chain for disclosures on climate change through CDP (CDP, 2019).

CDP provides information to investors and businesses, about their position and the potential risks. It offers a medium to disclose carbon emissions data, alongside their environmental performance in the field of water consumption and forest impacts. With the availability to benchmark against others in the same industry, businesses can compare their performance and identify opportunities for actions.

iii) Task Force on Climate-related Financial Disclosures (TCFD)

Climate change has been perceived as a financial risk that will have impact on companies' revenues, expenditures, assets, liabilities, capital, and financing. The TCFD provides a framework for translating climate risks and opportunities into financial metrics, enabling organisations, such as PRI, GRI, SASB, CDP, etc., to align their standards and indicators for informing investors about "emerging mega risks" such as climate change. In 2019, it was reported that 785 companies and organisations have committed to support the TCFD, of which 411 are non-financial and other companies (i.e. Energy, Transportation, Materials & Buildings, Agriculture, Food, and Forest Products) (TCFD, 2020).

Under the TCFD, businesses and organisations are recommended to disclose information relating to Governance around climate-related risks and opportunities; actual and potential impacts of climate risks and opportunities on the organisations' Strategy and planning over short, medium and long term; the organisation's Risk Management process and strategy; and Metrics and Targets used to assess and manage relevant climate-related risks and opportunities including the disclosure of Scope 1, Scope 2 and, if appropriate, Scope 3 GHG emissions and related risks. Instead of businesses stating how their operations can impact the environment, the TCFD is about how the changing climate and the environment can impact on businesses and operations. The inclusion of scenario analysis under TCFD structures findings such that businesses can evaluate their performance and how strategies may differ. Thus, the TCFD could be considered as a means to identify where the business is lacking.

A survey by TCFD in 2019 reported the top reasons for implementing TCFD Recommendations were for "Good corporate citizenship / Reputational Benefits" and "Investors are requesting this information" indicating that TCFD Recommendations are influential to establishing a good name for the business. (TCFD, 2019) The TCFD Recommendations were also seen as having encouraged the enhancement of climate-related practices and attention on climate-related issues as well as providing information for users of TCFD and investors with information to facilitate financial decision-making such as investing in the business and capital allocation.

As TCFD is currently voluntary, companies are not incentivised to do so unless investors demand for the information, though the need to prove their sustainability credentials may force companies to disclose. Public sectors have updated relevant guidelines, such as the European Commission (European Commission, 2017), and policies, such as UK Financial Conduct Authority (FCA, 2020), to align and reflect the TCFD.

TCFD allows businesses and organisations to identify opportunities, such as ways of improving resource efficiency or choices to products and services.

iv) Global Reporting Initiative (GRI)

The GRI sets up common standard for organisations to report sustainability impact, assisting organisations in structuring disclosure. Organisations identify material topics to report impacts and influence and use topic specific standards to guide the reporting and recommendation structure. The GRI Standards are compatible with CDP information request framework, and information requested in CDP questionnaire can be included in sustainability reports prepared in accordance with the GRI Standards. It is reported that the GRI Standards can also link up with HKEx ESG reporting guide. In 2019, it was reported 1,429 organisations have reported to have prepared sustainability reports in accordance with GRI Standards either in Core, providing minimum information needed, or Comprehensive, with the additional disclosure in strategy, ethics, integrity, and governance, option (GRI, 2020).

GRI are divided into four series, the set of Universal Standards that sets out the reporting structure, method for reporting contextual information about the organisation and how the organisation manages a material topic, and Topic-specific Standards covering economic, environmental and social topics that are used to report information on an organisation's impact.

v) Sustainability Accounting Standards Board (SASB)

The Sustainability Accounting Standards Board (SASB) standards consist of a set of 77 globally applicable industry-specific standards that identify the minimal set of financially material sustainability topics and associated metrics. It helps companies to identify ESG and sustainability topics and provide reporting framework that could be included in the TCFD recommendation. (SASB, 2020) The SASB standards

has been referenced and used by more than 200 organisations, aligning with ten[11] industries standards including Infrastructure, Renewable Resources & Alternative Energy, and Non-Renewable Resources. In 2019, it has been reported that 154 institutional investors, representing US$55 trillion in AuM from 19 countries, support and / or use SASB standards to enable informed decision making (SASB, 2020).

The SASB industry standards covers five dimensions of Environment, Social Capital, Human Capital, Business Model & Innovation, and Leadership & Governance and 26 issue categories.

In September 2020, SASB along with CDP, Climate Disclosure Standards Board (CDSB), GRI, and International Integrated Reporting Council (IIRC) have announced a shared vision for a comprehensive corporate reporting system and issued a statement of intent for aligning the various standards.

vi) Overview

Of the identified voluntary disclosure, CDP is most widely used by Hong Kong companies but TCFD is likely to be significantly more influential in the future. It is already explicitly part of HKEx ESG Reporting Guidelines. Further:

- The private finance stream for COP26 headed by Mark Carney as the UN's Special Envoy for Climate Action and Finance is lobbying for TCFD's recommendations to be mandatory for large companies.
- If IFRS Foundation proceeds with its proposed Sustainability Standards Board then climate change reporting based on TCFD will be its first focus area.

Adoption of TCFD will be greatly facilitated if the Hong Kong Government sponsors the development of scenarios which companies owning buildings can use for their TCFD reporting. Such scenarios would make their task of reporting against TCFD much easier. It also makes the report more valuable as they are done on a common basis and thus provide more valid comparisons. This will help both investors and the government agencies responsible for overseeing improvements in Hong Kong's buildings.

These disclosures, while not explicitly stating for the need to reduce carbon emissions, forces businesses to contemplate carbon in terms of its impact to the climate. Disclosures can help build up a company's reputation and for these have a market uptake, recognition for companies using such standards is needed. As there are currently no incentives for companies to adhere to such reporting frameworks, with the exception of TCFD, it may be worth considering guidelines for developer on how to disclose such risks.

11. Industries include Health Care, Transportation, Services, Financials, Consumption, Technology & Communication, Resource Transformation, Non-Renewable Resources, Renewable Resources & Alternative Energy, Infrastructure.

5.7.2 Zero Carbon Standards

Zero Carbon Standards such as Publicly Available Specification (PAS) are voluntary standardisation schemes that defines good practice and a method for establishing integrity for reporting. The application of such specifications gives claims for organisation and can help guide organisations' action into achieving better carbon performance.

i) PAS 2060 Carbon Neutrality

Developed by British Standards Institutes (BSI), the PAS2060 Specification builds on existing environmental standards[12] and sets out requirements to achieving and demonstrating carbon neutrality. It provides a common and consistent approach to how carbon neutrality can be demonstrated. The Specification is applicable to businesses and organisations across all areas including buildings, transport, manufacturing, product lines, and events, to make claims about carbon neutrality. Documents submitted under this specification would be made public, meaning businesses and organisations will be disclosing their carbon reduction plan and actions (BSI, 2014).

Through this set of Specification, businesses and organisations can make claims about their commitment to sustainability and actions on reducing carbon emissions. It comprises four stages: (1) Measure GHG emissions based on accurate and complete raw data; (2) Reduce through Carbon Management Plan by declaring commitment to carbon neutrality through strategic actions and targets with timescale for actions; (3) Offset residual carbon emissions by high quality certified carbon credits; and (4) Document & Validate commitment and achievement of carbon neutrality with supporting statement and public disclosure. Businesses and organisations are required to define the subject for measurement, baseline date, achievement and commitment period. All of Scope 1 and Scope 2 emissions are measured under this specification while Scope 3 emissions contributing to more than 1% of total carbon footprint would be measured. Validation on the state of Carbon Neutrality can be achieved through independent third party, audited by verified external party, or through self-validation.

While businesses and organisations can claim to be carbon neutral, declaration made in conformity to PAS2060 gives more credibility to the state and actions towards achieving carbon neutrality. Declarations of achievements in carbon neutrality are made retrospectively and applicable for the period covered by validated data. Declarations on commitment are valid for a period of 12 months and requires businesses and organisations to continually monitor and revalidate their state on an annual basis in order for the statement of declaration to remain true. At the end of the process, businesses and organisations may pursue certification under this Specification through an accredited certification party.

12. Such as ISO14000 series on environmental management that helps organisation to mininmise negative effects on the environment and compliance to applicable laws, regulations, and requirements; and PAS 2050 on assessment of lifecycle greenhouse gas emissions, a standard on the process of carbon footprint assessment of goods and services.

ii) PAS 2080 Carbon Management in Infrastructure Verification

This Specification is designed to address the management of carbon in infrastructure, looking at the whole lifecycle of carbon used in the project. This is applicable to those involved in the delivery of infrastructure, including asset owners / managers, designers, constructors, and product/material suppliers. It assesses the delivery, supply chain management and roles of various stakeholders (e.g. designers and contractors) play for the duration of the project, how carbon is measured and monitored. With its application, projects may be able to identify where carbon can be reduced that may result in a reduction in cost of infrastructure (BSI, 2016).

An infrastructure project in UK adopted an approach to carbon reduction centred on PAS 2080:2016 methodology that sets out the framework for calculating and reporting carbon. A carbon baseline was calculated during the appraisal stage to allow design teams to identify carbon hotspots while during tendering, contractors were assessed based on the technical and professional understanding of PAS 2080. Contractual requirements were established for continued monitoring throughout construction. The project achieved a savings of 6,000 tonnes of carbon during design stage and is anticipated to achieve an overall carbon savings of at least 6,500 tonnes in total by the end of the project, amounting to around £12 million. (SWECO, n.d.)

6 POLICY RECOMMENDATIONS

Undertaking this review of international standards and approaches has highlighted not only Hong Kong's progress but also the significant changes still required to achieve net-zero carbon by 2050. Effective and immediate action is required to steer Hong Kong towards a sustainable future, towards which the building sector can make a significant contribution.

Hong Kong currently employs a wide range of measures to encourage the decarbonisation of the building sector. This review has highlighted several different issues with the current approach. Firstly, the regulatory floor has significant scope to improve in line with best practise taken from equivalent regulations in Singapore, China and the UK. Secondly, the measures designed to encourage the deepest efforts to decarbonise beyond the regulatory minimums can be expanded and more strongly incentivise the building sector. These measures currently lack direction and the ability to measure their progress against the necessary milestones required to achieve net-zero.

