Hong Kong Smart Green Building Design

Best Practice Guidebook

HKGBC
香港綠色建築議會

Funding Support

CONSTRUCTION INDUSTRY COUNCIL
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Hong Kong Smart Green Building Design Best Practice Guidebook

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About HKGBC

The Hong Kong Green Building Council Limited (HKGBC) is a non-profit, member led organisation established in 2009 and has become a public body under the Prevention of Bribery Ordinance since 2016. The HKGBC strives to promote the standards and developments of sustainable buildings in Hong Kong. The HKGBC also aims to raise green building awareness by engaging the public, the industry and the government, and to develop practical solutions for Hong Kong's unique, subtropical built environment of high-rise, high density urban area, leading Hong Kong to become a world's exemplar of green building development.

Our passion for a sustainable built environment is the motivating force to achieve our goals. The wide experience and deep insight of our members and experts is the underlying foundation for real results.

To learn more about the HKGBC, please visit www.hkgbc.org.hk.

Our Vision

To help save the planet and improve the wellbeing of the people of Hong Kong by transforming the city into a greener built environment.

Our Mission

To lead market transformation by advocating green policies to the Government; introducing green building practices to all stakeholders; setting design, construction and management standards for the building profession; and promoting green living to the people of Hong Kong.

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Abbreviations

AEM	Active Energy Management
AFDD	Automated Fault Detection and Diagnostics
AHU	Air Handling Unit
AI	Artificial Intelligence
ALS	Ambient Light Sensor
AM	Asset Management
AMR	Automatic Meter Reading
API	Application Programming Interface
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
AVA	Air Ventilation Assessment
BAS	Building Automation System
BD	Big Data
BEAM	Building Environmental Assessment Method
BEC	Business Environment Council
BESS	Battery Energy Storage System
BIM	Building Information Modelling
BIPV	Building-Integrated Photovoltaics
BMS	Building Management System
BT	Bluetooth 5.0
BREEAM	Building Research Establishment Environmental Assessment Method
BSOMES	Building Services Operation and Maintenance Executives Society
CAPEX	Capital Expenditure
CCTV	Closed Circuit Television
CdTe	Cadmium Telluride
CIC	Construction Industry Council
CMC	Centralised Monitoring Centre
CMMS	Computerised Maintenance Management System
COP	Coefficient of Performance
CO_2	Carbon Dioxide
CSP	Concentrating Solar Power
CSTCB	Hong Kong Cyber Security and Technology Crime Bureau
DDC	Direct Digital Control
DV	Data Visualisation
EC	Electronically commutated
ELS	Excavation and Lateral Support
EMSD	Electrical and Mechanical Services Department
EPS	Electric Power System
ESS	Energy Storage System
ES1&2	One & Two Exchange Square
ES3	Three Exchange Square
EU	European Union
EV	Electric Vehicle
FiT	Feed-in Tariff
FM	Facility Management
FSGIM	Facility Smart Grid Information Model
F&B	Food & Beverage
GIS	Geographic Information System

GPS	Global Positioning System
GRESB	Global Real Estate Sustainability Benchmark
GWP	Global Warming Potential
HA	Hong Kong Housing Authority
HEPA	High Efficiency Particulate Air
HFCs	Hydrofluorocarbons
HFOs	Hydrofluoroolefines
HKCERT	Hong Kong Computer Emergency Response Team
HKD	Hong Kong Dollar
HKGBC	Hong Kong Green Building Council
HKL	Hongkong Land
HKSAR	Hong Kong Special Administrative Region
HVAC	Heating, Ventilation, and Air-Conditioning
IAQ	Indoor Air Quality
iBMS	Integrated Building Management System
IEEE	Institute of Electrical and Electronics Engineers Standards Association
IEQ	Indoor Environmental Quality
IGU	Insulated Glass Unit
IoT	Internet of Things
IP	Internet Protocol
IPCC	Intergovernmental Panel on Climate Change
IT	Information Technology
IWBI	International WELL Building Institute
I/O	Input/Output
I&T	Innovation and Technology
KPI	Key Performance Indicator
kW	Kilowatt
LCC	Life Cycle Cost
LED	Light-emitting Diode
LEED	Leadership in Energy and Environmental Design
Li-ion	Lithium Ion
LIDAR	Light Detection and Ranging
MEMS	Micro Electromechanical Systems
MERV	Minimum Efficiency Reporting Value
ML	Machine Learning
NEMA	National Electrical Manufacturers Association
NFC	Near Field Communications
ODP	Ozone Depletion Potential
OGCIO	Office of the Government Chief Information Officer
OPEX	Operating Expenditure
OTTV	Overall Thermal Transfer Value
O&M	Operations & Maintenance
PDPO	Personal Data (Privacy) Ordinance
PHEV	Plug-In Hybrid Electric Vehicle
PLC	Programmable Logic Controller
$PM_{2.5}$	Particulate Matter 2.5
PSI	Public Sector Information
PV	Photovoltaics
RCx	Retro-commissioning

REHVA	Representatives of European Heating and Ventilating Associations
RFID	Radio Frequency Identification
ROI	Return on Investment
RT	Refrigeration Tonne
SARS	Severe Acute Respiratory Syndrome
SBD	Sustainable Building Design
SCADA	Supervisory Control and Data Acquisition
SDGs	Sustainable Development Goals
SiO_2	Silicon Dioxide
tCO_2	Total Carbon Dioxide
TF	The Forum
TiO_2	Titanium Dioxide
TVP	Technology Voucher Programme
UFAD	Underfloor Air Distribution
UK	United Kingdom
UN	United Nations
USD	United States Dollar
URA	Urban Renewal Authority
U.S.	United States
USGBC	U.S. Green Building Council
UV	Ultraviolet
VAV	Variable Air Volume
VOC	Volatile Organic Compound
VPN	Virtual Private Network
VRB	Vanadium Redox Battery
W	Watt
WELS	Water Efficiency Labelling Scheme
WorldGBC	World Green Building Council
WSD	Water Supplies Department
ZnBr	Zinc Bromide
3D	Three-dimensional
5G	Fifth Generation Mobile Network

Message from

Secretary for the Environment

Our country has demonstrated unwavering commitment to combating climate change in declaring that it will endeavour to achieve the peak of carbon emissions before 2030 and carbon neutrality before 2060. In Hong Kong, the 2020 Policy Address has unveiled the ambitious goal to achieve carbon neutrality before 2050. While striving towards this goal is no easy task, I am delighted that many key stakeholders in the community, including the Construction Industry Council (CIC) and the Hong Kong Green Building Council ("HKGBC"), have not only welcomed this goal but also rolled up their sleeves to play keenly their parts.

The Government will muster the support of all stakeholders and the general public to rise to the climate challenge. We will update the "Hong Kong's Climate Action Plan" next year to set out more proactive strategies and measures on mitigation, adaptation and resilience. At the forefront of the strategy is deepening decarbonisation in the built environment, which requires us to rethink our existing policy tools and to further leverage innovation and technology ("I&T"), including smart technologies for buildings.

We have already paved the foundation for harnessing I&T. In the short- to medium-term, on top of measures such as energy audits and energy saving projects, we will also capitalise on I&T to help achieve the Government's Green Energy Target, which seeks to improve the energy performance of the Government by 6% in the five years ending 2025. We will pilot innovative solutions through the "E&M InnoPortal", a platform to facilitate the development and testing of I&T solutions offered by start-ups and universities. We will also support the research and development of innovative decarbonisation and green technologies through the $200 million Green Tech Fund which is now open for application.

The *Hong Kong Smart Green Building Design Best Practice Guidebook* is a timely, informative and useful tool for professionals and the general public to understand the key concepts and practices of smart green buildings. The promises and benefits of smart green buildings cannot be better illustrated through the local and overseas case studies succinctly summarised. I am grateful for the contribution of HKGBC and hope this Guidebook would inspire more smart green buildings in Hong Kong as we strive towards a carbon-neutral smart city by mid-century.

Mr WONG Kam-sing, GBS, JP
Secretary for the Environment
The Government of the Hong Kong Special Administrative Region

Message from

Secretary for Innovation and Technology

I would like to extend my warm congratulations to the Hong Kong Green Building Council (HKGBC) on its success in publishing the *Hong Kong Smart Green Building Design Best Practice Guidebook*. It provides a practical and comprehensive reference for adoption of innovation and technology (I&T) in making our buildings smarter and greener and enhancing overall building performance.

The joint efforts of the HKGBC and the CIC are certainly in line with the Government's I&T policy, including smart city development. The Government has committed over HK$100 billion in the past three years to promote I&T development, and published for the first time in December 2017 our first Smart City Blueprint for Hong Kong. It contains 76 initiatives under six smart areas, among them no doubt a dedicated Smart Environment chapter. Following three years of hard work, we released earlier this month the *Smart City Blueprint for Hong Kong 2.0*. Under the Smart Environment chapter, we provide progress and updates on such initiatives like promoting energy efficiency and retro-commissioning (RCx) and use of smart technologies to develop more green buildings. *Blueprint 2.0* also sets out new initiatives and targets such as use of renewable energy on a wider and larger scale and adoption of technologies by government works departments in construction projects and operation and maintenance of our infrastructure and utilities. The ultimate goal is to enable our citizens perceive the genuine benefits from smart city development in their daily life.

I am sure this Guidebook would not only serve as an industry tool but also inspire all those involved in embracing green building technologies in building Hong Kong as a smart city. I certainly look forward to seeing fruition of the collaboration between Government and all stakeholders such as HKGBC and the CIC and inclusion of many more green building and other environmental protection initiatives when we update *Blueprint 2.0* in future.

Mr Alfred SIT Wing-hang, JP
Secretary for Innovation and Technology
The Government of the Hong Kong Special Administrative Region

Foreword from

Chairman of HKGBC

On behalf of the Hong Kong Green Building Council (HKGBC), we take great pleasure in presenting the Hong Kong Smart Green Building Design Best Practice Guidebook (the Guidebook) to accelerate the development of smart green built environment and communities.

The HKGBC is committed to introducing and promoting green building practices to building industry practitioners, developers, owners, operators and occupants. The publication of Smart City Blueprint for Hong Kong in 2017, and more recently Smart City Blueprint for Hong Kong 2.0, highlights opportunities to I&T to enhance the performance of green buildings. Hence this Guidebook is a timely publication which provides practical design and operation guidelines and strategies for advancing smart green buildings with a view to optimise the performance of new and existing buildings.

Fundamental design principles that make smart green buildings resilient, and 32 strategies for smart green buildings categorised under six key themes: building design & operations, health & wellbeing, energy performance, material & waste management, water performance, and mobility & transportation are presented in the Guidebook. Good practices are also demonstrated with overseas and local case studies.

We would like to take this opportunity to thank the Steering Committee and various industry stakeholders including developers, consultants, contractors, utility, professional bodies, government departments and universities etc. on their contribution to the development of the Guidebook. We would also like to express our gratitude to the CIC for its funding support for the production of this Guidebook.

We hope that the Guidebook provides useful information and inspiration for the building industry to embrace innovation and technology to build a smart green built environment which not only enhances operational efficiencies but also the health, sustainability, and quality of living and working environments in Hong Kong.

Mr CHEUNG Hau-wai, SBS
Chairman
Hong Kong Green Building Council

Executive Summary

The Hong Kong Smart Green Building Design Best Practice Guidebook provides practical guidelines and inspiration for smart green building design and features. The Guidebook comprises of 5 key chapters – definitions and trends are introduced, smart green strategies for new and existing buildings are presented, and local and overseas best practice case studies are reflected on. References for policy adjustments and greater public awareness are made at the end of the Guidebook. Further details of the strategies are also provided in the Appendices.

The Guidebook's introduction chapter provides a definition of smart green buildings and shows how technology is redefining the interface between smart and green buildings. Reference is made to relevant industry guidelines and initiatives. Ongoing advancements and the everchanging nature of smart building technology is also acknowledged and examples of emerging technology are presented.

The second chapter introduces the Internet of Things (IoT) as the fundamental 'backbone' to smart green buildings and its linkage to other technology to enable data sharing and automation of building functions. IoT as a foundation of smart green buildings provides a holistic view of building performance, and enables predictive analytics, which allow building operators/owners to drive goals and outcomes that improve user experience.

Fundamental design principles that make smart green buildings resilient to change are highlighted in the second chapter. An overview of the recommended 32 strategies for smart green buildings categorised under 6 key themes is provided – building design & operations, health & wellbeing, energy performance, material & waste management, water performance, and mobility & transportation. Details of each strategy, such as benefits, technologies and design requirements, and benchmark cases, are elaborated in the Appendices. The recent COVID-19 pandemic has changed the culture of how buildings are managed by emphasising on the importance of keeping a healthy, safe and clean environment in buildings. This chapter concludes with examples of smart technology that promote healthier and safer buildings to minimise the risks of infectious disease outbreaks.

The third chapter showcases overseas case studies with good practices of implementing smart green strategies to optimise overall building performance. Selected cases are Empire State Building in New York City and The Edge in Amsterdam. Similarly, leading local case studies that have adopted smart technology and green practices are presented in the fourth chapter, including One Taikoo Place, Double Cove, Victoria Dockside and Exchange Square.

The final chapter concludes with suggestions in the areas of policy, industry practices, public awareness and education. The Guidebook highlights the importance of integrating both smart and green aspects of a building throughout its life cycle to enhance operational and user efficiencies, health and sustainability outcomes, to facilitate a smart green market transformation in Hong Kong's built environment.

CHAPTER 1

Introduction

Smart green technology is currently playing a crucial part in building development and will continue to in the future. Innovative and transformative technology is being adopted to improve operational efficiency, cost effectiveness and living standards. The use of interconnected technologies and communications infrastructure has enabled buildings to be more responsive and for devices and occupants to communicate inside and outside the building.

The building industry plays an important role in achieving Hong Kong's vision of smart and sustainable development. Technology is progressively being employed in buildings to improve sustainable building design and reduce environmental impacts throughout the entire building life cycle from design to operation. Such examples include smart energy and water meters, biophilic design, and solar technologies for natural lighting and energy generation. Smart green buildings will in turn have a positive impact on people's health and wellbeing and enhance user experience in buildings and its surrounding environment.

It is the goal of this Guidebook to provide developers, building owners, operators, and managers as well as other building professionals with inspiration and practical guidelines to implement smart green building design, features and operations. Ultimately, this will lead to better decisions and planning to accelerate the development of smart green built environment and communities.

This Guidebook will introduce a definition of smart green building and other relevant key concepts, such as smart city, low carbon city and urban resilience. Emerging trends of smart green building technology will also be touched on. An overview of 32 practical design and operation strategies for advancing smart green buildings, and optimising the performance of new and existing buildings will be set out, referencing good practices of both local and overseas case studies. These strategies are categorised into 6 key themes pertaining to building performance.

This Guidebook will address cybersecurity and data privacy concerns that are relevant to the adoption of smart green technology. With a better understanding of how technology can be used to optimise overall building performance, the interface between smart and green can be re-defined.

For information on urban microclimate design and integrated project delivery, please refer to HKGBC's Guidebook on Urban Microclimate Study.[1] This guidebook introduces the principles of urban microclimate studies, strategies to optimise microclimate conditions, and good practices locally and overseas. The guidebook introduces 4 key parameters (wind, thermal radiation, temperature, and precipitation) and 31 strategies in urban microclimate design.

[1] Hong Kong Green Building Council. (2018). *HKGBC Guidebook on Urban Microclimate Study*. Available from: https://www.hkgbc.org.hk/eng/engagement/file/UMC_Guidebook_amended_reduced.pdf

WHAT IS A SMART GREEN BUILDING?

Despite becoming a global trend, there is currently no universal definition for ‘smart green building’ in the industry. By understanding the respective intents and scopes of smart green buildings, the interrelationship between the two can be clarified and defined.

Smart building is often synonymised with ‘automated building’ and ‘intelligent building’. A smart building makes use of smart technologies, including automated systems, integrated building management systems (iBMS), digital infrastructure, data gathering devices, remote monitoring, etc. Interconnected technologies and communications infrastructure enable smart buildings to become more responsive, and for occupants and devices to communicate within and outside buildings. Data collected is used for analysis and optimisation of overall building performance, including cost-effectiveness, operational performance, space utilisation and flexibility, human comfort, safety and security, culture, and health and sanitation.

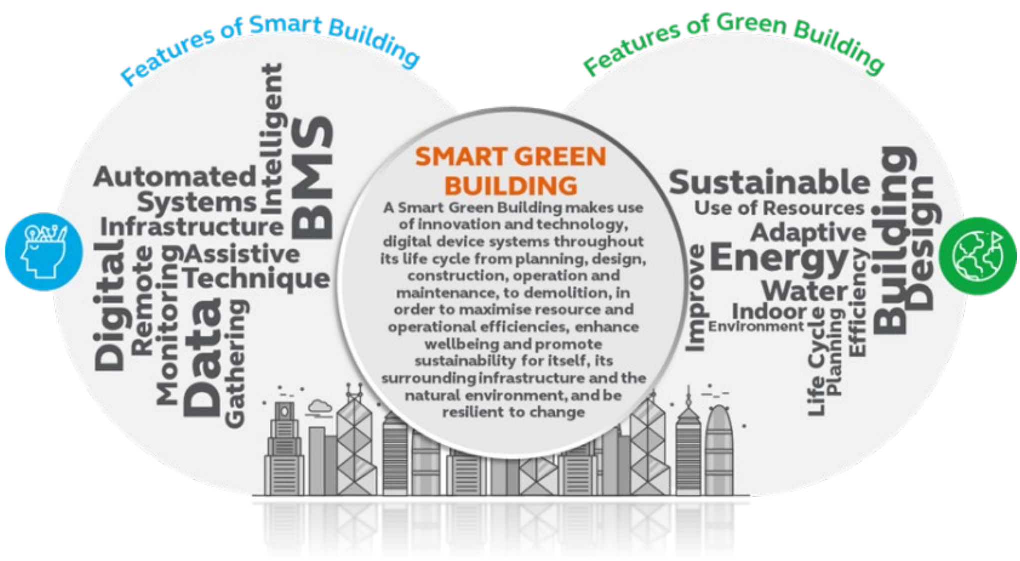
Green building focuses on environmental sustainability and sustainable building design. As a broad and generic term, green building is viewed as a multi-disciplinary subject covering the practice of reducing environmental impacts throughout the design, construction, or operation of a building, and enhancing occupant wellbeing. This can be achieved by life cycle planning, efficient use of resources, promoting renewable energy and the use of sustainable materials, pollution and waste reduction, improvement to indoor environment, and adaptable design to the changing environment.

Globally and locally, there are green building certification systems that showcase the environmental performance of buildings, of which the most widely adopted are Building Environmental Assessment Method (BEAM) Plus, Leadership in Energy and Environmental Design (LEED) and Building Research Establishment Environmental Assessment Method (BREEAM). These certifications help to promote green buildings to become industry standard. Global and local targets around overall energy use and carbon emission reductions have been set, such as Climate Action Plan 2030+, Paris Agreement, United Nations’ (UN) Sustainable Development Goals (SDGs). The built environment is a key sector that could greatly contribute to achieving these targets, hence it is crucial for the industry to gauge building energy and carbon performance. Further details can be found in Chapter 1.3.

There is a clear interrelationship between smart and green buildings – automated systems and digital infrastructure can help to reduce environmental impacts as well as optimise the internal environment to enhance occupant wellbeing in a building. As such, smart green building can be defined as follows:

“A smart green building makes use of I&T, digital device systems throughout its life cycle from planning, design, construction, operation and maintenance, to demolition, in order to maximise resource and operational efficiencies, enhance wellbeing and promote sustainability for itself, its surrounding infrastructure and the natural environment, and be resilient to change.”

Figure 1 – Redefining the interface between smart and green buildings



OTHER KEY CONCEPTS

Smart green building touches on several key concepts, which are mentioned throughout this Guidebook. These concepts are summarised in Table 1 below:

5G Network (5G)	5G is the fifth generation mobile network, which is intended to virtually link everyone and everything together, including machines, objects and devices. 5G wireless technology delivers higher multi-Gbps peak data speed with ultra-low latency, more reliability, large network capacity, enhanced availability, and a uniform experience to more users.
Application Programming Interface (API)	API is an intermediary that enables two unrelated applications to communicate with each other (e.g. creation of new applications and services in the business context). This can facilitate data sharing and the interconnectivity between devices, platforms, and people.
Artificial Intelligence (AI)	AI is defined as "the theory and development of computer systems able to perform tasks normally requiring human intelligence, such as visual perception, speech recognition, decision-making, and translation between languages."[2] AI based algorithms can predict changes so that operations can be adjusted with a more proactive approach. AI can also correlate relationships between inputs and outputs to make decisions or to identify root causes – all of which includes the application of machine learning, data mining or predictive data analytics.
Big Data (BD)	BD is extremely large data sets that can be computationally analysed to reveal patterns, trends and insights. Sources of data include sensors, devices, computation, etc.
Circular Economy	Global population growth places unprecedented pressure on natural resources to meet consumer demands. The circular economy moves away from linear "take-make-dispose" by letting nothing made go to waste. In a circular economy, industrial systems are restorative and regenerative by intention. This concept aims to recuperate the value of a product when it comes to the end of its life cycle (e.g. repurposing, refurbishing and recuperating materials).
Cloud Computing	Cloud computing encompasses the delivery of computing services from storage to analytics, to processing power over the Internet, or "via the cloud". It allows vast amount of computing resources to be provided and easily accessed within minutes and is very reliable given widespread data redundancy.
Data Analytics	Data analytics encompass a variety of statistical techniques that analyse current and historical data to generate meaningful insights and make predictions about future or otherwise unknown events.
Data Mining	Data mining often employs the same methods and overlaps significantly with machine learning, but while machine learning (ML) focuses on predictions and data mining focuses on the discovery of previously unknown properties in the data.
Data Visualisation (DV)	DV refers to the digital and visual representation of statistical data or information gathered from other touch points throughout the world. Infographics, heat maps and bubble charts are all forms of DV.

[2] Marr, B. (2018). *The Key Definitions of Artificial Intelligence (AI) That Explain Its Importance*, Forbes. Available at: https://www.forbes.com/sites/bernardmarr/2018/02/14/the-key-definitions-of-artificial-intelligence-ai-that-explain-its-importance/#35dfbe6f4f5d

Digitalisation	Digitalisation refers to the process of converting information into a digital format which is 'readable' by computers. The backbone of digitalisation relies on the deployment of vast numbers of sensors that measure a large variety of properties to empower functions, such as pattern recognition, self-correction or compensation, ML and reasoning.
Green City	A green city is often synonymous with 'eco-city' and 'low carbon city', and focuses on reducing environmental impacts through waste and emission reduction, promoting recycling and renewable energy sources, boosting housing density while increasing the amount of open space and encouraging sustainable local business.
Integrated System	An integrated system involves combining several sub-systems and ensuring they coordinate and function alongside one another as one big system. An integrated system can deliver additional system capabilities not available before in individual systems.
Internet of Things (IoT)	IoT refers to web connected sensors, devices, machines, and natural objects that are provided with unique identifiers and the ability to autonomously communicate and transfer data over a network. It has allowed for unstructured machine generated data to be centrally collected, correlated, and analysed for insights that can drive improvements. This interconnection via the internet of computing devices based on different means of addressability and wired or wireless technologies, enables a wide range of applications that are real-time and autonomous. With data generated at a granular level, it leads to the capability requirements for intelligence to turn data into actionable information.
Machine Learning (ML)	ML is a subset of AI which focuses on computer algorithms that improve automatically through experience. ML algorithms build mathematical models based on sample data, known as "training data", to make predictions or decisions without being explicitly programmed to do so.
Resilient City	A resilient city is one that minimises the damage and risk incurred from disasters along with the capacity to return to a stable state. With reference to Hong Kong 2030+, a resilient city should be reflective, robust, redundant, flexible, resourceful, inclusive and integrated.[3]
Smart City	A smart city makes use of innovation and technology to "make its components, infrastructure, utilities and services more efficient and interactive with people".[3] Such technology helps to address urban challenges and improve the overall quality of living. According to the Blueprint, there are 6 major areas in which Hong Kong will pursue smart city development, including smart mobility, smart living, smart environment, smart people, smart government, and smart economy.[4]
Wireless Technologies	A wide variety of wireless data technologies exists, with some in direct competition with one another, and others designed for specific applications. Wireless technologies can be evaluated by using a variety of different metrics, but those relevant to smart buildings are data rate, range of transmission, and cost for implementation.

Table 1 – Other key concepts of smart green buildings

[3] The Government of HKSAR. Planning Department. (2016). *Hong Kong 2030+: A Smart, Green and Resilient City Strategy*. Available at: https://www.hk2030plus.hk/document/Hong%20Kong%202030+%20A%20SGR%20City%20Strategy_Eng.pdf

[4] The Government of HKSAR. Innovation and Technology Bureau. (2017). *Hong Kong Smart City Blueprint*.

RELEVANT GUIDELINES AND INITIATIVES PERTAINING TO SMART GREEN BUILDINGS

Smart green technology can facilitate buildings to achieve environmental targets both locally and globally. Table 2 summarises key local and global guidelines, initiatives, and targets, which are of great relevance to smart green buildings.

Guidelines or Initiatives	Details	Website for Further Details
Advancing Net Zero (WorldGBC)	A global initiative that aims to promote and support the acceleration of net zero buildings to 100% by 2050.	https://www.worldgbc.org/advancing-net-zero
BEAM Plus	Hong Kong's green building rating system, which embraces a wide range of sustainability issues and covers the full building life cycle. The HKGBC is the certification body, with BEAM Society Limited undertaking the assessment process. The scheme covers assessments for new and existing buildings, neighbourhood, and interiors.	https://www.hkgbc.org.hk/eng/beam-plus/introduction/index.jsp
Better Places for People (WorldGBC)	This global project promotes sustainable built environment, as well as the health, wellbeing, and productivity of people within them, including green and healthy workspaces, retail buildings, homes, etc.	https://www.worldgbc.org/better-places-people
BREEAM (Building Research Establishment Ltd)	Green building rating system commonly used in United Kingdom (UK). BREEAM aims to promote sustainable environments that enhance the wellbeing of the people who live and work in them, help protect natural resources and make for more attractive property.	https://www.breeam.com/
Hong Kong's Climate Action Plan 2030+ (Environment Bureau)	This report has a section that outlines two major areas where Hong Kong can save energy and promote carbon efficiency – buildings and infrastructure in both the private and public sectors.	https://www.enb.gov.hk/sites/default/files/pdf/ClimateActionPlanEng.pdf
Goal #7 "Affordable and Clean Energy" under UN's SDGs	Global actions for all countries to undertake in partnership. Goal #7 focuses on ensuring access to affordable, reliable, sustainable and modern energy for all. It includes targets on increasing the share of renewable energy in the global energy mix and improving the global rate of energy efficiency – both of which buildings have a large impact on.	https://sustainabledevelopment.un.org/?menu=1300

Guidelines or Initiatives	Details	Website for Further Details
Goal #11 "Sustainable Cities and Communities" UN's SDGs	Goal #11 focuses on making cities and human settlements inclusive, safe, resilient and sustainable. It includes targets on building sustainable and resilient buildings using local materials, provision of sustainable transport, and promoting sustainable urban waste management.	https://sustainabledevelopment.un.org/?menu=1300
Green Design Guide for Material Resources Optimisation in Building Life Cycle (HKGBC)	This guide aims to raise awareness of the building material waste problem and provides guidelines during planning and design stages to minimise building material waste for the Hong Kong building industry.	https://www.hkgbc.org.hk/eng/engagement/guidebooks/green-design-guide/images/Green_Design_Guide_Eng.pdf
Green Tenancy Driver for Office Buildings (HKGBC)	A five-stage roadmap for property developers, landlords, property management companies and tenants on the green tenancy concept for offices.	http://got.hkgbc.org.hk/eng/files/assets/basic-html/index.html#1
Hong Kong Green Office Guide (HKGBC)	This guide provides green guidance and best practices to stakeholders on the constraints, opportunities and benefits arising from different environmental aspects of the building and facilities for office premises.	http://hkg-training.hkgbc.org.hk/green_office_guide/eng/files/assets/basic-html/index.html#1
HKGBC Guidebook on Urban Microclimate Study (HKGBC)	This guidebook aims to provide knowledge and inspiration about urban microclimate design for practitioners in the building industry, and thereby contribute to the improvement of Hong Kong's outdoor environment.	https://www.hkgbc.org.hk/eng/engagement/guidebooks/urban-microclimate-study/index.jsp
Hong Kong Smart City Blueprint 2.0 (Innovation and Technology Bureau)	This blueprint outlines the measures for Hong Kong to undertake to pursue smart city development, such as adopting Building Information Modelling (BIM) technology, smart parking and remote sensing devices for pollution monitoring.	https://www.smartcity.gov.hk/node/1.html
Smart City Blueprint 2.0 Advisory Report (Smart City Consortium)	A review of the first Smart City Blueprint and the way forward.	https://smartcity.org.hk/upload/articles_lv1/0/20200427021602_156.pdf
LEED (USGBC)	The most commonly used green building rating system worldwide. LEED provides a framework for healthy, highly efficient, and cost-saving green buildings, and is identified as a symbol of sustainability achievement and leadership globally. The rating system covers all building types and all building phases.	https://www.usgbc.org/help/what-leed

Guidelines or Initiatives	Details	Website for Further Details
Paris Agreement within UN's Framework Convention on Climate Change	Effective from 2016, this agreement has set targets that aim to reduce the threat of climate change globally. Green buildings in Hong Kong play a vital role in achieving energy savings and reducing carbon emissions locally and contributing to the global target set by the Paris Agreement.	https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement
Sustainable Building Design (SBD) Guidelines (Buildings Department)	The practice note promulgates streamlined measures to promote sustainable building design, including site coverage of greenery requirements, building separation and setback.	https://www.bd.gov.hk/doc/en/resources/codes-and-references/practice-notes-and-circular-letters/pnap/APP/APP152.pdf

Table 2 – Summary of relevant guidelines and initiatives pertaining to smart green buildings

EMERGING SMART GREEN BUILDING TECHNOLOGIES

A wide array of smart building technology has transformed the way buildings are built and operated. Such technology advancements will continue to shape future building management by further driving operational efficiencies and sustainability outcomes. Table 3 presents examples of emerging smart green building technology and trends that are anticipated to be available in the market in the future.

Advanced Building Materials	
Aerogel insultation materials	Aerogel insulation material makes use of a hydrophobic nanoporous aerogel structure to produce an ultra-thin wall insulation. It can also be applied to produce silica-based products – a core material for super-insulating windows installed in buildings.
Graphene	Graphene is a sheet of single carbon atoms bonded together in a honeycomb shape. It has been referred to as a miracle material as it is 200 times the strength of steel and 6 times lighter, as well as being biodegradable. Graphene can be incorporated in concrete production to create a composite material 2 times stronger and 4 times more water-resistant than traditional concrete.
Self-healing materials	Self-healing materials are synthetically created substances that can repair damage to themselves without any external diagnosis of the problem or human intervention. Using self-healing materials reduce repair costs and enhance building safety. There is growing potential to incorporate self-healing capabilities into concrete, steel, and glass.
Sensor embedded composite materials	A composite material is made when 2 or more existing materials are combined to create a unique material with new characteristics distinct from the original components. When bringing materials together, it is also possible to add a sensing element to monitor and report on any changes in the materials, such as stresses and strains, or the environment around it. Increasing demand for structural health monitoring in buildings has recently stimulated research into composite materials that have embedded sensing capabilities.
Smart bricks	Smart bricks have the capacity for thermal energy control. With their modular design, smart bricks are easy to connect and create space to accommodate electricity and plumbing networks in buildings.
Building Management and Operations	
Blockchain	Blockchain is a growing list of records, referred to as blocks, which are linked and secured using cryptography. A blockchain has no central owner but is a distributed ledger that is replicated, shared, and synchronised across systems and geographies. Blockchain can connect data-generating machines inside buildings to enhance building operations.
Horizontal elevators	Horizontal elevators offer many advantages compared to vertical elevators. Vertical elevators can occupy a substantial amount of floor space of the building. Since horizontal elevators can transport more people in a single shaft, the buildings can afford to have fewer and smaller shafts. Hence, horizontal elevators can increase the usable floor area of a building, therefore increasing the building's commercial value.
Recirculating shower	A recirculating shower system filters used water and allows the water to be reused immediately. Together with advanced water treatment facilities, this system can be used to facilitate grey water reuse and smart water management in buildings.
Smart dust	Smart dust refers to tiny wireless Micro Electromechanical Systems (MEMS), which can detect everything from light, temperature and pressure to vibrations, magnetism, and chemical composition. Smart dust can serve as sensors within buildings to facilitate the operations of smart building functions. Smart dust can detect structural stresses of buildings and initiate warnings if necessary.

Energy Performance	
Advanced battery technologies	Recent breakthroughs in battery technologies, such as gold nanowire batteries. These batteries can be recharged 200,000 times in 3 months with no performance degradation – remarkable capacity relative to today's batteries. Advanced battery technologies can be coupled with the building's energy storage system to improve energy efficiency and reliability.
Perovskites solar cells	Perovskites present great prospects at becoming the core material of solar panels. It is cheap and has greater sunlight absorbing capabilities compared to silicon. This material reduces the cost of solar panels and allows for a wide variety of affordable solar solutions in buildings, from rooftop panels to vertical panels.
Piezoelectric technology	Piezoelectric materials can generate electricity from vibrations and mechanical stress. For example, if a road is embedded with Piezoelectric material, it can generate electricity from cars moving on top of it. In buildings, floors equipped with piezoelectric technology can generate electricity from people walking on it.
Thermal elastic metal	Thermal elastic metal serves as a solid coolant, which replaces conventional liquid refrigerants in air conditioners. This results in greater energy efficiency and carbon emission reduction.
Wireless charging	Wireless charging utilises simple inductive mechanisms to transfer energy between a power source and a battery situated in a device. Electricity is transmitted by changes in magnetic field intensity between two coils. This enables greater flexibility for building management and operations whilst enhancing user convenience. For example, it can be applied to electric vehicle (EV) vehicle charging.

Table 3 – Emerging trends in smart green building technology

CHAPTER 2

Practical Strategies for Smart Green Buildings

This chapter will begin by providing insights into the value of IoT for smart green buildings and the importance of cybersecurity and data privacy. 6 fundamental design principles with 32 recommended smart green building strategies for application in existing and new buildings are presented with easy-to-understand infographics. The chapter concludes with smart technologies that promote healthier and safer buildings and a matrix linking the strategies with applicable building types.

IoT AS A 'BACKBONE' TO SMART GREEN BUILDINGS

In the context of smart green buildings, IoT is making residences, workplaces, public areas, and retail malls smarter. IoT is a network of sensors, devices, machines and programmes that operate together to enable data sharing and automating actions based on building operators preferences. All these devices and platforms connect to a central open Internet Protocol (IP) backbone to provide a holistic view of building performance – integrating data which can be presented through powerful graphics and data-rich reports. Data analytics can also incorporate AI and ML to help buildings self-diagnose and optimise performance.

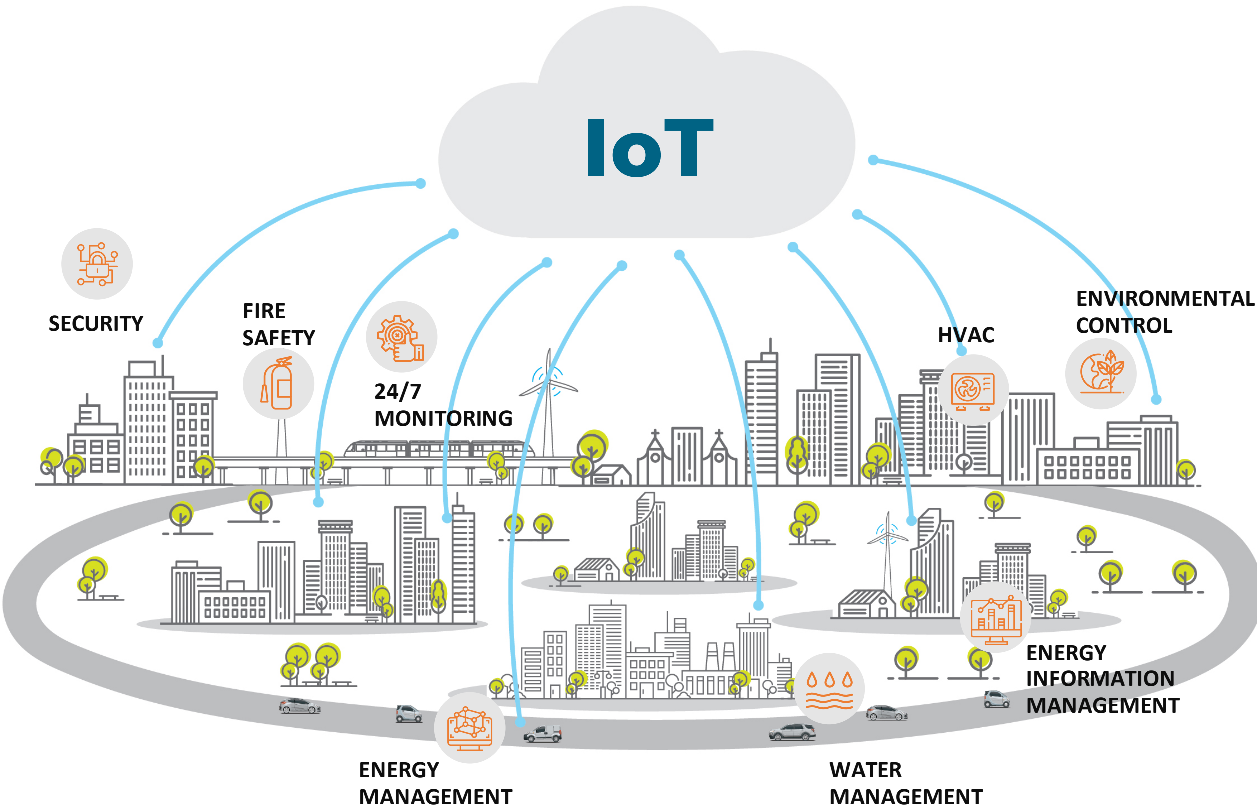


Figure 2 – IoT as a 'backbone' to smart green buildings

These platforms provide predictive knowledge of building or facility operating parameters, such as temperatures above or below service level agreement values or energy consumption rates above targeted operating ranges. Using analytics to understand what is happening in a building and then making appropriate corrections is probably the most important advance using IoT and smart building technology. This allows for quick resolution to issues and makes it possible to take pre-emptive steps to resolve problems before they emerge. The adoption of open protocols or open standards architecture is key to the application of IoT and smart building technologies.