To live up to the title of Asia's "World City", Hong Kong needs to take the lead in this area and show what is possible with effective collaboration and ambition.

6.1 Policy Priority: Decarbonisation Roadmap

A building-sector specific roadmap must be developed which outlines the steps that will be required to achieve net-zero by 2050. Operational and embodied carbon emissions from new and existing buildings, as well as renewable energy, should be analysed. Currently, Hong Kong's strategy expires in 2030 under the Environment Bureau's Climate Action Plan 2030+. This contains general guidance that does not require concrete action with associated deadlines. A detailed study will be required to establish the necessary timelines and mechanisms for ensuring progress, but this should be completed with urgency. It is suggested that a recognised framework such as Science Based Targets is used to ensure completeness. This process will require cross-departmental collaboration, as well as advice from industry, in line with the Environmental Bureau's Long-term Decarbonisation Strategy.

6.2 Policy Instruments

6.2.1 Improve Regulatory Tools

Upgrade the BEC and the Energy Efficiency Labelling Scheme (MEELS & VEELS)

The Energy Code review has shown that there is significant potential to raise the regulatory floor and tighten regulations. More-efficient technologies and the engineering skills to apply them are currently available which means the Government can demand more of all stakeholders within the building sector. Aligning Hong Kong with global best practise and adopting timelines for the introduction of new technologies, allowing the market to adapt, will ensure that the minimum standard for Hong Kong's buildings remains high enough to close the gap to net-zero carbon in time. This will be an ongoing process, requiring regular reviews as new technologies become available.

There are several points of action that should be highlighted. Firstly, the Super Low Energy programme in Singapore suggests that a 40% energy saving is possible for new buildings based on current technologies. Currently, the BEC is tightening requirements less than 10% every three years. BEC should include sections for external lighting for medium- and large-scale water heating systems to ensure that large energy-consuming systems are covered, as in Shenzhen and Singapore. Although it is difficult to quantify the effect of including this in but ensuring that external lights have their energy consumption controlled will make a positive difference. Lighting Power Density requirements should also be tightened in line with the strictest international standards for each space type. A timeline for the introduction of International Efficiency Class 4 for motors must be introduced in line with the EUs approach to continue the drive for efficiency.

Introducing international testing standards such as VDI or ISO for lifts would help to reduce regulatory hurdles, provide a more complete picture of energy consumption and introduce a grading system, allowing more efficient lifts to clearly advertise their benefits. Harmonised international standards help to drive efficiency improvements for manufacturers.

The timeline for updating MEELS must be significantly shortened; it took eleven years for Grade 1 COP requirements to increase by 50% from 3 to 4.5 for Single Package Type Room Air Conditioners. This will ensure that only the most energy-efficient equipment can earn the highest grade and the associated benefits. China Environment Labelling also covers more categories than MEELs, showing scope for product categories currently under VEELs to be moved to MEELs. Low efficiency equipment must be banned from Hong Kong because the extra energy consumption will contribute for the entire lifespan of the product.

To further develop an understanding of actual energy consumption in buildings across Hong Kong, requirements for sub-metering should be significantly expanded within the BEC. The current metering requirements only include medium- and

large-scale AC installations, lifts, escalators and passenger conveyors and high-power circuits. This means that energy-consumption cannot be assigned with enough clarity to different sub-systems such as lighting or small equipment power – computers, photocopiers and televisions. These items already have minimum energy-efficiency standards set but effective sub-metering will ensure that Building Managers and other stakeholders have high-quality data that they can then act on. This will expand the opportunities to identify energy savings during Energy Audits. Furthermore, data collected and submitted to the Government will have greater detail, enabling more effective policy making going forward.

Upgrade the EAC

Currently, the EAC covers only commercial buildings and the commercial portion of mixed-use buildings. It should be expanded so its scope includes all buildings under Schedule 1 of the BEEO, the same as the BEC. The 10-year gap between audits is also not frequent enough to drive progress and address deficiencies in each building's performance - Singapore Energy Audits for cooling systems are conducted on a 3-year cycle. A balance between retro-commissioning requirements and retrofit must be struck but it is essential that existing buildings are regularly reviewed, and energy-efficiency measures are implemented.

For the EAC to be effective, EMOs - with a reasonable carbon payback period and positive cost-benefit analysis - identified during the Energy Audit process need to be both enforced and incentivised. Currently, there are no requirements for the implementation of any EMOs – even Category 1 EMOs, which require little to no cost. A full and effective policy should be established to ensure that the EAC effectively addresses operational emissions of existing buildings and that building owners are supported during implementation.

Evaluate Building Envelope Requirements

Consistently review the Overall Thermal Transfer Value (OTTV) code to ensure that the requirements are in line with the decarbonisation strategy. This should include evaluating the regulations around external shading to encourage shading to be used wherever it is beneficial. The current regulations disincentivise usage beyond a width of 750mm, when all energy-saving measures must be maximised to their full potential.

Require Public Disclosure

At the building level, mandate the public disclosure and rating of energy consumption and emissions data to enable benchmarking and comparisons between properties. The public disclosure of data submitted to the Hong Kong's Electrical and Mechanical Services Department (EMSD), through a grading system similar to the Hong Kong Green Building Council's BEST tool or the NABERS system in Australia, will help to ensure that building owners are held accountable for the carbon emissions of their properties, incentivising energy-efficiency. A grading system also provides opportunities for both private and public sector bodies to set lease requirements. Public disclosure also incentivises owners of underperforming buildings to achieve higher grades or face potential reputational damage.

6.2.2 Incentivise the Market

Update the Gross Floor Area Concession Scheme

The current GFA Concession Scheme in Hong Kong has highlighted the Green Building movement and introduced improvements to newly constructed buildings including energy, waste and water savings. Currently, the same GFA concession is granted to buildings of any BEAM Plus rating and performance verification post-occupancy is not required. This means that developers do not have the motivation to pursue higher tier ratings or strive for the energy efficiency required for net-zero by 2050.

Realigning this incentive to focus purely on energy efficiency requirements would make a more significant contribution to decarbonisation, which should be the Governments priority. Linking GFA concessions with verified improvements in performance is essential. There are several options to carry this out including linking with BEAM Plus Energy Use credits or the approach used by the Super Low Energy Building programme in Singapore – accreditation is given to buildings that achieve 40% energy savings compared to regulations. This ensures that GFA directly incentivises decarbonisation and incentivises deep energy savings.

Introduce Public-Private Partnerships for Existing Buildings

Developing the framework for addressing the challenge of existing buildings is currently in progress with the publishing of the Technical Guidelines for Retro-commissioning, along with the EAC. The long payback periods and expertise required present barriers to implementation. Public-private partnerships, established and organised by a cross-agency body, are a solution to these issues. This will allow the government to utilise external expertise, capital and manpower while attracting private companies to participate with incentives and mitigated risks. An example can be seen in the UK with the RE:FIT programme which shows how frameworks implemented by the government can be extremely effective at tackling this specific issue.

The framework should be expanded to private buildings once it has been established by introducing mandatory retro-commissioning requirements to ensure that all existing buildings are addressed. This should be in line with Singapore's requirement to undertake retro-commissioning approximately every 3 years for chilled water plants.

A framework should also be established for implementing the updated EAC. High capital costs and long payback periods are barriers for large retrofits, such as replacing inefficient chillers, and green finance will be required to address the scale of this challenge.

Participate in Emissions Trading

Cap-and-trade systems are the most commonly used ETS in the market. Success cases include the EU ETS, New Zealand's ETS and Japan's ETS, all of which have been launched and operating for over 10 years. China has also launched ETS pilots in 8 provinces, including Shenzhen and Guangdong. Launch of a national carbon trading scheme is anticipated in the coming year. However, ETS are normally established to cover high-energy consuming sectors such as power plants, agriculture and industrial processes. Unique to Japan's ETS is the inclusion of commercial sector to cover the emissions from the energy consumed by office buildings and other commercial facilities. This program is the first urban cap-and-trade scheme in the world.

Creating an urban cap-and-trade system for Hong Kong would be a major incentive towards capturing the price of excessive carbon emissions in the building sector, and the city could develop its own ETS. Alternatively, there is an opportunity for Hong Kong to tap into China's national ETS after its launch, although the scope of the national ETS may be restricted to coal-fired power plants in the short term. The timeline and development of the scope and emissions cap will align with China's net-zero target for 2060, which will be outside the control and review of Hong Kong's own decarbonisation strategy.

Another opportunity will be through the Carbon Connect initiative launched by the Greater Bay Area Green Finance Alliance, which aims to establish a cross-border carbon trading market. A regional ETS that could cover the commercial sector would be highly beneficial to Hong Kong's building industry. The Carbon Connect initiative would also be able to offer increased oversight and control compared to the national ETS.

Mandate Corporate Disclosures

Use of standards and disclosures may be driven by directed regulations and requirements, such as from HKEX using TCFD in which one of the aspects of transitional risk can involve analysis and preparedness for decarbonisation. Disclosure of Scope 1, 2, and 3 carbon emissions, such as CDP, or application of science-based targets guides businesses in how to report carbon emissions and identify actions.

As adoption is voluntary and is merely referenced as a potential structure, there is opportunity, Hong Kong can explore the opportunities for mandatory disclosure to prompt changes in business behaviour and operations as businesses will be held accountable for the reported information. Further, the Hong Kong Government, should develop scenarios which companies owning buildings can use for their TCFD reporting. This makes the task of reporting against TCFD much easier and makes the report more valuable as they are done in accordance to a common framework and thus provide more valid comparisons, providing valuable information for investors and the government agencies responsible for overseeing improvements in Hong Kong's buildings.

6.2.3 Influencing behaviour change

Increase Renewable Energy Generation

Key initiatives in Hong Kong encouraging use and generation of renewable energy (RE) stems from the Scheme of Control Agreements (SCA) with the two power companies, FiT Scheme and RE Certificates, to encourage the private sector to invest in RE.

Comparatively, the FiT rate in Hong Kong somewhat matches with international examples such as UK[13] and can provide returns on investment in the long run. With current pricing, payback is possible and may not pose a large problem, though entry into RE generation may still be a hurdle due to initial setup costs. Hong Kong can explore means of facilitating entry to RE in the form of aiding capital setup and hardware installation as renewable energy incentives listed under SCA revolves mainly around FiT. While CLP provided aid to identify the solar potential of properties to identify potential for installation, there are no indications of subsidies on hardware setup.

Electricity companies in Hong Kong have contributed towards decarbonisation through changes in fuel mix and promotion of FiT and REC schemes, though energy saving and energy efficiency is still a focus of their efforts as demonstrated by their subsidies for improvement of hardware (e.g. retrofitting equipment) and energy saving funding schemes. Availability of physical space in Hong Kong limits the potential for large scale RE installations, such as solar or wind farming on a commercial scale, though efforts have been made by CLP and HKE to small scale RE. Hong Kong can explore incorporating renewable energy installations on public infrastructure to provide power to public facilities (e.g. road lighting).

Explore New Technology

International examples have demonstrated there is a high cost associated with CCS, particularly with regards to transportation and spatial requirements. In Hong Kong, CLP has identified CCS as part of its strategy towards long-term decarbonisation while HKE have as yet to make such identification. Further investigation into the potential of CCS, locally or within the region of GBA, will allow electricity companies to identify whether local storage of carbon is possible and viable.

With the maturity of technology, the cost of electrolysers is anticipated to fall, causing a decrease to the cost of renewable hydrogen and making hydrogen more feasible as a source of green energy. The generation and use of hydrogen is considered to be at a very early stage in Hong Kong, with its concept not well understood by public compared to other forms of energy saving / efficiency measures. Exploration in the commercial viability of locally produced hydrogen is recommended.

Implement Carbon Tax and Tariffs

Internationally, carbon pricing / taxing is possible due to the country's ability to integrate and promote RE generation. Sweden, UK, and Singapore have all taken proactive approaches to encouraging RE generation on a large scale by companies or private organisations, such as housing estates in Singapore's case, thus providing alternatives for energy producers. Instead of taxation on carbon, China placed taxation on fuel source in the attempt to curb polluting fuel use. In contrast, Hong Kong's limited RE potential may restrict its ability to decarbonise, thus making carbon pricing or carbon tax a difficult measure to be implemented or accepted.

With carbon tax being a levy on pollution, generally as a result from the production, distribution or use of fossil fuels, limited options for choice to adopt alternative (renewable) energy sources meant consumers are restricted to adopting measures and technologies for improving energy efficiency in order to reduce energy consumption and in turn carbon emissions. Therefore, to provide more options, Hong Kong is recommended to make RE more widely available for carbon emitting facilities to choose alternative fuels.

6.2.4 Build Capacity through Public Sector Procurement

To kickstart the implementation of some of the recommendations made, the public sector should take the lead. In the same way BEAM Plus requirements imposed on Government projects, this will provide opportunities to build capacity and expertise and drive widespread adoption. This can be seen with the Public Sector Taking the Lead in Environmental Sustainability programme in Singapore. The public sector has consistently set strict requirements for all buildings that the Government uses, driving decarbonisation. This approach also influences the private sector by and building capacity and skills and demonstrating that compliance is possible. The public sector can undertake pilot projects as well as rollout large-scale programmes.

To address embodied carbon, during the public procurement process, Government projects should implement an LCA requirement to address the lack of data in this area and inform more detailed policy going forward. An action available now is a requirement to follow the Construction Industry Council carbon labelling scheme for construction materials.

Improving the design standards for Government offices and public housing is another capacity builder. If achieving these standards requires a new approach to follow an extremely high standard of energy-efficiency, these buildings will act as examples other projects can follow. The private sector should simultaneously be encouraged and incentivised to do the same once the standards have been established.

To address the challenges around existing buildings, particularly around retro-commissioning and the implementation of the EAC, the Government property portfolio should be the first addressed. Heavily linked with the recommendations

outlined in Incentivising the Market, this will provide the opportunity to demonstrate compliance with an updated BEC and EAC, as well as build the capacity required to complete the process, from Energy Assessors to installation technicians. This can also be the first stage of implementing a widespread PPP for existing buildings.

Another example of this strategy is setting energy-efficiency requirements for all Government leases. This would force building owners to upgrade the energy-efficiency of their buildings if they want Government tenants. This is linked with the proposed rating systems for buildings, utilising or building upon examples such as HK BEST or NABERS, where the Government should stipulate a minimum Grade A requirement.

6.3 Institutional Arrangement: Dedicated Cross-Agency Body

To implement this decarbonisation roadmap, a dedicated cross-agency body should be formed with members from relevant bureaus including, but not limited to, the Environment Bureau, the Development Bureau, the Transport and Housing Bureau, and the Financial Services and the Treasury Bureau. This body should be responsible for coordinating all incentives and regulations necessary for the building sector to achieve net-zero by 2050. This body is essential to ensure that any steps taken are not siloed and that effective decarbonisation across the whole sector is the sole priority.

6.4 Conclusion

It is important to emphasise that these policies will not immediately decarbonise Hong Kong's building industry, but instead be a positive step to advancing net-zero. All stakeholders within the building industry will need to contribute a significant amount of effort and resources to achieve net-zero by 2050. Steps must be taken now to keep this target within reach.

7 APPENDICES

7.1 Civic Exchange: Towards a Better Hong Kong: Pathways to Net-zero Carbon Emissions by 2050

Long-term deep decarbonisation strategy in cities

The Paris Agreement has raised the awareness of the threat of climate change to nations across the world. Countries are committed to set targets and deliver strategies to reach net-zero carbon emissions by 2050 and cities can play a significant role in achieving net-zero emissions. In view of cities contributing 70% of the total energy-related CO_2 emissions worldwide, many cities have committed to implement their own targets to achieve carbon neutrality, in some cases even before 2050. Adelaide and Copenhagen for example aim to reach complete decarbonisation by 2025, while London, New York and Sydney aim to achieve 100% decarbonisation by 2050.

As a developed international city, Hong Kong has as much potential as cities like London and New York in terms of achieving net-zero carbon by 2050. Since 2010, the Hong Kong Government has implemented initiatives to address climate change and emissions in energy conservation and efficiency, electricity generation, construction, transportation and waste management. In 2010, the Hong Kong Government announced plans to reduce carbon intensity by 50-60% by 2020 compared to levels in 2005. In 2017, the Hong Kong Government established Hong Kong's Climate Action Plan 2030+, which targets to reduce Hong Kong's carbon intensity and carbon emissions from 2005 levels by 65-70% and 26-36% by 2030 respectively. The current estimated progress of carbon intensity reduction is 33.3% and 1.2% for carbon emissions in 2017, which seems far behind the targets set for 2020 and 2030. In 2019, Civic Exchange conducted a study investigating the long-term impacts of the current policy, along with the achievability of the 2020 and 2030 targets. Findings of this study are stated below.

Deep decarbonisation in Hong Kong

The 2019 Civic Exchange study involved a detailed modelling exercise that evaluated the medium- and long-term impacts on CO_2e emissions in Hong Kong considering two scenarios, a "current policy scenario" based on Hong Kong's Climate Action Plan 2030+ and a "decarbonisation scenario". Both scenarios use 2017 as the base year and are based on identical assumptions about GDP and population growth.

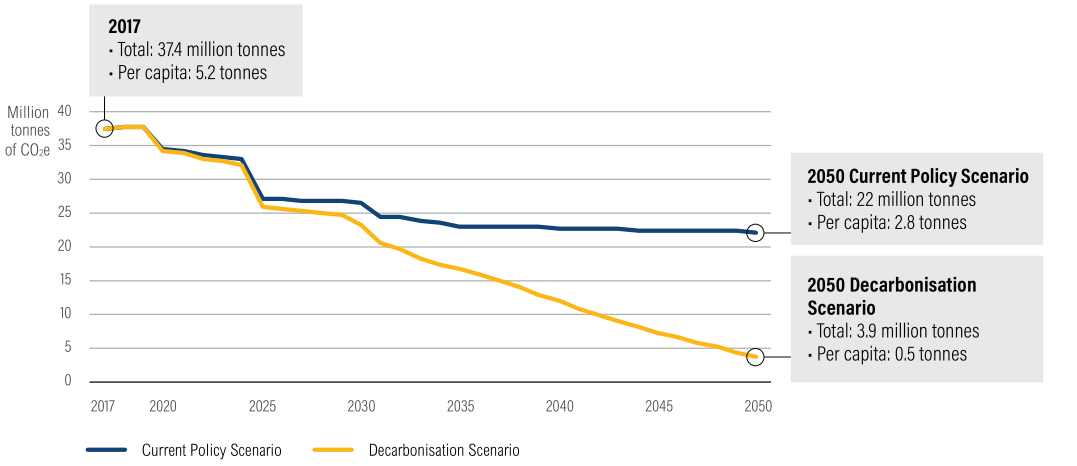
The decarbonisation scenario reflects optimal pathways towards achieving net-zero emissions by 2050. The principal recommendations include:

- A split electricity supply with 60% from imported renewable energy and nuclear energy, 35% from local gas-powered plants with carbon capture and storage (CCS) and 5% from local renewable energy and waste-to-energy.

- Increasing the energy efficiency of buildings by 11-40%.
- Reducing emissions from mobility by mandating electric vehicle sales, discouraging car sales and other policies.

FIGURE 28 Projected greenhouse gas emissions in Hong Kong under the current policy scenario and the decarbonisation scenario

source: Civic Exchange: Pathways to Net-zero Carbon Emissions by 2050

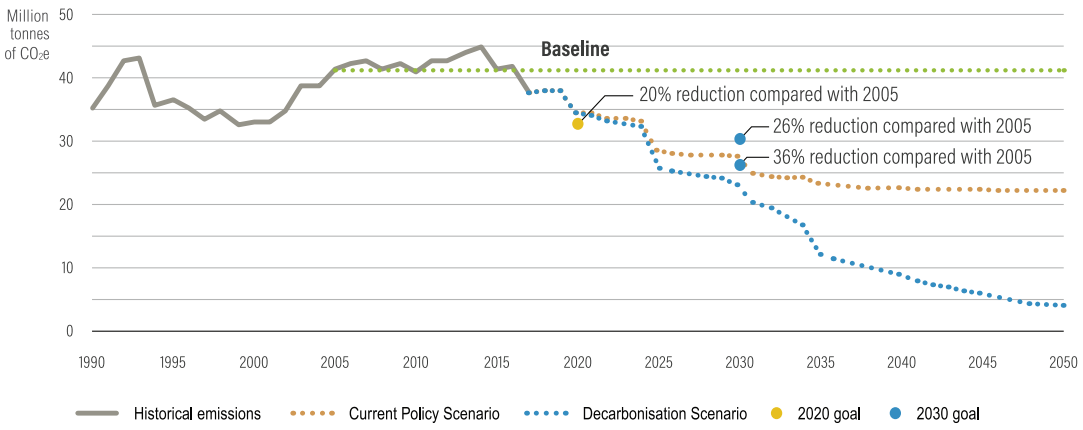


Note: Significant drops in 2024–25 and 2030–31 reflect the retirement of coal-fired power plants. Emissions include energy and industrial processes; waste and land use change and forestry are excluded.