Smart building systems are beneficial, however if they cannot interoperate or communicate with one another, their uses are limited. The development of open standards allows building systems to communicate with each other in a common protocol language, which standardises and spells out the way devices and systems interact with each other. An example of open protocols is American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE)'s open-source BACnet. One of the main benefits of open standards architecture is the ability to easily integrate new IoT devices and systems (provided they communicate using an open protocol language), without needing to obtain separate systems to manage each new device. Open protocols help drive efficiency, especially if implemented across a group of buildings.

The application of IoT in a building enables the automation of decision-making, enhances efficiency and reduces operating costs. IoT helps drive outcomes and goals specific to a facility performance, operators and occupants. The end goal for building owners is to improve user experience and processes, increase a building's operational effectiveness and reduce energy consumption, and hence optimise the financial performance of a building. However, for many applications to work, there needs to be sensor points in place with appropriate zoning of mechanical systems. Hence, it is easier to apply IoT in new buildings than in retrofits.

Another critical aspect of applying IoT technology is the involvement of all stakeholders – from consultants, designers, owners, facility managers, Information Technology (IT) professionals and even tenants. Stakeholder engagement is key to the integrated design of effective systems and operations. IoT building can be used to ensure an open, secure, scalable and adaptable building design, which can meet various stakeholder goals and building performance objectives.

Three critical aspects that should be considered when designing buildings to be smarter and more operationally efficient are:

1. **Technology integration and interoperability:** take a holistic approach to integrating systems that comprise the network backbone. The various devices and systems should be flexible for future expansion as new technologies emerge and as the needs of an organisation change. They should be scalable, adaptable, and able to integrate with existing systems that are already in place.
2. **Smart building data analysis:** while advanced systems can aggregate, filter, and translate a large amount of data to provide actionable insights, operators and users should also be trained to analyse and understand relevant data to make smarter decisions.
3. **Cybersecurity and data privacy:** increased connectivity and data capture can lead to data leaks and breaches. Organisations should employ a smart building platform that incorporates cybersecurity. Instituting data collection, storage and use governance, among other cybersecurity policies, will also help secure company data.

HONG KONG CYBERSECURITY AND DATA PRIVACY CONSIDERATIONS

Smart buildings leverage IoT, AI, BD, and other intelligent technologies to expand their capabilities. Such technologies enable the connectivity of different building systems and allow for the opportunity to gather and share data. However, associated with increased connectivity and data capture is vulnerability to data leaks, breaches, cybersecurity or privacy challenges. Hence, it is crucial to be mindful of privacy and cybersecurity.

Smart buildings can safeguard data through a number of security measures. For instance, networks can be secured through the application of firewalls and by performing risk assessments. Understanding methods hackers may use and developing security from the bottom-up can improve the strength of building systems. Developing clear policies on data, in terms of collection, storage and usage, enable building managers to transparently communicate the types of data being captured. Ultimately, while no system has complete security, smart buildings should aim to implement platforms that integrate cybersecurity and data privacy policies, and ensure they are in line with any relevant laws and regulations.

Hong Kong Data Protection and Privacy

In Hong Kong, data protection and privacy are governed by the Personal Data (Privacy) Ordinance (PDPO)[5]. This law essentially gives Hong Kong data subjects the right to be informed about which personal data is being collected, how the data is used, the right to object to this, and the ability to access their own data. However, as technology continues to improve, the city is continuing to look into intensifying the Government's cybersecurity capabilities concerning new security risks and the promotion of cybersecurity awareness in the community.

In recent years, the global cybersecurity landscape has changed, and ways of hacking and breaching data have diversified. Hong Kong is currently experiencing thousands of security incidents per year. Common attacks on businesses include ransomware, cryptomining, and business email compromise. Despite increased frequency of damages from cyber-attacks, many businesses merely review their security protection, rather than initiate further preventative measures. The Innovation and Technology Bureau[6] expressed that most cyber-attacks target systems with security vulnerabilities or insufficient user vigilance, with monetary gain as the main objective. To support an increasingly digital and smart city, information and cybersecurity are important considerations, and local businesses, the Government and the general public need to continuously improve and review their security protocols.

There are several organisations that can offer support to help strengthen cybersecurity and privacy policies:

- In 2016, the Government initiated the Technology Voucher Programme (TVP) to encourage local enterprises to utilise relevant technology and enhance cybersecurity measures against cyber threats. The TVP has approved over 150 applications involving the upgrade of information systems and cybersecurity.
- The Hong Kong Computer Emergency Response Team (HKCERT) can be contacted for computer and network security incident reporting and advisory for local businesses. HKCERT also organises seminars and promotional activities on cybersecurity related topics.
- The Office of the Government Chief Information Officer (OGCIO) has a Cybersecurity Information Portal which provides guidelines and information on cybersecurity tools. The OGCIO also organises IT security events and seminars to promote public awareness on cybersecurity.

[5] Office of the Privacy Commissioner for Personal Data (2018). *The Personal Data (Privacy) Ordinance.* Available from: https://www.pcpd.org.hk/english/data_privacy_law/ordinance_at_a_Glance/ordinance.html
[6] The Government of HKSAR. Innovation and Technology Bureau (2018). *Our Role.* Available from: https://www.itb.gov.hk/en/about_us/role.html

FUNDAMENTAL DESIGN PRINCIPLES FOR A SMART GREEN BUILDING

Building designs vary from project to project based on the client's requirements and constraints of the actual site. Integrating new technologies into the architectural, structural, and building services design help create a smart green building. However, a smart green building should not be based on technologies alone, instead it should be determined by the smart and green benefits that the building achieves through both passive and active design solutions.

Our environment and technologies are rapidly changing, and building owners, architects, engineers should design buildings that are responsive and adaptive to changes in the environment as well as to changes in use and operation over the building life cycle.

Building design can either improve or impede performance, longevity, use, and after-use management. Incorporating concepts such as circular economy, resilience, energy efficiency and net zero carbon into the design of buildings can facilitate in extending their lifespan for which they are fit for purpose. Adaptable design can bring about increased economic productivity through reduced operation and maintenance costs and improved health and environmental impacts such as better air quality. Some of the key design fundamentals and themes that can be considered are as follows:

Resilience to Climate Change

Climate change is a very real and complex issue for both new and existing buildings in Hong Kong. Extreme rainfall events, rising sea levels, flooding due to mega typhoons in Hong Kong are occurring more often and the ability to adapt to these changes in the environment are inevitable in building design.

Surface water management strategies can be implemented in early site planning and design stage, such as increasing storm drainage capacity to avoid accumulation of runoff within the site, providing temporary water storage to ease the pressure on the drainage system, increasing greenery and providing porous paved areas for soaking up water, and installing permanent door/gates as flooding barriers to retain the water from entering the site.

Climate surveillance and warning system can reduce risks of damages to the building structure, the owner's property (e.g., private vehicles stored in underground car parks) can save lives by evacuating building users in case of an emergency. Uninterrupted backup power can also ensure critical building systems are still in operation during extreme events.

Other design features, such as providing shades in outdoor areas, improved connectivity (e.g., via footbridges, tunnels, etc.) between buildings, and a public transport system will facilitate crowd movement and help sustain economic activities during adverse weather.

Designing for Adaptable and Flexible Use

The lifespan of a typical high-rise building in Hong Kong on average can easily exceed 50 to 60 years whereas in the case of a smart green building, an even longer life expectancy is anticipated. Throughout the life cycle of the building, the use of the space may change, and it is important that a smart green building is able to embrace and transform with the changes to preserve the structure and further extend its life.

Methods such as modular units and moveable interior walls, are providing greater flexibility and enhancing resource efficiency for residential and commercial buildings. These methods support the efficient and effective use of a building during its lifetime, such as repurposing a commercial building into housing, using modularity to downsize a home or an office, or supporting sharing and mixed functionality.

Proper distribution of facilities hub and meter cabinets/rooms can minimise future changes when there is a change of layout or tenants. Providing flexibility in building services and the IoT system would greatly enhance building operation over the years.

Appropriate lighting/air conditioning zoning and control are also important to facilitate operational needs, while pre-wired horizontal distribution systems in ceilings or floors, and adequate spaces reserved for maintenance can cater for future relocation of building services equipment and improve the efficiency of the building without causing major disruption to tenants and other building users.

Future Expansion

Buildings may require future expansion due to growing needs of building users and operators. Hence, buildings should be designed with spare plantroom capacity to enable the retrofitting of additional telecom, fibre-optic and building services system in the future. This adaptable and flexible design would open up future retrofitting opportunities throughout the life cycle of a building.

Role of Existing Buildings in Driving Smart and Sustainable Development

Figures from Hong Kong's Climate Action Plan 2030+ report[7] show that 70% of carbon emissions in Hong Kong is generated from electricity, of which 90% is consumed by buildings. The report further cites that commercial and residential sectors consume a combined 92% (65% for commercial and 27% for residential) of the electricity in Hong Kong. With over 42,000 existing buildings in Hong Kong[8], there is significant potential to improve their energy efficiency and enhance their environmental management practices, which would greatly contribute to the city's overall target in carbon emissions reduction.

While not all buildings will be able to implement an upgrade to their systems due to varied limitations, such as funding, location and spaces, existing building designs, etc., key building industry stakeholders (e.g., facility management, building maintenance professionals, tenants, etc.) can contribute to creating a sustainable built environment through smart operational practices aided by different strategies, which are reflected on in this Guidebook.

Through exercises, such as RCx, total building maintenance, building innovation/upgrading, alteration and additions, revitalisation, rehabilitation, etc., building industry stakeholders are able to further understand the different issues related to operations and identify areas for improvement. Generally, there are five key steps to existing building commissioning, which are shown in the diagram below:

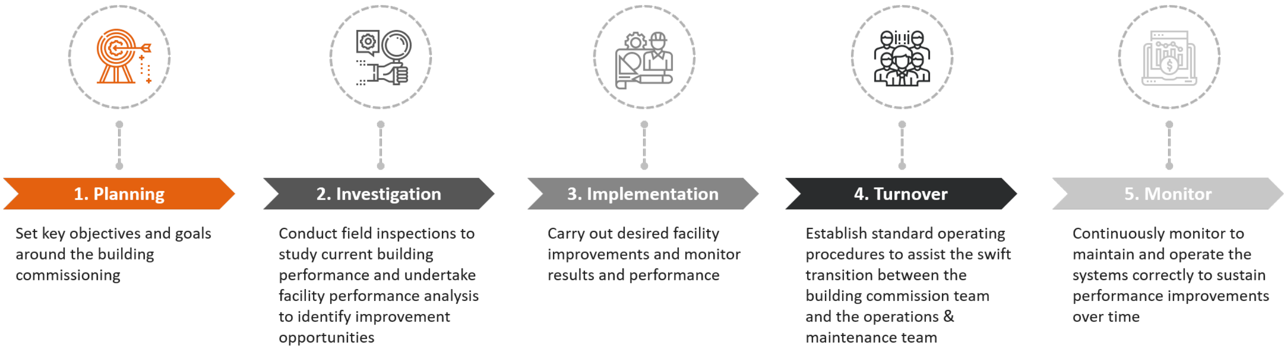


Figure 3 – Five key steps to existing building commissioning

[7] The Government of HKSAR. Environment Bureau (2017). *Hong Kong's Climate Action Plan 2030+.* Available from: https://www.enb.gov.hk/sites/default/files/pdf/ClimateActionPlanEng.pdf

[8] Hong Kong Green Building Council (2021). *BEAM Plus Existing Buildings.* Available from: https://www.hkgbc.org.hk/eng/beam-plus/beam-plus-existing-buildings/index.jsp

A collaborative effort from building owners, operators, tenants, and other users are needed to gradually transform the existing old, grey building stock in Hong Kong into a sustainably operated capital resource. Below are several local examples of how smart strategies and technologies have been implemented to enhance the environmental performance of existing buildings and their surrounding built environment.

1. TW Smart Parking mobile application at Tsuen Wan Town Centre by Urban Renewal Authority (URA)	2. eResidence ("Starter Homes" Pilot Project) by Urban Renewal Authority	3. Improvements to various public housing estates by Hong Kong Housing Authority (HA)
In 2018, URA developed the "TW Smart Parking" mobile application, a shared platform that makes use of real-time information from car park control and management systems. Through the application, users can access real-time information regarding parking availability and fees for 7 carparks in Tsuen Wan South. With support from Google Maps and Global Positioning System (GPS), users can find out the optimum route to the nearest car park to save time searching for available parking spaces and use that time for other experiences, such as shopping. This also reduces waiting time and environmental impacts from reduced on-street parking.	The Ma Tau Wai Road/Chun Tin Street Project by URA was approved in 2018 to pilot their "Starter Homes" concept, named eResidence. eResidence has deployed biophilic and sustainable building design with a total greenery coverage of 30%. Smart dynamic glass, specifically low e-glass double glazing, has been incorporated in the windows of living rooms and bedrooms. Solar panels have also been adopted at the podium and rooftop levels of the buildings. Home automation system has been utilised so that residents can monitor their household energy consumption, humidity, Volatile Organic Compound (VOC) levels; and retrieve building management and waste collection information for their units. BIM was also used to enhance project management during design and construction phases as well as for building maintenance.	Over the years, HA has implemented various improvements to their existing public housing estates to make them smarter and greener. In 2012, HA initiated a 3.5 year-programme to replace existing light fittings in communal areas of all existing public estates with electronic ballast to generate energy savings. In terms of biophilic design, HA also completed greening projects for their existing public housing and created themed parks in 22 existing public housing buildings to enhance a sense of character in these estates.

Table 4 – Implementation of smart strategies and technologies in existing buildings and their surrounding built environment in Hong Kong to enhance their environmental performance

OVERVIEW OF SMART GREEN STRATEGIES

This chapter provides an overview of 32 recommended smart green strategies categorised into 6 key themes which can be implemented in new and/or existing buildings. Each theme is presented in an easy to read and practical manner; supported with infographics to illustrate how the various strategies can be applied and their key functions.

For details on the 32 smart green strategies, please refer to the following appendices:

Appendix A – Building Design & Operations

A1. Building Information Modelling (BIM)
A2. Digital Twin
A3. Near Field Communications (NFC)
A4. Robotics for Building Operations
A5. Integrated Facility Management System
A6. Washroom of the Future
A7. Smart Space Utilisation
A8. Smart Surveillance

Appendix B – Health & Wellbeing

B1. Advanced Solar Technologies for Natural Lighting
B2. Smart Artificial Lighting
B3. Smart Thermal Control
B4. Biophilic Design
B5. Smart Air Filtration
B6. Smart Light Poles
B7. Occupant Automation System

Appendix C – Energy Performance

C1. Automated Fault Detection and Diagnostics (AFDD)
C2. Smart Grid Compatibility and Technology
C3. Energy Storage System (ESS)
C4. High Performance Chillers and Refrigerants
C5. High Efficiency Motors and Drives
C6. Solar Technology for Electricity Generation
C7. Micro-wind Turbines

Appendix D – Material & Waste Management

D1. Smart Dynamic Glass
D2. Nanotechnologies
D3. Automatic Waste Collection Systems

Appendix E – Water Performance

E1. Smart Water Metering and Monitoring
E2. Water Efficient Fixtures and System Controls
E3. Grey Water Reuse and Harvesting Rainwater
E4. Smart Irrigation

Appendix F – Mobility & Transportation

F1. Smart Green Parking
F2. Intelligent People Flow
F3. Autonomous Vehicles

'Building Design & Operations' as a theme focuses on smart green technologies that can be adopted throughout a building life cycle (from design to construction to operations and maintenance) to enhance efficiency of building performance and enable flexible, adaptive building design. Building professionals are increasingly adopting technologies at the initial design and construction stages to enable seamless communication and information flows throughout the other stages of an asset's life cycle.

Below are some examples of smart green strategies that could be implemented in a building to enable flexible design and enhanced operations:

A1. Building Information Modelling

BIM is the creation and sharing of three-dimensional (3D) models and data of the building to enable seamless integration throughout a building's life cycle.

BIM promotes better decisions in terms of cost and sustainability to be made, as well as facilitate more efficient operations, when paired up with the building management system (BMS).

A2. Digital Twin

Digital Twins are virtual models of buildings that can be developed during initial design stages to give building professionals a real-time view of the integrated systems of the building.

Digital Twins allow building operators to efficiently monitor building operations and systems in real-time, including the environmental performance of buildings, thus generating long-term cost savings.

With more advanced building technology being introduced in the market, they are increasingly being adopted to enhance the efficiency of building operations and management, such as near field communications and robotics for building operations.

A3. Near Field Communications

NFC, as a technology that enables contactless communication using magnetic field induction between devices in short range, is often used for on-the-go smart building management capabilities.

NFC can enhance user experience and efficiency of building operations, for instance, with improving security processes and access control while using less manpower.

A4. Robotics for Building Operations

Robotics are also being used in all types of building (e.g., commercial, functional, residential) to perform a number of functions, including cleaning, security, customer services.

Robotics can enhance the operational efficiency of buildings by eliminating the need for manual labour and allowing them to focus on more thought intensive complex tasks.

Reducing environmental impacts

Promoting better occupant wellbeing

Enhancing operational efficiencies

Generating cost savings

Smart technologies are also commonly used to maximise the performance of buildings.

A5. Integrated Facility Management System

An integrated facility management system is the 'brain' of a smart building where all information and data from various technologies adopted throughout the building are combined, displayed and managed to enhance the operational efficiency of the asset.

Such system gathers the data in a way that allows real-time tracking and analysis of building performance, enabling better decisions to be made for operations and maintenance.

A6. Washroom of the Future

Sensors can be adopted to enable smart washroom functions and analytics, such as real-time tracking of washroom conditions, monitoring of ammonia threshold levels, and inventory tracking of toilet consumables.

By tracking the conditions of smart washrooms and understanding the patterns and trends in toilet consumable usages, building operators can benefit from long-term cost savings, due to less wastage of resources.

A7. Smart Space Utilisation

Through space utilisation analytics, spaces in a building can be managed in an adaptive and intelligent way to enable multi-functional spaces for building users.

By adopting smart space utilisation in office or co-working spaces, this can create a more agile and competitive work environment, thus encouraging better collaboration and interaction.

A8. Smart Surveillance

Smart surveillance technology analyses the data from intelligent cameras and other security devices, using AI or ML, to perform access control, pattern and incident detection.

Quicker access control and pattern detection by smart surveillance technology can enhance convenience for occupants and significantly impact the safety and wellbeing of building users.

Reducing environmental impacts

Promoting better occupant wellbeing

Enhancing operational efficiencies

Generating cost savings

Building Design & Operations

The infographic below illustrates how the various strategies related to building design & operations could be implemented in a building:

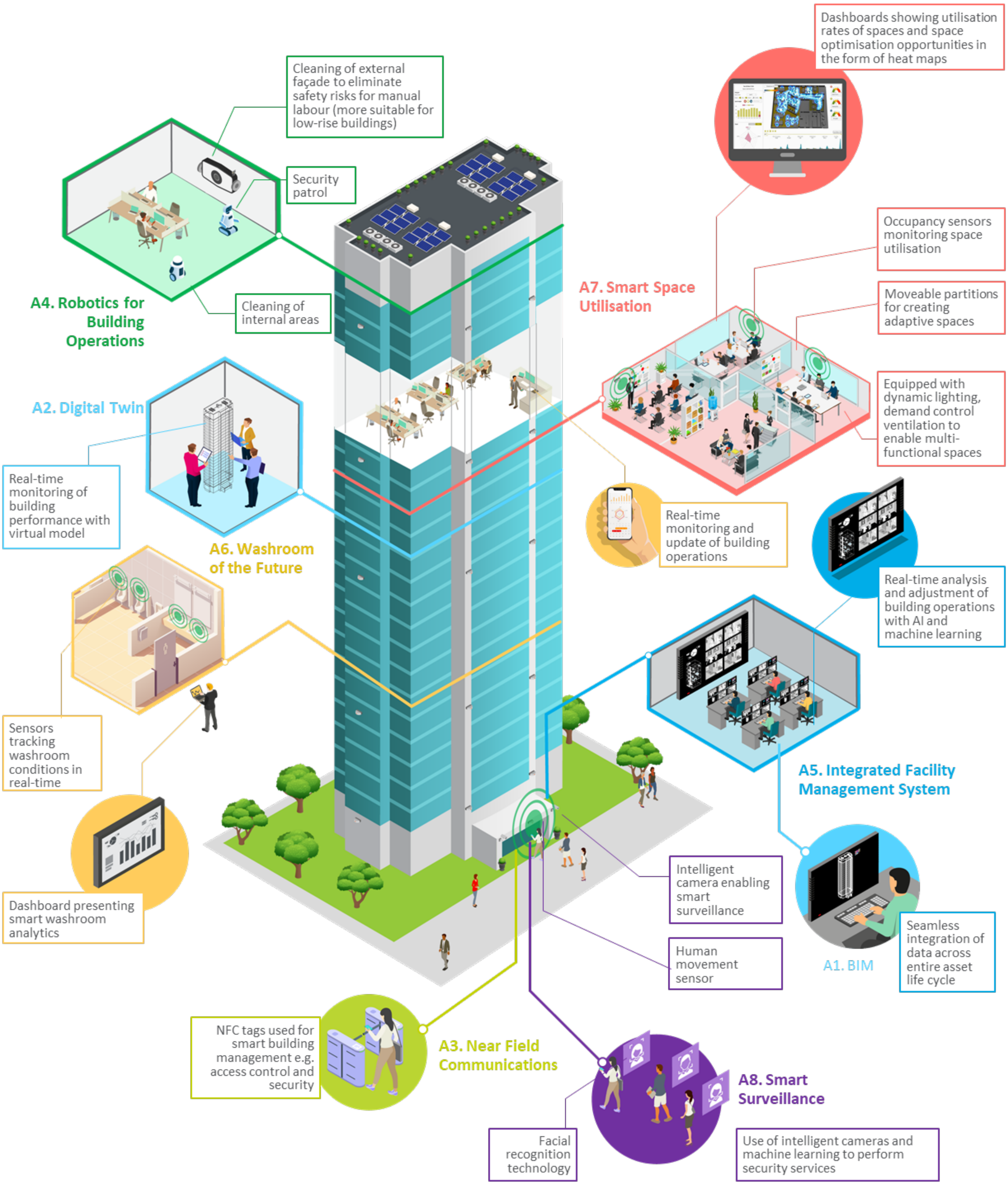


Figure 4 – Building strategies on building design & operations

'Health & Wellbeing' as a theme refers to the use of smart technologies to maintain and enhance the environmental quality of a building and its built environment, which could significantly impact the health and wellbeing of its users. The following are examples of smart green strategies that could be implemented in a building to improve its lighting, thermal and air quality.

B1. Advanced Solar Technologies for Natural Lighting

Automated solar technologies refer to advances in concentrating solar power (CSP) (e.g., heliostats and solar tubes) and automated shading systems that maximise natural lighting inside buildings.

Use of solar technologies can generate energy savings of 15% to 40% from reduced use of artificial lighting as well as positively impact occupant wellbeing with enhanced comfort and reduced eye strain – lighting preferences are controlled remotely.

B2. Smart Artificial Lighting

Smart lighting is the enhanced controllability and automation of lamp responses through the adoption of IoT and ambient light sensor (ALS) technologies. Users can control lighting preferences through a smartphone application/mobile device.

By personalising lighting preferences and collecting real-time insights on lighting usage, this can enhance occupant wellbeing and operational efficiency of the building, as well as generate long-term cost savings from reduced energy wastage.

Thermal comfort is another factor that is integral to the health and wellbeing of building users, which can be optimised through smart technology.

B3. Smart Thermal Control

Smart thermal control system allows building users to customise and adjust the temperature settings in and around the space they occupy according to their needs and preferences through a mobile device.

Through personalising and automating temperature settings, user comfort is enhanced. Real-time insights on thermal settings can be collected to optimise operational efficiency and generate energy and cost saving in the long run.

Reducing environmental impacts

Promoting better occupant wellbeing

Enhancing operational efficiencies

Genrating cost savings

There is a growing trend in the implementation of smart technologies to improve the indoor air quality of buildings as well as the outdoor quality of the surrounding environment.

B4. Biophilic Design

Biophilic design in buildings focuses on incorporating greenery in and around a building (e.g., vertical garden walls), using sensors to provide information, and maximising views of nature in the interior to enable occupants to feel connected with nature.

Biophilia directly benefits physical and mental health and wellbeing of building users by reducing stress levels, improving cognitive functions and productivity. Biophilia also helps in improving air ventilation and quality.

B5. Smart Air Filtration

Smart technology and devices could be used to improve and monitor Indoor Air Quality (IAQ). The use of air filters and filtration technology enhances air purification and filtration, such as acoustic air filtration and 3G filter technology.

By filtering the air, this can improve indoor air quality, which would have a direct impact on the health and comfort of building users. By operating a more efficient air filter, less maintenance work is also required for ducts.

Interactive smart building controls are increasingly promoted to enhance user comfort and experience in buildings, such as smart light poles, and occupant automation system.

B6. Smart Light Poles

Smart light poles integrate cellular broadband internet connections, and multiple data capturing sensors, to compile and broadcast information. They can be implemented in the surrounding built environment of buildings.

Through the collection of real-time data, sensors and predictive analytics, smart light poles can help optimise the balance between energy usage, citizen comfort and public safety.

B7. Occupant Automation System

In recent years, there has been a growing trend in the use of home automation systems in residential buildings, which allow residents to monitor and control their home from remote locations, using mobile devices and IoT.

Occupant automation systems enhance user convenience by tailoring preferences to user needs. Collection of real-time insights can optimise operational efficiency and energy savings, thus generating cost savings in the long-term.

Reducing environmental impacts

Promoting better occupant wellbeing

Enhancing operational efficiencies

Genrating cost savings

Health & Wellbeing

The infographic below illustrates how the various strategies related to health & wellbeing could be implemented in a building and its surrounding built environment:

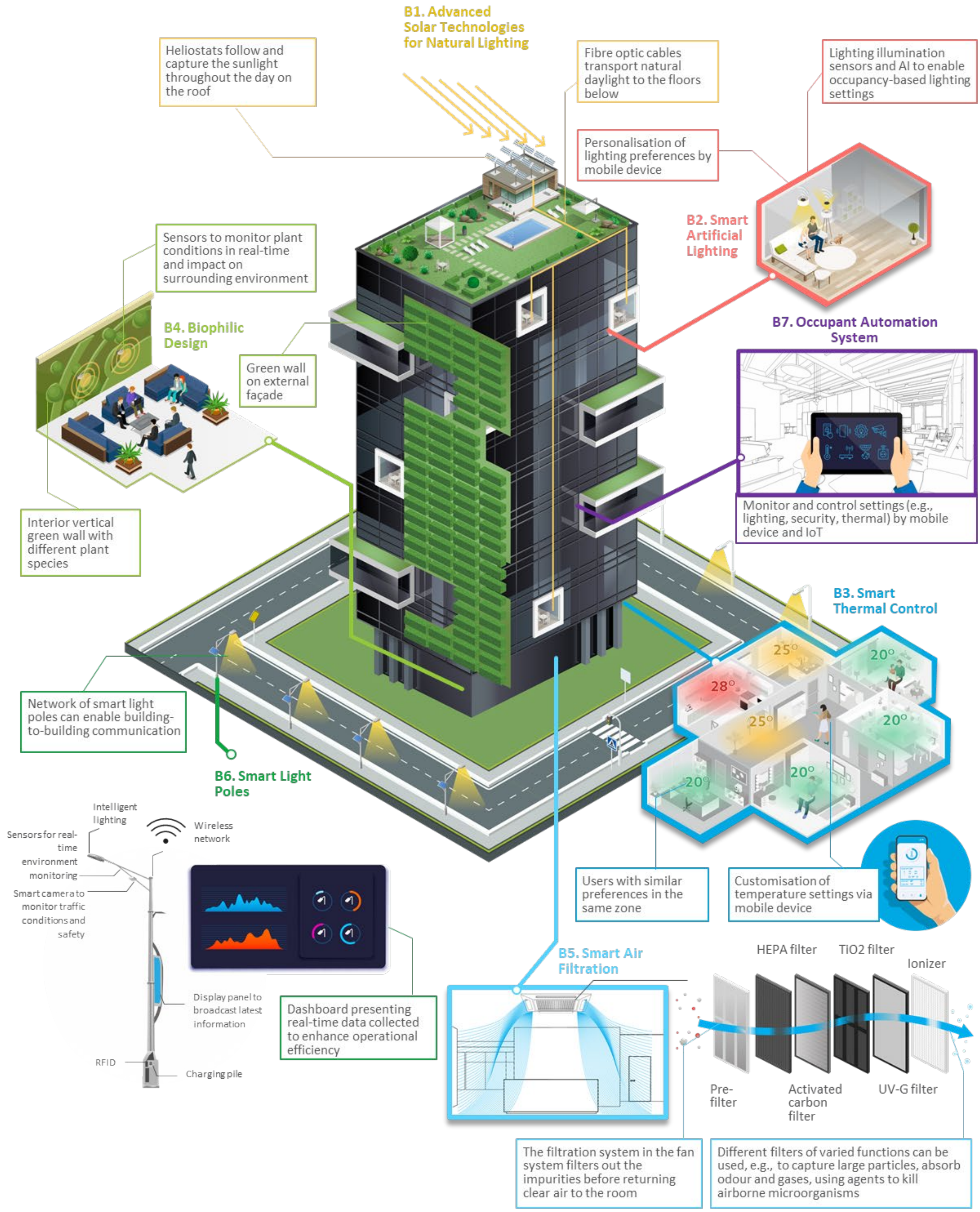


Figure 5 – Building strategies on health & wellbeing

'Energy Performance' as a theme focuses on adopting smart technologies to achieve higher energy efficiency in a building, which could improve overall asset environmental performance. The following are examples of smart green strategies that could be implemented in a building to improve overall energy performance.

Buildings of multiple asset classes are increasingly adopting smart energy management technology to monitor the energy performance of buildings. This can be enhanced with AI and ML technology to achieve optimum results.

C1. Automated Fault Detection and Diagnostics

AFDD is an automatic process by which faulty operation, degraded performance, and failed components are detected and understood. This is typically an add on to the BMS to enable predictive maintenance.

AFDD can help to generate energy savings by identifying faulty and inefficient operations and promoting zero breakdown of equipment. Operational efficiency can also be enhanced through predictive maintenance.

C2. Smart Grid Compatibility and Technology

Smart grid represents a modern grid concept that enables safe and secure two-way flows of electricity and information between customers and electricity providers. This is increasingly being promoted by the HKSAR Government as part of a wider effort to energy efficiency for buildings.

By integrating renewable energy and distributed energy generation and storage, this could generate long-term cost savings through effective management of the supply and demand of electricity.

C3. Energy Storage System

ESS provides operational flexibility to manage load for a smart building and in the broader context of smart grid. For a building with ESS, load shifting can help the building owner to optimise energy cost by consuming energy during non-peak periods at a lower cost rate while maintaining the same comfort and operation.

ESS promotes energy efficiency and use of renewable energy as well as enhances the operational efficiency of buildings by allowing end-users to use the stored energy in power outage situations. By selling energy back to the grid, building owners can accrue cost savings in the long run.

Reducing environmental impacts

Promoting better occupant wellbeing

Enhancing operational efficiencies

Generating cost savings

Building operators are increasingly adopting more energy efficient equipment and system controls in buildings to improve the overall energy performance and generating cost savings in the long-term.

C4. High Performance Chillers and Refrigerants

Chiller technology is improving with the adoption of IoT – An IoT based system enables real-time analysis of data that is critical for gauging the operational health of a network of chillers, identifying if any problems are in place, and also promoting predictive maintenance. In terms of recent refrigerant technology, there has been a move towards accelerated reduction of hydrofluorocarbons (HFCs) and refrigerants with short atmospheric lives.

Improved chiller efficiency can generate energy savings in the Heating, Ventilation, and Air-Conditioning (HVAC) system and utilising advanced refrigerants also help to minimise environmental impacts. This higher energy efficiency can enhance overall operational efficiency of the building and results in cost savings.

C5. High Efficiency Motors and Drives

Brushless/Electronically commutated (EC) motors rely on semiconductor switches to turn stator windings on and off at the appropriate time. They are increasingly being adopted due to their high power-to-weight ratio, high speed, electronic control, and low maintenance need.

EC motors can generate significant energy savings ranging from 20% to 40% for new and existing buildings. Together with minimum maintenance requirements, this can enhance operational efficiency and result in cost savings.

There is a growing trend in the industry to adopt renewable energy sources in buildings where possible.

C6. Solar Technology for Electricity Generation

Solar technology focuses on the conversion of energy from sunlight into electricity, either directly using photovoltaics (PV), indirectly using CSP or a combination. Advancements include increasing application of Building-Integrated Photovoltaics (BIPV).

Use of solar technology can reduce environmental impacts by minimising harmful emissions generated by fossil fuel-based technology. Solar technology requires relatively less maintenance, thus can generate cost savings in the long run.

C7. Micro-wind Turbines

Micro-wind turbines are efficient wind turbines that are much smaller in scale and generate lower cost of electricity with units half the size of traditional micro-wind turbines. They are suitable for residential/commercial energy production and are increasingly being integrated in the architectural design of buildings.

Promoting renewable energy sources, such as wind energy, improves the overall environmental performance of a building. Cost savings can also result from the reduced need for fossil fuels.

Reducing environmental impacts

Promoting better occupant wellbeing

Enhancing operational efficiencies

Generating cost savings

Energy Performance

The infographic below illustrates how the various strategies related to energy performance could be implemented in a building and its surrounding built environment:

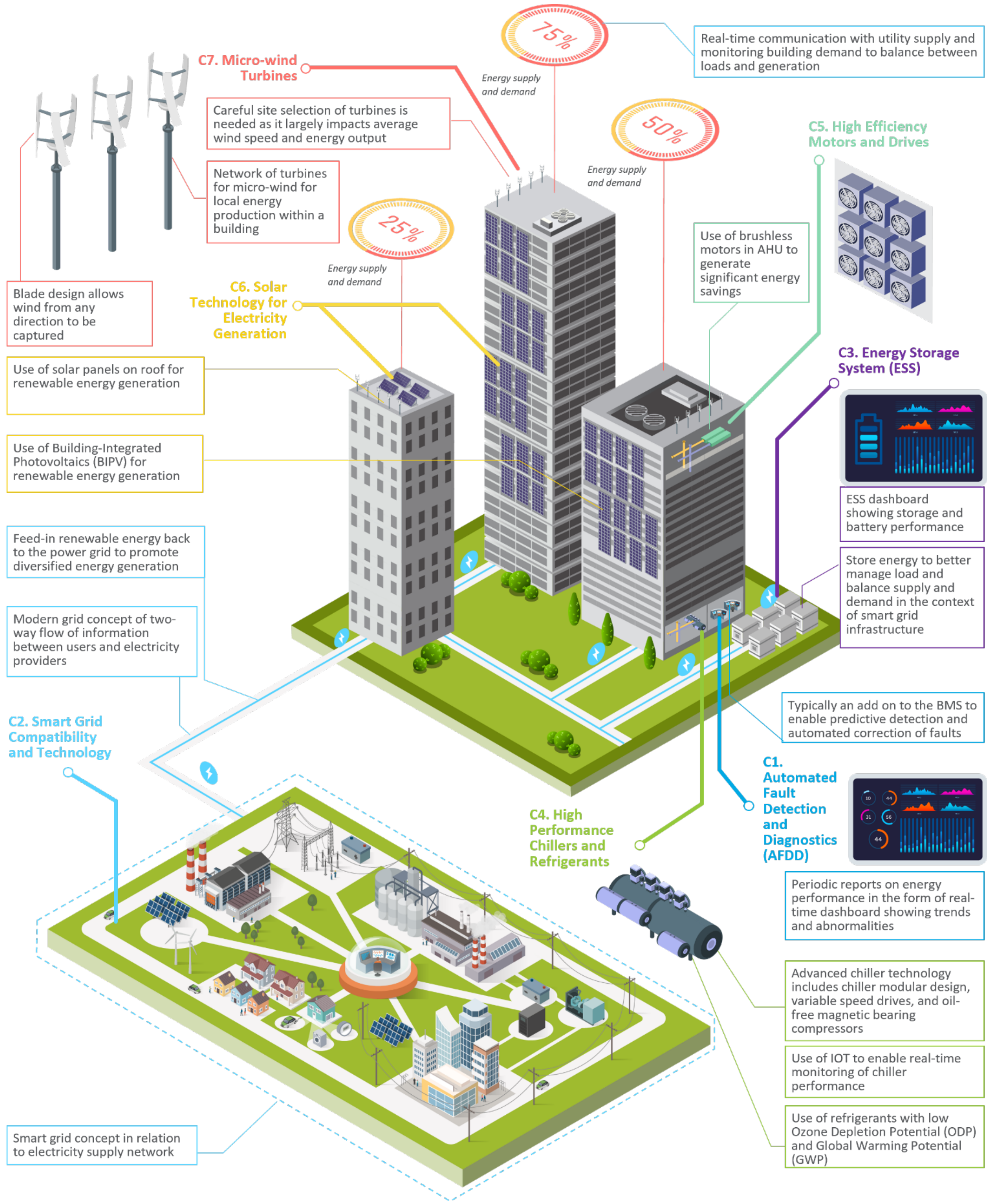


Figure 6 – Building strategies on energy performance

The theme of ***'Material & Waste Management'*** promotes the optimised use of building materials as well as sustainable practices and waste reduction, reuse and recycling. Below are examples of smart green strategies that could be adopted to enhance the performance of building materials and waste management.

With more advanced forms of building materials being introduced in the industry, building professionals are increasingly exploring smarter material selection to improve the overall environmental performance of buildings.

D1. Smart Dynamic Glass

Smart glass is an innovative building material that can change its glazing properties (e.g., level of tint) automatically in response to the surrounding environment, or manually based on the needs of the users.

By automating the control of glazing properties, smart glass enhances operational efficiency and occupant wellbeing with improved indoor lighting quality. Reduced heat gain in the interior can generate cost savings in the long-term.

D2. Nanotechnologies

Nanotechnologies can be applied in many different forms in the building material to enhance building performance and efficiency, with applications spanning across coatings, paints, concrete, glass, thermal insulations, etc.

Nanotechnologies can enable building operations to become smarter and greener, e.g., self-cleaning and self-healing properties. This improves the environmental performance of buildings, quality of environment for users, and operational efficiency due to reduced maintenance needs.

Smart green technologies to enhance the efficiency of waste management are also evolving, such as automatic waste collection systems with pneumatic properties.

D3. Automatic Waste Collection Systems

An automatic waste collection system enables the automated collection, transportation, recycling, separation and combustion of waste produced inside a building.

Automatic waste collection system improves building operations due to automated processes. It also reduces environmental impacts associated with traditional waste management.