The analysis presented in the report demonstrates that Hong Kong can reduce its carbon emissions by 90 per cent by 2050 relative to 2005 levels and offset the remaining 10 percent which comes from hard to abate sectors.

FIGURE 29 Progress toward meeting the 2020 and 2030 targets under the current policy and the decarbonisation scenario

source: Civic Exchange: Pathways to Net-zero Carbon Emissions by 2050



The 2019 Civic Exchange study also presents the progress toward meeting the 2020 and 2030 targets under the current policy and the decarbonisation scenario. Figure 29 indicates that the lower-level targets for 2030 are projected to be attainable under the current policy scenario, while additional actions under the decarbonisation scenario will alleviate the amount of reduction to meet the higher-level targets. However, meeting the 2020 goals appear to be challenging under the current policy scenario, where a delay of at least two years is expected.

It is concluded that to progress towards a net-zero emissions future, Hong Kong must begin planning and taking accelerated action now. It needs to adopt a significantly more aggressive decarbonisation target, with annual reductions of 6.6 per cent beginning immediately and continuing through 2050.

The study team analysed the sources of Hong Kong's emission-reduction potential and found that the greatest potential for reducing emissions comes from improving electricity generation, making buildings more energy efficient and increasing the sustainability of mobility. Such policy recommendations include developing local renewable energy, replacing town gas with zero-carbon electricity or carbon hydrogen, improve energy auditing and enhancing public transport and infrastructure.

Making Buildings More Energy Efficient

In Hong Kong, activities in buildings account for more than 90% of the electricity consumption and 60% of the GHG emissions, excluding embodied carbon in building materials (EMSD, 2018). Therefore, energy reduction in buildings is crucial in achieving net-zero emissions.

If the current policies remain unchanged, total building energy consumption will increase by 21% by 2050, due to a projected increase in the population of Hong Kong. In comparison, under the decarbonisation scenario, total building energy consumption should be reduced by around 20% by 2050. To achieve this 20% reduction, the report suggested four policies that will help increasing building efficiency:

1. Set targets, track performance/ bench-mark and improve transparency

Despite the HKGBC's voluntary electricity consumption reduction targets for all buildings other voluntary schemes targeting building owners, including the Science-Based Targets (SBT), the schemes seem to have not delivered the anticipated results. The report recommends introducing performance-tracking and benchmarking systems that requires annual assessment and disclosure of performance. Existing Benchmarking and Energy Saving Tool (HK BEST), benchmarking tool of EMSD can be used as reference to build on.

2. Tighten Policies and Regulations
The report suggests that guidelines relating to energy consumption such as Building Energy Code, Mandatory Energy Efficiency Labelling Scheme, Overall Thermal Transfer Value and Residential Thermal Transfer Value should be reviewed and tightened regularly based on cost-benefit analysis. Incentives to promote green building such as tax incentives and gross floor area concessions should be revised and reformed. The current requirement for developers to obtain benefits are lenient leading to developers only achieving the bare minimum to reach the requirements. Hence, the government should either tighten the requirements or impose sanctions to the developers that do not commit to ensure building sustainability.

3. Improve Energy Audits and Increase Retrofitting
Currently, energy audits for commercial buildings are conducted every ten years and building owners are not required to response and take actions to the recommendations provided in the audits. It is proposed that energy audits should be conducted every five years and building owners should be required to implement the audit recommendations.

The government could also provide more training to the industry to retrofit more inefficient buildings and expanding the coverage of building types through public buildings, commercial buildings and energy systems.

4. Improve Demand Management and User Behaviour
Improving user behaviour by providing public education, training, regulations and cultural influences can affect the energy consumption of buildings and the carbon footprint. For instance, changes can be made to lighting and air-conditioning usage and demand of energy will be greatly reduced.

In order to raise the awareness of building energy consumption in residential and commercial buildings, CLP has launched benchmark programmes to compare the usage of energy with similar building premises. CLP has also launched smart meters, which encourages monitoring of energy consumption and encourages energy saving. Information obtained by the premises can be analysed and improvements can be made accordingly.

Lastly, it is suggested that the Government should set up a “Greening Residential Buildings Fund” to support the transformation into a smart and sustainable city. Building owners can utilise the fund to incorporate green features and smart devices which promotes energy efficiency. A similar grant scheme targeting commercial buildings was launched in 2009-2012 – the Buildings Energy Efficiency Funding Scheme, which can act as a case study for future use.

7.2 Scope 1, 2 and 3 Emissions Explainer

To delineate direct and indirect GHG emission sources and to avoid the 'double counting' of emissions, the GHG Protocol Corporate Standard developed a globally recognised system to classify GHG emissions of a company into 3 scopes. The standard provides guidance for different types of organisations to measure and report for their greenhouse gases emissions.

Scope 1: Direct GHG Emissions

Scope 1 emissions are defined as direct GHG emissions, which occur from sources that are owned or controlled by the company. For instance, the following activities contribute to Scope 1 emissions:

- Fossil fuel combustion from company owned and controlled facilities such as boilers and furnaces
- Fossil fuel combustion from company owned vehicles
- On-site manufacturing in specific industries, such as chemical production which cause process emissions
- Fugitive emissions from refrigerant systems and other sources

Since Scope 1 emissions are directly controlled by businesses, they can reduce emissions by first identifying the major sources of emission. Companies should prioritise removing sources of emissions if possible. Fossil fuel combustion and carbon-intensive activities should be avoided. If operations in specific industries do not allow elimination of such activities, the next strategy should involve reducing GHG emissions by increasing the operation efficiency. This includes investing in upgrading the equipment to improve the efficiencies. Followed by replacing sources with low-carbon alternatives, being biofuels, on-site renewable energy. Switching company owned vehicles to electric vehicles would also cut Scope 1 emissions.

Scope 2: Electricity Indirect GHG Emissions

Scope 2 emissions are indirect emissions coming from the generation of purchased electricity consumer by a company. It also includes purchased steam, heating and cooling for businesses' own use. Scope 2 emissions physically arise at the site of electricity generation.

It was found that electricity generation accounted for 65.8% of all GHG emissions in 2017 in Hong Kong (Environmental Bureau, 2020), while73.4% of the electricity generated was for commercial and industrial use in 2019 (Census and Statistics Department HKSAR, 2019). Hence, businesses play a significant role in reducing Scope 2 emissions.

Some energy suppliers provide 100% green electricity these days. By changing purchasing habits and switching to low-carbon energy supplier, businesses can easily cut scope 2 emissions. Business can also contribute by monitoring and reducing their energy demand at their facilities. At office buildings, businesses should assess their electricity consumption through metering and billing. Lighting, IT, HVAC and other

equipment should be upgraded, and occupancy sensors should be installed when in need. For manufacturing facilities, businesses should ensure their operations are optimised to run at maximum efficiency.

Scope 3: Other Indirect GHG Emissions

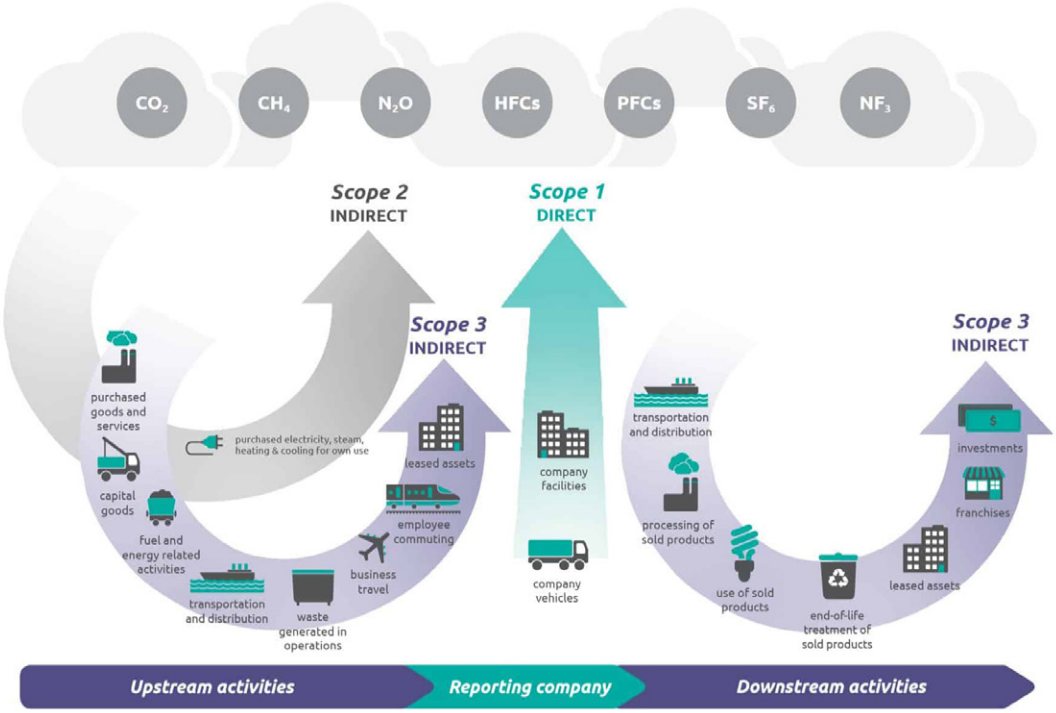
Scope 3 emissions, also known as value chain emissions, are other indirect emissions resulting from the activities of the company, but produced by sources that are not owned and controlled by the company. Examples are extraction and production of purchased materials, transportation of materials and fuels, and consumer use of sold products and services. Business travel and third-party transportation are also considered as Scope 3 emissions.