Reducing environmental impacts

Promoting better occupant wellbeing

Enhancing operational efficiencies

Generating cost savings

Material & Waste Management

The infographic below illustrates how the various strategies related to material & waste management could be implemented in a building and its surrounding built environment:

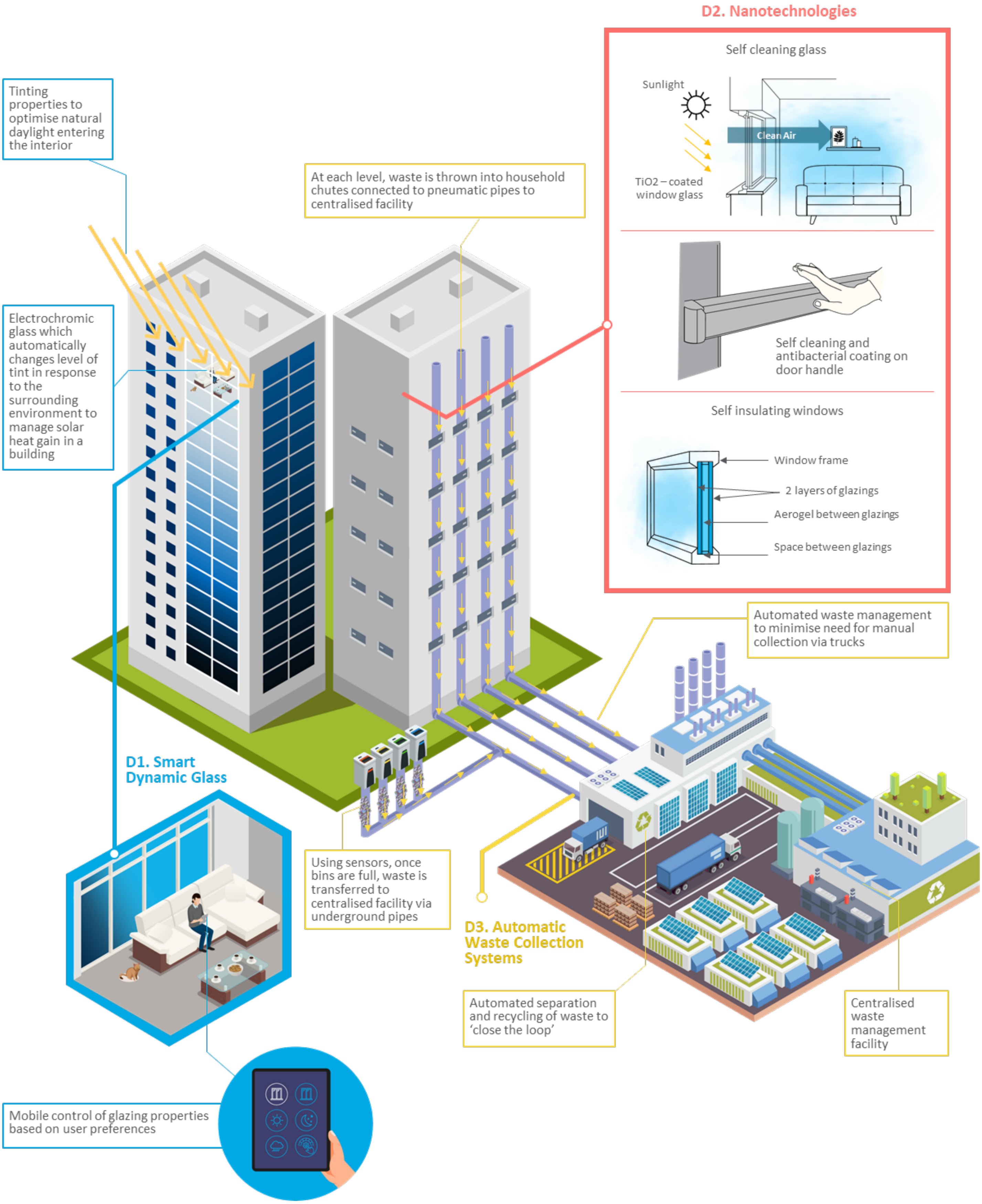


Figure 7 – Building strategies on material & waste management

'Water Performance' as a theme focuses on the use of innovative technology to enhance water reduction and conservation practices within a building. Such technologies can be applied to multiple asset classes. Below are examples of smart green strategies that could be implemented to improve the overall water performance of buildings.

Building professionals are constantly exploring ways to better monitor the usage levels of water and other utilities to improve building performance. Smart water management can be integrated into building operations, such as smart water metering and monitoring.

E1. Smart Water Metering and Monitoring

Smart water meters measure and monitor water consumption and quality as well as detect leakages. They also relay information in real-time at the building level, and occasionally at the neighborhood level, about the quantity and quality of water usage.

Smart water metering and monitoring has a wide variety of benefits, including water conservation, quick detection of water quality issues, minimised operational interruptions, and reduced operational costs.

Water efficient system and equipment are also commonly adopted in buildings to promote water conservation practices.

E2. Water Efficient Fixtures and System Controls

This focuses on water conservation solutions that reduce potable water usage for amenities and building services, such as efficient showerhead, motion sensing urinal, dual flush toilet, low flow faucets, and supply shut off by motion detectors or doors sensors, etc.

Efficient use of water improves overall environmental performance of buildings by also reducing energy usage, which could also generate significant cost savings.

E3. Grey Water Reuse and Harvesting Rainwater

Reusing grey water and harvesting rainwater support the reduction of potable water usage. Water collected can be reused for non-potable purposes, such as toilet flushing, heat reduction, irrigation, street cleansing etc.

Reusing water reduces the need for potable water usage and energy use for water treatment and pumping. There are also potential cost savings associated with water reuse.

E4. Smart Irrigation

Smart irrigation systems tailor watering schedules and run times automatically to meet specific large-scale landscape needs, which can significantly improve outdoor water use efficiencies.

By adjusting the watering schedule and intensity through monitoring the actual conditions of the site, overall water consumption is reduced, while also generating cost savings and enhancing operational efficiencies.

Reducing environmental impacts | Promoting better occupant wellbeing | Enhancing operational efficiencies | Generating cost savings

Water Performance

The infographic below illustrates how the various strategies related to water performance could be implemented in a building and its surrounding built environment:

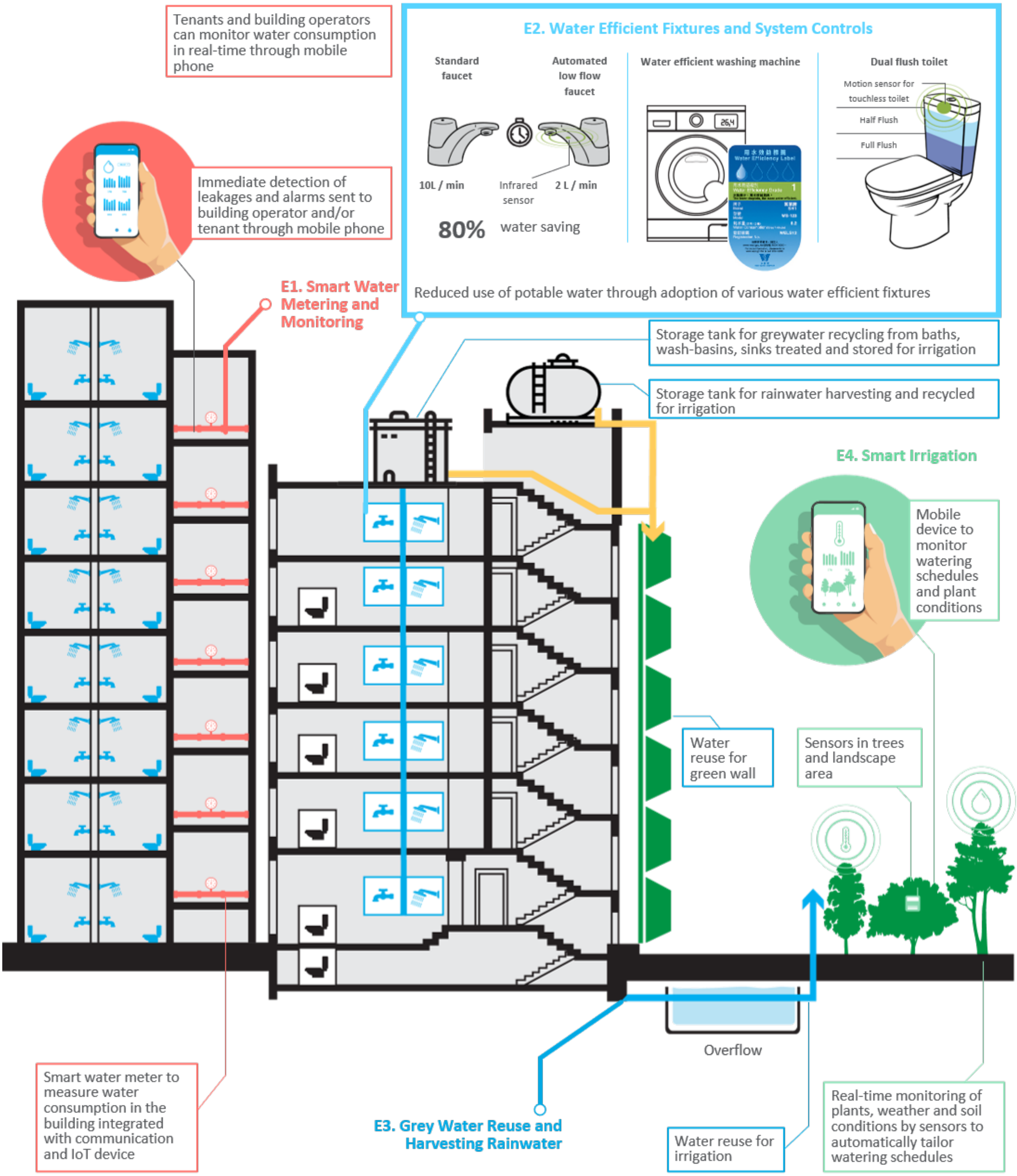


Figure 8 – Building strategies on water performance

'Mobility & Transportation' as a theme refers to the use of innovative technologies to promote green modes of transport and mobility with less carbon footprint, which alleviates the impact on climate change. The following are examples of smart mobility strategies that could be implemented in buildings and its surrounding built environment to promote more efficient use of space and resources.

F1. Smart Green Parking

Smart parking includes use of automated parking applications and technologies to efficiently manage parking spaces within a building, such as automated parking systems, real-time tracking of parking availability, parking management through smartphones, applications of near field communication or radio-frequency identification (RFID) technology.

Increasing use of EV facilities and smartphone applications that manage parking availability can help reduce environmental impacts through minimising unnecessary car travel as well as improve overall user experience and parking operations. Horizontal/vertical parking systems that optimise space utilisation can ultimately generate some cost savings.

F2. Intelligent People Flow

Intelligent people flow solutions aim to create a seamless user experience from the front door to the required destination in a building through the use of IoT, AI and other advanced technologies, including predictive and automatic call entry of elevators, and personal mobility services enabled by smartphone applications.

Intelligent people flow can enhance user convenience, comfort, and security by connecting building access, elevators, and intercom systems (for homeowners and tenants) via smartphone application. There are also opportunities for energy savings through optimising the use of elevators.

F3. Autonomous Vehicles

Autonomous vehicles are small pods meant for public transportation and serve as on-demand transport for quick point-to-point travel. Autonomous vehicles are generally sized for individual or small group travel, typically carrying not more than ten passengers per vehicle.

Autonomous vehicles do not require use fossil fuels and thereby provide a clean mode of transportation. Enabled by IoT and sensors, autonomous vehicles have proven to be a reliable mode of transportation that reduces the risk of potential accidents.

Reducing environmental impacts

Promoting better occupant wellbeing

Enhancing operational efficiencies

Generating cost saving

Mobility & Transportation

The infographic below illustrates how the various strategies related to mobility & transportation could be implemented in a building and its surrounding built environment:

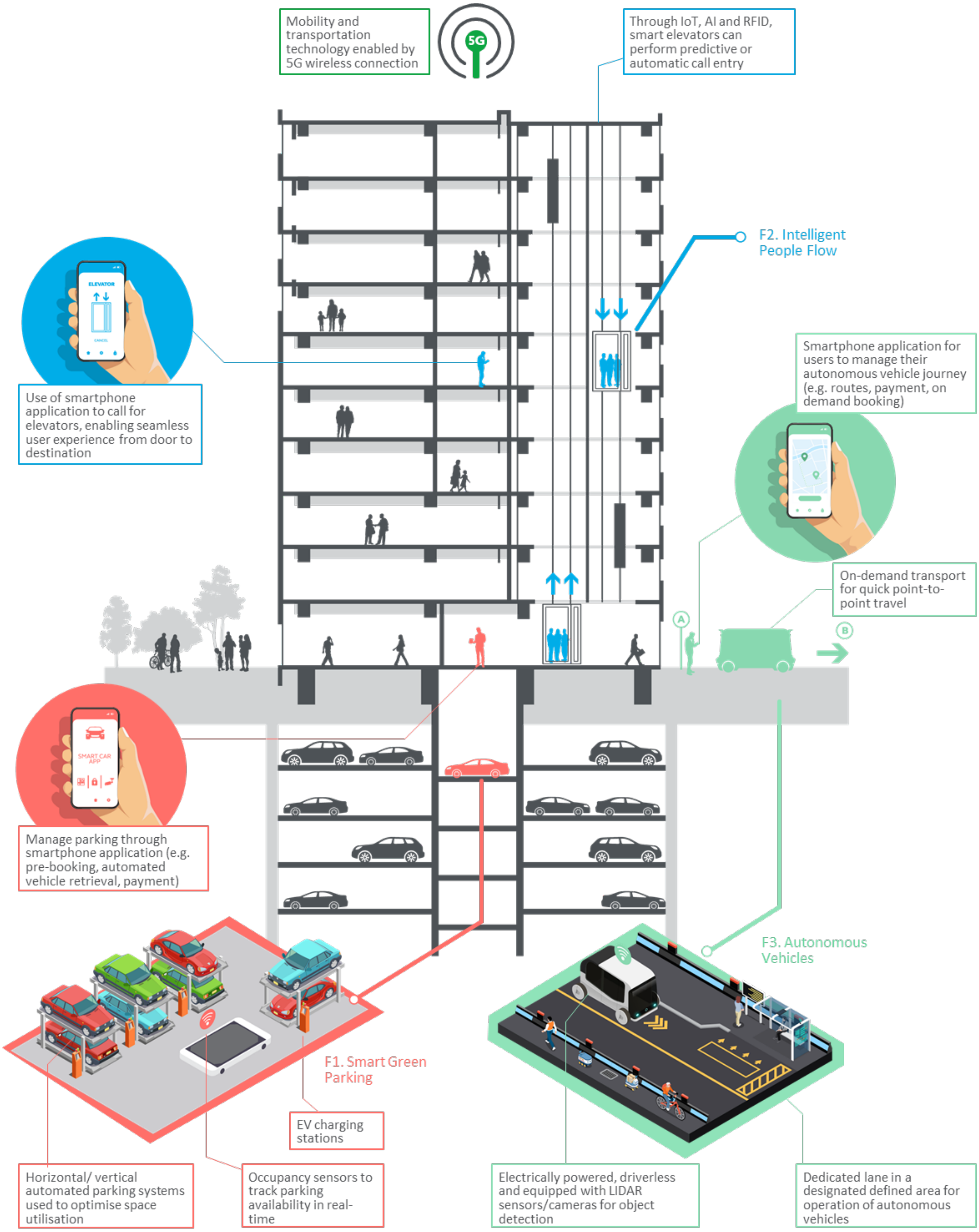


Figure 9 – Building strategies on mobility & transportation

SMART TECHNOLOGY TO PROMOTE HEALTHIER AND SAFER BUILDINGS

The pandemic has highlighted the importance of creating healthy environments, particularly in social locations and workplaces. As the pandemic affects the health and wellbeing of building users, buildings will have to adjust to maintain a safe environment. An outbreak impacts certain elements of a building, such as high-touch surfaces, lobbies and common areas, and the ways people use shared spaces and operate buildings. This emphasises the need to focus on strategies to support the improvement of indoor environments. Both existing and new buildings can leverage technology, ongoing monitoring, data analytics, and other strategies to minimise risks and promote safer healthier buildings.

Below is an overview of various technologies that can be deployed by building owners or operators to promote safer indoor building environments:

Theme	Technology
Building Operations and Touchless User Experience	**Parking** Carparks can use touchless systems with automated license plate recognition technology, which allows a camera to read registered plate numbers. Users can also utilise a smartphone application to register their plate number to gain access. The system then calculates time spent in the parking area, and automatically charges the user. Such systems eliminate the use for any form of physical contact. **Doors** Contactless hygienic switches for doors allow for the opening and closing of doors without any physical contact. The switches are activated when a hand is held over the sensor. The system converts near infrared waves into microwaves to reduce malfunctions, and they are easy to install. Additionally, recent technology allows users to enter a secure workplace using a Bluetooth signal on smartphones. This works through a smartphone app, which authenticates the user's identity. The user can then hold their phone near a reader and be allowed entry. This technology eliminates the need to touch screens or swipe cards to enter. **Smart lighting** Through Bluetooth or Wi-Fi, lighting systems can be connected to a home hub, which allows the user to control lighting through a smartphone, tablet or other gadgets. Aside from eliminating the need for light switches, smart lighting systems allow remote control of lights and scheduling of lighting preferences. **Robots** Robots can be used to clean premises. They can plan cleaning routes and carry out autonomous patrols, relieving the burden on janitors and preventing infections. UV-C robots are intelligent robots designed for indoor virus prevention. They are equipped with ultraviolet (UV) light systems used to disinfect and kill diseases, viruses, and bacteria. **Remote operations and digital services** Through secure Virtual Private Network (VPN) connection, building operators can remotely access, operate and monitor fire safety, security and building automation systems to reduce presence on-site. **AI algorithms** Through the use of infrared imaging for rapid and multiple body temperature monitoring, individuals with high temperatures can be identified and by cross referencing their healthcare history, travel records and weather patterns, AI algorithms have the potential to predict disease outbreaks before they happen. AI algorithms can also be used to facilitate predictive building maintenance work by identifying the system/facilities that require inspection to ensure they are running properly and avoid any impacts on building performance, which may also affect the health and wellbeing of occupants.

Theme	Technology
Building Services and Air Quality	**High Efficiency Particulate Air (HEPA) filter** A HEPA filter is a type of mechanical filter used in air purifiers. It traps air contaminants by forcing air through a fine mesh. A HEPA filter is designed to capture almost all particles in the air passing through it that are 0.3 microns or larger in size. This makes it very effective in removing viruses from air streams, as long as they pass through the filter. Minimum Efficiency Reporting Value (MERV) 13 or higher bag filters are recommended due to their higher fan energy and pressure drops. They are also a good retrofit solution. However, it should be noted that a filter of higher MERV rating would increase the load of the HVAC system, therefore the system design should be reviewed in detail before switching to filters of higher ratings. Filters need to be regularly cleaned and inspected to ensure their proper functioning. **UV light air purifier** UV light air purifiers use short-wave UV-C light to keep airborne viruses and other microorganisms from reproducing and infecting indoor spaces. As air is forced through the system, the UV light directly disinfects the air. UV-C air purifiers can be sold as stand-alone devices, or as systems installed into pre-existing residential or commercial HVAC units. **IAQ sensors** IAQ sensors can be integrated into a building's HVAC system to help inform the system if there is a need to improve ventilation when IAQ levels are unhealthy. Sensors can measure Carbon Dioxide (CO_2), VOCs, temperature, humidity, light, and occupancy. For instance, IAQ sensors can be implemented in toilets to measure and monitor odour concentration levels, such as ammonia, hydrogen sulfide, etc. **HVAC settings optimisation** BMS and HVAC operations can be optimised for improved indoor environment and safety of building occupants. Relevant measures include: • Switching air handling units (AHU) with recirculation to 100% outdoor air to enhance ventilation of spaces with outdoor air; • Maintaining ventilation systems to run at lower speed and switching off demand control at nights and on weekends; • Switching the ventilation speed to higher speed at least 2 hours before the building usage time and to lower speed at least 2 hours after the building usage time; • Maintaining humidity setpoints of >40%; • Keeping toilet ventilation in operation 24/7; and • Implement Representatives of European Heating and Ventilating Associations (REHVA) and ASHRAE recommendations for safest indoor conditions. **Mechanical ventilation in common areas** Common areas, such as lift lobbies and common corridors, may have limited access to natural ventilation. A mechanical ventilation system should be in place to maintain a desirable indoor environment for these areas. During the design stage of the system, expected people flow in common areas should be taken into consideration to plan for the capacity of the ventilation system. The ductworks and related system components should be located in accessible locations for regular maintenance and repair work. The system should also be designed in a way that facilitates outdoor air dilution through the ventilation system. **Underfloor HVAC system** Underfloor Air Distribution (UFAD) is an alternative to traditional overhead air distribution, which uses a raised floor supply plenum to supply conditioned air through floor diffusers. Advantages of an underfloor system include improved air quality compared to overhead systems, warmer supply air so that people do not feel discomfort, and localised air distribution, which can be adjustable for individual comfort control.
Vertical Transportation	**Elevators** Elevators can have touchless control panels in the form of holographic buttons so that the user does not have to touch anything. A passenger can simply hover a finger close to the button and wait for it to change colour. Alternatively, elevators can have anti-bacterial lift buttons.

Theme	Technology
	Elevators can also be called through a smartphone application, where users are given the ability to call an elevator remotely from anywhere in the building (e.g., destination dispatch controls). The application displays the user's assigned elevator, its current status, and gives an alert when the elevator is approaching. Sensor technology and algorithms can also be used to enforce crowd control and restrict elevator occupancy to maintain social distancing. Elevators typically have a load weighing device, used to avoid carrying a higher load than it was designed for. Such device is usually set at 80%, however, this could be reduced to 20% to reduce the number of people to a safe level. **Escalators** A handrail UV Light-emitting Diode (LED) steriliser can remove germs from the handrails of escalators using powerful UV light. The steriliser continuously disinfects the rails during the operation of an escalator, so the surface is disinfected just before a passenger lays their hands on the handle. This technology is easy and convenient to install, all that needs to be done is to attach a steriliser to the escalator, without making changes to the existing facility. Escalators in many commercial buildings in Hong Kong have installed these devices, such as Taikoo Place and Lee Gardens.
Hydraulic Services	**Plumbing and drainage** There is a need to maintain the plumbing and drainage system of buildings to prevent the spread of disease. It is important to maintain the water seal in plumbing wastes, particularly when the building has been unoccupied, to prevent viruses from passing through pipes. Running water through drains frequently will help to prevent the U-shaped water traps from drying out. After the outbreak of Severe Acute Respiratory Syndrome (SARS) in Hong Kong in 2003, the transmission risk associated with faulty U-shaped water traps was identified. U-shaped water traps prevent foul odour and insects in the soil pipe from entering the premises. Any cracks or defects or dried pipes may lead to the spread of diseases. The vent pipe should be connected to the main pipe to ensure the smooth flow of water and waste since air and gas would be emitted to the outdoor environment through the vent pipe. There have been previous incidents in Hong Kong where vent pipes disconnected with waste pipes resulting in virus transmission across neighbouring flats. Vent pipes need to be regularly inspected and maintained especially for older existing buildings in Hong Kong, which tend to have exposed vent pipes, unlike those in new buildings which are installed in inner walls. As a lesson learnt from previous epidemic outbreaks, it is understood that alterations to drains/pipes without prior authorisation should be avoided and half a litre of water should be poured into each drain weekly to prevent the traps from drying. **Two-stack plumbing system** For high rise buildings, a huge downward flow pressure is created when effluent (water and waste) flows from the top of the building to the bottom, especially during hours of peak water usage. This carries the risk of breaking the water seals at lower floors. A two-stack system divides the plumbing system into an upper-floor group and a lower-floor group, which reduces the downward flow pressure of effluent by a huge margin. Some developers have already incorporated two-stack systems in high-rise buildings since the additional cost is relatively insignificant compared to the overall life cycle costs of the project. **Waterless urinals and sensor toilets** A waterless system saves water, requires less maintenance, and improves hygiene. The water in conventional urinals gives bacteria and viruses a moist environment to grow, whereas waterless urinals are designed to remain dry. Automated toilets can save water and power and reduce maintenance. Motion sensor control toilets also reduce physical contact with surfaces, creating a more hygienic environment. **Hands free tapware** Hands free tapware makes use of a sensor so that no contact is needed, creating a more hygienic tap that is less likely to be contaminated with bacteria and viruses. Hands free tapware can also contribute to significant water savings.

Theme	Technology
	Smart water leak detectors Water leak detectors can detect water leakage, flooding, or even an abnormally high level of humidity. These problems often arise from damaged or malfunctioning pipes and drainage system. Multiple sensors should be installed to ensure comprehensive monitoring of the system is in place. Some advanced systems can shut off water source upon discovering alarming levels. The detectors can be connected to the building management platform to notify facility managers immediately of the water leakage for further inspection and repair work to be carried out.
Materials and Wellbeing	**Nano septic coatings** Nano septic coatings are continuously self-cleaning surfaces. They can be applied to usually dirty, high-traffic public touchpoints, such as restroom door handles, handrails, etc. The coatings work 24/7, by continually oxidising organic contaminants utilising mineral nanocrystals, powered by any visible light. Nano septic coatings are safe, non-toxic materials, using no poisons, heavy metals, or chemicals. **Antimicrobial coatings and additives** Antimicrobial coatings and additives are developed to prevent the growth and spread of bacteria on surfaces. Coatings can be user-friendly, working on many different surfaces such as walls, door handles, light switches, counters, and other high-touch areas. Antimicrobial additives can be introduced into paints, inks, or lacquers during the manufacturing process to make them resistant to microbes.
Data Analytics and Insights	**Building management digital platform** Digital management platforms for smart green buildings use BIM, IoT and analytics. A digital platform is a cloud-based centralised management console, providing information relating to building systems and equipment, as well as facilitating operation and maintenance. The platform can sense body temperatures, measure fine particulate matter, and VOCs. This allows it to predict and monitor high-risk conditions, and allows for increased ventilation, UV light or air purification to improve IAQ. Such a platform combines sensors, AI, and data to improve the conditions of a built environment. Equipped with IoT infrastructure, risks from space and people can be easily identified, including locating at-risk pathways, understanding employee density patterns, plan optimised open offices, conduct contract tracing and alerting. **Building user app** A building user app can be developed to ensure crisis communication and safe use of facilities. This app can strengthen transparency on contact tracing, conduct space analytics and encourage occupant interaction.

Table 5 – Promoting a safer indoor building environment using various technologies

The pandemic has urged the community to think about adapting existing buildings and improving technologies for new ones. By implementing strategies such as the ones discussed above, buildings will be able to provide healthier, safer, and more resilient environments for everyone and the future to come.

LINKAGE TO BUILDING TYPES

The table below shows the linkage between the 32 recommended smart green strategies and the applicable building types for implementation. For further details on the strategies, please refer to Appendices A to F.

Building Types		Building Types								
			Industrial		Functional			Commercial		
		Residential	Factories / Warehouses	Data Centres	Educational Facilities	Hospitals	Other Community Facilities	Retail	Office	Large district developments
Building Design & Operations										
A1	Building Information Modelling	•	•	•	•	•	•	•	•	•
A2	Digital Twin	•	•	•	•	•	•	•	•	•
A3	Near Field Communications	•	•	•	•	•	•	•	•	
A4	Robotics for Building Operations	•	•	•	•	•	•	•	•	
A5	Integrated Facility Management System	•	•	•	•	•	•	•	•	
A6	Washroom of the Future		•	•	•	•	•	•	•	
A7	Smart Space Utilisation			•				•	•	
A8	Smart Surveillance	•	•	•	•	•	•	•	•	•
Health & Wellbeing										
B1	Advanced Solar Technologies for Natural Lighting	•		•	•	•	•	•	•	
B2	Smart Artificial Lighting	•	•	•	•		•	•	•	
B3	Smart Thermal Control	•	•	•	•		•	•	•	
B4	Biophilic Design	•	•	•	•	•	•	•	•	
B5	Smart Air Filtration	•	•	•	•	•	•	•	•	
B6	Smart Light Poles									•
B7	Occupant Automation System	•	•	•					•	
Energy Performance										
C1	Automated Fault Detection and Diagnostics	•	•	•	•	•	•	•	•	•
C2	Smart Grid Compatibility and Technology	•	•	•	•	•	•	•	•	•
C3	Energy Storage System	•	•	•	•	•	•	•	•	•
C4	High Performance Chillers and Refrigerants	•	•	•	•	•	•	•	•	•
C5	High Efficiency Motors and Drives	•	•	•	•	•	•	•	•	•
C6	Solar Technology for Energy Generation	•	•	•	•	•	•	•	•	•
C7	Micro-wind Turbines	•	•	•	•	•	•	•	•	•
Material & Waste Management										
D1	Smart Dynamic Glass	•	•	•	•	•	•	•	•	
D2	Nanotechnologies	•	•	•	•	•	•	•	•	•
D3	Automatic Waste Collection Systems	•					•	•	•	
Water Performance										
E1	Smart Water Metering and Monitoring	•	•	•	•	•	•	•	•	•
E2	Water Efficiency Fixtures and System Controls	•	•	•	•	•	•	•	•	•
E3	Grey Water Reuse and Harvesting Rainwater	•	•	•	•	•	•	•	•	•
E4	Smart Irrigation	•	•	•	•	•	•	•	•	•
Mobility & Transportation										
F1	Smart Green Parking	•	•	•	•	•	•	•	•	
F2	Intelligent People Flow	•	•	•		•			•	•
F3	Autonomous Vehicles									

Table 6 – Linkage between 32 recommended smart green strategies and applicable building types for implementation

Overseas Case Studies

This chapter presents smart building strategies employed in two overseas locations – United States (U.S.) and the Netherlands. The first case presents a historic landmark, while the second showcases a new development with the world's highest BREEAM rating.

New York City, U.S.

Case study: Empire State Building

- Usage: Commercial
- Year of completion: 1931 (5-year, USD 165 million Observatory Renovation retrofitting project, completed in December 2019)
- Building height: 1,454 ft, 102 storeys
- Site area: 208,879 sqm
- Ratings/Accreditation: LEED Gold for Existing Buildings v4, Energy Star certification, WELL Health-Safety rating, Fitwel certification, Global Real Estate Sustainability Benchmark (GRESB) 5 Star rating
- Developer: Empire State Inc., including John J. Raskob and Al Smith (1931); Empire State Realty Trust (2009)
- Architect: Shreve, Lamb and Harmon

Amsterdam, Netherlands

Case study: The Edge

- Usage: Commercial
- Year of completion: 2014
- Building height: 15 storeys
- Site area: 40,000 sqm
- Ratings/Accreditation: BREEAM-NL Outstanding New Construction
- Developer: EDGE / OVG Real Estate
- Architect: PLP Architecture

EMPIRE STATE BUILDING

Use of high-recycled content construction materials

Efficient direct digital controls (DDC) system

Chiller plant retrofit

The iconic Empire State Building, completed in 1931, is a 102-storey building located in New York's midtown area. In 2009, Empire State Realty Trust partnered with the Clinton Climate Initiative, Johnson Controls, Jones Lang LaSalle and the Rocky Mountain Institute with the purpose of bringing the building up to modern environmental standards and collaborate on the retrofit project.

High-efficiency triple-glazed window retrofit for all 6,514 windows

Enhanced thermal comfort from better windows

Over 6,000 radiators retrofitted to reduce heat loss

Modernised elevators with regenerative technology reducing energy usage by 50% to 75%

1. Building Design & Operations

- **Efficient DDC system -** largest wireless network to a single building allowing valves and vents to be monitored and centrally controlled
- Advanced **digital monitoring** and **BMS with sensors** throughout the building to monitor air quality and heating and cooling loads
- **Enhanced space utilisation with 300 tenants** – Tenants build out space in accordance with the building's high performance healthy sustainable **interior design guidelines** to optimise cost and energy savings
- **Compulsory green requirements** in lease contracts
- Through AI-enabled building infrastructure, produces an estimated **USD 3.4 million worth of health and climate value**

1

DDC System

2. Health & Wellbeing

- Enhanced **thermal comfort** from retrofitted windows
- **Tenant demand-controlled ventilation** enhancing air quality
- **Smart lighting** automatically adjusts lighting intensity according to **daylight availability** monitored by **photo sensors**
- **Over 6,000 radiators** embedded with heat-reflecting barriers along the exterior walls of the building to minimise heat lost directly through the wall
- New variable air volume (VAV) air handling layout to improve tenant comfort
- **MERV 13 filters** installed in the HVAC system
- Sensors (including **CO_2 sensors**) for **real-time monitoring** of fresh air in the building to reduce unnecessary **heating and cooling load and ensure healthy ventilation levels for Indoor Environmental Quality (IEQ)**

2

Intelligent lighting

3. Energy Performance

- **Chiller plant retrofit** and upgrades to controls, variable speed drives, and primary loop bypasses
- **Tenant energy management** - A EnNET/Active Energy Management (AEM) platform collecting 15-minute meter data and integrated with property management software for analysis/ evaluation (e.g., time series analysis)
- **Individual tenants are metered separately** for their energy consumption and are responsible for their own bills. With access to the building's energy information, they can compare their performance with other tenants
- **Carbon-neutral building** with carbon offsets of approximately 55 million kilowatt hours per year of renewable wind energy
- Energy-efficient modernisations made to existing equipment, such as use of a **smaller air-conditioning plant** instead due to the **decreased cooling load**
- Reduce cooling load requirements by 33% and peak electrical demand by **3.5 megawatts**

3

Chiller plant retrofit

4. Material & Waste Management

- **High-efficiency triple-glazed window replacement** - inserting low emissivity film and reusing existing glazing of over 6,500 windows for enhanced energy efficiency and heat retention; reducing **heat loss** by 33% and **solar heat gain** by 50%. Reused over 96% of existing window units and all work was performed on site
- Use of **high-recycled content construction materials** and **recycled content carpets, low off-gassing wall coverings, paints, and adhesives**

4

Triple-glazed window

5. Water Performance

- **Waterless urinals, ultra-low-flow toilets** and **hand-sensing faucets** reducing water usage by over 40% below Energy Policy Act Standards
- **Condenser water system** upgrades
- All water systems submetered with AI software to monitor and control water use in real time

5

Waterless urinals

6. Mobility & Transportation

- **Modernised elevators** equipped with **regenerative technology,** which captures energy that would otherwise be lost as heat and is fed back to the building's power grid system for other use. This technology utilises 50% to 75% less energy than the original system.

THE EDGE

65,000 sq. ft. of solar panels

Collection of rainwater on roof

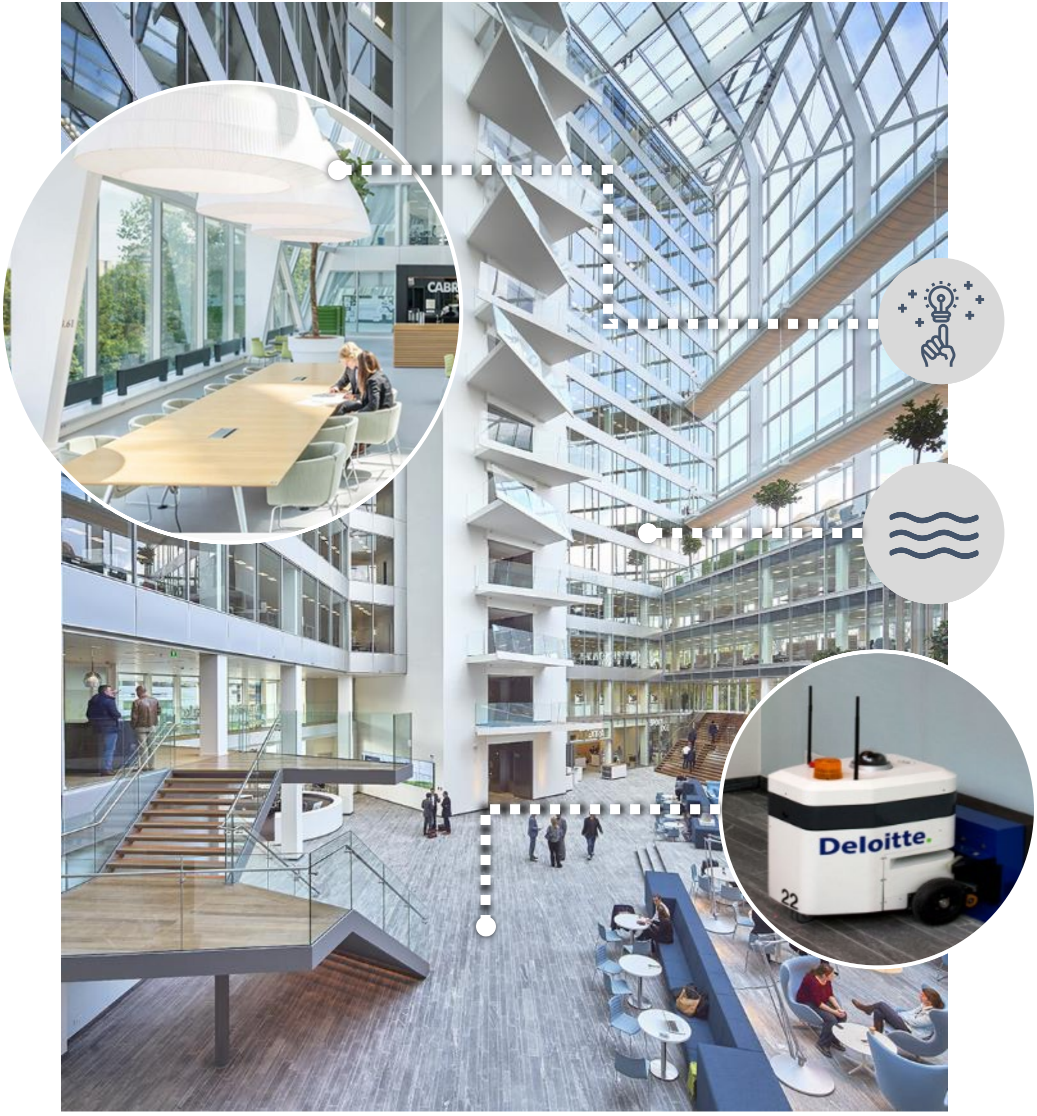
Ecological Corridor

Smart building design and orientation

The Edge, designed for the global financial firm and primary tenant Deloitte, opened in 2015. The aim of the project was to consolidate Deloitte's employees from multiple sites into a single environment, and to produce a smart building to accelerate Deloitte's transition into the digital age. The Edge offers an entirely new working environment, with the world's highest BREEAM rating (98.4%).

The building integrates various diverse smart technologies to promote collaboration and sustainability. The Edge's concept is "the new way of working" which entails resource efficiency in the traditional sense - it generates 102% of its own energy, but it is also about the most efficient use of the humans. It creates a new working environment powered by adaptable and intelligent workspaces. Deloitte workers share desks, under a concept known as "hot desking", workers may choose a work booth, a meeting room, a "concentration room", or a standing desk, depending on their needs that day. Employees also make use of a smartphone app to help navigate the building.

No employee has filed a comfort complaint, and 72% of employees report enjoying having a sense of control over their environment with the smartphone app. The Edge is one of the greenest buildings in the world and aims to prioritise the health, comfort and productivity of Deloitte employees and other occupants while maximising energy efficiency and sustainability.

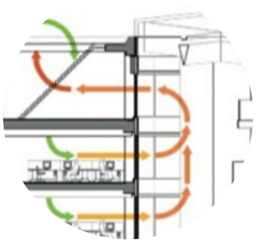


LED lighting system powered by Ethernet and 100% IP based

Every workspace is within 7 meters of a window

Use of RoboCop for security and cleaning

15-storey atrium creating a loop of natural ventilation



“Digital ceiling” packed with 30,000 sensors

500 bicycle parking spaces on-site

1. Building Design & Operations

- Smart **building orientation** based on sun path and each façade is uniquely designed (e.g., load bearing walls, louvers, solar panels)
- **Single IP backbone** for all building ecosystems to enable performance tracking and manage data analytics; and employees to control room comfort with **smartphone app**
- **“Digital ceiling”** packed with 30,000 sensors
- **Central dashboards** continuously measure and track building performance
- Use of **RoboCop** equipped with sensors for security patrolling and cleaning
- **EcoStruxure™ BMS** enables real-time access to critical building data on-site or remotely
- Hot desking and **space utilisation (**~2,500 employees share 1,000 desks)
- Use of **BIM** for effective project execution and sharing of data

RoboCop

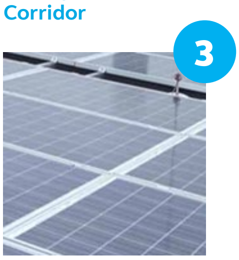
2. Health & Wellbeing

- **15-storey atrium** - Mesh panels between each floor let stale office air spill into open space creating a loop of **natural ventilation**
- **Ecological corridor** - Rich diversity of vegetation/birds/insects/bats on the north-facing terrace
- Every workspace is within 7 meters of a window
- Load bearing walls to the south, east and west have smaller openings to provide **thermal mass and shading**, and **solid openable panels** for ventilation

Ecological Corridor

3. Energy Performance

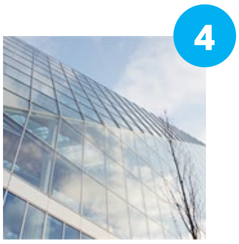
- **65,000 sq. ft. of solar panels** making use of neighbourhood level energy sourcing
- Energy-efficient **temperature control systems**
- Net zero energy building
- Uses **70% less electricity** than typical office buildings
- Energy generation for heating and cooling from an **aquifer thermal ESS** with two 129 meters deep wells
- **LED lighting system**, co-developed with Philips, is powered by Ethernet and 100% IP based
- LED system **reduced energy requirement by approx. 50%** compared to traditional TL5 lighting
- ~6,000 **luminaires** installed with multi-sensors for movement, lighting, infrared and temperature detection
- **Renewable energy** production (PV): 3 kWh PE/m² year



Solar Panels

4. Material & Waste Management

- North facades are highly **transparent** and use **thicker glass** for noise reduction from external traffic
- Transparent atrium façade allowing natural lighting
- **95%** of the materials used have a responsible origin



Thicker Glass

5. Water Performance

- **Rainwater collection** on roof for toilet flushing and landscape irrigation
- Estimated water consumption 4.1 m³/person a year, of which 20% is from greywater

Landscape irrigation

6. Mobility & Transportation

- 500 **bicycle parking spaces** on-site
- **Automated garage entry** with license-plate/employee recognition
- **EV charging**

Bicycle Parking Spaces

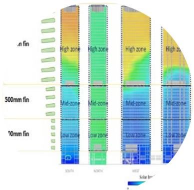
CHAPTER 4

Local Case Studies

Hong Kong is committed to creating a sustainable future and fostering a clean and healthy living environment. Many buildings have incorporated the concept of sustainability in their design and building management, to become greener and smarter. This chapter presents four local case studies – One Taikoo Place, Double Cove, Victoria Dockside and Exchange Square. These case studies highlight the implementation of different strategies and associated benefits.

Hong Kong			
One Taikoo Place	**Double Cove**	**Victoria Dockside**	**Exchange Square**
• Usage: Commercial • Year of completion: 2018 • Building height: 48 storeys • Site area: 144,426 sqm • Ratings/Accreditation: WELL, BEAM Plus and LEED Final Platinum certifications • Developer: Swire Properties • Architect: Wong & Ouyang	• Usage: Residential • Year of completion: 2016 • Building height: 18-35 storeys • Site area: 96,841 sqm • Ratings/Accreditation: First LEED Neighbourhood Development in Hong Kong, BEAM Platinum, China Green Building Design Label Three Star rating • Developer: Henderson Land Development (joint venture with New World Development & Peterson Group) • Architect: DLN Architects in collaboration with RSHP	• Usage: Mixed-use • Year of completion: 2019 • Building height: 66 storeys • Site area: 39,500 sqm • Ratings/Accreditation: K11 MUSEA – Donut Playhouse and Salisbury Garden – BEAM Plus Provisional Platinum, K11 ATELIER – LEED Platinum & BEAM Plus Gold, K11 MUSEA & K11 ARTUS – LEED Gold, Rosewood Hotel Hong Kong – LEED Gold & BEAM Plus Gold • Developer: New World Development • Architect: Kohn Pedersen Fox Associates, James Corner Field Operation, Ronald Lu & Partners, LAAB Architects	• Usage: Commercial • Year of completion: 1985 for One & Two Exchange Square (ES1&2); 1988 for Three Exchange Square (ES3); 2013 for The Forum (TF) • Building height: ES1: 52 storeys; ES2: 51 storeys; ES3: 33 storeys; TF: 5 storeys • Site area: 13,404 sqm • Ratings/Accreditation: The highest Platinum rating under Hong Kong's BEAM Plus Certification for Existing Buildings and the Grand Award in Facilities Management under Green Building Award 2019 • Developer: Hongkong Land • Architect: Palmer and Turner

ONE TAIKOO PLACE



High performance façade (Overall Thermal Transfer Value (OTTV) value 18 Watt/sqm lower than statutory requirement by 25%)

Curtain walls equipped with extra wide panels maximising sunlight

Solar responsive façade

One Taikoo Place, completed in 2018, is part of a redevelopment project of Taikoo Place, featuring eight other properties to create one of Hong Kong's best-planned business hubs. The redevelopment is an ongoing milestone project to realise Swire Properties' long-term vision to creative planning and community building. Through collaboration with international designers, Taikoo Place has become a vibrant office space surrounded by landscaped gardens, water features, restaurants, and cafes.

As part of the redevelopment project, One Taikoo Place was designed to the highest standards of efficiency and sustainability, combining the latest and most advanced sustainable/green technologies. During development, over 78% of the demolition debris was recycled in compliance with BEAM Plus requirements, and 68% of the construction waste was also recycled. The building is committed to elevating human health and the wellbeing of its occupants through implementing WELL Certification, and other smart and sustainable endeavours.

Over 2.5% renewable energy generated

34% annual energy savings exceeding BEAM Plus baseline performance

AI enabled smart building - Neuron

69,000 sq. ft. of green space/ landscaped plazas

Microclimate study to enhance human comfort at pedestrian level

Elevated walkways and pedestrian-friendly streetscapes

1. Building Design & Operations

- Comprehensive air ventilation assessment (AVA) study on microclimate and improvement areas, which enhances **natural ventilation**
- Integrated design approach
- **Building orientation** designed to enhance thermal insulation properties of the building and allow free ventilation during winter season
- **BIM model** is adopted throughout design, construction and operation
- **Comprehensive power monitoring system** installed
- **Comprehensive BMS system** installed
- HK's first AI-enabled smart building – Use of **Neuron** to track energy savings through advanced data analytic capabilities, ML and predictive maintenance. Neuron is a digital twin and foundation to **BIM-enabled asset management (AM) system** – this central platform improves operation workflows through digitalisation and automation

1

AI enabled smart digital platform - Neuron

2. Health & Wellbeing

- **69,000 sq. ft.** of landscaped area
- **CO_2 sensors** for fresh air demand control
- Beside the typical high efficiency filter, **UV-C filter** is used in AHU for killing air-borne germs and **active carbon filter** is used in AHU for odour removal
- **Healthy food vending machine** located in B2/F shuffle lobby
- Health & Wellbeing information available in digital directory and website

2

Landscaped area

3. Energy Performance

- 34% annual energy savings **exceeding BEAM Plus baseline** performance
- 28% annual energy savings **exceeding LEED baseline** performance
- **Over 2.5% of total building energy** to be provided by renewables
- HK's first-ever commercial building to use a **waste-to-energy, tri-generation system** using biodiesel from waste cooking oil. **Residual heat** used to further provide hot water and serve absorption chillers for chilled water generation
- A combined **green roof and solar PV system** for green energy. The cooling effect from the green roof can improve efficiency of the solar PV system
- **Passive and active systems** to reduce both energy demand and consumption during operations
- **High-efficiency lighting fixtures** equipped with daylight and motion **sensors** to help reduce energy use
- AHU with electrically commutated plug fans to achieve greater energy savings
- Annual Coefficient of Performance (COP) of chiller is up to 7.43 through **chiller plant optimisation** with big data analysis on existing Swire commercial building
- **High performance façade** and **curtain walls** equipped with extra wide panels (~3 meters) maximising harbour views and natural lighting
- **Solar responsive facade** with mixed coatings and horizontal shading devices to achieve targeted thermal performance and energy savings

3

Solar PV system

4. Material & Waste Management

- 78% of demolition waste recycled: 68% of construction waste recycled
- Low carbon emission concrete and rebar with recycled content used for construction resulting in over 25% carbon emission reduction compared with other Swire commercial buildings
- 13 existing caisson piles from former Somerset House are reused and form a part of foundation system of One Taikoo Place
- Early power energisation and B5 generators are used for temporary power supply on construction

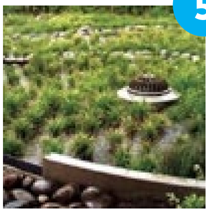
4

Solar responsive façade (13 nos of existing piles reused)

5. Water Performance

- **Rainwater collection** for irrigating green spaces
- >40% freshwater savings **exceeding BEAM Plus baseline** performance

5



Rainwater collection

6. Mobility & Transportation

- **Elevated walkways** and pedestrian-friendly streetscapes enhancing connection to surrounding transport hubs and buildings

6

Elevated walkways

DOUBLE COVE

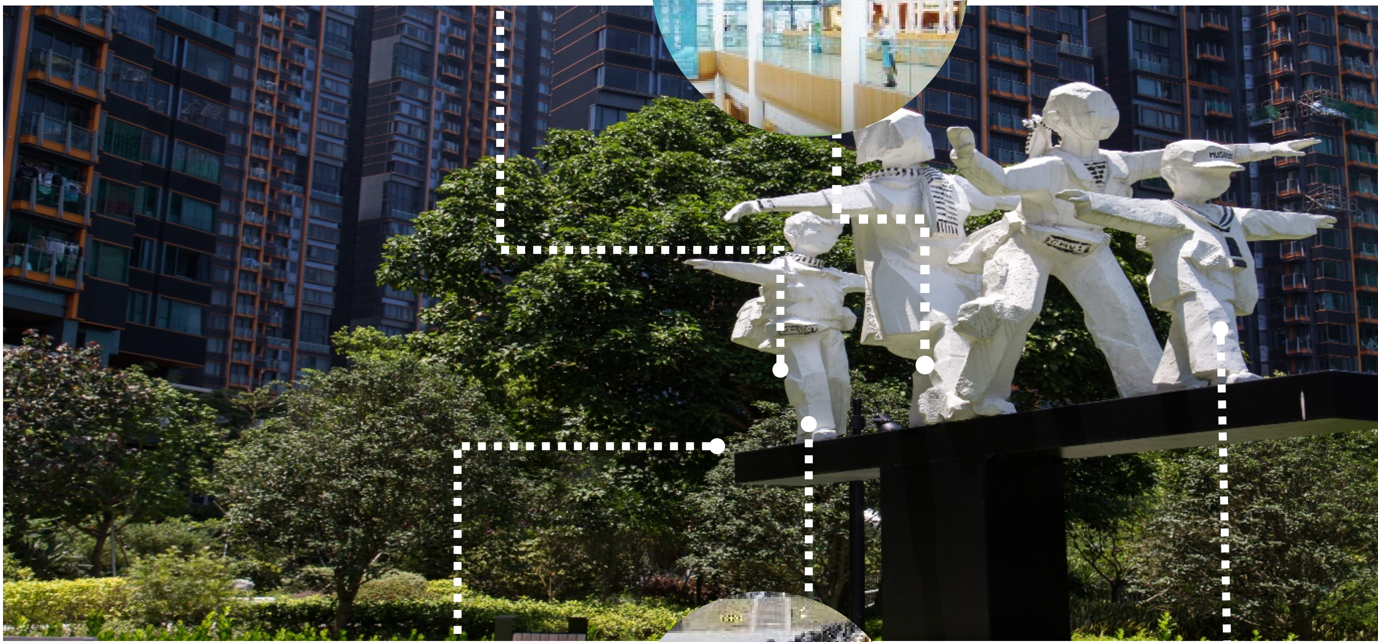
Double Cove was developed with a vision for a sustainable living community. It aims to set a high standard of promoting sustainable living within the neighbourhood. The development offers panoramic views of two bays and is bordered by extensive woodland and coastline. Double Cove's master plan features sustainable housing in 21 residential towers, ranging from 10 to 35 storeys in height.

The sustainable design concepts for the Double Cove development were devised by the Architects in collaboration with Environmental Consultants for the project. The development abides to a "Living in a Park in a walkable community" concept focused around low-carbon living, reduced energy consumption, and enhanced microclimatic and landscape qualities. A passive environmental design strategy was adopted for the project, through a natural, holistic approach to the design process with the intention of delivering a healthy and low-carbon living environment. LEED for Neighbourhood Development also guided the planning and design with abundant green space, covering 50% of the site.

- Residents cited an outstanding score of **97% for overall satisfaction**
- 87% satisfaction with **biophilia, plants and greenery**
- 84% satisfaction with **on-site opportunities to exercise**
- 50% satisfaction with **acoustics in flats**

Use of low-VOC materials for enhanced indoor air quality

Hybrid ventilated shopping arcade



Woodland and green spaces cover nearly 50% of the total site area with over 2,700 trees planted

Communal bike rental services and over 65 EV charging stations

Themed artworks to encourage residents to enjoy the communal landscaped spaces

Indoor air quality sensors and ventilation control

Extensive use of energy efficient installations and electrical appliances in residential flats

Home automation system controlled by smart devices

1. Building Design & Operations

- **Elimination of the conventional "birthday cake" design** (viz. multiple towers sitting on a large podium) by adopting standalone residential towers and clubhouse building to enhance the wind/view permeability and reduce heat island effect, through the **voluntary AVA** successfully done as a game changer
- Use of **BIM** to achieve better planning, design and quality of construction and minimise waste
- **Smart spatial arrangement** for effective wind penetration and reduce heat island effect
- Use of **BMS** system to manage building performance
- **Stepped building height profile** to facilitate daylight access to residential flats

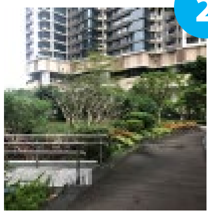
1

BIM

2. Health & Wellbeing

- **Native species** in landscaped areas – more adaptable to local climate, less maintenance and water required
- Comprehensive **tree protection measures** – preserve existing woodland and create a new woodland extension
- **Total landscaped area is ~50% of total site area** – woodlands, green roofs, green walls, sky gardens, water features and landscaped amenities
- Reserved views of Starfish Bay and Wu Kai Sha Wan in HK
- Enhanced ventilation and use of **low-VOC** materials throughout for enhanced IAQ
- **IAQ sensors** and ventilation control
- **Home automation system** accessed from smart devices to manage energy consumption and carbon reductions
- **Themed artwork of the "Symphony of Nature" concept** to encourage the residents to enjoy the outdoor and indoor communal spaces for wellbeing

2



Extensive landscaped areas

3. Energy Performance

- **Hybrid ventilated shopping arcade with green roof** to reduce building energy consumption
- **15% reduction in energy consumption** due to green features
- **Energy saving elevators** (e.g., switched off when not being used)
- **Lighting** is equipped with sensors and set to minimal levels when not needed. Lighting is also set with time control in parks
- Extensive use of **energy efficient installations and electrical appliances** with Grade 1 or 2 Energy label

3

Shopping arcade with green roof

4. Material & Waste Management

- **Double-glazed curtain wall** and **low-e tinted glass** for reduction of heat gain
- **Waste sorting is promoted** to record how much waste has been collected
- **Extensive recyclable waste collection facilities** provided in all residential towers
- **Recycled wood pavement** is used

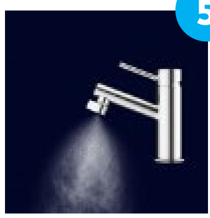
4

Low e-tinted double-glazed curtain wall

5. Water Performance

- **Rainwater recycling system**, **low-flow water closets** and **water saving faucets**
- **Recycled rainwater harvesting** captures 1,700 cubic meters of water each year, saving around 70% of water consumption for water features

5



Water saving faucets

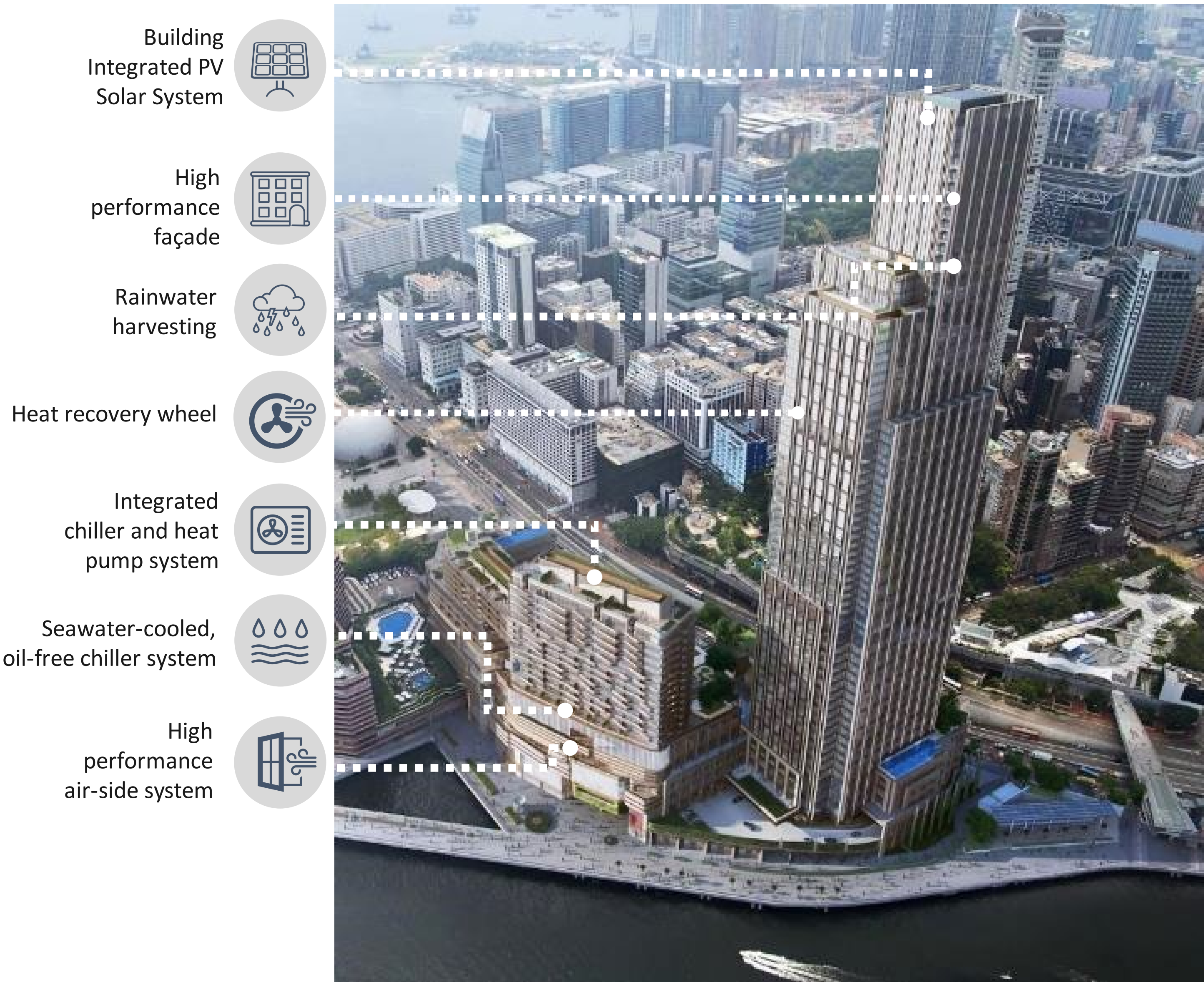
6. Mobility & Transportation

- **Low-carbon transport options**, include a covered walkway with direct access from all residential towers to public transportation, over 65 EV charging stations, and communal bicycle bays
- **Communal bike rental services** for all residents including 1.36km cycle trails, and 2.3km of **jogging paths** within the development

6

Communal bicycles

VICTORIA DOCKSIDE



In 2019, Mr. Adrian Cheng unveiled Victoria Dockside, a USD 2.6 billion, 3 million-square-foot global art and design district conceived and created by himself in collaboration with 100 creative powers to reinvigorate Hong Kong's iconic Tsim Sha Tsui waterfront.

The development project includes K11 MUSEA, the culture-retail global flagship of K11; K11 ATELIER, office buildings designed for the new culture of work-life integration; K11 ARTUS, a luxury serviced residence; and Rosewood Hong Kong, the ultra-luxury brand's first Hong Kong property. Through Victoria Dockside, Cheng's vision is to build the “Silicon Valley of Culture” in Greater China, injecting culture, art, architecture, design, nature and technology into different forms of commerce, forming a unique culture-commerce ecosystem that conserves traditional art and culture while incubating new ideas and innovation for tomorrow's generation.

“Urban Window” allows for visual connection from the inland to the harbourfront, as well as enhancing ventilation with sea breezes

Exterior Green Wall offers urban biodiversity and predominant native planting species that echoes the fluid lines of the adjacent harbour

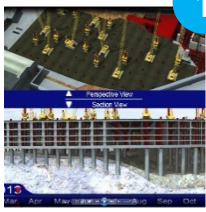
Urban greenery for climate adaptation

Walkable neighbourhood featuring excellent outdoor thermal comfort for communities

1. Building Design & Operations

- **BIM** was used during design stage for building design, architecture and façade structure
- **Utilise underground resources:**
  - 23% mechanical carparking system – puzzle carpark
  - 100% termination junction box ready for EV
  - Life Cycle Analysis: Embodied energy of the structure design is reduced by 4.3% at MUSEA and 1.35% at ARTUS
  - Compactor in the refuse room to reduce the collection journey of garbage trucks
  - Food waste composter collect food waste from all Food & Beverage (F&B) retailers to reuse as fertiliser after processing

1

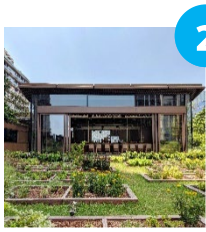


BIM

2. Health & Wellbeing

- Nature Discovery Park opened to foster awareness about sustainable urban living, urban biodiversity
- **50,000 sq. ft.** extensive interior and exterior **greenery**
- IAQ **live monitoring**
- **CO_2 sensors** installed on each floor to modulate fresh air intake
- **Sensors** to monitor daylight and control dimming

2

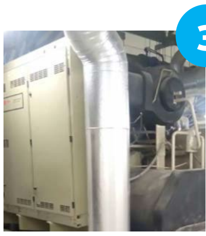


Nature Discovery Park

3. Energy Performance

- **Seawater-cooled, oil-free chiller system** anticipated to cut annual energy use by over 12% compared to the baseline of the US ASHRAE 90.1 Standard
- Energy use intensity is **1.5 times lower** than typical Hong Kong office buildings

3



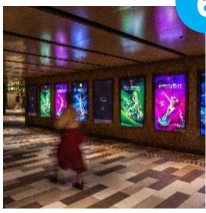
Seawater-cooled, oil-free chiller system

4. Material & Waste Management

- **Reuse of existing structures and foundations** of New World Centre, together with slurry walls as new basement walls
- Revitalised with **sustainable materials** (e.g., reconstituted and upcycled bio-wood, made from rice husks, sustainably sourced soil, limestone)
- Building façade is integrated with one of HK's largest **Building Integrated PV Solar System**, creating enough power to operate around 220 coffee machines
- Design of façade systems embraces a **performance balance analysis** on thermal and daylighting strategies
- MUSEA premises incorporate a façade with conical-shaped glass panels
- **Preserve existing basement minimise disturbance and waste:**
  - 100% reused sea wall and partial basement floor slab to reduce construction waste and less disturbance to the environment
  - Approximately 6,500 MT structural steel reserved to facilitate the Excavation and Lateral Support (ELS) works
  - Embodied carbon (including transportation) is about 17,823 Total Carbon Dioxide (tCO_2)
  - Reduce waste and pollution to the Victoria Harbour
  - Unconventional technology to save embodied carbon of steel materials

4

Preserve existing basement to minimise waste

5. Water Performance	**Rainwater harvesting** is designed to provide 100% of irrigation water **Seawater cooling** takes advantage of the harbourfront site's natural resources, which eliminate large-scaled cooling towers and reduce a significant amount of potable water use - Provide **water dispersers** with multi-stage filtration, offering high quality clean water at different temperatures (hot, cold and warm) for our visitors - Use **sea water toilet flushing** to reduce potable water consumption	5  Rainwater Harvesting
6. Mobility & Transportation	**Basement level connectivity** to MTR Stations **Paved pathway** providing direction from neighbouring ferry piers - Underground car parking with **EV charging** facilities **Occupancy sensors** for car parking, and parking availability is shown on street level - Elevators equipped with **destination control** functions - Large hotel service elevator **with dual modes** for efficient use and energy saving during normal operation, and special use for delivery of transformer	6  Connectivity to MTR Stations

EXCHANGE SQUARE

In App IAQ monitoring and smart thermal comfort

Smart LED lights with season colour mode

Cadmium Telluride (CdTe) power glass

Smart escalator monitoring for predictive maintenance

Nanotechnology for enhancing hygienic and cleaning conditions

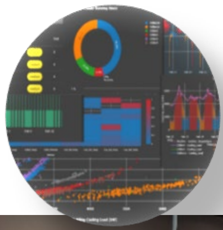
Exchange Square is a major development that sets the benchmark in Hong Kong for prestigious, globally oriented, 24-hour business complexes. It is home to many leading international investment banks and financial institutions.

Built in the 1980s, the entire complex consists of One Exchange Square which is comprised of 52-levels, Two Exchange Square is home to 51-levels, and Three Exchange Square which harbours 33-levels. In addition to Exchange Square, the development also features The Forum, a 5-storey office building that features a glass curtain wall façade that has been designed to resemble the surface of a diamond. The Forum (TF) was revitalised in 2014 and received LEED Platinum Certification.

Hongkong Land (HKL)'s ambitious nature to establish and create excellence in all of our properties drives our team to work under the philosophy of smart green innovation. Throughout the years, our operations have evolved and implemented continual upgrades, enhancements and retrofitted works to the building's façades and services systems. The Exchange Square complex demonstrates how a world-class prime office works towards excellence, and never stops innovating.

The efforts toward creating more sustainable buildings have also been recognised with numerous awards and certifications, including the highest Platinum rating under the Hong Kong's BEAM Plus Certification scheme for Existing Buildings and the Grand Award in Facilities Management under Green Building Award 2019.

Centralised Monitoring Centre at Exchange Square



Energy Platform with Fault Detection, ML and AI

IoT LoRaWan Platform connected to local BMS for system control

Smart Surveillance and Virtual Patrolling

New Digitalised Facility Management (FM) System for better data analysis

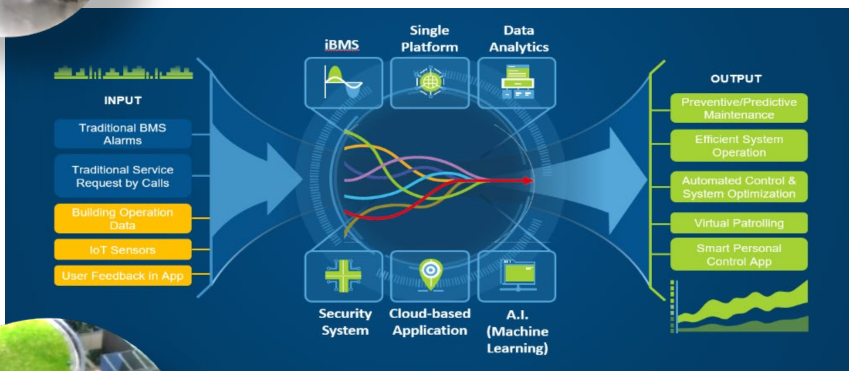
Property Management System with e-Procurement, e-Office Directory, etc.

Integrated Building Management System (iBMS) Platform for central monitoring, predictive and preventive maintenance

Smart Thermal Comfort Control with Self-Learning on Users Preferences

Integrated Smart Management Concept

Energy Efficiency Equipment, Smart Metering and Innovative Technologies are widely adopted during upgrades, renovations and retrofitting works, applying an integrated smart management concept



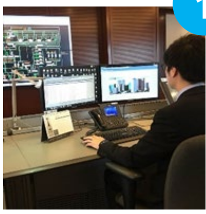
Green ideas such as Green Roof, PV System, Food Waste Decomposer, Water Saving Faucets, etc. are in place

1. Building Design & Operations

Setup of **Centralised Monitoring Centre (CMC)** to provide 24/7 operation and enhance operation reliability and efficiency, consisting of:-

- **iBMS**
- **Integrated FM system** with the use of **NFC**
- **LoRaWan IoT** platform, e.g. application of **Smart toilet** with the use of wireless odor sensor; Smart **fit-out control** using vibration, smoke and IAQ sensors
- **Smart lift and escalator system monitoring** with concept of predictive maintenance
- **Smart surveillance** with the adoption of **virtual patrol**

1



iBMS in CMC

2. Health & Wellbeing

- 450sqm of ultra light-weight **green roof** to reduce urban heat island effect
- **IAQ sensors** including CO_2, Particulate Matter 2.5 ($PM_{2.5}$) at each floor for monitoring and control
- **Real time IAQ display** for HKL's Office via HKL Internal App
- **Use of HKL App ("Centricity")** to promote health, well-being and sustainability to tenants and building users
- Tenants and user can control the indoor temperature and ventilation via Smart thermal comfort control which is equipped with AI learning on users' preferences

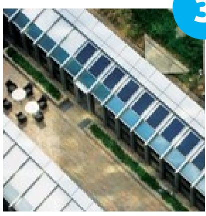
2

Smart thermal comfort control in Centricity app

3. Energy Performance

- By 2019, **the energy consumption has been reduced by 35.1%** as compared to 2008, equal to 13,706,600 kWh energy saved annually
- Chiller plant upgrade with **high performance sea-water cooled chiller** and **electromagnetic induction device** for sea water treatment
- **Energy management platform** with **ML** features for **fault detection** and **plant optimisation**
- **Solar PV system with smart grid compatibility** to offset carbon emissions
- **Smart artificial lighting retrofit with motion sensor** and high efficiency lighting fixtures
- Upgrade all AHU with plug fans for energy efficiency and system reliability

3



Solar PV system

4. Material & Waste Management

- Upgrade façade with **CdTe power glass** for generating electricity
- Apply **nanotechnology** for enhancing hygienic and cleaning standard
- **Digitalisation** to reduce paper consumption including using e-procurement system, e-office directory, e-business card and e-learning
- **Food waste decomposer** with 350kg daily handling capacity

4

CdTe power glass

5. Water Performance

- **Water saving retrofitting** to all faucets in toilets which bring a 60% water savings
- **LoRaWan Water Leakage sensor** for close monitoring

5

LoRaWan system

6. Mobility & Transportation

- **Destination control** in vertical transportation for better energy efficiency
- **EV charging** facilities
- **Automated license plate recognition** technology

6

Destination control

CHAPTER 5

Way Forward

This guidebook begins with introducing practical smart green building strategies and guidelines and ends with the presentation of overseas and local case studies. Smart green technology can play a crucial role in building development and operations, and Hong Kong is putting forth efforts to creating a smarter and more sustainable built environment through the implementation of these technologies. However, there is always a way to improve.

Three areas are identified to help improve Hong Kong's advancement in smart green buildings – public awareness and education, wider use of IoT and policy and industry practice. Hong Kong's current state in each area is discussed, and suggestions are made on how to move forward.

Public Awareness and Education

This is the first Guidebook for both smart and green buildings. While past works have focused on either ‘smart’ or ‘green’ buildings, this Guidebook has been developed to try and redefine the interface between the two. The local and overseas case studies highlighted in previous chapters show that there is awareness of smart green technologies. However, as this is the first Guidebook of this concept, there is still room for further promotion and education, to increase both public and professional knowledge.

This Guidebook is intentionally designed to be easy-to-understand and practical. It is suitable as a reference for industry practitioners as well as the general public. However, one guidebook is not sufficient. Further promotion of smart green buildings is needed to spread knowledge and awareness in an easy and accessible way.

Wider use of IoT

This guidebook has highlighted a wide array of practical, smart green technologies for adoption in new and existing buildings in Hong Kong. Among the technologies, IoT is the fundamental ‘backbone’ to smart green buildings, which enables sensors, devices, machines and programmes to work together to share data, automate building functions, perform predictive maintenance and undergo building performance management. Going forward, there will be a growing trend of applying IoT, especially in new buildings, to facilitate key decisions and optimise building performance. The development of open standards architecture will continue to mature to enable smart building systems to communicate with one another and ensure the design of open, secure, scalable and adaptable buildings meeting various stakeholder goals and building performance objectives.

Policy and Industry Practice

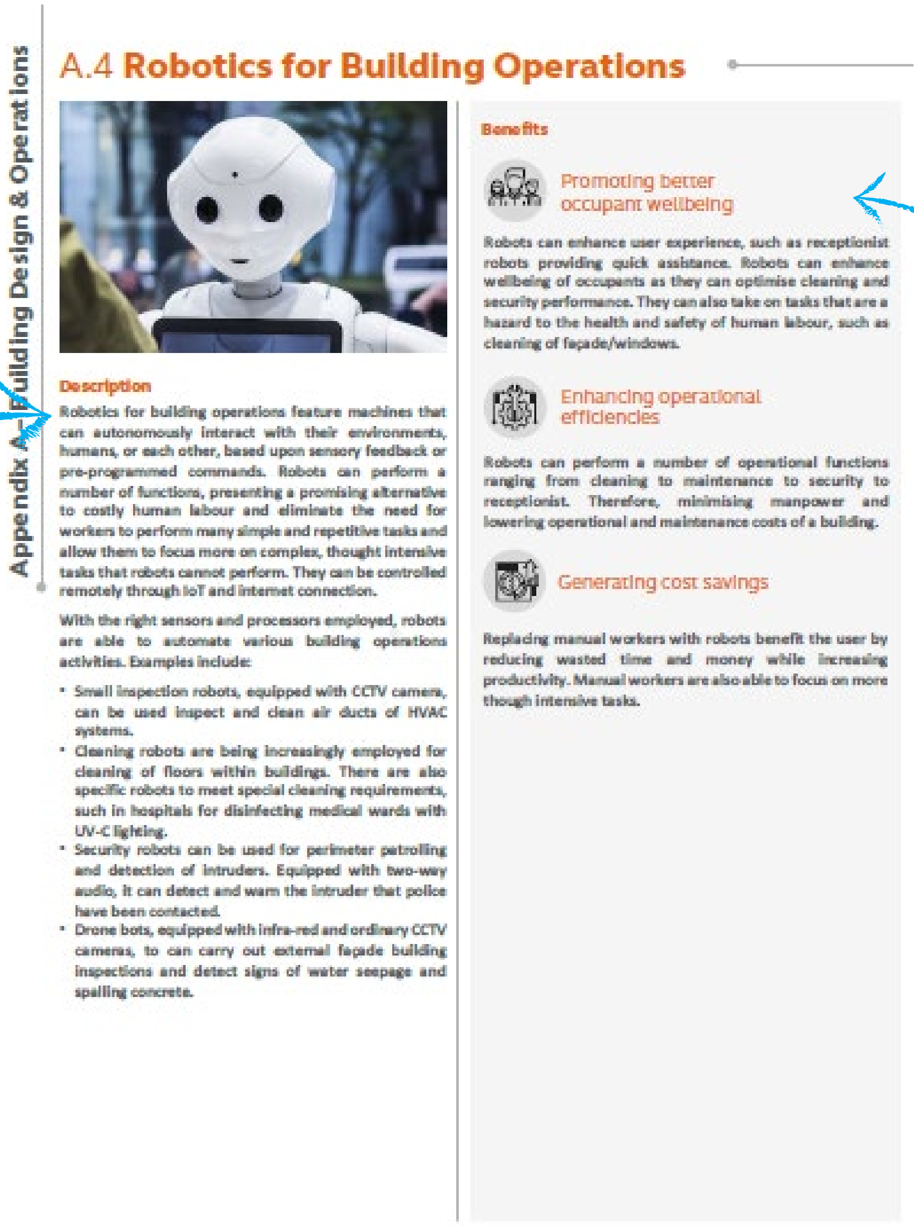
Hong Kong is striving to become a smarter city, and to use innovation and technology to create a more sustainable environment. Integrating smart building technologies is a way to support this vision. Over the past years, the Government has introduced the concept of Green Buildings, and how to incorporate the concept of sustainability into building design and management. It has launched several award schemes, such as the Green Contractor Award Scheme, to encourage sustainable design and construction. Green building accreditations, such as BEAM Plus, are increasingly being adopted. The Government has also reviewed the policy and measures on becoming a smart city and opening up government data. For instance, the Smart City Blueprint was developed. The Office of the Government Chief Information Officer now also provides annual open data plans, released on the Public Sector Information (PSI) portal. This is important to note, as open data provides raw materials for technology research and city innovation. The Hong Kong Cyber Security and Technology Crime Bureau (CSTCB) has also been set up to tackle technology related crime including cyber security and data privacy issues, as well as undertaking technology crime investigations, computer forensic examinations and technology crime prevention.

While this has shown growth and progress in Hong Kong’s effort to creating a sustainable future, there may be an opportunity for further policy encouragement to motivate developers to incorporate not only green, but smart green technologies as well. Communication between the Government and industry is paramount, as developers often find it difficult to implement such strategies without the suitable knowledge or support.