Scope 3 emissions are relatively harder to calculate but are important for companies to find out. It is possible that Scope 3 emissions account for over 90% of the total GHG emissions of a company. Therefore, measuring scope 3 emissions enables companies to understand their full value chain emissions and may concentrate on reducing the major GHG sources. GHG Protocol established the Corporate Value Chain (Scope 3) Standard along with calculation guidance document to support companies in calculating their Scope 3 emissions.

When the greatest indirect contributors of GHG are identified, companies can develop business strategies to reduce Scope 3 emissions. For example, raw materials should be sourced at a sustainable supplier, low-carbon transportation can be used for up-stream and down-stream deliveries and the products should be recyclable to reduce indirect emissions.

FIGURE 30 **Scope 1, 2 and 3 Carbon Emissions**

source: World Resources Institute, 2013



7.3 BEC Requirements for BSIs Explainer

The requirements in the BEC are categorised according to the four major BSIs in Hong Kong. A number of different strategies are employed to ensure the minimum standard of energy-efficiency. For the descriptions below, where requirements change depending on the equipment size or capacity, the requirements for the smallest and largest items have been listed.

Lighting Installations

Regulations here apply to all installations greater than 70W and are a legal requirement. In practical terms, this applies to a vast majority of areas but excludes areas such as lifts and small storage areas that require low levels of lighting.
The following measures are used to control the energy consumption of lighting installations:

1. Lighting Power Density (LPD)
The Lighting Power Density describes the power of all fixed lighting installations in a given space divided by the area of that space. A large range of spaces are described in the BEC. The power of the lighting installations is available because manufacturers of lighting installations provide power ratings, measured in Watts, in the catalogues of their products. The area of a given space inside the building, such as the office, is readily available from building layouts. Building Services Engineers then calculate the LPD once the quantity and type of lighting has been selected. Reducing the LPD will reduce the amount of energy required to light the same area over a given period, reducing operational carbon emissions.

2. Lighting Control Points
Lighting Control Points are switches that control a group of lights, typically organised by type or the area they illuminate. The quantity of Control Points is included in the BEC because it allows flexibility in the control of the lighting system and allows the minimum number of lights to be switched on to meet requirements at the time. This measure mandates a certain number of Control Points according to the floor area, with larger floor areas requiring more Control Points. For example, a worse-case scenario would be for all the lights on a large office floor to be switched on even if there is only a single occupant in the corner of the space. By providing the option to switch off unnecessary lights, operational carbon emissions can be reduced.

3. Automatic Lighting Control
Automatic control systems use one or more of the following criteria to control the lighting system: occupancy, time and daylight. Occupancy control uses a number of different technologies to detect if a space is occupied and will only switch the lights on when required or alternatively, switch them off when the system detects they are not. This type of control is used in places with unpredictable or occasional occupancy such as meeting rooms or storerooms. Lighting systems can also be

controlled by timers and set to dim or turn off according to schedules set by the Building Owner, Facilities Managers or relevant decision makers. This type of control is common in areas with consistent occupancy levels such as open-plan offices.

An important sub-section of automatic lighting control is daylight control. It uses sensors which measure the ambient light level in an interior space. When the light outside is bright and effectively illuminating the interior space, the artificial lighting level will be dimmed, saving energy. This type of control is normally used in spaces that are normally-occupied such as offices. This type of control is heavily linked with the design of the façade and the glazing area – larger windows increase the opportunities for this type of control because more light can enter the interior space.

These control systems are included in the code because they effectively reduce the total energy consumption of lighting systems by ensuring this energy consumption is more closely correlated with lighting requirements at any given time. The best control systems ensure that the minimum number of lights on their lowest possible settings are on while still maintaining a safe, pleasant working environment.

Air-Conditioning Installations

Mechanical Ventilation and Air Conditioning (MVAC) systems control the flow of air through a development and are primarily responsible for controlling the temperature and humidity of an interior space. For certain spaces, such as washrooms and kitchens, these systems are primarily responsible for ensuring the Indoor Air Quality (IAQ) is at an acceptable level by removing pollutants.

1. System Load Design Conditions

These conditions are the parameters that Building Services Engineers use to develop their MVAC system design. The Outdoor Design Conditions are the same for all buildings covered by BEC because it is only applied in Hong Kong where the climate is very similar. By stating these assumptions, the code is ensuring that unreasonable conditions are not selected, leading to unnecessary extra capacity and the oversizing of systems and equipment. There are two options available, each representing some of the worst outdoor conditions a building would normally operate in i.e. peak summer:

- 35°C Dry Bulb, lower than 29°C Wet Bulb – typically applied to spaces where the sensible heat loads are dominant, such as offices.
- 29°C Wet Bulb, lower than 35°C Dry Bulb – typically applied to spaces where the latent heat loads – which usually have higher Fresh Air requirements - are dominant, such as gymnasiums.

There are no specific requirements for Indoor Design Conditions because these can vary significantly based on the use of the space.

2. Separate Air Distribution System for Process Zone

An air distribution system is the equipment, such as the Primary Air Unit, fans and ducts, which supplies air to a space. This regulation states that a process zone – an area of a building which accommodates a single type of activity or process – needs to have a dedicated Air Distribution System, separate to that of a comfort-only zone. This allows the system responsible for the comfort-only zone to independently respond to changes in cooling load, caused by changes in occupancy or solar heat gain, and maintain consistent temperature and humidity set-points. By adapting to the load, this system can reduce its energy consumption whenever possible, improving occupant thermal comfort while reducing operational emissions. This regulation does not apply when the comfort-only zone takes <25% of the total airflow and ensures that for small, combined spaces, an expensive additional system is not required.

3. Air Leakage Limit of Ductwork

Applied to ductwork that operates with a static pressure > 750 Pa, this regulation specifies the maximum allowable air leakage limits for a given class of ductwork. Ducts, which need to work at higher pressures, have lower limits to ensure these pressures are maintained. From an energy-efficiency standpoint, air leakage is something to be avoided because fans must run at a higher speed to maintain the same pressures and additional energy must be spent cooling air which will not usefully cool a space. There are also issues regarding pollutant leakage if the air is returning from spaces such as chemical storage areas and kitchens. This regulation applies to the installation and Testing & Commissioning (T&C) stage during building construction and helps to ensure the workmanship of the relevant contractors.

TABLE 51 **Air Leakage Limits**

source: Association, 2000

Duct pressure class	Static pressure limit		Maximum air velocity	Air leakage limits litres/s/ m^2 of duct surface area
	Positive	Negative		
1	2	3	4	5
Low pressure - Class A	Pa 500	Pa 500	m/s 10	$0.027 \times p^{0.65}$
Medium pressure - Class B	1000	750	20	$0.009 \times p^{0.65}$
Low pressure - Class A	2000	750	40	$0.003x\ p^{0.65}$

Although the volume of air and the surface area of the duct system do not have a direct relationship, the limits listed in Table 51 are approximately equivalent to leakage rates of 6%, 3% and 2% for low, medium and high pressure duct systems respectively.

4. Maximum Air Distribution System Fan Power

The first part of this regulation applies to the supply air fan and return air fan of the Air Distribution System. These are fans responsible for the circulation to air-conditioned spaces. A minimum standard of energy-efficiency of the fans in the system is introduced to reduce operational energy consumption by restricting the power consumed per unit volume of air circulated:

- Variable Air Volume (VAV) systems: 2.1 Watts/Litre/second
- Constant Air Volume (CAV) systems: 1.6 Watts/Litre/second

VAV systems have higher allowed power draw because the fan speed will change according to the cooling demand in the space. This means when the fan is running at part load, the power consumption is lower and the energy consumption over the period of operation is also lowered. Fans in CAV systems run at the same speed for as long as the system is in operation.

Exemptions include when the system fan motor power is less than 2.5 kW and when the fan in an Air Distribution System consisting only of FCUs have motor powers less than 1 kW.

Unconditioned spaces served by mechanical ventilation such as washrooms and car parks are also included in this regulation. The whole system – meaning the fresh air fan and exhaust air fan – must comply if the total fan power is greater than 2.5 kW which excludes only very small systems. Here the maximum system motor fan power is 1.1 Watts/Litre/second.

5. Provision of Pumping System Variable Flow

Air Conditioning Installations use water to remove heat from the building by circulating chilled water to AC equipment. This section of BEC stipulates that the water-side system must be fitted with variable flow control; in response to variable cooling loads the system as a whole must be able to operate at 50% of the design flow. This can be achieved through several different methods, all of which must be automated: chiller and pump sequencing, valve control or modulation or variable/multi-speed pumps.

When the chiller plant, the equipment responsible for the generation of chilled water, has a design capacity of 350 kW or less, the system is exempt. A 350 kW chiller system would serve approximately 2000m^2 of floor area.

This reduces operational carbon emissions by reducing unnecessary energy use on cooling when the demand does not require it.

6. Water Piping System Maximum Frictional Loss
The maximum frictional loss requirement is included to ensure that unnecessary losses are not introduced along the length of pipe, ensuring pumps during the design stage are not oversized and, during operation, do not draw as much power. For pipes with diameters less than 50mm, the frictional loss must be under 400 Pa/m. The water flow velocity must be less than 2.5 m/s in the flowrate which is non-variable and less than 3 m/s with a variable flowrate. For pipes with diameters greater than 50mm, the maximum water velocity is 1.2 m/s.

At higher velocities, the frictional losses are increased. To address this requirement without changing the flowrate, the diameter of the pipes must be increased to reduce both the velocity and the frictional losses.

7. System Control – Temperature
Similar in design and purpose to the Lighting Control Points, each AC system must be provided with an automatic temperature control device. This ensures that the AC system adapts to the cooling load and can maintain the internal temperature at a set point, reducing the chance of overcooling or overheating. In cooling mode, the device must be able to adjust the set point temperature of the space it serves up to 29°C, while in heating mode it must be capable of being turned down to 16°C. In cooling mode, which is the dominant mode in Hong Kong, providing a set point up to 29°C ensures that occupants can select a set-point which requires a lower power consumption, increasing operational flexibility. Temperature control allows the AC system to run at part load whenever the set point is reached.