Therefore, to better support industry practitioners, the Government can continue to release open data plans to support the development of smart green buildings. They can further provide sources of information relating to smart green building design, features, and operations, to aid developers in implementing different strategies. Lastly, industry practitioners can take this Guidebook as a reference, and motivation, to further learn about smart green buildings.

APPENDICES

Smart building technology that enhances environmental performance and efficiency and reduces operating costs are becoming increasingly adopted in the industry. Over the years, such technology has been evolving to drive improvements and further advancements are continued to be made. This section provides a comprehensive set of practical smart green strategies under 6 key themes for industry practitioners to consider adopting throughout a building's life cycle, whether it is designing a new building or retrofitting an existing building. The strategies are written in a manner that is easy-to-understand and includes indications of application to building type, life cycle stages and ease of implementation. High level information on the technology and design requirements, and costs are also provided. The diagrams below illustrate how each of the strategies are set out.


Appendix A – Building Design & Operations

A.4 Robotics for Building Operations

Description

Robotics for building operations feature machines that can autonomously interact with their environments, humans, or each other, based upon sensory feedback or pre-programmed commands. Robots can perform a number of functions, presenting a promising alternative to costly human labour and eliminate the need for workers to perform many simple and repetitive tasks and allow them to focus more on complex, thought intensive tasks that robots cannot perform. They can be controlled remotely through IoT and internet connection.

With the right sensors and processors employed, robots are able to automate various building operations activities. Examples include:

- Small inspection robots, equipped with CCTV camera, can be used inspect and clean air ducts of HVAC systems.
- Cleaning robots are being increasingly employed for cleaning of floors within buildings. There are also specific robots to meet special cleaning requirements, such in hospitals for disinfecting medical wards with UV-C lighting.
- Security robots can be used for perimeter patrolling and detection of intruders. Equipped with two-way audio, it can detect and warn the intruder that police have been contacted.
- Drone bots, equipped with infra-red and ordinary CCTV cameras, to can carry out external façade building inspections and detect signs of water seepage and spalling concrete.

Benefits

Promoting better occupant wellbeing

Robots can enhance user experience, such as receptionist robots providing quick assistance. Robots can enhance wellbeing of occupants as they can optimise cleaning and security performance. They can also take on tasks that are a hazard to the health and safety of human labour, such as cleaning of façade/windows.

Enhancing operational efficiencies

Robots can perform a number of operational functions ranging from cleaning to maintenance to security to receptionist. Therefore, minimising manpower and lowering operational and maintenance costs of a building.

Generating cost savings

Replacing manual workers with robots benefit the user by reducing wasted time and money while increasing productivity. Manual workers are also able to focus on more though intensive tasks.

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General description of the smart green strategy

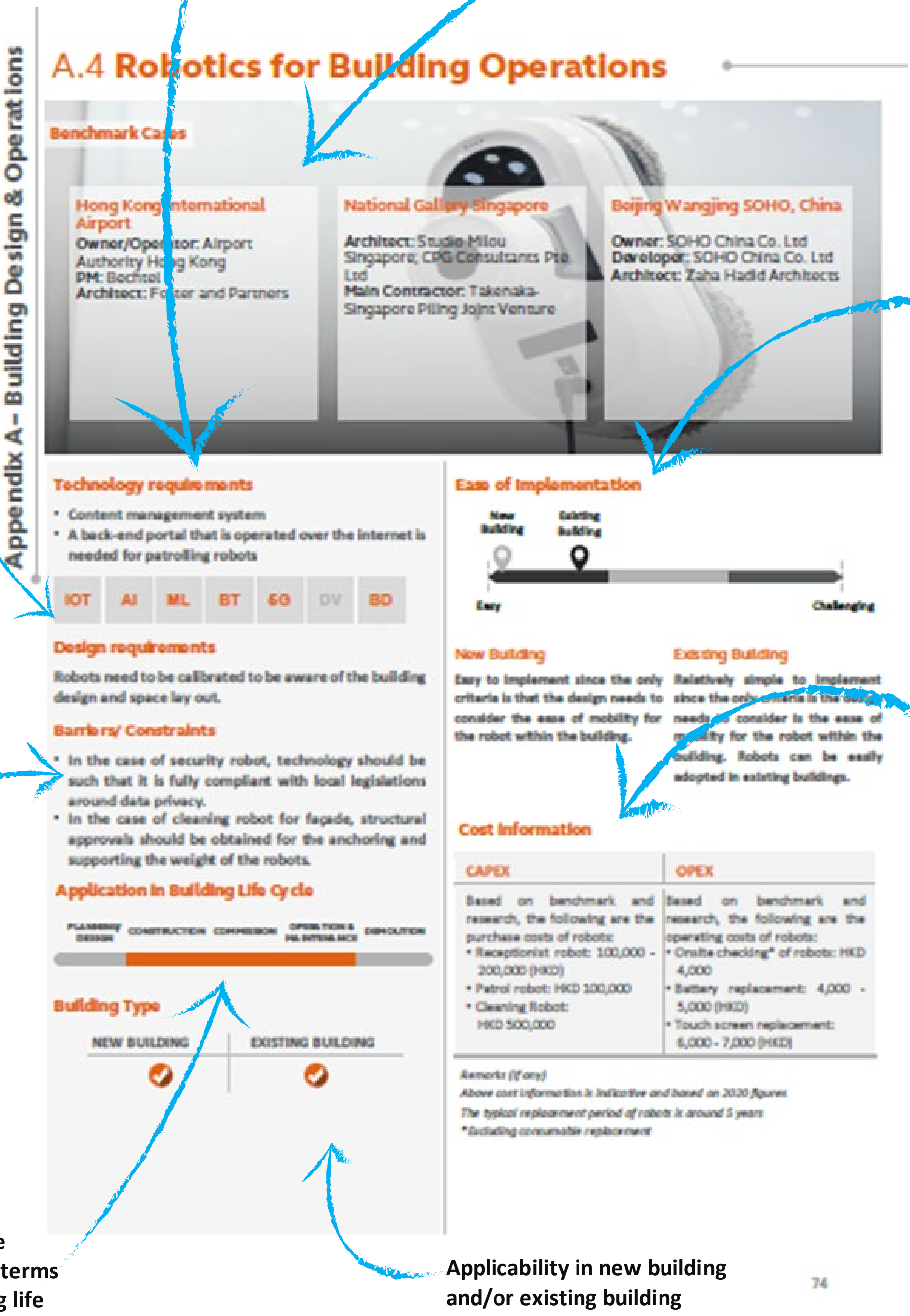
Description of benefits from implementation, pertaining to environmental sustainability, operations, wellbeing, and cost savings

Technology and design requirements for implementation (e.g. physical infrastructure and software)

Reference local and global benchmark cases

Indication of which type of technology is used to enable the strategy. Please refer to the following abbreviations:

- IoT – Internet of Things
- AI – Artificial Intelligence
- ML – Machine Learning
- BT – Bluetooth 5.0
- 5G – Fifth Generation Mobile Network
- DV – Data Visualisation
- BD – Big Data



Appendix A - Building Design & Operations

A.4 Robotics for Building Operations

Benchmark Cases

Hong Kong International Airport	National Gallery Singapore	Beijing Wangjing SOHO, China
Owner/Operator: Airport Authority Hong Kong PM: Bechtel Architect: Foster and Partners	Architect: Studio Milou Singapore; CPG Consultants Pte Ltd Main Contractor: Takenaka-Singapore Piling Joint Venture	Owner: SOHO China Co. Ltd Developer: SOHO China Co. Ltd Architect: Zaha Hadid Architects

Technology requirements

- Content management system
- A back-end portal that is operated over the internet is needed for patrolling robots

IOT | AI | ML | BT | 5G | DV | BD

Design requirements

Robots need to be calibrated to be aware of the building design and space lay out.

Barriers/ Constraints

- In the case of security robot, technology should be such that it is fully compliant with local legislations around data privacy.
- In the case of cleaning robot for façade, structural approvals should be obtained for the anchoring and supporting the weight of the robots.

Application in Building Life Cycle

PLANNING/ DESIGN | CONSTRUCTION | COMMISSION | OPERATION & MAINTENANCE | DEMOLITION

Building Type

NEW BUILDING | EXISTING BUILDING

Ease of Implementation

New building | Existing building

Easy — Challenging

New Building

Easy to implement since the only criteria is that the design needs to consider the ease of mobility for the robot within the building.

Existing Building

Relatively simple to implement since the only criteria is the design needs to consider is the ease of mobility for the robot within the building. Robots can be easily adopted in existing buildings.

Cost Information

CAPEX	OPEX
Based on benchmark and research, the following are the purchase costs of robots: • Receptionist robot: 100,000 - 200,000 (HKD) • Patrol robot: HKD 100,000 • Cleaning Robot: HKD 500,000	Based on benchmark and research, the following are the operating costs of robots: • Onsite checking* of robots: HKD 4,000 • Battery replacement: 4,000 - 5,000 (HKD) • Touch screen replacement: 6,000 - 7,000 (HKD)

Remarks (if any)
Above cost information is indicative and based on 2020 figures
The typical replacement period of robots is around 5 years
**Excluding consumable replacement*

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“Easy” No difficulty for adoption

“Moderate” Minor challenges for adoption

“Challenging” Several challenges may be involved for adoption

Indicative capital and operating costs for implementation. Cost information assumptions are based on research and for reference only. Please refer to the following abbreviations:

- CAPEX – Capital Expenditure
- OPEX – Operating Expenditure

Barriers and constraints in adoption

Applicable stages, in terms of building life cycle

Applicability in new building and/or existing building

Promote smart green technologies throughout building life cycle from design to construction to operations and maintenance to demolition for efficient usage/management.

Encourage use of smart green technologies at initial design and construction stages of the building life cycle

- A.1 Building Information Modelling
- A.2 Digital Twin

Promote smart and green technologies in building operations and management

- A.3 Near Field Communications
- A.4 Robotics for Building Operations

Through smart technologies, encourage efficient monitoring of building operations and maximise performance

- A.5 Integrated Facility Management System
- A. 6 Washroom of the Future
- A.7 Smart Space Utilisation
- A.8 Smart Surveillance

A.1 Building Information Modelling (BIM)

Description

BIM is the creation and sharing of 3D models & data of an asset in its environment and enables seamless integration of all stages of the asset's life cycle from planning, design, construction to operation. BIM offers better communication and understanding, which ultimately leads to better information flows and effective project delivery. Leveraging BIM enables other follow-on technologies, such as IoT, blockchain and Geographic Information System (GIS), thus enabling the creation of a more comprehensive information platform. There are varied levels of maturity of BIM from 3D model (Levels 2 to 3) to inclusion of information on construction sequencing, cost, and project life cycle (Levels 4 to 6).

BIM can be used as a guidance tool for operations and maintenance to inform owners and operators of real-time building performance. At this stage in the life cycle, the BIM model could be simplified to store only required information for building operations purposes. Relevant training to building operators and professionals on BIM is also essential.

In Hong Kong, BIM is increasingly being recognised as a fundamental strategy that underpins the future improvements of Government buildings and infrastructure. Several policy initiatives that promote wider use of BIM are:

- Buildings Department. (2016). Building Information Modelling Practice Note for Authorised Persons, Registered Structural Engineers and Registered Geotechnical Engineers ADV-34.
- Construction Industry Council. (2020). BIM Standards Version 2.
- Construction Industry Council. Certification of BIM Coordinators and Accreditation of BIM Coordinator Courses.
- Development Bureau. (2017). Technical Circular (Works) No. 7/2017, Adoption of Building Information Modelling for Capital Works Projects in Hong Kong.
- Electrical and Mechanical Services Department. (2019). BIM-AM Standards and Guidelines Version 2.0.

Benefits

Reducing environmental impacts

Use of BIM, especially during early design stage, enables more sustainable projects with designers and planners creating more cost and schedule scenarios in a fraction of the time, allowing them to think more creatively about new sustainability solutions. It also helps in the reduction of waste generated and avoidance of excess materials.

Promoting better occupant wellbeing

Wellbeing on a neighborhood level can be enhanced as pre-set requirements (e.g. lighting level adjustments) promote the right balance between energy usage, citizen comfort and better public safety.

Enhancing operational efficiencies

BIM can promote more efficient operations when paired up with building management systems for better and faster FM responses. IoT data about the building, such as sensor measurements and control signals from the building systems, can also be incorporated into FM software to support analysis of building operation and maintenance.

Generating cost savings

BIM can significantly reduce costs by minimising construction stage risk, enabling other digital tools, as well as undertaking multiple analyses and simulations on budgets, regulations and energy consumption.

A.1 Building Information Modelling (BIM)

Benchmark Cases

Grade A Office & Retail at NKIL 6556, Kai Tak, Hong Kong

Developer: Rich Union Development Limited
Project Manager: Nan Fung Development Limited
Executive Architect: Ronald Lu & Partners (Hong Kong) Ltd
Design Architect: Snøhetta Overseas Architecture
Landscape Architect: Urbis Ltd.

Ocean Park Water World, Hong Kong

Developer/Operator: Ocean Park Corporation
Designer: ProSlide Technology, Vertex Productions; WTI
Contractors: Gammon Construction Limited; Themebuilders
Consultants: AECOM; LCI Productions; MR ProFun; ProSlide Technology

1 Triton Square, London

Owner: British Land Company Programmable Logic Controller (PLC)
Architect: Arup Group Limited
Building Services: Arup Group Limited
Project Manager: M3 Development Management Ltd.

Technology Requirements

- Implementation of BIM requires a software which best suits the kind of analysis the user would like to achieve.

IOT | AI | ML | BT | 5G | DV | BD

Design Requirements

- No specific design requirements.

Barriers/Constraints

- Availability and accuracy of as-built drawings and other relevant information for existing building may be limited.
- Need for comprehensive training and relevant software during operations and maintenance stage.
- Reluctance amongst some in the industry to adopt BIM.

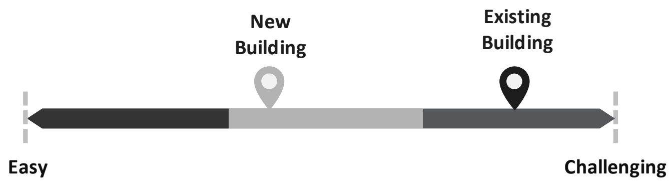
Application in Building Life Cycle

PLANNING/ DESIGN | CONSTRUCTION | COMMISSION | OPERATION & MAINTENANCE | DEMOLITION

Building Type

NEW BUILDING	EXISTING BUILDING
✓	✓

Ease of Implementation



New Building

Relatively easier to implement in new buildings provided that the BMS has adequate functions and input/output (I/O) points for the implementation of data analytics software.

Existing Building

More difficult to implement for existing building since an older building with shorter remaining life cycle may not be able to justify the return on investment (ROI) in scanning, modelling and data input to the BIM model.

Cost Information

CAPEX	OPEX
As a very general rule of thumb, the CAPEX and OPEX can cost between 1-10% of project cost. However, this depends on the complexity of each project, as the design, scope and size between each project can vary largely, which would affect the costs.	

Remarks (if any)
Above cost information is indicative and based on 2020 figures

A.2 Digital Twin

Description

Digital Twins are virtual models of an asset, which comprises of three key components:

- Data – It is developed and informed by a huge amount of design and operational data captured by sensors;
- Algorithm – A collection of data models, algorithms and advanced analytics is deployed to forecast the building health throughout its life cycle; and
- Knowledge – Data is constantly gathered and fed into the model to improve the accuracy of the digital twin as well as maintaining up-to-date information.

Digital Twins are maturing as more data sets become available through the proliferation of IoT devices. Key maturity stages of digital twin are as follows:

- Digital twin ready: A virtual representation of an asset developed allowing for seamless interaction with other digital services.
- Operational twins: Apply the digital twin to fulfill at least one functional purpose (e.g. monitor asset health).
- Live operational twins: Equip operational twins with live data streams by integrating with the building's facility management system to enable real-time monitoring.

Digital twins enable simulation modelling to test "what if" scenarios, identify risk mitigating actions, and enhance building performance. This allows building operators to perform:

- Asset strategy optimisation: Identify critical parts of the building system and develop effective operational strategies to optimise building performance and reduce costs; and
- Asset strategy analysis: Quantitative evaluation of the effects risk-mitigating actions may bring on minimising downtime, reducing cost and enhancing reliability.

Relevant training should be provided to building industry stakeholders to ensure they have the adequate expertise to design and manage the digital twin model.

Benefits

Reducing environmental impacts

Through integrating AFDD and energy performance monitoring technology, digital twin enables building operators to monitor the overall environmental performance (e.g. monitoring of carbon footprint, air quality and pollution, energy efficiency) of the building.

Promoting better occupant wellbeing

Wellbeing on a neighborhood level can be enhanced as pre-set requirements (e.g. lighting level adjustments) promote the right balance between energy usage, citizen comfort and better public safety.

Enhancing operational efficiencies

A digital twin of a building facilitates AM by giving building managers and users a real-time view of the integrated systems of the building. This can enable a number of functions, such as dashboards of building health to specific applications like asset and people tracking, hot desking, integration with transit and parking, and building operations based on conditions rather than fixed schedules. A digital twin serves as an advanced analytics tool for building operators to identify failures easily, anticipate the life span and develop optimised maintenance strategy.

Generating cost savings

Digital twins help buildings operate more efficiently by helping to predict and avoid unexpected costs, identify system inefficiencies, and better estimate when replacement parts are needed. Predictive maintenance can also enable additional repair costs to be saved.

A.2 **Digital Twin**

Benchmark Cases

Microsoft's regional Headquarters at Frasers Tower, Singapore

Developer: Frasers Centrepoint Limited
Architect: DP Architects

Hong Kong International Airport

Owner/Operator: Airport Authority Hong Kong
Project Manager: Bechtel
Architect: Foster and Partners

Hong Kong University of Science & Technology Campus

Architect: Simon Kwan & Associates and Percy Thomas Partnership

Technology Requirements

- Cloud-based network for data transmission
- Common data environment
- A platform as an interface to manage the digital twin model
- Wireless internet
- Sensors (e.g. monitoring building performance - heat intensity, motion, light intensity, etc.)

IOT	AI	ML	BT	5G	DV	BD

Design Requirements

- IoT enables digital infrastructure and backbone within the building.

Barriers/Constraints

- Cybersecurity – Cyber intruders could potentially use a digital twin to gain access to confidential building information.
- Availability and accuracy of as-built drawings and other relevant information for existing building may be limited.
- Reluctance amongst some in the industry to adopt BIM.

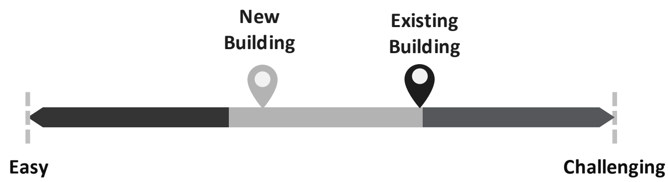
Application in Building Life Cycle

PLANNING/ DESIGN | CONSTRUCTION | COMMISSION | OPERATION & MAINTENANCE | DEMOLITION

Building Type

NEW BUILDING	EXISTING BUILDING
✓	✓

Ease of Implementation



New Building

Relatively easy to be implemented at the initial design stage of the building.

Existing Building

More difficult to implement for existing buildings since older buildings with shorter remaining life cycle may not be able to justify the ROI in scanning, modelling and data input to the digital twin model.

Cost Information

CAPEX	OPEX
As a very general rule of thumb, the CAPEX and OPEX can cost between 1-10% of project cost. However, this depends on the complexity of each project, as the design, scope and size between each project can vary largely, which would affect the costs.	

Remarks (if any)
Above cost information is indicative and based on 2020 figures

A.3 Near Field Communications

Description

NFC is a secure form of contactless communication using magnetic field induction between devices within a short range. 'Passive' NFC tags, have an antenna and a chip, are being incorporated to transmit additional information to smart devices, for example, a retail poster that activates a discount coupon or street signs that open a map of the city when users are lost. Similarly, 'active' NFC tags are larger in size and are battery-powered, which allows the tag to broadcast signals and transfer data in real-time. The decision to choose between passive or active tags mainly depends on the functions required and budget.

There is a growing trend of using NFC in construction and building management field - some examples include:

- Implementing Computerised Maintenance Management Systems (CMMS) to manage, track and monitor the performance of assets, capital equipment and inventory by tapping;
- On-the-go smart building management capabilities;
- Flexibility in identity and access control solutions, such as affixing NFC tags to mechanical keys and positioning at locations throughout a building;
- Automatic and contactless payment systems for retail uses to speed up the billing and payment process;
- Use of NFC cards/tags for car park access, control and payment; and
- Enhancing the user experience in elevators by taking passengers to intended floor through NFC tags and reader.

Benefits

Promoting better occupant wellbeing

The rise in NFC technology holds massive potential to improve daily user experience in buildings, such as how people get around, how they pay, and even how they access information. Users have the flexibility to choose between using ID cards, phones or other mobile devices, and the coming years will bring even more options.

Enhancing operational efficiencies

NFC can greatly enhance smart building management capabilities and allow processes to become more seamless and secure. For example, NFC can help improve security operations with less manpower requirements.

A.3 Near Field Communications

Benchmark Cases

International Financial Centre, Hong Kong

Developer: Sun Hung Kai Properties
Architect: César Pelli & Association Architects
Executive Architect: Adamson Associates Architects
Structural Engineer: Ove Arup & Partners

Johnson Controls HQ, One Albert Quay, Cork, Ireland

Developer: JCD Group
Building Owner: Green REIT PLC
Architect: Henry J. Lyons

Hong Kong University of Science & Technology Campus

Owner: HSBC
Architect: Foster and Partners
Structural Engineer: Arup Group; Cleveland Bridge Ltd
MEP Engineer for design: J. Roger Preston Limited
Main Contractor: John Lok/Wimpey Joint Venture

Technology Requirements

- A cloud-based network for transmission of data.

IOT	AI	ML	BT	5G	DV	BD

Design Requirements

- Installation of receivers and transmitters (e.g. tags) for NFC readers linked to a cloud-based network for transmission of data regarding transactions.
- NFC mobile devices with a controller chip to be tapped against the NFC tags.

Barriers/Constraints

- Cybersecurity concerns with the potential for cyber intruders to use a digital twin to gain access to confidential building information.

Application in Building Life Cycle

PLANNING/ DESIGN | CONSTRUCTION | COMMISSION | OPERATION & MAINTENANCE | DEMOLITION

Building Type

NEW BUILDING	EXISTING BUILDING
✓	✓

Ease of Implementation

New Building | Existing Building

Easy | Challenging

New Building

NFC system can be easily installed and included in the design stage of a new building.

Existing Building

The installation of NFC system is relatively easy with the retrofitting of existing buildings, provided that key locations to position the NFC tags have been strategically identified.

Cost Information

CAPEX

Based on benchmark and research, the following are the installation costs for the relevant equipment:
- RFID Card (13.56MHz): HKD 1.33 - 2.34
- Reader System: HKD 16,000+
- Antenna: HKD 2,400
- Antenna Cable: HKD 1,600
- RFID encoder: HKD 35,100

Remarks (if any)
Above cost information is indicative and based on 2020 figures

A.4 **Robotics for Building Operations**

Description

Robotics for building operations feature machines that can autonomously interact with their environments, humans, or each other, based upon sensory feedback or pre-programmed commands. Robots can perform a number of functions, presenting a promising alternative to costly human labour and eliminate the need for workers to perform many simple and repetitive tasks and allow them to focus more on complex, thought intensive tasks that robots cannot perform. They can be controlled remotely through IoT and internet connection.

With the right sensors and processors employed, robots are able to automate various building operations activities. Examples include:

- Small inspection robots, equipped with Closed Circuit Television (CCTV) camera, can be used inspect and clean air ducts of HVAC systems.
- Cleaning robots are being increasingly employed for cleaning of floors within buildings. There are also specific robots to meet special cleaning requirements, such in hospitals for disinfecting medical wards with UV-C lighting.
- Security robots can be used for perimeter patrolling and detection of intruders. Equipped with two-way audio, it can detect and warn the intruder that police have been contacted.
- Drone bots, equipped with infra-red and ordinary CCTV cameras, can carry out external façade building inspections and detect signs of water seepage and spalling concrete.

Benefits

Promoting better occupant wellbeing

Robots can enhance user experience, such as receptionist robots providing quick assistance. Robots can enhance wellbeing of occupants as they can optimise cleaning and security performance. They can also take on tasks that are a hazard to the health and safety of human labour, such as cleaning of façade/windows.

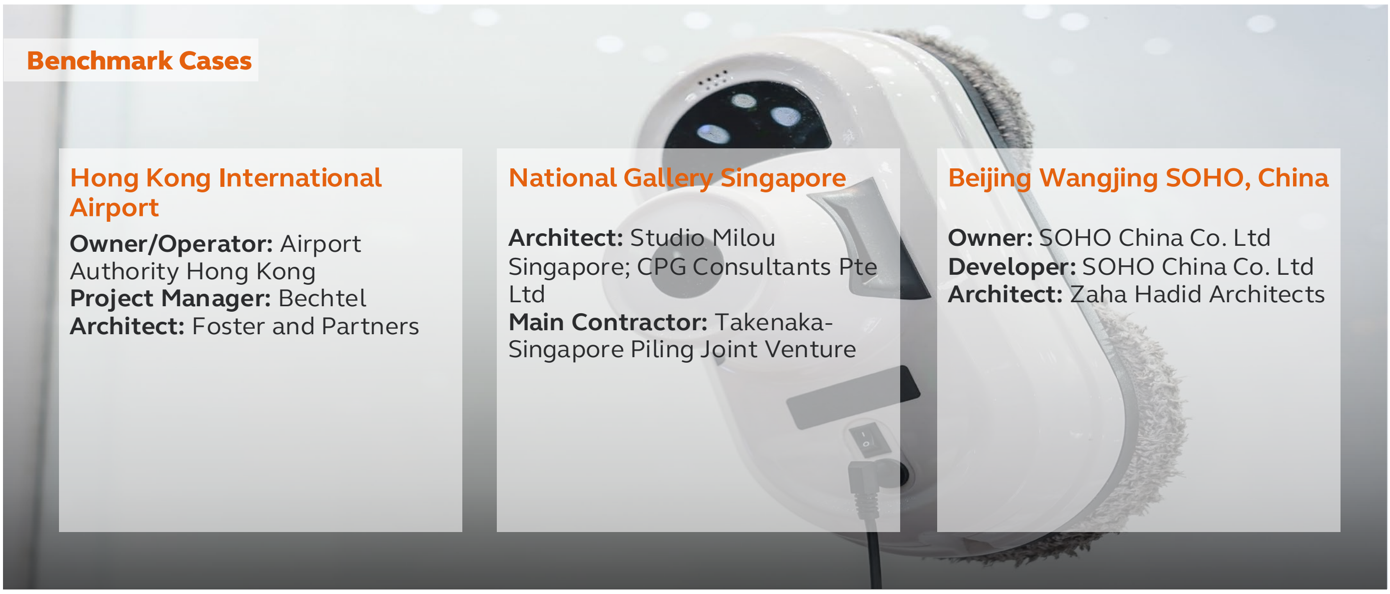
Enhancing operational efficiencies

Robots can perform a number of operational functions ranging from cleaning to maintenance to security to receptionist. Therefore, they can minimise manpower and lower operational and maintenance costs of a building.

Generating cost savings

Replacing manual workers with robots benefits the user by reducing wasted time and money while increasing productivity. Manual workers are also able to focus on more though intensive tasks.

A.4 Robotics for Building Operations



Benchmark Cases

Hong Kong International Airport

Owner/Operator: Airport Authority Hong Kong
Project Manager: Bechtel
Architect: Foster and Partners

National Gallery Singapore

Architect: Studio Milou Singapore; CPG Consultants Pte Ltd
Main Contractor: Takenaka-Singapore Piling Joint Venture

Beijing Wangjing SOHO, China

Owner: SOHO China Co. Ltd
Developer: SOHO China Co. Ltd
Architect: Zaha Hadid Architects

Technology Requirements

- Content management system
- A back-end portal that is operated over the internet is needed for patrolling robots

IOT | AI | ML | BT | 5G | DV | BD

Design Requirements

- Robots need to be calibrated to be aware of the building design and space layout.

Barriers/Constraints

- In the case of security robot, technology should be such that it is fully compliant with local legislations around data privacy.
- In the case of cleaning robot for façade, structural approvals should be obtained for the anchoring and supporting the weight of the robots.

Application in Building Life Cycle

PLANNING/ DESIGN | CONSTRUCTION | COMMISSION | OPERATION & MAINTENANCE | DEMOLITION

Building Type

NEW BUILDING	EXISTING BUILDING
✓	✓

Ease of Implementation

New Building

Easy to implement since the only criteria is that the design needs to consider the ease of mobility for the robot within the building.

Existing Building

Relatively simple to implement since the only criteria is the design needs to consider is the ease of mobility for the robot within the building. Robots can be easily adopted in existing buildings.

Cost Information

CAPEX	OPEX
Based on benchmark and research, the following are the purchase costs of robots: • Receptionist robot: HKD 100,000 - 200,000 • Patrol robot: HKD 100,000 • Cleaning Robot: HKD 500,000	Based on benchmark and research, the following are the operating costs of robots: • Onsite checking* of robots: HKD 4,000 • Battery replacement: HKD 4,000 - 5,000 • Touch screen replacement: HKD 6,000 - 7,000

Remarks (if any)
Above cost information is indicative and based on 2020 figures
The typical replacement period of robots is around 5 years
**Excluding consumable replacement*

A.5 **Integrated Facility Management System**

Description

An integrated FM system is the brain of a smart building where all information is combined, displayed and managed to deliver the superior operational, efficiency and security value of a smart building. It involves a single user interface, with mobile compatibility, for various building operation functions, such as Operations & Maintenance (O&M), security management, data management and analytics of tenant/occupant database, e-procurement, e-service request, complaints, access/FM, access control management, interfacing with landlord etc.

This system helps gather enormous amount of building performance data in real-time. Analysis of such data provides insights for decision-making, operational and maintenance adjustment. The analysis of data and corresponding actions are automated due to advanced algorithms that is either rule-based or with AI and ML capabilities.

Benefits

Reducing environmental impacts

All-time monitoring and optimised control of building systems will help minimise inefficient use of resources.

Promoting better occupant wellbeing

Optimal control of various operations allows users to efficiently use facilities, including:

- Monitoring of access controls for enhanced security;
- Management of internal temperature settings, indoor air quality and humidity for better comfortability;
- Monitor and control of any toxic gas emissions or smoke; and
- Times and requirements for warm-up and cool down cycles within different zones of a building.

Enhancing operational efficiencies

All-time monitoring with operational data allows the AFDD regime for preventive and early detection to correct any faults and problems so that the operator can provide early repairs and minimise possible downtime.

Generating cost savings

Such iBMS will:

- Allow for optimal operation of plant and facilities;
- Be more precise with energy usage;
- Minimise breakdowns and repair cycles; and
- Be more efficient for monitoring and operations for equipment start-ups and shut down for proper sequences.

A.5 Integrated Facility Management System

Benchmark Cases

Leadenhall Building, London

Developer: The British Land Company PLC and Oxford Properties Group Inc.
Owner: C C Land Holdings Ltd
Architect: Rogers Stirk Harbour and Partners
Project Manager: 3M; WSP
Main Contractor: Laing O'Rourke

The Crystal, London

Developer/Owner: Siemens
Architect: WilkinsonEyre Architects; Perkins+Will
Main contractor: ISG
Project Manager: Turner & Townsend

Intel PTK1 Development Centre, Israel

Developer: Intel
Contractor: Afcon Holdings
Architect: Dagan Mochli

Technology Requirements

- Integrated FM System will encompass both hardware and software requirements.
  - Hardware – this will require computer hardware usually associated with BMS systems and equipment sensors that provide more advanced features of data gathering, real time monitoring, operations and control.
  - Software will be in line with new up to date hardware and would be interfaceable with BIM.

IOT | AI | ML | BT | 5G | DV | BD

Design Requirements

- Space will be taken up in the BMS room of the building or a separate control room can also be set up for the same.

Barriers/Constraints

- Cybersecurity concerns with the potential for cyber intruders to hack the system and gain access to confidential building information.

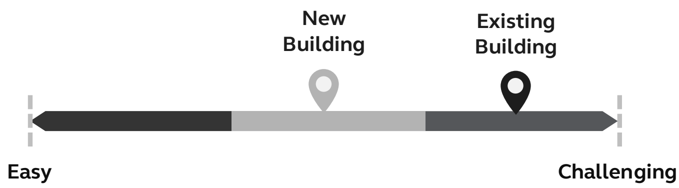
Application in Building Life Cycle

PLANNING/ DESIGN | CONSTRUCTION | COMMISSION | OPERATION & MAINTENANCE | DEMOLITION

Building Type

NEW BUILDING	EXISTING BUILDING
✓	✓

Ease of Implementation



New Building

Relatively easy to implement since designer in early stages can:

- Specify the exact requirement and specifications required for the systems of a particular building;
- Plan and design space require for housing the particular hardware (BMS space); and
- Choose the appropriate system available on the market to suit requirements.

Existing Building

More difficult to be implemented as more effort is required to consolidate and combine information to be managed in a single platform, if existing systems are already in place.

Cost Information

CAPEX	OPEX
As a very general rule of thumb, the CAPEX and OPEX can cost between 1-10% of project cost. However, this depends on the complexity of each project, as the design, scope and size between each project can vary largely, which would affect the costs.	

Remarks (if any)
Above cost information is indicative and based on 2020 figures

A.6 Washroom of the Future

Description

Smart washroom analytics and sensors support the online tracking of washroom conditions, allowing cleaning managers to deploy resources and respond to cleaning requests in a timely manner. Resource savings can also be achieved. Some key features include:

- Counting of the number of people entering the toilet by sending alert when pre-set usage threshold reached;
- Users are able to share feedback on toilets that require cleaning by sending an alert through Cleaner Alert Button;
- Smart RFID-based Cleaner Attendance System to enable smart device to track attendance of worker;
- Emergency alerts derived from smoke sensors;
- Fill sensors in waste bins to avoid bin overflow; and
- Tracking of odour concentration levels with sensors and pre-set thresholds to trigger alerts when there are high concentration levels.

There are various policy initiatives in Hong Kong promoting smart washrooms. Examples include the HKD 600 million government budget devoted to renovate public toilets and equip the toilets with smart features by Electrical and Mechanical Services Department (EMSD).

Benefits

Reducing environmental impacts

Energy savings will be generated through adopting sensor technologies to better manage and control water and energy consumption in toilets.

Promoting better occupant wellbeing

Optimised cleaning schedules and enhanced hygiene also positively impacts the overall user experience.

Enhancing operational efficiencies

Operational efficiency of cleaning and management of washrooms can be enhanced by:

- Optimised cleaning schedules through predictive cleaning and better understanding of trends of footfall/ usage levels;
- Real-time monitoring of inventory usage and toilet consumables; and
- Notifications for cleaning with sensors. This will ensure the cleanliness and hygiene of the toilet is up to standard at all times.

Generating cost savings

By understanding trends in toilet consumable usages and predictive inventory planning, there will be less resource wastage and more cost savings in the long term.

A.6 **Washroom of the Future**

Benchmark Cases

Marina Bay Sands, Singapore

Developer: Las Vegas Sands Corporation
Architect: Moshe Safdie Architects, Aedas
Project Manager: 3M; WSP
Main Contractor: Ssangyong Engineering and Construction

Intel Headquarters at Santa Clara, California

Architect: HRGA Architecture
Interior Design: Gensler

Electrical and Mechanical Services Department (EMSD) Headquarters, Hong Kong

Developer/ Owner/ Facility Management: EMSD, HKSAR Government
Architect/Planner: BLEND Architecture Limited
Project Manager: EMSD
Sustainable Design Consultant: Ove Arup & Partners Hong Kong Limited

Technology Requirements

- Installation of sensor and IoT technologies at various points of the washrooms to monitor various parts of the toilets, from usage levels to cleaning needs to consumables and inventory tracking.

IOT | AI | ML | BT | 5G | DV | BD

Design Requirements

- No specific design requirements.

Barriers/Constraints

- No specific barriers/constraints.

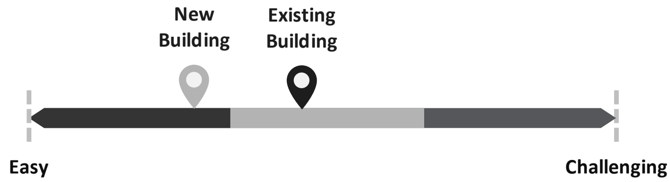
Application in Building Life Cycle

PLANNING/ DESIGN | CONSTRUCTION | COMMISSION | **OPERATION & MAINTENANCE** | DEMOLITION

Building Type

NEW BUILDING	EXISTING BUILDING
✓	✓

Ease of Implementation



New Building

Depending on the type of washroom condition to be tracked, installation of sensors is relatively easy and should be considered during design stage of a project.

Existing Building

Slightly more difficult to retrofit toilets with sensors for more optimised usage, operations and management.

Cost Information

CAPEX

Different products from different manufacturers can vary by design, form, function and cost. Benchmark costs are as follows:
- Auto urinal and sensor: HKD 7,215;
- Auto WC with sensor: HKD 23,045;
- Auto hand dryer: HKD 5,290; and
- Sensor soap dispenser: HKD 3,800.

The costs for additional smart washroom features (e.g. built-in sensors) depend on a case-by-case basis.

Remarks (if any)
Installation costs depend on size and number of fixtures
Above cost information is indicative and based on 2020 figures

A.7 **Smart Space Utilisation**

Description

An adaptive, intelligent space in a building opens up all kinds of possibility for different usage. Basic systems such as high-speed Wi-Fi, quick charging facilities, video and audio system provided in a common area create multi-functional spaces for building users. These spaces facilitate a professional working environment, which provides an alternative to offices to reduce travel time if working remotely is a possibility. In an office building, co-working is a type of space where space utilisation can be maximised.

Smart occupancy sensors capture and communicate space utilisation rates. This enables analytics to provide immediate insights on the use of spaces and allow for improvement opportunities. Analysing space utilisation promotes energy conservation and reduces related energy costs. Understanding utilisation patterns of spaces also allow operations to be managed appropriated, such as optimised cleaning frequencies and security processes.

Benefits

Promoting better occupant wellbeing

Smart offices and space utilisation can foster a more agile and competitive work environment. With more activity-based working and other spaces designed for different types of work, this can encourage better collaboration and interaction, and foster creative thinking and innovation.

Enhancing operational efficiencies

The use of analytics results in higher efficiency of FM activities, such as cleaning, lighting usage, and HVAC control.

Generating cost savings

- Travel time is reduced for residents if they work in co-working office.
- Cost savings brought about by energy conservation and better use of space.

A.7 Smart Space Utilisation

Benchmark Cases

The Crystal, London

Developer: Siemens
Architect: WilkinsonEyre Architects; Perkins+Will
Main Contractor: ISG
Project Manager: Turner & Townsend

RBC Waterpark Place III, Toronto

Developer: Oxford Properties Group
Architect: WZMH Architects
Builder: EllisDon
Engineering: WSP, RJC Engineers

The Edge, Amsterdam

Developer: OVG Real Estate
Architect: PLP Architecture
Main tenant: Deloitte
Interior architect: Fokkema & Partners

Technology Requirements

- All technology requirements in any typical office space would be required e.g. sensors for utilisation studies, Wi-Fi, etc. As this is more of a tenant initiative, the building space should be flexible to allow for the adoption of tenant-based technology.

IOT	AI	ML	BT	5G	DV	BD

Design Requirements

- Different hardware and software features to meet the needs of different users. Examples below:
  - Private office/cabins
  - Dedicated desks
  - Hot desks
  - Event space
  - Meeting rooms
  - Mail room
  - Cafeteria/pantry

- Consideration of physical space requirements and building types are needed to enable open plan design, agile office layout, and shared spaces. Appropriate fundamental infrastructure should also be provided by the landlord to enable smart, adaptable spaces.

Barriers/Constraints

- No specific barriers/constraints are identified to implement this strategy.

Application in Building Life Cycle

PLANNING/DESIGN | CONSTRUCTION | COMMISSION | **OPERATION & MAINTENANCE** | DEMOLITION

Building Type

NEW BUILDING	EXISTING BUILDING
✓	✓

Ease of Implementation

New Building
Existing Building

Easy — Challenging

New Building / **Existing Building**

It is relatively easy to implement the solution to new as well as existing buildings once the space for it has been identified.

Cost Information

CAPEX	OPEX

The installation and operating costs depend on what kind of technological equipment is featured in the area. The approximate costs of the most common equipment are as follows:

- 100-inch LED Screen for meeting room: HKD 15,600
- Computer: HKD 20,000
- Installation costs for the above equipment: HKD 30,000
- Maintenance costs per annum for the above equipment: HKD 35,900

Costs for occupancy sensors vary from HKD 230 to HKD 1,000 depending on the type used and building environment.

Remarks (if any)
Above cost information is indicative and based on 2020 figures

A.8 Smart Surveillance

Description

Smart Surveillance utilises CCTV for security, which is a commonly used technology globally. Data from intelligent cameras, and other measurement devices, such as microphones and location tracking can be added and analysed via advanced analytical techniques such as AI, deep learning, and data analytics.

The software connects to all cameras and starts processing data using edge analytics. Such technology and data will enhance building security and safety in areas such as footfall analysis, access control, crowd movement and pattern detection, incident detection, etc.

Smart surveillance can be performed in real time, or data can be collected and saved for the purpose of evaluation when necessary.

Benefits

Promoting better occupant wellbeing

Through the advanced smart surveillance technology, security and safety measures can be optimised (e.g., access control, pattern detection, incident detection). Any potential incidents can be easily detected. This enhances the overall safety and wellbeing of building users.

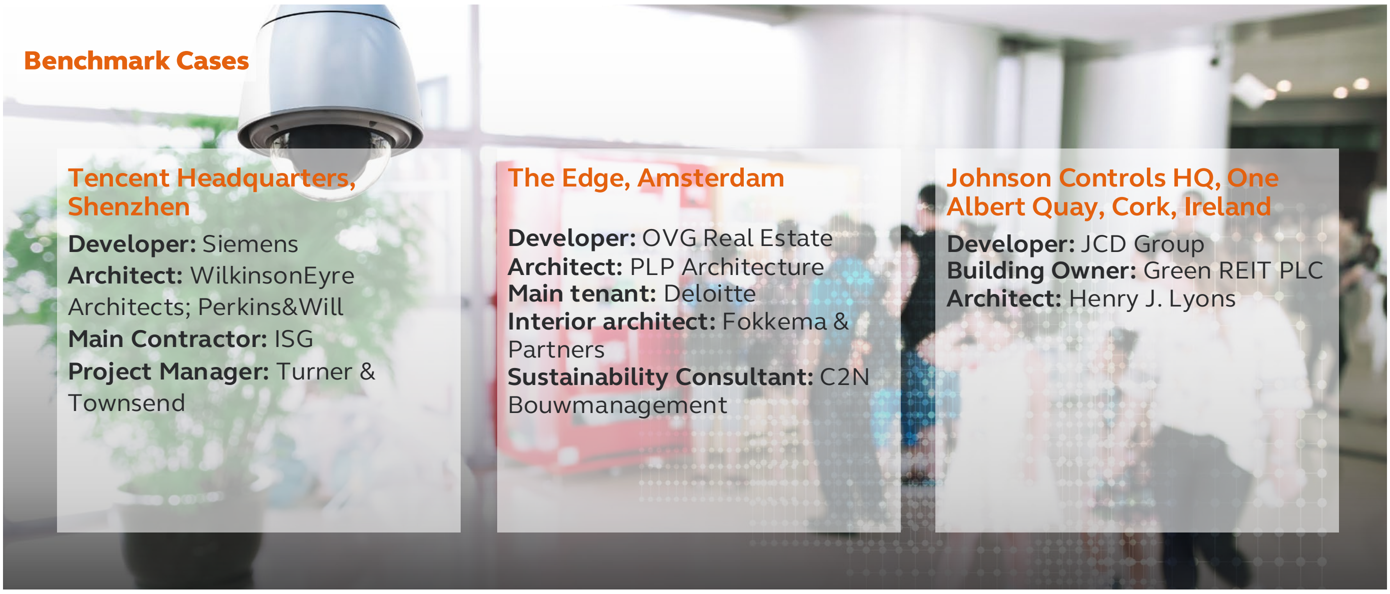
Enhancing operational efficiencies

Safety and security measures can be enhanced with optimised surveillance in all areas of a building. For instance, quicker pattern detection or incident detections through the use of intelligent cameras; and efficient access control measures and location tracking, enabling the granting of access quicker.

Generating cost savings

By using technology to optimise security and safety measures, there is an opportunity to reduce the amount of security labour required.

A.8 **Smart Surveillance**



Benchmark Cases

Tencent Headquarters, Shenzhen

Developer: Siemens
Architect: WilkinsonEyre Architects; Perkins&Will
Main Contractor: ISG
Project Manager: Turner & Townsend

The Edge, Amsterdam

Developer: OVG Real Estate
Architect: PLP Architecture
Main tenant: Deloitte
Interior architect: Fokkema & Partners
Sustainability Consultant: C2N Bouwmanagement

Johnson Controls HQ, One Albert Quay, Cork, Ireland

Developer: JCD Group
Building Owner: Green REIT PLC
Architect: Henry J. Lyons

Technology Requirements

- Installation of sensor and IoT technologies in all areas of the buildings, especially access points. Video analysis software (e.g. video analytics) is required. Hardware necessary includes CCTV cameras, microphones, Wi-Fi or BT tracking.
- A location, such as a control centre, is needed to manage, visualise, and act upon the data and information received.

IOT	AI	ML	BT	5G	DV	BD

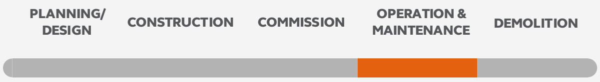
Design Requirements

- No specific design requirements.

Barriers/Constraints

- Due to the use of cameras, there may be cybersecurity and privacy risks pertaining to identity and facial recognition. Secure fire walls must be in place to avoid possible hacking. Such information should also only be collected for building security and safety purposes.

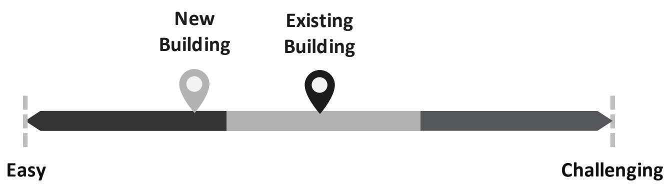
Application in Building Life Cycle



Building Type

NEW BUILDING	EXISTING BUILDING
✓	✓

Ease of Implementation



New Building

Relatively easy to implement. Smart surveillance requires the use of CCTV technology which is commonly adopted in the industry. Existing CCTV would need to be integrated into a centralised, software system for the running of analysis algorithms.

Existing Building

More difficult for existing buildings as existing CCTV would need to be integrated into a centralised, software system for the running of analysis algorithms.

Cost Information

CAPEX	OPEX
Sensor systems and operational software for a smart surveillance system would be approximately HKD 5,500,000 per system installed (for a 550,000 square foot office building).	OPEX is typically approximately 10% of the CAPEX.

Remarks (if any)
Above cost information is indicative and based on 2020 figures

Health & Wellbeing

Through smart technologies, maintain and enhance the environmental quality of the building and its built environment for the health and wellbeing of the users.

Improve lighting quality for better occupant comfort

- B.1 Advanced Solar Technologies for Natural Lighting
- B.2 Smart Artificial Lighting

Optimise thermal comfort for building users

- B.3 Smart Thermal Control

Improve indoor and outdoor air quality

- B.4 Biophilic Design
- B. 5 Smart Air Filtration

Interactive smart building controls

- B.6 Smart Light Poles
- B. 7 Occupant Automation System

B.1 Advanced Solar Technologies for Natural Lighting

Description

Advanced solar technologies and automated shading systems maximise natural lighting in buildings. These technologies include advances in CSP, solar thermal energy and transparent solar cells. CSP technologies include heliostats and solar tubes, which are computer-controlled mirrors that keep the sun reflected on a predetermined target.

Solar technologies vary in efficiency in terms of lighting provision and quality, depending on the passive or active design used. For instance, the lighting intensity of a light shelf, a passive architectural device used to reflect natural daylight into a building, can be different.

An automated shading system integrates with existing building controls, provides exterior shading and utilises heat absorptive/reflective material to perform responsive thermal control.

Property developers and building operators are increasingly exploring cutting-edge solutions to maximise natural lighting in building designs. However, it is important to maintain a balance between maximising natural lighting and avoiding excessive solar heat gain to avoid driving HVAC costs up.

In Hong Kong, approvals from the Buildings Department may be required for use of solar technologies. This could be either in the form of minor works submission or approval process for exterior building works, depending on the building design and installations required. Reference can be made to the following guides for more information:

- ASHRAE. (2019). Standard 90.1-2019 - Energy Standard for Buildings Except Low-Rise Residential Buildings
- ASHRAE. (2018). Standard 189.1-2018 - Standard for the Design of High-Performance Green Buildings Except Low-Rise Residential Buildings
- EMSD. (2019). Guidance Notes for Solar PV System Installation
- Whole Building Design Guide. (2016). Resource Page on Daylighting

Benefits

Reducing environmental impacts

- Use of solar energy can reduce the use of artificial lighting, achieving energy savings ranging from 15% to 40%
- Artificial lighting produces a lot of heat, however, if properly controlled, natural lighting generates minimal heat

Promoting better occupant wellbeing

Natural lighting has a direct impact on occupant wellbeing with reduced eye strain, increased visual performance and enhanced comfort, therefore improving productivity.

Enhancing operational efficiencies

Lighting quality can be controlled by remote access/control, which would also enhance operational efficiencies for building managers.

Generating cost savings

There may be some initial investment in installing the system. However, minimising the use of artificial lighting will reduce electricity/HVAC costs in the long run, which could make up for the upfront capital costs.

B.1 Advanced Solar Technologies for Natural Lighting

Benchmark Cases

Trade and Industry Tower in Kai Tak Development Area

Developer: Siemens
Architect: WilkinsonEyre Architects; Perkins&Will
Main Contractor: ISG
Project Manager: Turner & Townsend

Pixel Building, Australia

Developer/Owner/Builder: Grocon Property Ltd.
Architect: Studio505
Structural Engineer: VDM Pty. Ltd.
Landscape design: Studio 505; University of Melbourne

Al Bahar Tower, Abu Dhabi

Owner/Developer: Abu Dhabi Investment Council
Architect: Aedas UK; Diar Consult
Structural engineer: Arup Group Limited
MEP engineer: Arup Group Limited
Project Manager: Mace Limited
Main Contractor: Al-Futtaim Carillion

Technology Requirements

- To optimise the use of natural lighting, installation of heliostat sun tracking technology is required.

IOT | AI | ML | BT | 5G | DV | BD

Design Requirements

- Site evaluations are required to assess the roof slope, roofing material, roof framing spacing, location, and weather for the design of shading devices/heliostats technologies.
- Installation of lighting shafts, mirrors, weather/temperature sensors are also required.

Barriers/Constraints

- Possible location constraints, such as blockage of sunlight from surrounding buildings may impact the expected benefits and efficiency of the technology
- Relevant statutory approvals may impede the implementation process

Application in Building Life Cycle

PLANNING/DESIGN | CONSTRUCTION | COMMISSION | OPERATION & MAINTENANCE | DEMOLITION

Building Type

NEW BUILDING	EXISTING BUILDING
✔	✔

Ease of Implementation

New Building — Existing Building

Easy — Challenging

New Building

Installation of technologies optimising natural lighting for new buildings can be planned/incorporated during the building design stage.

Existing Building

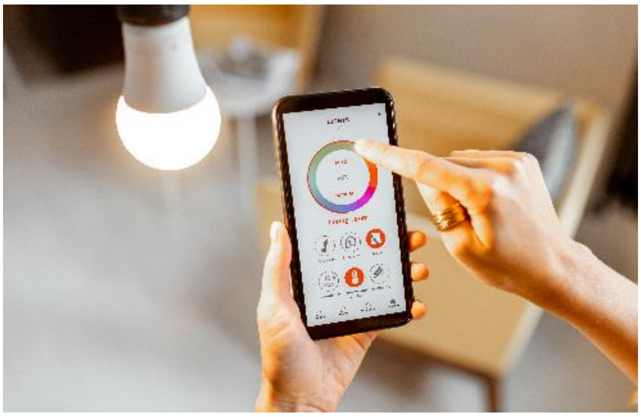
Retrofitting technologies/devices, such as heliostats/shading devices to existing buildings and structures would be relatively challenging and dependent on individual building. For instance, whether the existing structure can support the system, or sufficient spaces are available within the interior.

Cost Information

CAPEX	OPEX
A heliostat system costs around HKD 10-15 million for supply and installation costs.	Regular maintenance, which includes reflector cleaning and maintenance check, costs around HKD 82,000 per annum. Motor replacement costs around HKD 38,000 per annum.

Remarks (if any)
Above cost information is indicative and based on 2020 figures

B.2 **Smart Artificial Lighting**



Description

Smart lighting is the enhanced controllability and automation of lamp responses through the adoption of IoT and ALS technologies. The lighting system is individually connected to a central control by ethernet cable or wireless technology, which enables user to personalise lighting quality, such as dimming, colour changing, and occupancy-based settings. Users can control settings by using a smartphone application.

Real-time data collected through smart lighting can provide valuable information for building operators to efficiently plan operations and activities, (e.g. breakdown of equipment) and optimise maintenance and energy reduction.

To optimise the use of smart lighting, lighting design can be integrated in the BIM model during early design stage to run simulations of lighting effects and test the costs for acquisition, operation and maintenance of various lighting design and concepts. Therefore, the benefits and quality of lighting can be considered at the beginning of the asset life cycle.

Benefits

Reducing environmental impacts

Reduction of energy wastage as sensor technologies can detect unoccupied spaces and automatically adjust the lighting settings.

Promoting better occupant wellbeing

Personalised lighting controls improve user wellbeing as they are able to adjust settings according to their needs.

Enhancing operational efficiencies

- Automatic and customised lighting controls and real-time data collection help optimise operational efficiency through predictive analytics and occupancy-based behaviour
- Real-time data contribute to timely repairs and maintenance of lighting system
- When there is a demand for changes in lighting design due to switch in tenancy, no additional cabling work is required from the landlord, as only reprogramming of the lighting system is required

Generating cost savings

More efficient use of lighting and energy savings will contribute to overall OPEX savings for the buildings.

B.2 **Smart Artificial Lighting**

Benchmark Cases

IBM Watson IoT Headquarters, Munich, Germany

Owner: IBM
Architect: Jahn architects; Universal
Designer: Map Project Office; Universal Design Studio
Interior design: The Switzer
Project Manager: VOK DAMS Event GmbH; Ce+Co.

The Crystal, London

Developer: Siemens
Architect: WilkinsonEyre Architects; Perkins&Will
Main contractor: ISG
Project Manager: Turner & Townsend

Johnson Controls HQ, One Albert Quay, Cork, Ireland

Developer: JCD Group
Building Owner: Green REIT PLC
Architect: Henry J. Lyons

Technology Requirements

- Installation of IoT technologies and cloud-based system for the mobile device to wirelessly connect to and customise and control lighting settings.

IOT	AI	ML	BT	5G	DV	BD

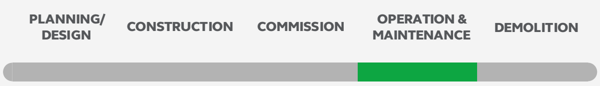
Design Requirements

- Motion and lighting sensors are positioned and connected to the wireless connection to optimise lighting condition.

Barriers/Constraints

- There are no major barriers or constraints identified regarding the implementation of smart artificial lighting.

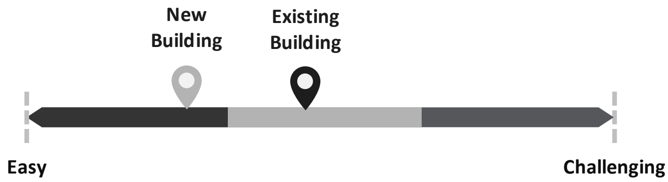
Application in Building Life Cycle



Building Type

NEW BUILDING	EXISTING BUILDING
✓	✓

Ease of Implementation



New Building

Installation of smart lighting system is easy to be included in the design stage of a new building. Simulations can also be tested with BIM model.

Existing Building

As additional installation of sensors, wiring, etc. in the lighting system is required, the level of difficulty to make such changes would be made much easier if other major renovation works is also being carried out in the existing building at the same time.

Cost Information

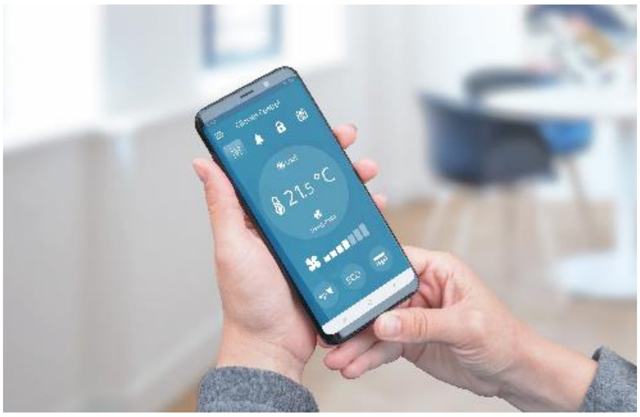
CAPEX	OPEX

Based on benchmarks and research, the relevant costs are as follows:

- HKD 1,000 - 3,000 per set of sensor control unit, including installation and commissioning
- HKD 30,000 for smart lighting system (50 lighting fixtures) including mobile control platform

Remarks (if any)
Above cost information is indicative and based on 2020 figures
The cost listed above covers annual license fees and maintenance fees

B.3 **Smart Thermal Control**



Description

Smart thermal control system allows buildings users to customise and adjust the temperature settings in and around the space they occupy in accordance with their needs and preferences through a smartphone or mobile device.

As users customise the settings, real-time data is collected to help build a profile to keep track of user preferences and further occupancy-based optimisation can be made by allocating users with similar preferences in the same zonal areas.

Consideration needs to be given to zoning design, duct system design and installation of flow regulators to enable individual thermal comfort controls in targeted occupant spaces.

Reference could be made to the following guide for more information:

- ASHRAE. (2020). Standard 55-2020 - Thermal Environmental Conditions for Human Occupancy

Benefits

Reducing environmental impacts

Reduction of energy wastage as temperature controls can reduce excessive cooling or heating.

Promoting better occupant wellbeing

Personalised temperature settings can bring about enhanced user comfort and positively impact overall health and wellbeing.

Enhancing operational efficiencies

Automated and personalised controls as well as real-time data collection optimise operational efficiency through predictive analytics, occupancy-based behavior.

Generating cost savings

Optimised thermal control and associated energy savings will contribute to OPEX savings for the buildings.

B.3 **Smart Thermal Control**

Benchmark Cases

IBM Watson IoT Headquarters, Munich, Germany

Owner: IBM
Architect: Jahn architects; Universal
Designer: Map Project Office; Universal Design Studio
Interior design: The Switzer
Project Manager: VOK DAMS Event GmbH; Ce+Co.

Intel R&D Campus SRR3, India

Developer: INTEL Technology India Pvt Ltd
Architect: Thomas Associates
Landscape architect: Thomas Associates

Al Bahar Tower, Abu Dhabi

Owner/Developer: Abu Dhabi Investment Council
Architect: Aedas UK; Diar Consult
Structural engineer: Arup Group Ltd.
MEP engineer: Arup Group Ltd.
Project Manager: Mace Limited
Main contractor: Al-Futtaim Carillion

Technology Requirements

- Application of IoT technologies, cloud-based system and related programming for the mobile device to wirelessly connect thermal control system. Through ML, user preferences can be stored electronically, therefore allowing settings to be adjusted automatically.

IOT	AI	ML	BT	5G	DV	BD

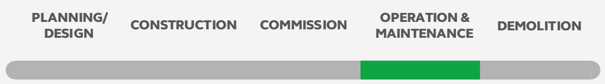
Design Requirements

- Sensors are positioned and connected to wirelessly to optimise thermal quality.
- Zoning design is also key. Thermal zones can be set based on thermal needs of a specific group of occupants. Consideration on duct system design is needed – downstream ductworks that are used to control the amount of constant temperature air delivered to the building zones need to be assigned accordingly.
- Installation of flow regulators are needed to allow flow control in designated zones. The device can modulate supply fan in response to the static pressure in the duct system.

Barriers/Constraints

- There are no major barriers or constraints identified regarding the implementation of smart thermal control.

Application in Building Life Cycle



Building Type

NEW BUILDING	EXISTING BUILDING
✓	✓

Ease of Implementation

New Building

Installation of smart thermal control system is easy to be included in the design stage of a new building.

Existing Building

Challenging to implement in existing buildings as fundamental changes to the air distribution systems and controls of the duct and HVAC system would be required to achieve localised control functionality. The level of difficulty varies on a case-by-case basis.

Cost Information

CAPEX	OPEX
The costs of smart thermal sensor will be around HKD 200 - 1,200 per unit, including smart end-terminals, gateways, network server, application server.	Other retrofit cost varies with the type and scale of the AC system.

Remarks (if any)
Above cost information is indicative and based on 2020 figures

B.4 **Biophilic Design**

Description

Biophilic design for buildings uses sensors and technology to promote greenery in and around a building, such as vertical garden walls and indoor planting, as well as maximising views of nature and the penetration of natural daylight into interior spaces so that building users can feel connected with nature while living in an urban environment.

Different plant species have varying benefits, for instance, certain species help with air filtration, such as Dracaena can effectively remove acetone and Bromeliad can remove VOC content. Through use of sensors, real time information can be gathered on indoor air quality which can be used by building operators to identify improvement opportunities. Biophilic design can be adopted in all asset and building types. The growing trend of moving towards clean living and wellbeing through transporting nature indoors is anticipated to continue.

Benefits

Reducing environmental impacts

Biophilic design brings about several key environmental benefits, including improved IAQ and ventilation, enhanced outdoor air quality through photosynthesis, plants absorbing toxin and pollutant levels, and promotion of biodiversity.

Promoting better occupant wellbeing

Biophilic design organises spaces with a human focus, which has numerous direct benefits to the human physical health and mental wellbeing, including lowering stress levels, improving cognitive functions and productivity. Transforming views from grey to green help create a healthier, calming and restorative building environment.

Enhancing operational efficiencies

Biophilia, such as Ammonia, Benzene, Formaldehyde, Trichlorethylene and Xylene, promote passive air quality control on pollutants with easy maintenance. Technologies and sensors can also provide information on when the plants need water and maintenance.

Generating cost savings

Use of biophilia helps to purify the air with limited cost investments as it is a much cheaper alternative as compared to large scale air purifiers.

B.4 **Biophilic Design**

Benchmark Cases

Zero Carbon Building, Hong Kong

Owner: Construction Industry Council
Architect: Ronald Lu & Partners (Hong Kong) Limited
Project Manager: AECOM Asia Company Ltd
Landscape architect: Urbis Ltd
Main Contractor: Gammon Construction Limited

Central Government Complex of HKSAR, Tamar, Hong Kong

Owner: The Government of the Hong Kong Special Administrative Region
Contractor: Gammon and Hip Hing Construction (Joint Venture)
Architect: Rocco Design Architects Associates Ltd.

Apple Park, Silicon Valley

Developer: Apple Inc.
Architect: Foster and Partners
Interior landscape: Rudolph and Sletten and Holder Construction
Exterior landscape: Truebeck Construction
Landscape Architect: Olini

Technology Requirements

- Sensors embedded in biophilic design to emit real time information on quality of air and on the water schedule for the various plant needs

IOT | AI | ML | BT | 5G | DV | BD

Design Requirements

- Design of a building externally and internally needs to incorporate biophilia and greenery as part of the overall design. Considerations for maintenance system and regime also need to be given (e.g. irrigation).

Barriers/Constraints

- There are no major barriers/constraints identified regarding the adoption of biophilia in buildings.

Application in Building Life Cycle

PLANNING/ DESIGN | CONSTRUCTION | COMMISSION | OPERATION & MAINTENANCE | DEMOLITION

Building Type

NEW BUILDING	EXISTING BUILDING
✓	✓

Ease of Implementation

New Building | Existing Building

Easy — Challenging

New Building

Biophilic design features are easy to implement in new buildings since it could be incorporated during the design stage.

Existing Building

Spatial constraints may restrict the building to incorporate large biophilic design features in the space especially for an existing building. However, small planters are still an effective technique of providing air cleansing capability as well as creating a more visually comforting and enjoyable environment.

Cost Information

CAPEX	OPEX
A 2.5m x 2.5m area of vertical greenery costs HKD 35,000. Price would vary with the species of plant and size of vertical greenery required.	The scope of maintenance work includes on-site checking, plant pruning, replacement of dead plant with new plant, fertilisation, and pest control. Maintenance cost is around HKD 2,800 per month. (HKD 33,600 per annum)

Remarks (if any)
Above cost information is indicative and based on 2020 figures

B.5 **Smart Air Filtration**

Description

Smart technology and devices can improve and monitor IAQ as well as enhance air purification and filtration. Example technologies include:

- Acoustic air filtration by applying acoustic air vibration mechanism in the HVAC system. The acoustic energy causes rapid air vibration of the particles, which significantly increases the particles' traveling distance and their chance of being captured by the filter fibres.
- 3G-filter technology effectively collects particles, gaseous contaminants and organic compounds. The collected microorganisms are destroyed daily by UV-radiation, while active carbon layers absorb gaseous contaminants. 3G-filters offer comprehensive protection against nuclear-, biological- and chemical threats. The system promotes high efficiency for removing fine particles, bacteria & virus and harmful gases together with massive dust holding capacity achieved in low pressure drop.

It is recommended in the BEAM Plus New Buildings that filtration media installed after construction and prior to building occupancy should achieve a MERV of 13 to ensure adequate IAQ. Advanced technology that uses a pre-conditioning technique such as acoustic agglomeration or air ionisation can maximise filtration capability while minimising pressure loses. Research on an acoustic pre-conditioned air filtration technology shows a 10% increase in the filtration efficiency (on $PM_{2.5}$) for a MERV 11 filter. The application of the new techniques can be used to upgrade existing HVAC system at the PAU/AHU, air ducts, or as a standalone air filtration unit.

With air quality sensors, an integrated building management platform can provide real-time monitoring of air filtration performance and quality to building users. The Hong Kong Environmental Protection Department’s IAQ Certification Scheme, China’s RESET and International WELL Building Institute’s (IWBI) WELL standards provide useful guidance on this.

Benefits

Reducing environmental impacts

Air filtration and purification technology directly improves IAQ. With the use of equipment and technologies that operate at a lower pressure drop, this also reduces energy consumption.

Promoting better occupant wellbeing

Air quality directly impacts users' health and wellbeing as well as their comfort. Room specific air filters allow customised services according to user preferences and can also be controlled remotely.

Enhancing operational efficiencies

By operating a more efficient filtration system, it can reduce the maintenance required for duct works.

B.5 Smart Air Filtration

Benchmark Cases

Bloomberg Headquarters, London

Owner: Bloomberg LP
Architect: Foster and Partners
Project Manager: AECOM Asia Company Ltd
Main contractor: Sir Robert McAlpine
Environmental Engineer: Sweco Group
Lighting Engineer: Tillotson

The Edge, Amsterdam

Developer: OVG Real Estate
Architect: PLP Architecture
Main tenant: Deloitte
Interior architect: Fokkema & Partners
Sustainability Consultant: C2N Bouwmanagement

Port of Portland Headquarter

Owner: Port of Portland
Architect: ZGF Architects LLP
Main Contractor: Hoffman Construction Company

Technology Requirements

- Installation of acoustic filtration technologies and other devices in the MVAC/HVAC system.

IOT	AI	ML	BT	5G	DV	BD

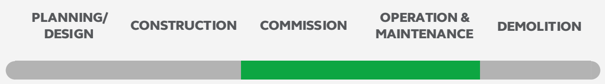
Design Requirements

- Positioning and installation of IAQ sensors synced to the air filtration system to enhance air purification capabilities.

Barriers/Constraints

- The high costs of filters (e.g. HEPA) could be a potential barrier to its adoption.

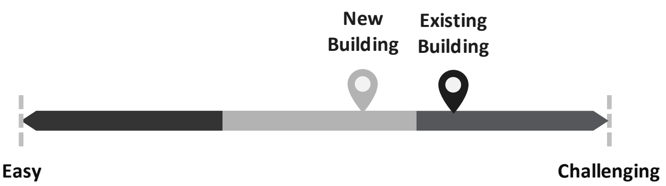
Application in Building Life Cycle



Building Type

NEW BUILDING	EXISTING BUILDING
✔	✔

Ease of Implementation



New Building

Installation of smart air filtration and acoustic technologies/ devices is relatively less challenging, as it could be incorporated in the design stage of the HVAC system of a new building.

Existing Building

Sufficient space is required to incorporate and retrofit smart air filtration devices for an existing system which can be challenging for some buildings.

Cost Information

CAPEX	OPEX
Individual standalone device (acoustic) for air filtration costs around HKD 5,000 each. An IAQ sensor cost from HKD 1,450 to 3,980 approximately. HEPA filters, which are effective in trapping pollutants, are about 10 times more expensive than typical filters. Installation cost of filter vary with the scale of the HVAC system.	Filter replacement costs from HKD 200 to 600. Renewal costs may vary with the scale of the HVAC system.

Remarks (if any)
Above cost information is indicative and based on 2020 figures

B.6 **Smart Light Poles**

Description

Smart light poles integrate cellular broadband internet connections, multiple data capturing sensors, and at times, renewable power sources to compile and broadcast information. A network of next generation LED streetlights or smart light poles act as a platform for sensing technologies to collect real-time information in a neighborhood, including location specific data on weather, pollution, traffic and people flow, noise and air pollution, etc. This information is then used to increase operational efficiency, such as enhanced security, parking and traffic management, and resource metering. They can also feature a number of add-on components, such as security and energy-saving lighting controls, billboards, and charging stations.

Key technologies that can be integrated with smart light poles include:

- Weather/air quality/noise/radar sensors for real-time environmental monitoring;
- Smart camera for observing traffic conditions, guide maintenance decisions and emergency services deployment;
- Cloud-based technology and big data analytics platforms for instant data transfer and analysis; and
- Smart microphones for detection of noises associated with anti-social behaviour, emergencies or crimes.

Cameras on smart poles may pose concerns around privacy and facial recognition. Ways to overcome such concern include:

- Use of low-resolution camera (e.g. 320 x 240 pixels) camera that only extract count data and no images will be archived. Once the images are captured and analysed, it will then be discarded; and
- Other alternatives instead of visual measures: radar sensors can be used to replace ultrasound or infrared camera. It will not be affected by weather or lighting conditions.

Benefits

Reducing environmental impacts

- Smart light poles incorporate energy-saving features including light-emitting diode or LED lighting with a Smart Lighting Management System. LEDs use less energy and emit less CO_2.
- In the absence of human movements, lights can be dimmed to a certain degree to save more energy.

Promoting better occupant wellbeing

Wellbeing on a neighborhood level can be enhanced as pre-set requirements (e.g. lighting level adjustments) promote the right balance between energy usage, citizen comfort and better public safety.

Enhancing operational efficiencies

Real-time information captured can be tracked and monitored over time to identify areas for operational improvements.

B.6 **Smart Light Poles**

Benchmark Cases

Kwun Tong/Kai Tak Development Area, HK

Pilot Multi-functional Smart Lampposts Scheme by the Office of the Government Chief Information Officer, HKSAR Government

Royal Botanic Garden, Sydney, Australia

Telecom/Smart City Infrastructure Provider: Optus, ENE.HUB

Robina Shopping Centre, Gold Coast, Australia

Developer: Apple Inc.
Architect: Foster and Partners

Technology Requirements

- Cloud-based network, BD and IoT and sensor technologies are the backbone of smart light poles. 5G data networks in the future will be the catalysts for such technologies.

IOT	AI	ML	BT	5G	DV	BD

Design Requirements

- Integrated smart poles can feature a number of add-on components, including environmental monitoring, security, energy saving lighting controls to charging stations. Smart poles are also equipped with sensors and closed-circuit cameras to collect real-time information, such as air quality, traffic/pedestrian flow, weather data, microclimate, lighting adjustment, for better and smarter management of an area.

Barriers/Constraints

- Cybersecurity and privacy risks pertaining to identity, facial recognition, and personal information collection. The public may be concerned with potential issues of information leakage.

Application in Building Life Cycle

Building Type

NEW BUILDING	EXISTING BUILDING
✓	✓

Ease of Implementation

New Building

Installation of smart lamp posts in new development areas is relatively easy as long as it is considered in the planning and design stage in the master plan.

Existing Building

Installation of smart lamp posts in existing large-scale developments is relatively simple, given that the supporting infrastructure is adequate.

Cost Information

CAPEX
Each smart light pole* costs around HKD 120,000. Costs may vary based on the functions featured.

Remarks (if any)
Above cost information is indicative and based on 2020 figures
**Functions include HD camera, weather sensor, emergency call system, wireless AP etc.*

B.7 **Occupant Automation System**

Description

Occupant automation systems can be used in all asset and building types. In recent years, there has been a growing trend of the use of home automation systems in residential buildings, which allow residents to monitor and control their home from remote locations using mobile devices and IoT. These devices are connected to a home automation system via Wi-Fi, which allows the automated and easy control of various functions inside a home, including lighting, climate, and entertainment appliances. The system also provides real time air quality measures (e.g. temperature, humidity, $PM_{2.5}$, CO_2), as well as security controls (e.g. access control, alarm systems).

Motion sensors connected to an alarm system enhances security control by monitoring the people coming in and out of the area. Motion sensors also enable energy savings, for instance by monitoring the number of people in a zone and adjusting the air conditioning intensity accordingly, and switching off lights in areas where no movement of people is captured.

These systems can also extend to incorporate specific functions for elderly users:

- Fall sensors connected to an alarm system
- Video calls capability for day-to-day check-up by medical professionals
- Door sensors to monitor the in-out of the occupant

Benefits

Reducing environmental impacts

Installation of an occupant or home automation system can bring about significant energy savings as building users can better control resource use. Energy efficiency and low carbon practices can be promoted by understanding power consumption patterns and auto switch off appliances and lights when no motion is detected.

Promoting better occupant wellbeing

Occupant wellbeing is improved through enhanced user convenience and friendliness, with respect to security, power consumption, thermal comfort, etc. The system can be tailored to different user needs. Younger generations can also be attracted to adopt this technology to assist and improve the quality of life for elderly.

Enhancing operational efficiencies

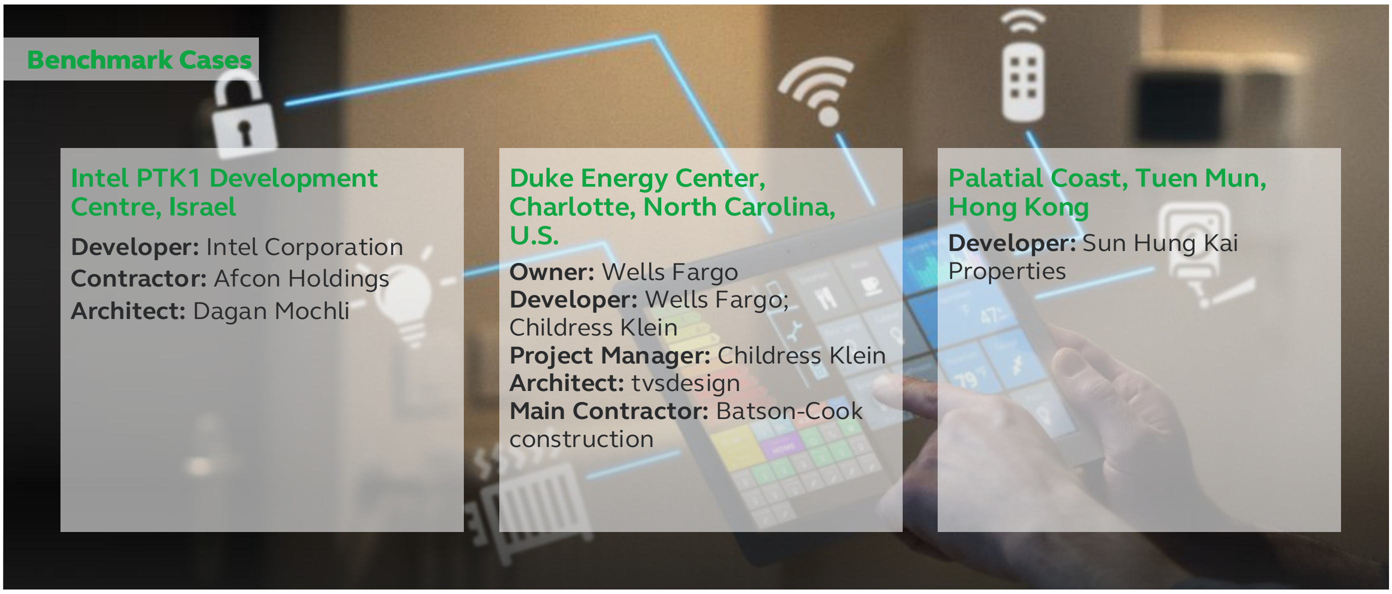
Integrating the occupant automation system with the building's BMS will significantly optimise operational efficiencies, especially with the analytics performed on real-time information collected.

Generating cost savings

More efficient use of the appliances will contribute to energy saving and reduces the OPEX of the buildings.