This requirement does not apply to unitary AC units which are typically used in small-scale applications such as single rooms in residential units.

8. System Control – Humidity
Following the same principle as temperature control, a humidity control device must be capable of adjusting the relative humidity set-point for each system. For humidification systems, the set-point must be adjustable up to 60% relative humidity. For dehumidification systems, which are much more common in Hong Kong, the set-point must be adjustable down to 30% relative humidity. Once again, this allows an increase in operational flexibility.

9. System Control – Zone
Each AC zone should have a separate temperature control device. Zones must not be across multiple floors, except where the zone is a dedicated perimeter zone that is designed to exclusively address envelope heat gains from the sun. In occupied zones, the controls cannot allow the cooling of previously heated air and vice versa, as well as simultaneous heating and cooling. Exceptions include:

- Zones with peak supply air flowrates ≤140 L/s
- If > 75% of the energy for reheating is provided from a renewable or site-recovered energy source
- Other specific design and process scenarios and conditions which limit energy wastage but still satisfy the requirements

10. Off-Hours Control

The requirement here is for the AC system to have a mode which reduces energy consumption outside of regularly occupied hours. This control option must be automatic for installations greater than 10 kW and can be implemented in two different ways:

- Control Setback - maintain the temperature at least 5°C above the cooling set point and 6°C below the heating set point during regular occupied hours. This significantly reduces the energy demand by reducing the cooling/heating requirements imposed on the system.
- Equipment Shutdown - alternatively, the equipment can be shutdown:
  - At certain times according to a pre-set weekly schedule.
  - Using an occupant sensor when no occupant is detected for a period up to 30 minutes.

For AC installations smaller than 10kW that would normally serve approximately 65m² of floor area, manual control must be readily accessible so units can be switched off when the space is not in use. This would typically be an area served by a few split AC units or Fan Coil Units.

Hotels have slightly different requirements. The control setback must be implemented by an in-room master control device, commonly implemented using the room key card, which reduces the supply air, fan speed or cooling set point when the room is not occupied.

Additional regulations are included within this section to address indoor air quality concerns, particularly moisture migration. Dampers must be included to prevent moisture ingress at the fresh air intake and exhaust air discharge points.

This control method ensures that the AC system is not serving a space that is not occupied, preventing AC installations from being run 100% of the time. This reduces operational carbon emissions.

11. Isolation of Zones

If an AC system is serving several zones with different functions operated or occupied at different times needs to be able to serve these zones independently. This is achieved through the use of separate controls and isolation devices that automatically shut-off the conditioned supply air, fresh air to, and exhaust air from, the area.

An isolation area must be under 2300m² and cannot be across multiple floors. There are several exceptions to this regulation, such as areas that are designed to be continuously occupied. This ensures that the control of AC installations more closely follows occupancy patterns, reducing the gap between actual and required AC energy consumption.

12. Control of VAV Air Distribution System
In a VAV system, the supply air flowrate is varied while the static pressure is kept constant. This is achieved by varying the fan output pressure. This clause states that the static pressure controller should be located along the length of the duct so that the maximum set point is 300 Pa.

Ensuring a high-level of energy efficiency and system effectiveness requires close control but this requires extensive monitoring and control systems. By giving a value for the maximum set point, this clause ensures that these two factors are balanced. Sensors are placed in locations where the data input for the control system is detailed enough to ensure efficient fan speed adjustment while ensuring the number of sensors required is not unnecessarily large.

13. Demand Control Ventilation (DCV)
This clause states that carpark ventilation systems should be able to run at 50% or less of the design capacity based on the detected contaminant level. This ensures that the system can run at reduced level when the level of contaminants such as carbon monoxide, carbon dioxide and/or nitrogen oxides is low. Sensors detect the contaminant level and modulate the system of fans that remove contaminated air and provide fresh air to the space. This can be achieved with 2-speed fans or controlling multiple single-speed fans connected in parallel. In car parks, this requirement only applies to systems greater than 11 kW.

For AC systems, DCV is equivalent to Automatic Lighting Control and ensures the system responds to the number of occupants in the space by measuring the CO_2 level and modulating the amount of fresh air supplied to the space. This requirement applies to conditioned spaces with fresh air flowrates above 1400 Litres/second. Systems are also exempt if they have exhaust air energy recovery which helps to reduce fresh air cooling requirements by using exhaust air to heat up the incoming air. DCV applies to both Air Handling Units and Primary Air Units, the two major pieces of equipment in large AC systems.

14. Thermal Insulation
Insulation around pipes and ductwork helps to minimise energy loss during heating/cooling distribution. This clause stipulates the minimum parameters of the insulation for number of different applications. These include: Chilled Water Pipework, Refrigerant (suction) Pipework and Ductwork and AHU Casing. Parameters specified focus mostly on the thickness of the insulation, but also address protection from moisture and the surface coefficient – which controls how much heat is reflected away by the outside material. The required thicknesses are split up according to the space in which they are used- outdoors, in an unconditioned area, or in a conditioned area.

15. Air Conditioning Equipment Efficiency

This clause lists requirements for the Coefficient of Performance (COP) of a range of AC equipment, including Unitary, Variable Refrigerant Flow (VRF) and Variable Air Volume (VAV) systems, as well as Chillers and Heat Pumps. The COP describes the energy efficiency of a piece of equipment, and is best shown in equation form:

$$COP_{COOLING} = \frac{\text{(Heat removed from the space (W))}}{\text{(Work done to remove heat (W))}}$$

A piece of equipment with a higher COP removes more heat from a space while consuming the same amount of electrical energy over the same period of time. For consistent evaluation, the COP must be given at standard rating conditions which are specific to Hong Kong.

A sample of COP requirements are shown below. The COP depends not only on the type of equipment but also whether it is air- or water-cooled, as well as the cooling capacity.

- **Unitary**

Smaller, room-type unitary units such as window-mounted and split wall-mounted configurations are covered under the Mandatory Energy Efficiency Labelling Scheme (MEELS), described in Section 3.2.1. Equipment must achieve Grade 1 or 2.

TABLE 52 BEC 2018 Unitary Systems COP

	Air-Cooled Min. COP	Water-Cooled Min. COP
Unitary	≤ 7.5kW: 2.3 ≥ 200 kW: 3.1	3.3

Other types of unitary equipment such as Fan Coil Units, commonly found in restaurants, shops and offices, are covered under this section, as shown in Table 52 BEC 2018 Unitary Systems COP. Unitary systems are typically of a lower capacity because they are less efficient than centralised systems.

- **VRF systems**

Under BEC, systems classified here are larger systems, from 20kW to over 200kW. This is equivalent to over 60 indoor cooling units and will be controlled by a computer with automatic controls.

TABLE 53 BEC 2018 VRF Systems COP

	Air-Cooled Min. COP	Water-Cooled Min. COP
VRF System	≤ 20kW: 3.6 ≥ 200 kW: 3.3	4.5

• **Chillers**

Minimum COPs are given for common chiller types found in Hong Kong. Chillers are part of the largest AC systems, serving shopping malls, hotels and office towers.

TABLE 54 BEC 2018 Chillers COP

	Air-Cooled Min. COP	Water-Cooled Min. COP
Reciprocating & Scroll Chiller	≤ 400kW: 2.8 ≥ 400 kW: 2.9	≤ 500kW: 4.2 ≥ 1000kW: 5.3
Screw & VSD Screw Chiller	≤ 400kW: 3.0 ≥ 400 kW: 3.1	≤ 500kW: 4.8 ≥ 1000kW: 5.5
Centrifugal & VSD Centrifugal Chiller	3.2	≤ 1000kW: 5.4/5.3 ≥ 1000kW: 5.8

• **Heaters**

TABLE 55 BEC 2018 Heat Pump COP

	Air-to-Water COP	Water-to-Water COP
Heat Pump	≤ 100kW: 2.8 ≥ 500kW: 3.1	≤ 500kW: 4.4 ≥ 500kW: 4.5

16. Cooling Tower Efficiency

Cooling towers are required within large AC systems to reject unwanted heat from a Chiller. The minimum water flow is specified per cooling tower fan power as follows:

- 1.7 L/s per kW for centrifugal fans
- 3.4 L/s per kW for propeller or axial fans

This ensures fans are not oversized for the amount of cooling they contribute too. For cooling towers with fan(s) with a total power greater than 3.7 kW, controls must be implemented to allow power to be reduced to 30% of designed input power at 50% of design air flow. In addition, the fan speed must be adjustable to control the temperature of water leaving the condenser. This is usually achieved with a variable-speed drive fan.

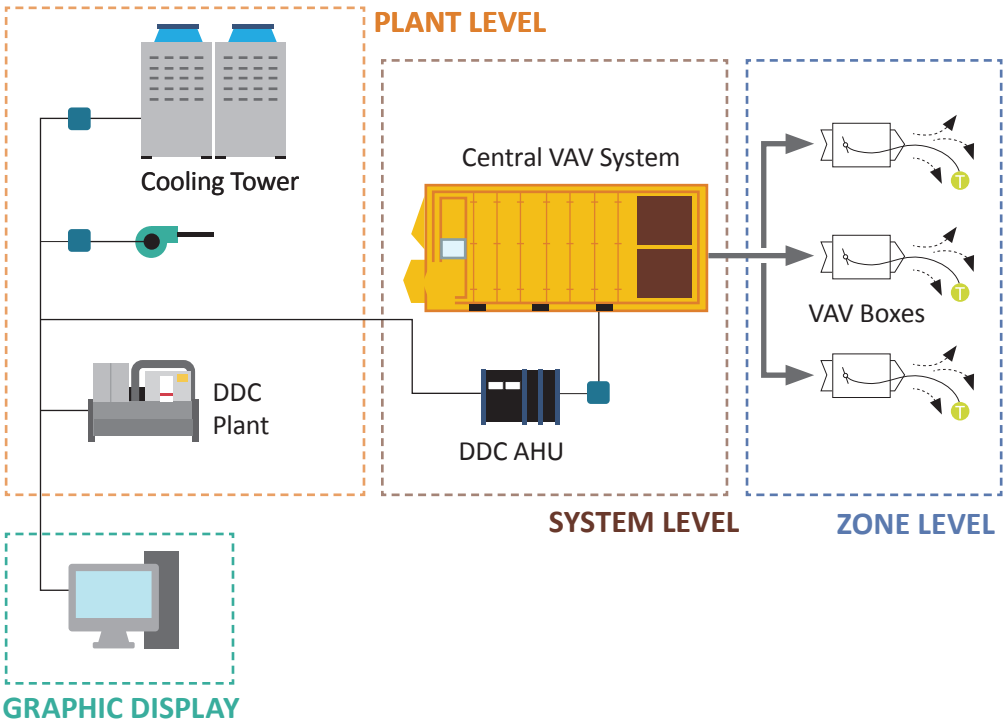
17. Provision of Energy Metering

Energy Metering is an important energy-efficiency measure because it allows for monitoring of equipment and systems. Accurate information on the state of systems can identify areas that either require maintenance or have the potential to be upgraded.