By raising awareness of the energy consumption for the users' immediate environment, it will encourage more energy conscious behavior change and help generate savings on a wider scale.

B.7 **Occupant Automation System**



Benchmark Cases

Intel PTK1 Development Centre, Israel

Developer: Intel Corporation
Contractor: Afcon Holdings
Architect: Dagan Mochli

Duke Energy Center, Charlotte, North Carolina, U.S.

Owner: Wells Fargo
Developer: Wells Fargo; Childress Klein
Project Manager: Childress Klein
Architect: tvsdesign
Main Contractor: Batson-Cook construction

Palatial Coast, Tuen Mun, Hong Kong

Developer: Sun Hung Kai Properties

Technology Requirements

- Occupant or home automation systems typically work on a customised application provided by the supplier, which can be controlled by a smartphone or mobile device. It works on IoT technology, which connects all devices to the Internet to enable data transfer within the network.

IOT	AI	ML	BT	5G	DV	BD

Design Requirements

- Typical smart solutions are wall mounted or floor stands connected to Wi-Fi and BT. One system can support all smart devices in a residential unit and can also be customised based on the needs of the users.

Barriers/Constraints

- As the data gathered by the system may be sensitive, there may be concerns around data privacy and integrity during the implementation of this strategy.

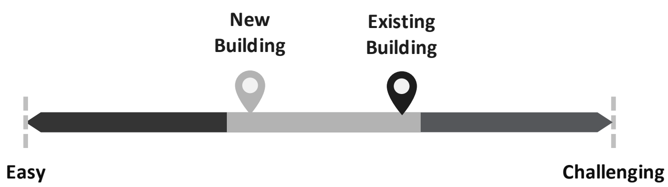
Application in Building Life Cycle

PLANNING/ DESIGN | CONSTRUCTION | COMMISSION | OPERATION & MAINTENANCE | DEMOLITION

Building Type

NEW BUILDING	EXISTING BUILDING
✓	✓

Ease of Implementation



New Building

Occupant or home automation system are relatively easy to be incorporated into new buildings during design stage.

Existing Building

Occupant or home automation system is a widely used technology and does not require any major design changes or requirements but additional installation/retrofit of sensors may be required.

Cost Information

CAPEX	OPEX
The cost of home automation system ranges from HKD 5,000 to 10,000 for 2 -3 systems and up to HKD 55,000 for a complete home automation system with multiple features. The robotics and AI system costs HKD 320,000 for commercial use.	The maintenance costs for home automation systems range from HKD 300 to 500 per month. The robotics and AI system incur HKD 43,500 of warranty extension fees for each additional year.

Remarks (if any)
Above cost information is indicative and based on 2020 figures
The operational costs of the robotics and AI system only involve electricity fees for battery charging only. No regular maintenance is required.

Achieve higher energy efficiency for a building with the use of smart and green technologies.

C.1 Automated Fault Detection and Diagnostics (AFDD)

Description

AFDD is an automatic process by which faulty operation, degraded performance, and failed components are detected and understood.

Typically based on BMS/Building Automation System (BAS) with trend data to achieve predictive detection of faults and diagnosis of their causes, enabling correction of the faults before additional damage to the system, loss of service, or excessive energy use and cost result. Periodic reports on energy performance and real-time dashboards can also show abnormal trends and alerts.

Through data analytics, ML based algorithms and AI controls, AFDD system can continuously optimise system operation efficiency taking into account of ever-changing factors, such as weather conditions, occupancy level, equipment load. This strategy is key for continuous commissioning.

Below is a list of the latest standards/certifications relevant to AFDD application for reference:

- ASHRAE. (2018). Guideline 36-2018, High-Performance Sequences of Operation for HVAC Systems
- ASHRAE. (2019). Handbook 2019 – HVAC Applications: Chapter 63 – Smart Building Systems: Section 1 - Automated Fault Detection and Diagnostics
- International Organisation for Standardisation. (2018). ISO 50001 – Energy Management

Benefits

Reducing environmental impacts

- Energy savings through identifying inefficiency and continuous optimisation.
- Prolong life cycle of equipment or components lead to less material used.
- Minimise the chance of major breakdown which may results in environmental pollution, e.g. refrigerant leak.

Promoting better occupant wellbeing

Deviation of indoor environment quality can be detected and resolved earlier, which will help to improve occupant satisfaction.

Enhancing operational efficiencies

Through adopting AFDD, predictive maintenance and operations can be performed to enhance higher reliability and promote zero breakdown, therefore not impacting the functionality of building services.

Generating cost savings

Operational cost saving from avoiding under-performing processes and prolonging equipment or components life cycle.

C.1 Automated Fault Detection and Diagnostics (AFDD)

Benchmark Cases

Intel PTK1 Development Centre, Israel

Developer: Intel Corporation
Contractor: Afcon Holdings
Architect: Dagan Mochli

University of Iowa, U.S.

Implementation of Fault Detection and Diagnostics technology across 20 buildings at University of Iowa campus

Technology Requirements

- BD from BMS/BAS or other pervasive sensory system that is accurate, adequate and continuously available and monitored during building operation.

IOT	AI	ML	BT	5G	DV	BD

Design Requirements

- Sensitivity and false-alarm rate are two key performance indicators (KPI) for quantifying performance of an AFDD tool, which is affected by the underlying design characteristics in terms of
  - sensors and control signal used;
  - design data used;
  - training data required; and
  - user-selected parameters.
- Above characteristics need customisation and tuning for analytics to effectively identify faults and inefficiencies.

Barriers/Constraints

- Lack of understanding of BIM and its benefits because it is a new and developing technology.
- A narrowing skills gap in the BIM modelling area.
- Reluctance amongst some in the industry to adopt BIM.

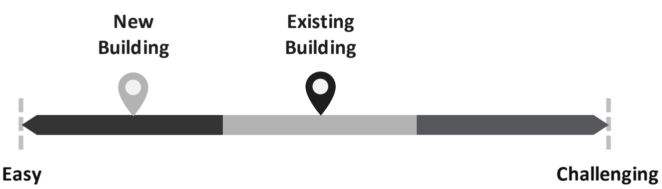
Application in Building Life Cycle

PLANNING/ DESIGN | CONSTRUCTION | COMMISSION | OPERATION & MAINTENANCE | DEMOLITION

Building Type

NEW BUILDING	EXISTING BUILDING
✔	✔

Ease of Implementation



New Building

Provided the BMS has adequate functions and I/O points, implementation of AFDD or data analytics software will be easy. Implementation settings of the analytics can take reference from the new system specification from the supplier/manufacturer.

Existing Building

May encounter few challenges, such as irrelevant system condition and performance, due to deterioration and system modification over time. Hence, additional system function and performance testing to determine the actual system parameters would be required.

C.2 Smart Grid Compatibility and Technology

Description

The smart grid represents a modern grid concept that enable safe and secure two-way flows of electricity and information between customers and electricity providers. The strategy is intended to enable a new kind of load response, whereby loads and generation are on equal footing with equal visibility of the value of electricity in real time.

Energy efficiency in buildings is increasingly being promoted by the Hong Kong Government through a number of initiatives and policies, including the Feed-in Tariff (FiT) scheme and selling of cleaning energy back to the power grid at higher than market rates.

Below is a list of the latest standards/certifications relevant to smart grid technology for reference:

- ASHRAE/National Electrical Manufacturers Association (NEMA). (2016). Standard 201-2016 Facility Smart Grid Information Model (FSGIM)
- ASHRAE. (2019). Handbook 2019 – HVAC Applications: Chapter 63 – Smart Building Systems: Section 3 Smart Grid Basics
- Institute of Electrical and Electronics Engineers Standards Association (IEEE). (2011). Guide for Smart Grid Interoperability of Energy Technology and Information Technology Operation with the Electric Power System (EPS), End-Use Applications, and Loads

Benefits

Reducing environmental impacts

Smart grid strategy focuses on the integration of renewables and distributed energy generation and storage (e.g. fuel cells), hence promoting the use of such green technologies by enhanced benefits in terms of potential lower cost from effective managing the supply and demand of electricity.

Enhancing operational efficiencies

Support grid reliability by allowing utility to better manage generators, storage and loads for balancing grid-wide supply and demand.

Generating cost savings

Potentially lowering the cost of electricity results from more effective managing the supply and demand of electricity by utility.

C.2 Smart Grid Compatibility and Technology

Benchmark Cases

The Mirage, Las Vegas

Owner: MGM Resorts International
Developer: Steve Wynn
Architect: Joel Bergman, Roger Thomas, Don Brinkerhoff, Gensler

Tianjin Eco-city, China

Developer: Sino-Singapore Tianjin Eco-City Investment and Development Co., Ltd. (SSTEC) – joint-venture between Keppel Group and Tianjin TEDA Investment Holding Co., Ltd.

Technology Requirements

- Energy management system adhere to international standard (e.g. ASHRAE 201P - Facility Smart Grid Information Model) shall be incorporated for interoperation and communication with energy service providers.

IOT | AI | ML | BT | 5G | DV | BD

Design Requirements

- Incorporation of building capability to automatically shift and shed loads, as well as system integration with energy storage via battery or EV, renewable energy and other on-site generation, in order to respond to grid condition.

Barriers/Constraints

- Utility grid infrastructure to be established.
- International standard for defining the information model to enable buildings to manage electrical loads and generation sources in response to communication with smart grid (e.g. ASHRAE 201P - Facility Smart Grid Information Model) is still under development.

Application in Building Life Cycle

PLANNING/ DESIGN | CONSTRUCTION | COMMISSION | OPERATION & MAINTENANCE | DEMOLITION

Building Type

NEW BUILDING	EXISTING BUILDING
✓	✓

Ease of Implementation

New Building

Interoperability with implementation of an Energy Management system integrate controls on renewable energy, on-site generation, demand response mechanism, and electrical storage is required. Therefore, it needs to be incorporated at the start of the planning and design for new building.

Existing Building

Implementation may be more challenging for existing buildings as there is a need to integrate demand response mechanism with existing systems to control the building's energy load. There may also be spatial challenges to cater for on-site generation and ESS in existing buildings in order to be compatible with smart grid.

C.3 **Energy Storage System**

Description

ESS provides operational flexibility to manage load for a smart building and in the broader context of the electric grid – interaction with the smart grid infrastructure. For a building with ESS, load shifting can help the building owner to optimise energy cost by consuming during non-peak period at a lower cost rate while maintaining the same comfort and operation. There is also a growing need for ESS to store renewable energy. ESS is also essential in maintaining and ensuring the electrical grid is operating correctly - balancing supply and demand.

The following are best practices for safety and property protection associated with ESS:

- Provision of approved device to preclude, detect, and control thermal runaway (generally found within the Battery Management System);
- Incorporate appropriately certified inverter systems;
- Incorporate robust cybersecurity controls within ESS which is commonly remotely configurable and connected to the Internet;
- Room housing and other components shall be non-combustible and comply with local codes; and
- Firefighting and detection system must be installed to the relevant code requirements.

Below is a list of the latest standards/certifications relevant to ESS for reference:

- IEEE. (2019). 2030.2.1-2019 Guide for Design, Operation, and Maintenance of Battery Energy Storage Systems, both Stationary and Mobile, and Applications Integrated with Electric Power Systems
- IEEE. (2015). 2030.2-2015 Guide for the Interoperability of Energy Storage Systems Integrated with the Electric Power Infrastructure
- IEEE. (2016). 2030.3-2016. Standard Test Procedures for Electric Energy Storage Equipment and Systems for Electric Power Systems Applications

Benefits

Reducing environmental impacts

Essential elements for the use of wind/solar energy and the smart grid infrastructure, all of which are either promoting renewable energy sources or promoting efficiency in the use of energy.

Enhancing operational efficiencies

End-users and consumers benefit from higher resilience as buildings can be self-sufficient for some period when there is a power outage.

Generating cost savings

Building owners can be benefit from lowered electricity costs through load shifting, and even profit by selling electricity back to the grid.

C.3 Energy Storage System

Benchmark Cases

DMG Mori Tokyo Global Headquarters, Japan

Owner: MGM Resorts International
Developer: Steve Wynn
Architect: Joel Bergman, Roger Thomas, Don Brinkerhoff, Gensler

Hybrid Energy Storage System for Vodafone New Zealand

Critical Infrastructure Provider: Vertiv Collaboration between Vertiv, Vodafone New Zealand and New Zealand Government

Technology Requirements

- Recent years advancements of battery energy storage systems (BESS) are ideally suited for smart grid purpose with its high reliability, efficiency and maintainability.
- Currently four advanced battery solutions are most deployed: Sodium Sulfur battery, Vanadium Redox Battery (VRB), Zinc Bromide (ZnBr) battery, and Lithium Ion (Li-ion) battery.

IOT	**AI**	**ML**	BT	5G	**DV**	**BD**

Design Requirements

- Design parameters required include physical battery room allocation, electrical cabling, power electronics, modular design, and most importantly the load expectation and design of capacity.
- The use of ESS or BESS will be also a design consideration to support the rapid charging of Plug-In Hybrid Electric Vehicle (PHEV) and other EVs.

Barriers/Constraints

- Spatial constraints may be encountered as an energy storage system requires a large amount of floor space.

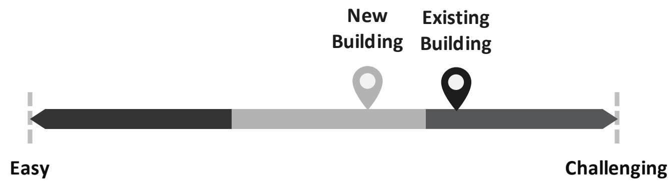
Application in Building Life Cycle

PLANNING/ DESIGN | CONSTRUCTION | COMMISSION | OPERATION & MAINTENANCE | DEMOLITION

Building Type

NEW BUILDING	EXISTING BUILDING
✔	✔

Ease of Implementation



New Building

Investment in ESS is often justified only when there are cost savings due to utility incentives or downsizing equipment capacity. Hence, implementation of ESS in new building needs to be integrated with the overall design and construction.

Existing Building

Investment in ESS is often justified only when there are cost savings due to utility incentives or downsizing equipment capacity. It is relatively more challenging for existing building to implement ESS since there are more costs associated to the modification of electrical system and architectural layout.

Cost Information

CAPEX

The capital costs* of battery technology types are as follows:

- Li-ion: HKD 4,650-9,300 / kW-hour
- VRB: HKD 2,713-3,875 / kW-hour
- NAS: HKD 2,713-3,875 / kW-hour
- ZnBr: HKD 1,163-1,938 / kW-hour

Remarks (if any)
Above cost information is indicative and based on 2020 figures
**Excluding installation cost*
Installation cost is around 20-30% of project cost, depending on the size of installation

C.4 High Performance Chillers and Refrigerants

Description

Advanced technologies for chillers include the use of IoT. An IoT based system will allow for constant streaming of real-time data that is critical for gauging the operational health of the network of chillers and promotion of predictive maintenance. With this technology, chillers can connect to the cloud, where information is transmitted, analysed and presented in real-time to give a view into how chillers are performing.

Chillers operate as part of the complex HVAC system, including the cooling tower system, pumping system and airside system. Evaluating overall chiller plant performance therefore involve an analysis of total power consumption of the compressor, pumps, cooling tower fans, etc. Various adjustments focusing on optimal chilled water set points, chiller sequencing and load balancing, peak demand management, cooling tower water management, etc. can only be performed with operational data. Hence, IoT can provide the tools for such optimisation by providing real-time monitoring from each part of the chiller plant, supply/return temperatures from the chiller and cooling tower, water flow rates from the condenser water loop, etc. to facilitate true optimisation.

In terms of recent refrigerant technology, there has been a move towards accelerated reduction of HFCs and refrigerants with short atmospheric lives. The best synthetic gas alternative to HFCs is HFOs (hydrofluoroolefines), with very low Global Warming Potential (GWP), such as R-1234ze(E). R-1234ze(E) allows to minimise the global warming impacts, in combination with high energy efficiency. Its Ozone Depletion Potential (ODP) is equal to zero (0) and the GWP is 7 (according to the European Union's (EU) F-gas Regulation based on Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report). The GWP value is less than 1 according to the IPCC Fifth Assessment Report

Below is a list of the latest standards/certifications relevant to high performance chillers and refrigerants for reference:

- ASHRAE. (2019). Energy Standard for Buildings Except Low-Rise Residential Buildings
- ASHRAE. (2018). High-Performance Sequences of Operation for HVAC System
- Business Environment Council (BEC). (2018). EMSD - Code of Practice for Energy Efficiency of Building Services Installation

Benefits

Reducing environmental impacts

- Energy savings in the HVAC system due to improved chiller efficiency at full and part load.
- Utilising refrigerants with ultra-low ODP and GWP will minimise environmental impacts.

Enhancing operational efficiencies

Next generation chillers equipped with smart connection to the cloud can enable collection and monitoring of real-time operational to predict maintenance or upgrade needs.

Generating cost savings

Overall operational cost savings of HVAC system results from high energy efficiency and minimise major overhaul of chillers which may involve replacement of expensive components.

C.4 High Performance Chillers and Refrigerants

Benchmark Cases

Standard Chartered Bank Building, Hong Kong

Owner: Hang Lung Properties
Architect: Palmer and Turner
Interior design: Palmer and Turner
Main contractor: Gammon-Nishimatsu JV

New World Zengcheng Comprehensive Development Project, Guangzhou

Developer: New World China Land Limited
Architect: Guangzhou Hanhua Architects & Engineers; Janson Xian Architect and Associates
Designer: Leung Wong Gu Architects (Hong Kong) Office Co., Ltd.; Guangzhou Xian Jianxiong United Architectural

Marina Bay Sands, Singapore

Developer: Las Vegas Sands Corporation
Architect: Moshe Safdie Architects, Aedas
Main contractor: Ssangyong Engineering and Construction

Technology Requirements

- No specific technology requirements.

IOT | AI | ML | BT | 5G | DV | BD

Design Requirements

- Consideration on the following should be given when designing chillers – building load, capacity arrangement, schematic design with air side system. Life cycle cost (LCC) analysis shall be carried out to consider the cost for equipment, installation, testing & commissioning, operation & maintenance, and depreciation, when selecting the best equipment.

Barriers/Constraints

- Privacy concerns as chillers are connected and send raw data to the cloud.
- Concerns over the harmful effects of refrigerants used – Extra attention on the transition of using more climate-friendly refrigerant with consideration based on a balance of safety, environmental impacts, cost/efficiency, and public regulations.

Application in Building Life Cycle

PLANNING/DESIGN | CONSTRUCTION | COMMISSION | OPERATION & MAINTENANCE | DEMOLITION

Building Type

NEW BUILDING	EXISTING BUILDING
✓	✓

Ease of Implementation

New Building | Existing Building

Easy | Challenging

New Building

Implementation of next generation chillers and refrigerants in new buildings is relatively easy to be incorporated into the design of new buildings.

Existing Building

Implementation in existing buildings may be more challenging. Gap analysis of the LCC between existing chillers and potential replacement options should be carried out to select the best solution and commence at the right time.

Cost Information

CAPEX

Capital cost (per square meter of building area) ranges from HKD 300 to 500.

Oil-free chiller supply & installation cost ranges from HKD 7,500 to 8,000 per refrigeration tonne (RT).

Remarks (if any)
Above cost information is indicative and based on 2020 figures

C.5 High Efficiency Motors and Drives

Description

Brushless/EC motors rely on semiconductor switches to turn stator windings on and off at the appropriate time. They are high power-to-weight ratio, high speed, electronic controlled, and require low maintenance. There is a trend in the HVAC and refrigeration industries to use brushless motors instead of other types of AC motors due to the dramatic reduction in power required for operation. HVAC systems also use brushless motors as the built-in microprocessor allows for programmability, control over airflow, and serial communication.

EC plug fans for air handling units use high performance impeller, motor and electronics system which are optimally adjusted to one another, leading to an overall efficiency of well above 60%. An important feature of EC plug fans is the integrated variable speed for optimum operational efficiency. EC fan also generates less noise compared to other types of fans. Application of EC plug fan can be in fan grid configuration depending on the airflow required, space available and required redundancy. Replacement of less efficient belt-driven fans into EC plug fan in fan grid formation in air handling units is also a recommended.

Below is a list of the latest standards/certifications relevant to high efficiency motors and drives for reference:

- ASHRAE. (2019). Energy Standard for Buildings Except Low-Rise Residential Buildings
- BEC. (2018). EMSD – Code of Practice for Energy Efficiency of Building Services Installation
- Building Services Operation and Maintenance Executives Society (BSOMES). (2016). Article - Conversion of belt-drive VSD fan with EC plug fan for VAV AHU system in office building

Benefits

Reducing environmental impacts

Energy savings generated by EC fans have been proven to be particularly substantial for existing buildings, with savings of up to 40%, compared to savings of 20% to 30% for new buildings.

Enhancing operational efficiencies

Relatively less maintenance required compared to traditional motors due to less friction and wear & tear from the brushless design.

Fan grid design also provides resilience as compared to traditionally single belt driven fan within an air handling unit.

Generating cost savings

Overall operational cost savings of mechanical pumps and fans system due to greater energy efficiency and reduced need for maintenance.

C.5 High Efficiency Motors and Drives

Benchmark Cases

MGM Macau

Owner: MGM Resorts International
Architect: Wong Tung & Partners
MEP consultancy: Cundall

One Taikoo Place, Hong Kong

Developer: Swire Properties Limited
Architect: Wong & Ouyang
Structural engineer: Arup Group Ltd.
MEP engineer: J. Roger Preston Limited

Pacific Place, Hong Kong

Developer: Swire Properties Limited
Architect: Wong & Ouyang
Structural Engineer: Leslie E. Robertson Associates
Main Contractor: Shui On Construction & Materials

Technology Requirements

- No specific technology requirements.

IOT | AI | ML | BT | 5G | DV | BD

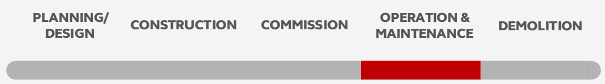
Design Requirements

- Consideration on the following should be given when adopting EC, brushless motors: air/water flow, pressure, motor torque and rpm. These are similar requirements to traditional motors. LCC analysis shall be carried out to consider the cost for equipment, installation, testing & commissioning, operation & maintenance, and depreciation, when selecting the best equipment.

Barriers/Constraints

- No specific barriers/constraints.

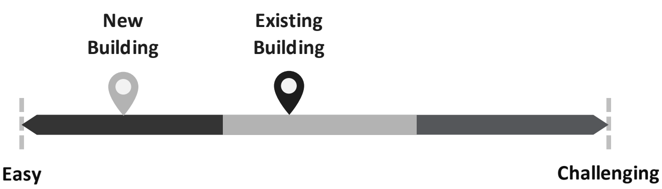
Application in Building Life Cycle



Building Type

NEW BUILDING	EXISTING BUILDING
✓	✓

Ease of Implementation



New Building

Implementation of EC, brushless motors in new buildings is easy to be incorporated in the design stage of new buildings. A LCC analysis would be sufficient to demonstrate the benefits of selecting EC motors over traditional options.

Existing Building

Similar to any retrofitting projects, the investment needs to be justified with the energy saved. While applications such as retrofit belt-driven fans to EC plug fans demonstrates considerable energy saving, there are greater costs associated with modification work in an existing building hence it is more challenging.

Cost Information

CAPEX	OPEX
An EC fan* costs around HKD 6,000 per piece. Installation cost is around HKD 5,000 per air handling unit.	Maintenance cost is around HKD 2,000 per year.

Remarks (if any)
Above cost information is indicative and based on 2020 figures
**Centrifugal type with speed control integrated, 1085rpm, flow 1605 m3/h, static 292 Pa*

C.6 **Solar Technology for Electricity Generation**

Description

Solar power is the conversion of energy from sunlight into electricity, either directly using PV, indirectly using CSP, or a combination. CSP systems use lenses/mirrors and tracking systems to focus a large area of sunlight into a small beam for renewable electricity generation.

Advanced solar technology includes increasing application of BIPV, e.g., facade, pavement, shades), competitiveness from lower production/installation cost (e.g. printed solar panels), and power conversion efficiency (e.g. organic solar cells).

To promote renewable energy adoption in the community, utility companies such as Hong Kong Electric and China Lighting & Power have implemented a FiT scheme as incentive with payback electricity rates between HKD 3 and HKD 5 per unit. Smart electricity meter will be required for the system to connect to the grid, with consumption or generation detailed into half-hourly interval data and operational feedback in case there is any outage, disconnection or other abnormalities.

Below is a list of the latest standards/certifications relevant to solar technology for reference:

- EMSD. (2016). Technical Guidelines on Grid Connection of Small-scale Renewable Energy Power System
- IEC. (2020). PV in Buildings Part 1 & 2: Requirements for building-integrated PV modules
- IEEE. (2019). Recommended Practice for Installation and Maintenance of Lead-Acid Batteries for PV Systems (937-2019)

Benefits

Reducing environmental impacts

Unlike fossil fuel-based technologies, solar power does not lead to any harmful emissions, noise pollution, nor generate any waste when generating renewable solar energy.

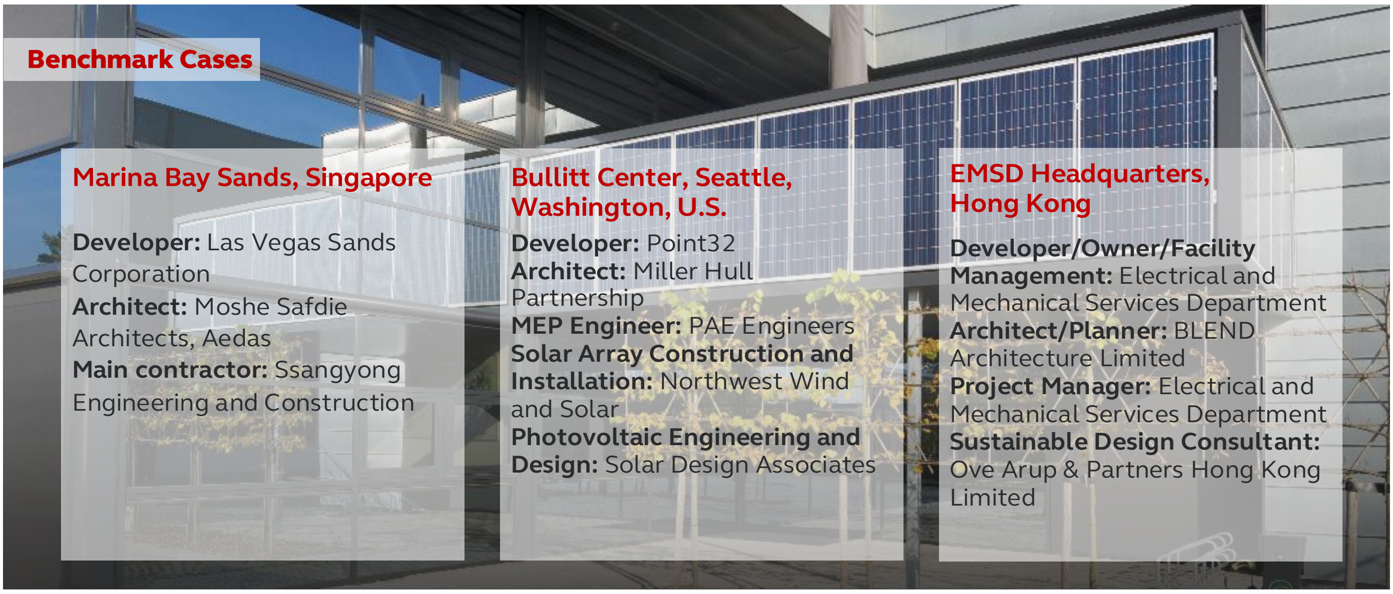
Solar energy is a source that can be harnessed in all areas of the world and is available every day.

Generating cost savings

Generating useful energy from the sun eliminates the need and cost for fuel. Hence, energy needs can be met with the electricity generated by the solar system which reduce the energy bills.

Solar energy system generally does not require a lot of maintenance. The only maintenance will be regular cleaning to ensure the efficiency of solar power generation. The system includes no moving parts and solar panels typically have 20-25 years of lifespan, whereas the inverter and cabling have more than 10 years of lifespan.

C.6 **Solar Technology for Electricity Generation**



Benchmark Cases

Marina Bay Sands, Singapore

Developer: Las Vegas Sands Corporation
Architect: Moshe Safdie Architects, Aedas
Main contractor: Ssangyong Engineering and Construction

Bullitt Center, Seattle, Washington, U.S.

Developer: Point32
Architect: Miller Hull Partnership
MEP Engineer: PAE Engineers
Solar Array Construction and Installation: Northwest Wind and Solar
Photovoltaic Engineering and Design: Solar Design Associates

EMSD Headquarters, Hong Kong

Developer/Owner/Facility Management: Electrical and Mechanical Services Department
Architect/Planner: BLEND Architecture Limited
Project Manager: Electrical and Mechanical Services Department
Sustainable Design Consultant: Ove Arup & Partners Hong Kong Limited

Technology Requirements

- No specific technology requirements.

IOT	AI	ML	BT	5G	DV	BD

Design Requirements

- Detailed assessment of the "sun-hours" at the potential location for installation is required to determine the design in terms of positioning, facing angle, panel material/type, sizing of panels, inverters, batteries and controller, such that model of the annual yield of energy generation and total cost can be determined.
- Solar radiation sensors could be incorporated to optimise the performance of solar installations.

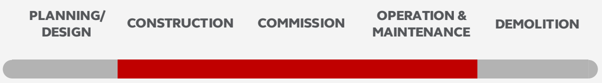
Other Requirements

- Statutory approvals may also apply in line of the impacts on building structure, fire refuge area, etc.

Barriers/Constraints

- Spatial limitations (e.g. limited roof space).
- Shading caused by nearby buildings, especially in a dense environment.
- Potential difficulty of installing panels on rooftops due to ownership issues.

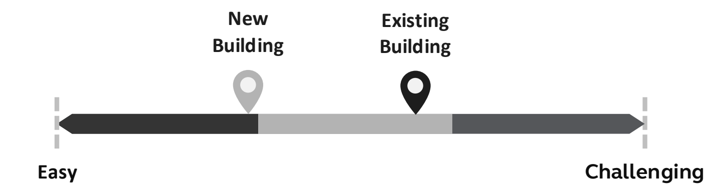
Application in Building Life Cycle



Building Type

NEW BUILDING	EXISTING BUILDING
✔	✔

Ease of Implementation



New Building

Installation of solar technology and panels is relatively easy in new buildings, provided that the statutory approvals are met, and suitable location can be selected with sufficient sun-hours.

Existing Building

Installation of solar panels is more challenging in existing buildings due to spatial limitations in Hong Kong. Most consideration would be given to the roof. The installation would also need to comply with various statutory codes on building structure and fire safety.

Cost Information

CAPEX
A rooftop PV system (per square meter of panel) costs around HKD 9,000.

Remarks (if any)
Above cost information is indicative and based on 2020 figures

C.7 Micro-wind Turbines

Description

Micro-wind turbines are efficient wind turbines that are much smaller in scale and generate lower cost of electricity with units half the size of traditional micro-wind turbines. They are suitable for residential/ commercial energy production and are increasingly being integrated with the architectural design of buildings. Micro-wind generation is a technique of microgeneration that uses the flow of wind energy to produce electricity locally within a building. The primary consideration when implementing micro-wind turbines should be given to careful site selection, as it determines average wind speed and potential annual energy output.

Below is a list of the latest standards certifications relevant to micro-wind turbines technology for reference:

- EMSD. (2016). Technical Guidelines on Grid Connection of Small-scale Renewable Energy Power System
- IEC. (2006). Standard 61400-2 Design Requirements for Small Wind Turbines
- US Department of Energy. (2007). Small Wind Electric System (A US Consumer's Guide)

Benefits

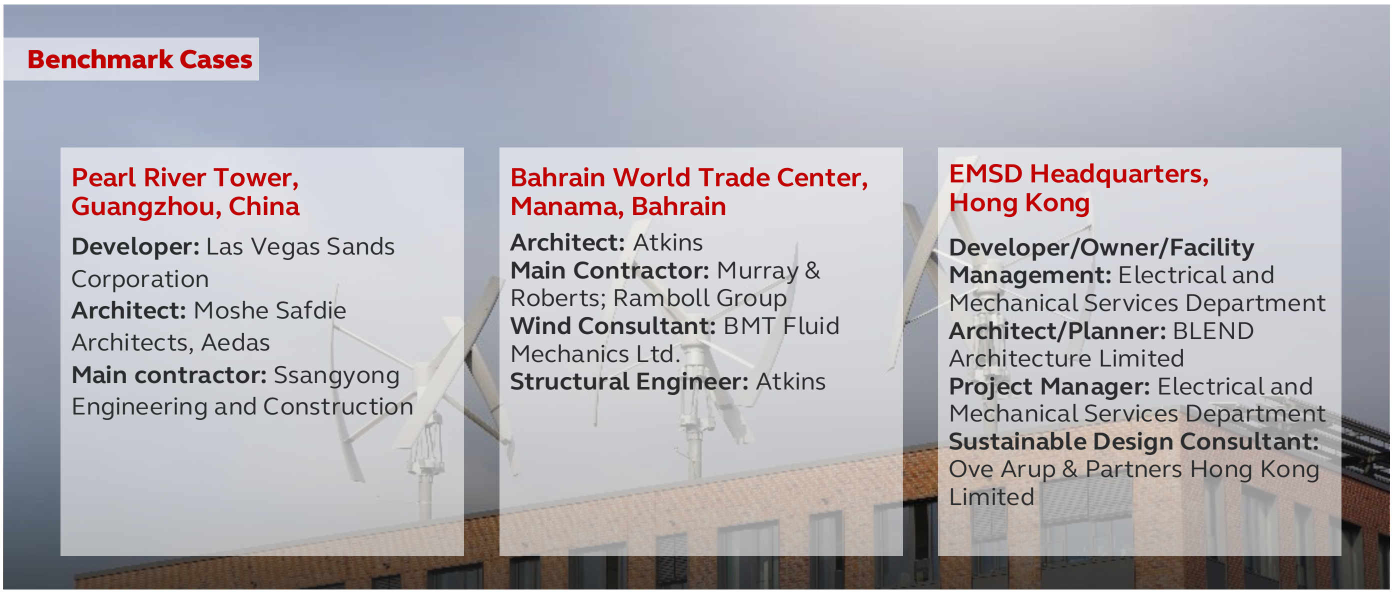
Reducing environmental impacts

Unlike fossil fuel-based technologies, wind energy does not lead to any harmful emissions, nor generate any waste when producing wind energy.

Generating cost savings

Generating wind energy eliminates the need and cost for fuel.

C.7 Micro-wind Turbines



Benchmark Cases

Pearl River Tower, Guangzhou, China

Developer: Las Vegas Sands Corporation
Architect: Moshe Safdie Architects, Aedas
Main contractor: Ssangyong Engineering and Construction

Bahrain World Trade Center, Manama, Bahrain

Architect: Atkins
Main Contractor: Murray & Roberts; Ramboll Group
Wind Consultant: BMT Fluid Mechanics Ltd.
Structural Engineer: Atkins

EMSD Headquarters, Hong Kong

Developer/Owner/Facility Management: Electrical and Mechanical Services Department
Architect/Planner: BLEND Architecture Limited
Project Manager: Electrical and Mechanical Services Department
Sustainable Design Consultant: Ove Arup & Partners Hong Kong Limited

Technology Requirements

- No specific technology requirements.

IOT | AI | ML | BT | 5G | DV | BD

Design Requirements

- Detailed assessment with interval measurements of wind at the potential location for installation is required to determine the design in terms of positioning, turbine type, sizing of turbine, inverters, batteries and controller, such that the annual yield of energy generation and total cost can be estimated.

Other Requirements

- Statutory approvals may apply with consideration on impacts on building structure, fire refuge area, and health & safety risk etc.

Barriers/Constraints

- Location with adequate and consistent wind is required to install wind turbines. Buildings in Hong Kong have limited roof space and wind may also be blocked by surrounding buildings. Altogether, it may be challenging to install micro-wind turbines and uncertainty on whether an acceptable ROI can be achieved.

Application in Building Life Cycle

Building Type

NEW BUILDING	EXISTING BUILDING
✔	✔

Ease of Implementation

New Building

Relatively easy to be incorporated in new buildings, provided that their use is suitable in the site environment. Site selection is a key parameter, as it determines average wind speed, which significantly impacts energy generation.

Existing Building

Implementation of micro-wind turbines is more challenging for existing buildings. It is harder to find desirable locations for wind turbines with sufficient average wind speed to provide energy generation.

Cost Information

CAPEX	OPEX
Installation costs vary greatly depending on local zoning, permitting, and utility interconnection costs. Small wind energy system costs from HKD 23,000 to 39,000 for every kilowatt (kW) of generating capacity.	Maintenance costs range from HKD 1,000 to 1,900 per year.

Remarks (if any)
Above cost information is indicative and based on 2020 figures

Material & Waste Management

Through smart green technologies, promote sustainable and optimum use of building materials and encourage waste reduction, reuse and recycling.

Encourage smart material selection to improve environmental performance

- D.1 Smart Dynamic Glass
- D.2 Nanotechnologies

Encourage efficient waste management

- D.3 Automatic Waste Collection Systems

D.1 **Smart Dynamic Glass**

Description

Smart glass is an innovative building material that has the ability to change its glazing properties (e.g. level of tint) automatically in response to the surrounding environment, or manually based on the needs of the users.

Smart glass provides different functions to enhance security and access of light. In translucent mode, the smart glass acts as an electronic blind providing privacy and security, while still allowing daylight penetration.

It can also provide different levels of natural daylight to the interior, maintaining views of the outdoor environment, while allowing sufficient daylight to penetrate depending on the setting of the desired lighting level.

There are two main technologies that can be applied to control the level of tint of the glass:

1. Electrochromic - by applying a small electric current through the glazing; and
2. Thermochromic - that reacts to the temperature of the glazing.

Either of the technologies typically involves additional layers of material between a typical insulated glass unit (IGU) when the glass is being manufactured. The electricity expenditure of smart glass is approximately 3 to 5 watts (W) per square metre.

Benefits

Reducing environmental impacts

- Potential net energy savings brought by reduction in heat gain of the indoor space by blocking the sunlight with the smart glass, thus reducing the cooling need and energy consumption.
- Utilise natural daylight and reduce reliance on artificial lighting, thus, reducing energy consumption on lighting system.

Promoting better occupant wellbeing

With the use of smart dynamic glass, indoor light quality can be controlled by maximising daylight, controlling glare and reducing heat thereby boosting productivity of the users. It also helps to reduce eye strain and drowsiness for the users as well.

Enhancing operational efficiencies

- Allow automatic lighting control based on weather change.
- Enhance privacy by providing shading.

Generating cost savings

Smart dynamic glass has the potential to save a building owner 20% of energy costs thereby promoting cost savings.