Chillers, heat pumps, unitary units and chilled/heated water plants (chillers/heat pumps plus all associated equipment) with cooling/heating capacities above 350 kW must have continuous monitoring of their power and energy input, power and energy output, and COP. Data points should be taken every 15 minutes and hourly, daily, monthly and annual data should be made available for 36 months. This allows the monitoring of performance over a longer time period. The same requirement applies to Air Handling Units (AHUs) with a total rated motor power of 5kW or above.

18. Provision of Direct Digital Control (DDC)

FIGURE 31 Overview of Digital Direct Control



DDC is responsible for the automatic control systems that monitor zone- and system-level demand and feedback this information to the AC system and chilled/heated water plant, as shown in Figure 31. The DDC acts as the 'brain' to control the equipment to match demand, using strategies discussed previously. It passes the monitoring data, in the form of demand for fan pressure, pump pressure and heating/cooling, to air distribution system controllers and from system-level data up to plant controllers. Input and output data points must be displayed graphically.

DDC applies to chilled/heated water plants with capacities above 350 kW that serve more than three zones as well as AC distribution systems with system motor fan powers greater than 7.45 kW.

Electrical Installations

This section of the BEC covers the following electrical installations:

- Circuits for lighting, AC, lifts & escalators and fixed motors.
- Circuits fed by essential power supplies and routine, regularly maintained equipment such as fireman's lifts and emergency lighting.

Exceptions include:

- Very high voltage situations such as certain chillers at 3.3 kV.
- Very low voltage situations such as CCTV systems that operate at 24 V.
- Specialist applications such as hospital equipment and industrial manufacturing equipment.
- Non-fixed appliances such as portable desk lamps and fans

These requirements help to ensure energy-efficient design by minimising iron and copper losses, losses due to phase current unbalance and harmonics and indirect losses as a result of temperature increases. They also address the utilisation of electrical power and any potential wastage.

1. Power Distribution Loss

Transformers are used in buildings to step-down, or decrease, the voltage of the electricity supplied by CLP/HKE to a voltage that is usable. This process incurs several different types of losses. As a result, this clause states that the following requirements are met:

TABLE 56 Minimum Transformer Efficiency

Transformer Capacity	Efficiency
< 1000kVA	98%
≥ 1000kVA	99%

Copper loss is the undesirable generation of heat within the conductors of an electrical circuit as a result of electrical currents passing through them. Controlling for copper loss helps to ensure that the circuit is sized correctly. The requirements here are based on the following equation, applied when the circuit is carrying the designed circuit current:

$$\text{Copper Loss \%} = \frac{\text{Total Copper Loss in conductors (W)}}{\text{Total active power transmitted through conductors (W)}}$$

The requirements are shown below:

TABLE 57 BEC 2018 Copper Loss Requirements

Circuit Type	Copper Loss
Main Circuit	≤ 0.5% of Total Active Power
Feeder Circuit	≤ 2.5% of Total Active Power
Sub-Main Circuit	Non-Residential (≤100m) - ≤ 1.5% of Total Active Power Non-Residential (>100m) - ≤ 2.5% of Total Active Power Residential - ≤ 2.5% of Total Active Power
Final Circuit	≤ 1% of Total Active Power

2. Motor Installation

Minimum standards for efficiency are given for single-speed motors. Efficiency requirements increase as motor power increases, from 80.7% for 0.75 kW motors to 96% for motors rated greater 200kW. This regulation simply ensures the most inefficient motors cannot be selected.

Motors must also be sized according to the anticipated system load in order to prevent oversizing. For motors above 5kW, the output power of the motor should not be greater than 125% of the anticipated system load. Exceptions include applications when a high starting torque is required, as well as motors that fulfil requirements stated elsewhere in BEC. These include efficiency requirements applied to AC equipment and cooling towers and electrical power requirements in lift & escalator installations.

3. Power Quality

The requirement is given in Power Factor, which measures the ability of the electricity supplied to perform useful work. The minimum Power Factor is 0.85 for:

- Three-phase circuit connection to the electricity supplier's meter
- Circuits ≥400A, both single- and three-phase.

To fulfil this requirement, a power factor correction device must be incorporated.

4. Total Harmonic Distortion

A higher value for Total Harmonic Distortion means more circuit heating and electromagnetic emissions and more losses inside the motors. Requirements here are based on the size of the designed circuit current. Circuits with larger designed currents have more stringent requirements because they have a greater absolute potential for energy loss. A harmonic correction device must be incorporated to fulfil in addition to the percentage requirements.

TABLE 58 BEC 2018 Maximum Total Harmonic Distortion of Current

Designed Circuit (I, in A)	Maximum Total Harmonic Distortion (THD) in Percentage of Fundamental Current
I < 40A	20.0%
40A ≤ I <400A	15.0%
400A ≤ I <800A	12.0%
800A ≤ I <2000A	8.0%
I ≥ 2000A	5.0%

5. Energy Metering

Energy meters collect data on electricity consumption and store this data for analysis. This allows opportunities for energy use accountability and optimisation and to identify potential additional energy-saving investments. Sub-meters can measure individual BSIs, providing clarity and allowing informed decisions to be made. Most importantly, it provides information for policy- and decision-makers to identify areas for improvement.

The requirement is for main and feeder circuits ≥400A to measure voltage, current, total power factor, total energy consumption, maximum demand and total harmonic distortion. Feeder circuits between 200A and 400A must have their current total energy consumption measured. The data should be trended every 15 minutes and provide hourly, daily, monthly and annual data which must be stored for 36 months, allowing trends to be identified.

The following BSIs must be separately metered:

- Entire chilled/heated water plant
- All lifts
- All escalators

Lift & Escalator Installations

This section covers all lifts and escalators located in buildings normally covered by the BEC. It includes:

- Passenger, bed passenger, freight, vehicle and fireman's lifts operating under normal conditions.
- Escalators and passenger conveyors
- Lifts and escalators attached to the façade of the building and owned by the building owner.

Several installations are excluded, typically with extremely specialist applications such as:

- Lifts in a performance stage
- Stairlifts
- Mechanised vehicle parking systems

1. Electrical Power

Limits on the active electrical power of the motor of a traction drive lift are given based on the rated speed and the size of the load being carried. These requirements are given for all values of rated load, from < 750 kg to ≥ 5000 kg per lift, and all values of rated speed, from < 1 m/s to ≥ 9 m/s. The maximum allowed power increases with both rated load and speed. The requirements for new buildings are different to those for major retrofitting works in existing buildings. The requirements are very slightly -up to 5% - stricter for new buildings than for existing buildings.

For escalators, the maximum rated power depends on the width, the rise i.e. the vertical distance of travel, and the rated speed. The requirements are split up according to escalator type: non-public service, public-service and heavy duty. Heavy duty escalators are those that are designed to operate continuously for at least twenty hours per day, seven days per week with high passenger loading. Ratings are provided for passenger conveyors based on similar criteria to escalators, except the vertical rise is replace by the length.

2. Utilisation of Power

As outlined in the Electrical Installations, the minimum total power factor is 0.85 for escalators, passenger conveyors and lifts. The same requirement for a power factor correction device also applies here.

The lift decoration load refers to the mass of the materials used inside the lift car for decorative purposes such as material finishes. The maximum load is given by a formula according to the rated load of the lift. This discourages heavy stone or marble interior finishes which would increase the energy consumption of the lift. Equivalent to control strategies based on occupancy, the Lift Parking Mode section requires, under normal operating conditions, at least one lift in a group of lifts to 'park' itself when traffic demand is low. This lift does not respond to passenger calls until it returns to normal operating mode.

The requirement for ventilation is for it to be shut off after the lift car has been idling for 2 minutes and then restarted once it is activated by passenger call. The maximum power consumption of a lift car ventilation fan should be ≤0.7W/L/s. For the AC, it should be shut off after the lift car has been idling for 10 minutes and only restart operation 5 minutes after the shut-off and once the lift is activated by a passenger call. This delay in reactivating the AC even if a passenger calls the lift is due to the lack of internal heat source inside the lift while it was idling – the AC will not be required immediately.

Studies in Hong Kong have found that regenerative braking can contribute to an energy saving of between 20 and 30% compared to lifts without this feature (Housing Authority, 2015). This measure recovers energy from the lift system during braking by using the motor to convert kinetic energy to electrical energy, which is then stored and used when the lift next moves. Regenerative braking must be provided to lifts with a rated speed ≥ 2.5m/s and a rated load ≥ 1000kg.

A maximum LPD value of 11W/m² is provided in the Lighting Installations section of the BEC, provided the installation does not exceed 70W. In practise, it is extremely unlikely for the installation to exceed 70W. Regarding lighting control, after idling for 10 minutes, the lift car lighting should power down to ≤ 50% of the total lighting power consumption.

Automatic speed reduction of escalators for periods when traffic demand is low must be implemented. There are no explicit requirements around implementation or scheduling.

3. Total Harmonic Distortion
There are requirements for the Total Harmonic Distortion that depend on the size of the motor's current. For lifts, escalators and passenger conveyors, as the current increases, the maximum Total Harmonic Distortion percentage decreases.

4. Metering and Monitoring Facilities
Meters must be provided for the electrical supply for each lift, escalator and passenger conveyor to measure the voltage, current, total power factor, total harmonic distortion, energy consumption, power, and maximum demand.
As mentioned previously, metering provides operational insights that allow opportunities to save energy to be identified. Measurements should be taken every 15 minutes and include hourly, daily, monthly and annual data and stored for 36 months to allow trends to be identified.

7.4 EAC Steps

STEP 1 – Collection of Building Information

Detailed information surrounding the building operation of energy-consuming systems surrounding the four main BSIs is collected. Comprehensive data collection enables the development of the full picture of energy consumption within the building; understanding these parameters is critical to identifying places for improvement. The information collected includes:

- Record of EMOs implemented within the previous 36 months, as well as any available audit reports
- Inventories of energy consuming equipment and relevant technical documents
- Drawings and system schematics showing the layout of relevant systems
- Day-to-day operational records, including the settings and actual output of:

  - Room temperature
  - Supply & return Chilled Water,
  - Supply & return air temperature

- Previous 36 months of energy consumption data (or since the buildings occupation if <36 months)
- Operation & maintenance programmes including major building alternations
- Floor Areas of major zones within the buildings

STEP 2 – Review of energy consuming equipment

After the collection of information has been completed, site inspections are conducted to see the equipment and systems in operation. More detailed, operational data is gathered:

- Equipment, capacity ratings and operating characteristics of:
  - AC installations: AHUs, Chillers, Unitary units etc.
  - Lighting installations
  - Lifts & Escalators
  - Other equipment, e.g. Plumbing & Drainage pumps

- Utilisation patterns of areas served by the four main BSIs:
  - Hours of operation
  - Occupant density (people per m^2)
  - Operation schedules of equipment

- Control mechanisms
- Data from electrical meters including electrical power quality
- Building envelope characteristics and other information affecting building energy consumption

Using the operation records and equipment rated power consumptions, the power and energy consumptions of each piece of equipment are calculated. If the relevant technical catalogue or operation schedule is not available, or are not reflective of actual operating conditions, standard testing methodologies are available to calculate the energy and power consumption of each piece of equipment. This methodology must be included in the report. External metering should also be employed if the installed meters are inadequate.

STEP 3 – Identification of Energy Management Opportunities

An evaluation and appraisal should be conducted on the data collected in Steps 1 and 2. This is focussed on the energy performance of each system against its corresponding operating conditions:

- Chiller/Heat Pump, VRF system (kWh/year)
- Air Distribution system (PAU & AHU, car park ventilation) fan power consumption (Watts/litres/second)
- Water Distribution system pump power consumption (Watts/litres/second)
- Lighting Power Density (Watts/m^2)

- All other equipment and systems
- Energy Use Intensity (EUI) of the building; this combines the energy consumption of all systems in the building and divides it across the total floor area (kWh/m²)

Potential EMOS are identified based off the original design, the calculated energy performance, guides and international standards and local good practise. EMOs are not purely technical but can also be behavioural and address operational decisions carried out by responsible parties. Potential EMOs include:

- Replacing equipment/systems with more efficient models, or changing the configuration of the current system
- Changing the operations of existing systems
- Deploying energy recovery systems
- Applying on-site renewables.

These are evaluated alongside 'low hanging fruit' opportunities such as:

- Ensuring the operational conditions of all systems are good by conducting thorough and regular maintenance
- Avoid excessive provisions on space temperature, lighting level, volume flow etc.
- Encourage occupant's behaviour change; switching off equipment and systems when they are not required. This could also include introducing automatic control or upgrading or refining current control parameters.
- Match operational schedules with operational requirements. This can be extended to adjusting the equipment capacity or configuration, so it matches the system load profile.

STEP 4 – Cost-Benefit Analysis of EMOs

This step applies to potential Category 2 and 3 EMOs because they require capital spending. An estimate for both the cost of the EMO and the potential energy savings are outlined in the report. The report should include:

- Methodical evaluations alongside all relevant technical information and operating data for consistent and fair analysis.
- The service life of the equipment and the reduction in energy efficiency of equipment during its life
- The price of energy
- Either:
  - As far as is practicable, a complete operating cycle of energy use management
  - Or, the methodology of projection of measure energy use of a complete operating cycle.
- Data from meters to corroborate measured energy use during the energy audit period.
- It is recommended that the Net Present Value and Internal Rate of Return are calculated for EMOs involving longer payback periods.

STEP 5 – Recommendations

After considering the cost-benefit analysis and the quality of the energy data, recommendations on the EMOs to be implemented are made. Recommendations require the following:

- Description, intended result and installation procedure
  - This could mean inspection, functional performance testing or data analysis
- Summary of the measured energy use of the relevant equipment/system during the energy audit period
- Known Operation & Maintenance plans of the building to see if implementation costs can be reduced
  - E.g. lighting retrofit at the same time as a false ceiling renovation
- Optional: suggestions for further study of potential equipment

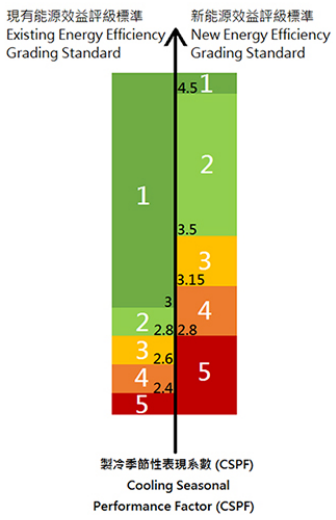
STEP 6 – Compiling the Energy Audit Report

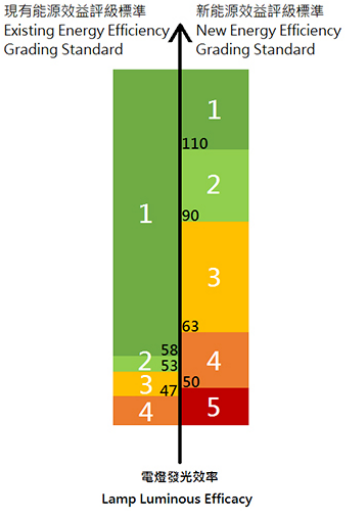
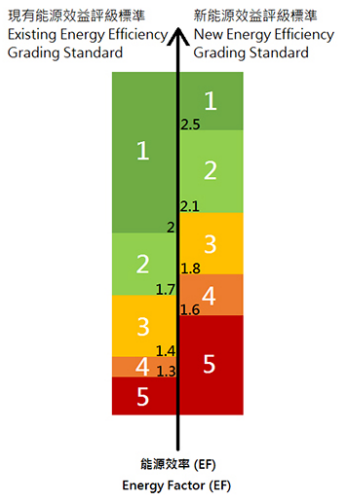
This step compiles all the data, analysis and recommendations completed in Steps 1 through 5 to present the EMO recommendations with predicted energy savings and capital costs. A complete record is made so the predicted energy saving can be verified during the EMO implementation period.

7.5 MEELS Grade 1 Requirements

Table 59 shows the current headline energy-efficiency requirements for Grade 1. Some of the requirements to achieve Grade 1 for some categories are additional to the single energy-efficiency requirement such as failure rate and rate of reduction of energy efficiency but these are not covered below.

TABLE 59 MEELS Grade 1 Requirements

Appliance	Grade 1 Requirement	Equation
Room Air conditioner	$F_{CSP} \geq 3$ $F_{CSP} \geq 4.50$	$F_{CSP} = \frac{\text{(Total Annual heat removed)}}{\text{(Total energy consumed)}}$ F_{CSP} is the Cooling Seasonal Performance Factor and the higher the number, the more heat is removed for a given unit of energy. The standard for Grade 1 will be changed from 3 to 4.5 on 31 December 2020, representing a 50% improvement. 

Appliance	Grade 1 Requirement	Equation
Refrigerator	$I_\varepsilon \leq 35\%$	$I_\varepsilon = \frac{\text{Annual Energy Consumption in test}}{\text{Average Annual Energy consumption}}$ I_ε is the energy consumption index and depends on a number of factors including the volume of the refrigerator. A lower percentage shows better energy-efficiency.
Compact Fluorescent Lamp (CFL)	Old: X ≥ 58 New: X ≥ 110	$E_r = \frac{\text{Luminous Flux}}{\text{Power Rating}}$ $E_m = \frac{\text{Luminous Flux}}{\text{Power Input}}$ X has the unit Lumen/ Watt which means it represents the amount of light produced per unit of electrical power. The more efficient the light fitting is, the higher the value. The average standard for Grade 1 will be upgraded from 58 to 110 on 31 December 2020, representing a 90% improvement. Furthermore, the updated requirements are aligned with those of LEDs under VEELS. 
Washing Machine	$E_{sp} \leq 0.130$	$E_{SP} = \frac{\text{Measured Energy consumption per cycle (kWh/cycle)}}{\text{Rated Washing capacity (kg)}}$ The Specific Energy Consumption is the energy consumed per cycle per kilogram of clothes washed. The same washing programme and water temperature is used for all tests.
Dehumidifers	Old: EF ≥ 1.98 New: EF ≥ 2.48	$EF = \frac{\text{Water Removed during capacity test (litres)}}{\text{Energy Consumption during test (kWh)}}$ The Energy Factor, EF, when applied to dehumidifiers, is the energy required to remove a specific quantity of water from the air. If more water is removed for the same quantity of energy, the EF increases, representing an increase in energy efficiency. The average standard for Grade 1 will be upgraded from 1.98 to 2.48 on 31 December 2020, representing a 50% improvement. 

Appliance	Grade 1 Requirement	Equation
Television	EEI < 0.13	$EEI = \frac{\text{On – mode Power Consumption (W)}}{\text{Constant + (Screen Area ×432.24) (W)}}$ Energy Efficiency Index, EEI, described the relationship between screen area and power consumption. This formula allows TVs with larger screen areas to consumer more energy, but this ratio remains approximately constant as screen sizes increases to maintain a Grade 1 rating.
Storage Type Electric Water Heaters	$I_\varepsilon \leq 75$	$I_\varepsilon = \frac{\text{Adjusted measured heat loss over 24 hours (kWh/24hr)}}{\text{Energy consupmtion over 24 hours (kWh/24hr)}}$ A more efficient heater will use less energy to maintain the same water temperature by losing less heat to the environment.
Induction Cookers	For units > 1200W $\eta \geq 88\%$ For units ≤ 1200W $\eta \geq 90\%$	This test measures the percentage of energy that is transferred to the pot from the induction stove.

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