D.1 **Smart Dynamic Glass**

Benchmark Cases

One World Trade Center, U.S.A

Owner: 1 World Trade Center LLC
Developer: Port Authority of New York and New Jersey; The Durst Organisation
Architect: Skidmore; Owings & Merrill LLP
Façade Consultant: Viridian Energy & Environmental LLC; Benson Industries, Inc; Permasteelisa Group

Al Bahar Tower, Abu Dhabi

Owner/Developer: Abu Dhabi Investment Council
Architect: Aedas UK; Diar Consult
Structural engineer: Arup Group
MEP engineer: Arup Group
Project Manager: Mace Limited
Main Contractor: Al-Futtaim Carillion

Ocean Financial Centre, Singapore

Developer: Keppal Land International Ltd
Architect: Pelli Clarke Pelli Architects; Architects 61
Structural Engineer: TY Lin International
MEP Engineer: Parsons Brinckerhoff Consultants Private Limited
Main contractor: Obayashi Corp.

Technology Requirements

- The control of the smart glass can be enhanced by the use of smartphone application to make the glass customisable and individual control over group of windows and even entire facades can be achieved.

IOT	AI	ML	BT	5G	DV	BD

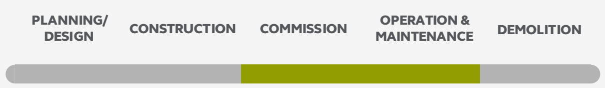
Design Requirements

- Installation of lighting sensors is required to determine the lighting level of the environment to optimise the transition of the glass. Zoning of different lighting groups may also be introduced for users with different preferences.
- Consideration also needs to be given to the impacts on curtain wall and structural loading.

Barriers/Constraints

- High costs of smart glass may be a potential constraint for implementation.

Application in Building Life Cycle



Building Type

NEW BUILDING	EXISTING BUILDING
✓	✓

Ease of Implementation

New Building

It would be relatively easy to incorporate smart dynamic glass in the early design stage of the building.

Existing Building

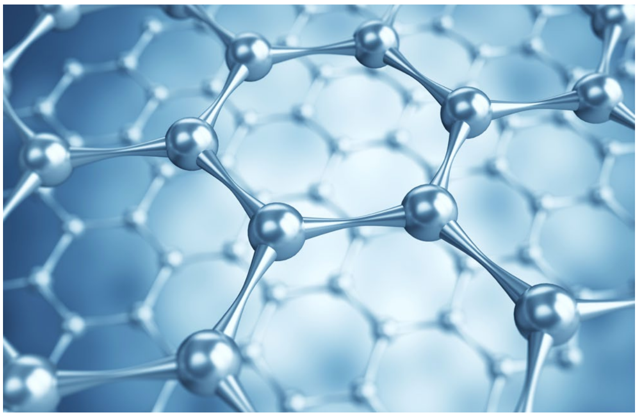
For existing buildings, replacement of the existing curtain walls would require major retrofitting works.

Cost Information

CAPEX
The price of smart window glass ranges from HKD 400 to 800 per square foot.

Remarks (if any)
Above cost information is indicative and based on 2020 figures

D.2 **Nanotechnologies**



Description

Nanotechnologies can be applied in different forms in the building material to enhance building performance and efficiency.

Common application of nanotechnologies in the building industry includes concrete, glass, thermal insulations, coating and paints, etc. Some benefits of applying nanotechnologies in the construction industry are highlighted below:

- Higher compressive strength and modulus of elasticity concrete – research shows that the addition of Silicon Dioxide (SiO_2) in concrete mixture increase the compressive strength and is able to form better transition zone inside the concrete by packing effect and chemical reactions and leading to improvements in durability;
- Self-cleaning and antibacterial coating - application of titanium dioxide (TiO_2) nanoparticles coating on glazing, interior surfaces, door handles, lift panels, etc. improves air-quality and hygiene by photocatalytic reactions and helps remove airborne pollutants such as VOCs and bacterial;
- Ultra-thin insulation – Micro and nano porous materials can be used in wall insulation which uses a hydrophobic nano porous aerogel structure. Another application of aerogels is silica-based products for transparent insulation, which leads to the possibility of super-insulating windows.

Benefits

Reducing environmental impacts

- Self-cleaning features could lead to water savings.
- Certain nanotechnologies can remove pollutants (e.g. VOCs) in the air.

Promoting better occupant wellbeing

There are a large variety of nanotechnologies now under development from self-cleaning coatings to additives for paint and concrete increasing the strength and usable life. These technologies offer a wide range of wellbeing benefits such as the ability to improve air quality under both indoor and outdoor environment.

Enhancing operational efficiencies

- Greatly reduce maintenance with pre-applied coating.
- Easy cleaning or self-cleaning.
- Reduce the need for repair and extend the building life.

Generating cost savings

The employment of nanotechnologies means that materials are longer lasting and exhibit better operational properties which means that they do not need to be replaced so frequently thereby cutting down on long term maintenance/replacement costs.

D.2 Nanotechnologies

Benchmark Cases

The Jubilee Church, Rome, Italy

Architect: Richard Meier and Partner Architects LLP
Structural engineer: Ove Arup and Partners, Italcementi Gruppo, Luigi Dell' aquila

Socar Tower, Baku, Azerbaijan

Developer: State Oil Company of The Azerbaijan Republic
Architect: Heerim Architects & Planners Co. Ltd.
Structural Engineer: Thornton Tomasetti
Main Contractor: TEKFEN Construction and Installation Co.,
Façade Consultant: ALT Limited; Permasteelisa Group

Hospital General Dr. Manuel Gea González, Mexico

Architect: Manuel Villagrán
Façade Design: Elegant Embellishments

Technology Requirements

- Depends on application to be used.

IOT | AI | ML | BT | 5G | DV | BD

Design Requirements

- It would require advance planning to incorporate the desired material in the early design stage.

Barriers/Constraints

- The real constraints are mainly related to roll out and availability of various nano technologies, as research & development is a lengthy process and requires considerable testing before certain nanotechnologies become commercially available.

Application in Building Life Cycle

PLANNING/DESIGN | CONSTRUCTION | COMMISSION | OPERATION & MAINTENANCE | DEMOLITION

Building Type

NEW BUILDING	EXISTING BUILDING
✓	✓

Ease of Implementation

New Building

Relatively easy to implement as there is little difficulty in applying nano-coating.

Existing Building

Easy to apply in existing buildings. Applications, such as TiO_2 coating can also be applied in the interior such as walls, flooring, carpets, etc. to help reduce air pollutants and improve air quality.

**This indication is only self-cleaning, anti-bacterial coatings for cleaning functions*

Cost Information

CAPEX

The cost of nano-glass coating ranges from HKD 400 to 2,500 per square meter.

Price varies based on the number of coats, product quality, and the applicator.

Remarks (if any)
Above cost information is indicative and based on 2020 figures

D.3 Automatic Waste Collection Systems

Description

Refuse from each floor of the buildings in a portfolio is drawn into a network of large (400-600 millimeters in diameter) pipes to a central facility. A negative pressure is created by the fan in the pneumatic pipes resulting in the waste being transferred at a speed of 70km/h.

The system enables automated monitoring of waste consumption, which decreases both the resources and time needed for this service.

For a fully automated system, once the waste reaches the facility, it is automatically separated and recycled, burned for energy or buried deep underground. Automatic waste recycling can also promote the circular economy concept of ‘closing the loop’ to facilitate buildings in becoming more sustainable and resilient in the future.

This system, however, has large spatial requirements, therefore would be limited to a community or district of smart buildings than be implemented for a singular building.

Odour leakage could be an issue encountered during the implementation of such system. An example of technological applications that could ease this problem is a misting system emits reactant (mixed with essential oils, plant compounds, and potable water), which converts odour compounds into non-volatile compounds.

Adequate training and communication on waste categorisation and system usage is also encouraged to avoid hygienic issues and ensure proper use of the system.

Benefits

Reducing environmental impacts

Reduce pollution typically associated with waste collection vehicles. Waste collection vehicles do not need to collect waste from different buildings/venues as they are automatically dawn into a network of large pipes to central facility for a neighbourhood.

Promoting better occupant wellbeing

Use of waste collection systems improves the safety aspects by removing the risk of accidents attributable to waste collection vehicles.

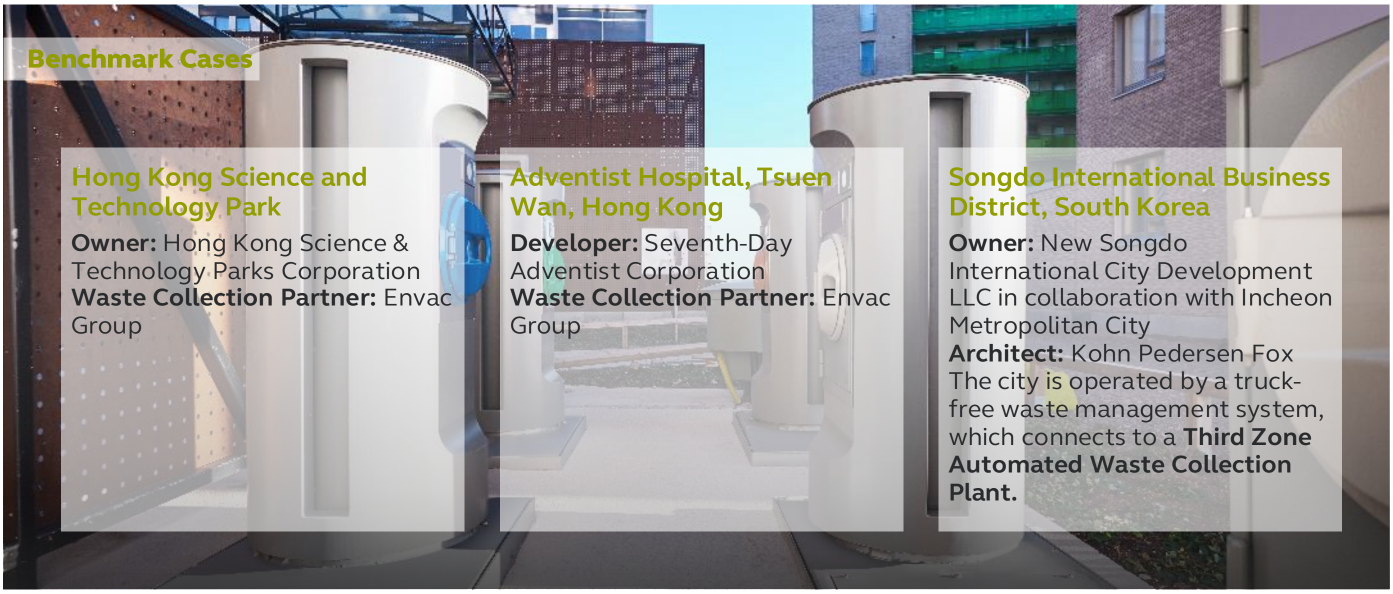
Enhancing operational efficiencies

As pipes are connected to all buildings, there is no need for the use of streetcorner trash bins or waste collection trolleys/vehicles. This reduces odour from traditional bins and enhances living environments and beautifies the area.

Generating cost savings

Potential reduction of OPEX for maintenance allows staff to focus on customer-facing experience.

D.3 Automatic Waste Collection Systems



Benchmark Cases

Hong Kong Science and Technology Park

Owner: Hong Kong Science & Technology Parks Corporation
Waste Collection Partner: Envac Group

Adventist Hospital, Tsuen Wan, Hong Kong

Developer: Seventh-Day Adventist Corporation
Waste Collection Partner: Envac Group

Songdo International Business District, South Korea

Owner: New Songdo International City Development LLC in collaboration with Incheon Metropolitan City
Architect: Kohn Pedersen Fox
The city is operated by a truck-free waste management system, which connects to a **Third Zone Automated Waste Collection Plant.**

Technology Requirements

- Typically, the system does not need a computer or software to execute control and monitoring function. Programmable Logic Controller (PLC) with control programmes will be installed on equipment control panels at various locations for the purpose.
- If Supervisory Control and Data Acquisition (SCADA) function is needed, a standard computer must be installed with a SCADA program (provided by the supplier) to control the system. If extra functions are required, a computer with appropriate software is provided by the supplier.

IOT	AI	ML	BT	5G	DV	BD

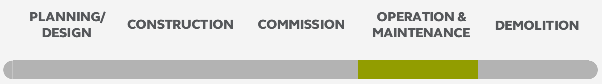
Design Requirements

- Physical infrastructure: waste inlet and a network of pipes (400-600 millimeters in diameter).
- Large physical space is also required.

Barriers/Constraints

- The system supplier is typically required to follow the master construction program. The whole planning, design and construction process typically takes 2.5 to 3 years.
- Sufficient recycling facilities downstream would be required to transport, manage and treat the waste.
- High costs associated with the system could also be a barrier to implementation.

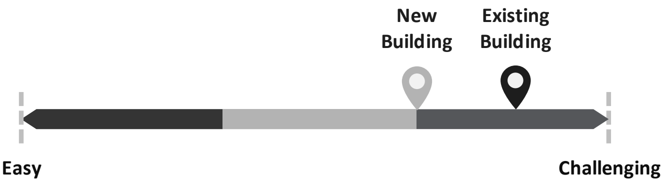
Application in Building Life Cycle



Building Type

NEW BUILDING	EXISTING BUILDING
✓	✓

Ease of Implementation



New Building

Challenging to implement due to large spatial requirements and potential hygienic issues, high costs associated with the system.

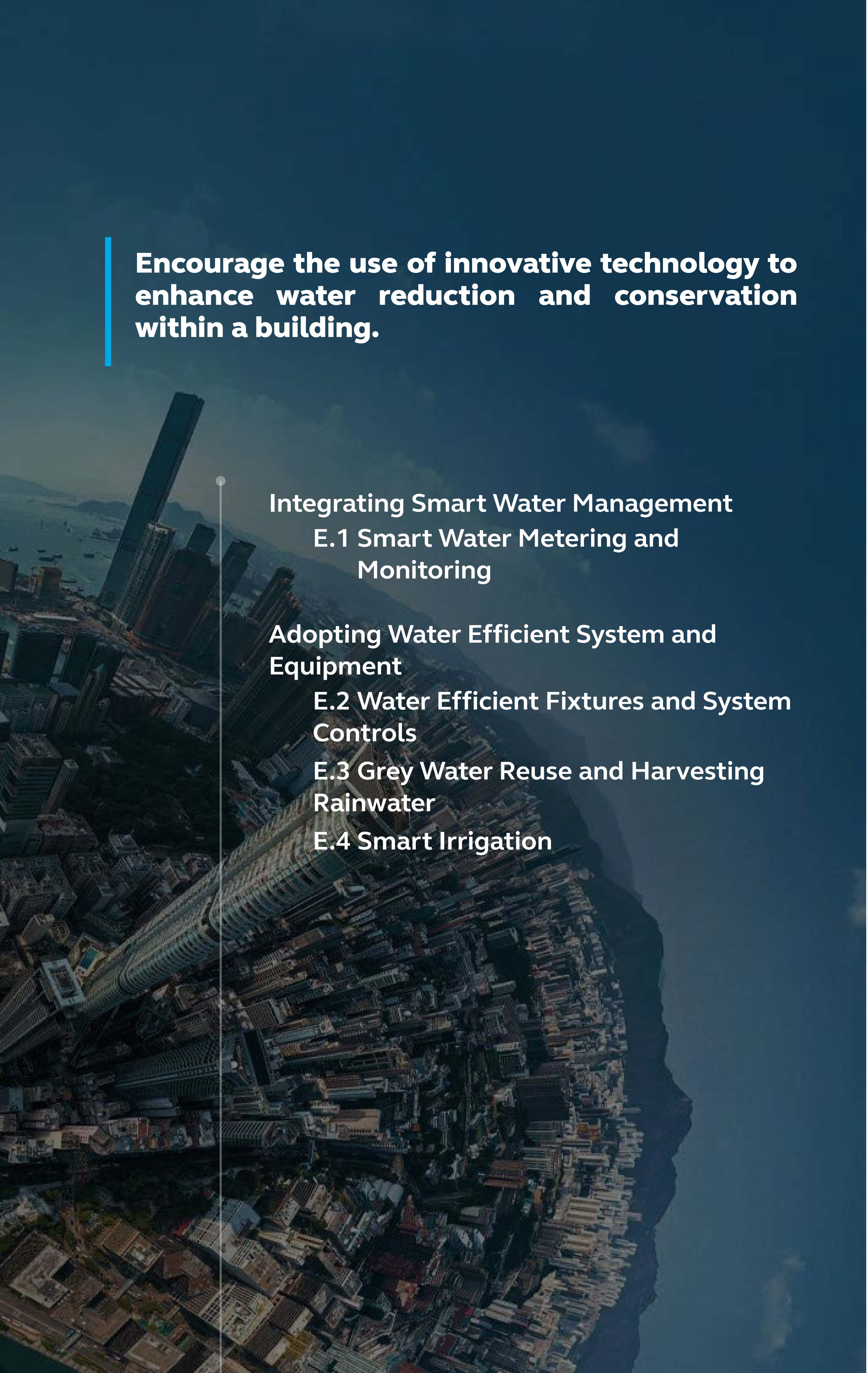
Existing Building

It would be particularly challenging for an existing building to install the full automation system on site especially covering all floors of the building. However, a downsized system may still be beneficial to the owners especially for a large estate with multiple buildings within the site.

Cost Information

CAPEX	OPEX
The installation cost is HKD 6,000 per unit 10 years ago. The inflation-adjusted price is HKD 9,000 per unit in 2018.	Operation and maintenance costs* range from HKD 35,000 to 80,000 per month for a system of normal scale, including the salary of a technician on standby for 8 hours per day.

Remarks (if any)
*Above cost information is indicative and based on 2020 figures unless specified otherwise *Electricity charge is excluded*



Encourage the use of innovative technology to enhance water reduction and conservation within a building.

E.1 Smart Water Metering and Monitoring

Description

Building development in Hong Kong should take into account Water Supplies Department's (WSD) smart water network management initiatives including implementation of Automatic Meter Reading (AMR), On-line Water Quality Monitoring, and Leak Detection (more applicable on a district level).

Smart water meters in the building help to measure water consumption by users and areas (e.g. cooling towers, toilets, kitchens, etc.), leakage detection, and quality monitoring, which are key to facility management and for driving sustainability initiatives.

Smart water meters can monitor as well as relay information within building level and also at neighbourhood level, in terms of providing real-time information on quantity and quality of water usage.

Below is a list of the latest standards/certifications relevant to smart water meters for reference:

- ASHRAE. (2017). Standard 189.1 – Standard for the Design of High-Performance Green Buildings
- WSD. (2017). Standard Specification E-89-01 AMR Outstation

Benefits

Reducing environmental impacts

Using water meters will promote water conservation by provision of timely water consumption information and patterns via internet and mobile application.
Support the identification of leaks and abnormal usage by analysing substantial changes in water usage patterns in high granularity in daily/ hourly or minutes intervals.

Promoting better occupant wellbeing

Water meters can raise a red flag and immediately detect water quality issues that can impact health risk due to water contamination such as high lead contamination in drinking water.

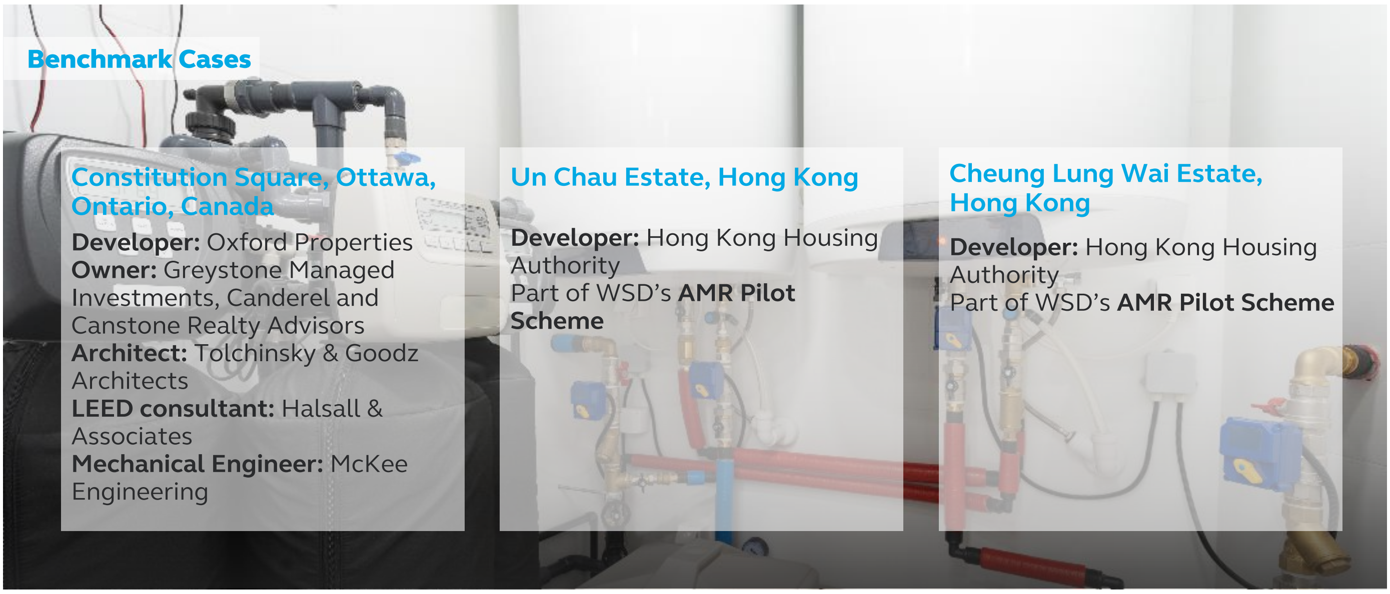
Enhancing operational efficiencies

Improve meter reading efficiency (e.g. automatic reading of water meters and reduce human error). Detection of abnormal water consumption (e.g. leakage of piping) that may result in building services system downtime and ultimately lower operational interruptions.

Generating cost savings

Operational cost saving from reduced water consumption as benefit from early detection of leakage and abnormal water usage.

E.1 Smart Water Metering and Monitoring



Benchmark Cases

Constitution Square, Ottawa, Ontario, Canada

Developer: Oxford Properties
Owner: Greystone Managed Investments, Canderel and Canstone Realty Advisors
Architect: Tolchinsky & Goodz Architects
LEED consultant: Halsall & Associates
Mechanical Engineer: McKee Engineering

Un Chau Estate, Hong Kong

Developer: Hong Kong Housing Authority
Part of WSD's **AMR Pilot Scheme**

Cheung Lung Wai Estate, Hong Kong

Developer: Hong Kong Housing Authority
Part of WSD's **AMR Pilot Scheme**

Technology Requirements

- Wired/wireless connection with accepted protocol to the network for recording and storing meter readings and transmitting data. Consideration needs to be given to data rate, power consumption, transmission range, etc.
- Inline hydropower harnessing devices may be required for meters installed at remote or inaccessible locations or where power supply is not readily available.

IOT AI ML BT 5G DV BD

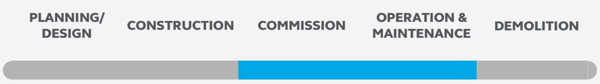
Design Requirements

- Identification of major water consumers and key parameters for management (e.g. flow rate for leakage and consumption monitoring, and water quality for potable use.) Meters should be deployed at strategic locations.
- Detailed meter design shall follow WSD's Standard Requirement for Supply and Installation of AMR Outstation.

Barriers/Constraints

- Traditionally meters are owned by utility company and obligation to maintain the meters are also under them.
- Privacy concerns pertaining to the sharing of data.

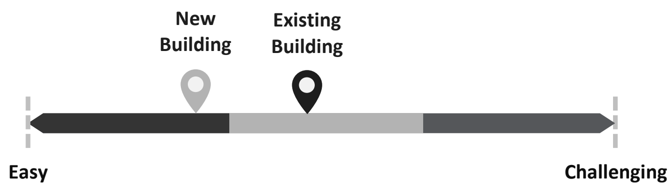
Application in Building Life Cycle



Building Type

NEW BUILDING	EXISTING BUILDING
✓	✓

Ease of Implementation



New Building

Basic requirement applies for WSD's AMR initiatives, which can be incorporated from new design. Detailed metering within buildings can be incorporated from the beginning of the system design.

Existing Building

Basic requirement applies for WSD's AMR initiatives which should be easily incorporated with small scale modification work.
Detailed metering within buildings should be carefully planned and managed with higher risk to the existing water system depending on the age and conditions.

Cost Information

CAPEX
Ultrasonic flow meter costs HKD 6,000 to 10,000 per piece. PH & water analysis meters costs HKD 2,000 to 3,000 per piece.*

Remarks (if any)
Above cost information is indicative and based on 2020 figures
** This does not include any wiring or labour costs associated with the installation*

E.2 Water Efficient Fixture and System Controls

Description

Water conservation strategies include solutions that reduce potable water usage in amenities and centralised building services.

Strategies for amenities include efficient showerhead, motion sensing urinal, dual flush toilet, reduced flush toilet (6 litres per flush), low flow faucets, water-efficient dish washer and washing machines, and supply shut off by motion detectors or doors sensors. Recent technology has improved dual flush performance with use of sensors to monitor and vary flush volume depending on the length of time the user is seated on the seat. User behaviour is also key to adopting these strategies. For instance, the desired benefits of dual flush toilets are only achieved when the reduced flush button is pressed for liquid waste and avoid flushing unnecessarily. Users should refer to water conservation solutions that have achieved industry standards or labels, such as Water Efficiency Labelling Scheme (WELS).

Strategies for centralised building services include cooling tower make up water control by total dissolved solids, boiler blow-down controls by total dissolved solids, steam condensate reuse, and steam traps maintenance.

Water conservation is being increasingly promoted in new government buildings through the installation of water saving devices, such as water-efficient taps, toilet/lavatory equipment, urinal equipment, showers and washing machines. Installation of such devices are also being retrofitted into existing buildings, where possible and applicable.

Below is a list of the latest standards/certifications relevant to water efficient fixtures for reference:

- ASHRAE. (2017). Standard 189.1 – Standard for the Design of High-Performance Green Buildings
- WSD. (2020). Particular guidelines and examples of recommended applications of water saving /water-efficient devices to be used in government projects
- WSD - WEL Scheme

Benefits

Reducing environmental impacts

Reducing water usage reduces the energy required to process and deliver it to homes, businesses, farms, and communities, which, in turn, helps to reduce pollution and conserve fuel resources.

Generating cost savings

Water conservation strategies reduces water and wastewater treatment costs and the amount of energy used to treat, pump, and heat water.

E.2 Water Efficient Fixture and System Controls

Benchmark Cases

Qianhai CTF Finance Tower, China

Developer: New World China Land Limited

Salesforce Tower, San Francisco, U.S.

Owner: TaiKoo Hui (Guangzhou) Development Company Limited
Developer: Guangzhou Da Yang Properties, Swire Properties Limited
Architect: Arquitectonica; Guangzhou Design Institute
MEP Engineer: Meinhardt

Zero Carbon Building, Hong Kong

Owner: Construction Industry Council
Architect: Ronald Lu & Partners (Hong Kong) Limited
Project Manager: AECOM Asia Company Limited
M&E / C&S engineer: Ove Arup & Partners Hong Kong Limited
Main Contractor: Gammon Construction Limited

Technology Requirements

- Sensors required to operate smart equipment such as low flow faucets and showerheads, motion detected urinals are a key technological requirement.
- Utilise amenities based on detailed list rating manufacturers and products on water-efficiency (e.g. WELS by WSD).

IOT	AI	ML	BT	5G	DV	BD

Design Requirements

- Design controls for centralised building services (e.g. cooling towers, boilers, etc.) according to industrial standards, such as ASHRAE and CIBSE design guideline.

Barriers/Constraints

- There are no major barriers/constraints for the implementation of water conservation strategies.

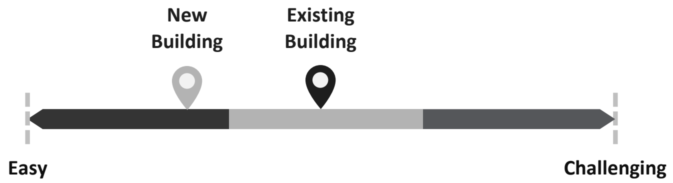
Application in Building Life Cycle

PLANNING/ DESIGN | CONSTRUCTION | COMMISSION | OPERATION & MAINTENANCE | DEMOLITION

Building Type

NEW BUILDING	EXISTING BUILDING
✔	✔

Ease of Implementation



New Building

Relatively easy to be incorporated as part of the centralised building services controls during design stage.

Existing Building

Typically involve modifications works on the amenities or installation/upgrade works on centralised building services controls.

Cost Information

CAPEX

The following are the costs of relevant equipment:
- Faucet*: HKD 4,500 - 8,000
- Toilet sensor: HKD 8,000 - 10,000
- Dual flush toilet: HKD 4,000 - 33,000
- Low flow urinal: HKD 5,000 - 10,000
- Urinal sensor: HKD $2,000 - 3,000

Remarks (if any)
Above cost information is indicative and based on 2020 figures
The above figures are based on Hong Kong Dollars (HKD)
**Equipped with sensor control and self-powered by hydro generator*

E.3 Grey Water Reuse and Harvesting Rainwater

Description

Various strategies can support the reduction of potable water usage and promote water reuse, including rainwater harvesting through building collection system or porous asphalt on pavement, greywater treatment and recycling from baths, washbasins and kitchen sinks, and AHU condensate recycling for non-potable use, such as irrigation, toilet flushing, boiler and cooling tower make up, heat reduction, street cleansing, water features, etc.

Grey water reuse and rainwater harvesting system should be designed in a way that ensures the effluent is fit for purpose and presents no undue risk to health. Adherence to WSD's Technical Specifications on Grey Water Reuse and Rainwater Harvesting (2015) is important during the design of the storage and treatment systems to avoid microbiological growth and bacteria proliferation, and that the treated effluent meets the water quality standards stipulated in the specifications. There are several types of treatments with the most common being chlorination, boiling, filtration and exposure to ultraviolet or natural sunlight. Regular inspection and cleaning of catchment, gutters, filters and tanks reduce the likelihood of contamination is also essential.

Emerging technology, such as closed-loop shower based on instant recycling of water can also help save energy for water heating.

Below is a list of the latest standards/certifications relevant to grey water reuse and rainwater harvesting for reference:

- ASHRAE. (2017). Standard for the Design of High-Performance Green Buildings
- WSD. (2015). Technical Specifications on Grey Water Reuse and Rainwater Harvesting, 1st Edition

Benefits

Reducing environmental impacts

- Strategies like water reuse and recycling help to prepare for the challenges of climate change and increasing demand for fresh water. Alternatives for water sources which are less susceptible to climate change should be explored.
- It also reduces the wastewater discharge to the environment.

Enhancing operational efficiencies

Reduction on potable water usage from utility, reduces the energy use by water treatment and pumping.

Generating cost savings

Potential cost savings from the reduction of water usage from utility supply which could also help reduce management fees.

E.3 Grey Water Reuse and Harvesting Rainwater

Benchmark Cases

Zero Carbon Building, Hong Kong

Owner: Construction Industry Council
Architect: Ronald Lu & Partners (Hong Kong) Limited
Project Manager: AECOM Asia Company Limited
M&E/C&S Engineer: Ove Arup & Partners Hong Kong Limited
Main Contractor: Gammon Construction Limited

Salesforce Tower, San Francisco, U.S.

Owner/Developer: Hines Interests LP; Boston Properties, Inc.
Architect: Pelli Clarke Pelli Architects; Kendall / Heaton Associates
Structural Engineer: Magnusson Klemencic Associates
MEP Engineer: WSP

Electrical and Mechanical Services Department (EMSD) Headquarters, Hong Kong

Developer/Owner/Facility Management: EMSD
Architect/Planner: BLEND Architecture Limited
Project Manager: EMSD
Sustainable Design Consultant: Ove Arup & Partners Hong Kong
Environmental Consultant: EBS Consultants; Langan Engineering

Technology Requirements

- Sensors required to operate reuse and recycling strategies are a key technological requirement.

IOT	AI	ML	BT	5G	DV	BD

Design Requirements

- Depending on the water reuse & recycling strategies, it may impact the architectural, water supply schematic, plumbing & drainage schematic, HVAC equipment design and controls, as well as toilet and kitchen-ware design, hence an integrated design within all the aspects of building is required.

Barriers/Constraints

- Spatial constraints may be encountered for the installation water reuse and recycling facilities (e.g., there may not be enough space to install a water tank on the roof especially for existing buildings)

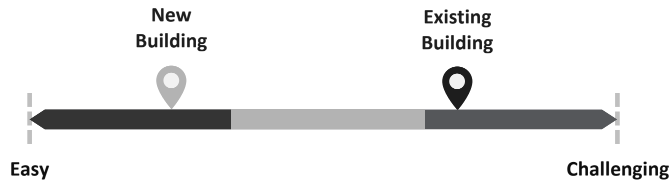
Application in Building Life Cycle

PLANNING/ DESIGN | CONSTRUCTION | COMMISSION | OPERATION & MAINTENANCE | DEMOLITION

Building Type

NEW BUILDING	EXISTING BUILDING
✓	✓

Ease of Implementation



New Building

Relatively easy to implement in new buildings provided that the relevant facilities are considered and incorporated during the design stage.

Existing Building

Challenging for existing buildings since it requires a large amount of space on the roof level for the installation of water tanks.

Cost Information

CAPEX
In the UK, the cost of equipment for a rainwater harvesting system can vary between £2,000 to 3,000 for an average sized family home (equivalent to HKD 20,500 to 30,800).

Remarks (if any)
Above cost information is indicative and based on 2020 figures

E.4 Smart Irrigation

Description

Smart irrigation systems tailor watering schedules and run times automatically to meet specific large-scale landscape needs (e.g. large park in residential development). These controllers significantly improve outdoor water use efficiencies. Unlike traditional irrigation controllers that operate on a pre-set programmed schedule and timers, smart irrigation controllers monitor weather, soil conditions, evaporation and plant water use to automatically adjust the watering schedule to actual conditions of the site, thereby reducing the overall consumption of water.

The appropriate location of the smart irrigation equipment would be critical since the system is exposed in outdoor constantly. Its location should minimise opportunities for unintentional damage or vandalism. Concrete pads and cages can be installed to protect the equipment.

Benefits

Reducing environmental impacts

Reduction on outdoor water usage from utility, hence also reducing the energy use by water treatment and pumping thereby leading to less usage of water reducing the overall environmental impacts.

Enhancing operational efficiencies

Improve meter reading efficiency (e.g. automatic reading of water meters and reduced human error). Detection of abnormal water consumption (e.g. leakage of piping) that may result in building services system downtime and ultimately lower operational interruptions.

Generating cost savings

Cost savings from the reduction of outdoor water consumption almost by 50%.

E.4 **Smart Irrigation**

Benchmark Cases

Qianhai CTF Finance Tower, China

Developer: New World China Land Limited

The Crystal, London

Developer/Owner: Siemens
Architect: WilkinsonEyre Architects; PerkinsWill
Main contractor: ISG
Project Manager: Turner & Townsend

Duke Energy Center, Charlotte, North Carolina, U.S.

Owner: Wells Fargo
Developer: Wells Fargo; Childress Klein
Project Manager: Childress Klein
Architect: tvsdesign

Technology Requirements

- Selection between 2 types of smart irrigation controllers: weather-based and on-site soil moisture sensors.
- Weather-based controllers use local weather data to adjust irrigation schedules. These controllers gather local weather information and make irrigation run-time adjustments, so the landscape receives the appropriate amount of water.
- Soil moisture sensor-based smart irrigation controllers use technologies to measure soil moisture content. When buried in the root zone of turf, trees or shrubs, the sensors accurately determine the moisture level in the soil and transmit this reading to the controller.
- Mobile applications enable remote control of irrigation system.

IOT | AI | ML | BT | 5G | DV | BD

Design Requirements

- No specific design requirements.

Barriers/Constraints

- No specific barriers/constraints.

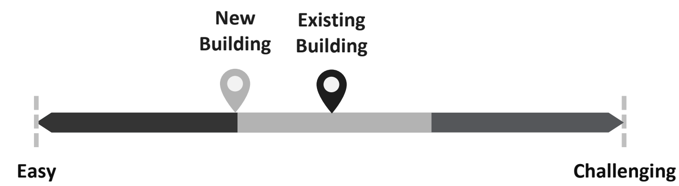
Application in Building Life Cycle

PLANNING/ DESIGN | CONSTRUCTION | COMMISSION | OPERATION & MAINTENANCE | DEMOLITION

Building Type

NEW BUILDING	EXISTING BUILDING
✓	✓

Ease of Implementation



New Building

Implementation is relatively easy in new buildings. Consideration should be given to the installation of proprietary system with sensors and controller.

Existing Building

Implementation is more difficult for existing buildings, as more effort is required to integrate sensors and controller with existing systems and landscape.

Cost Information

CAPEX
A commercial water monitoring and controller system for a hypothetical 100,000 square-foot office building costs between approx. HKD 54,000 to 93,000.

Remarks (if any)
Above cost information is indicative and based on 2020 figures

Innovative methods promoting green modes of transport and mobility with less carbon footprint.

Smart mobility strategies within the building and its surrounding built environment for efficient/ environmentally friendly use of space and resources.

- F.1 Smart Green Parking
- F.2 Intelligent People Flow
- F.3 Autonomous Vehicles

F.1 Smart Green Parking

Description

Smart parking includes use of automated parking applications and technologies to efficiently manage parking spaces within a building. Features include:

- Horizontal/vertical automated parking systems, which can optimise the space utilisation of parking spaces and enhance user convenience by helping drivers to park their cars automatically;
- Real time tracking of parking availability with the installation of occupancy sensors and presented in smartphone application for user convenience;
- Management of parking options by smartphone applications, which include various functions to enhance the user experience, such as pre-booking parking spaces to minimise traffic searching for vacant spaces, fee payment, automated vehicle retrieval, and providing information on real-time location and status of EV charging stations; and
- NFC or RFID technology can also be integrated into the overall parking system to enhance operational efficiency and user convenience.

There is also a growing trend of the adoption of EV charging stations for charging of EV vehicles and PHEVs.

In terms of on-street parking, the Government has been rolling out on-street smart parking meters since early 2021, as one of their latest smart mobility initiatives. Features include contactless payment, use of sensors for real-time availability of parking spaces, and supporting mobile app “HKeMeter” with remote payment functions.

Benefits

Reducing environmental impacts

Less navigation and travelling times reduce emissions by cars and lower consumption of fossil fuels. Ultimately, less pollution will be created.
EV charging provides fast charging stations and metering at designated locations within the car park. This will promote use of more EV vehicles which are environmentally friendly and more sustainable.

Promoting better occupant wellbeing

Due to smart applications of finding car parking and smart parking systems using robots, there will be less pollution and emission of gases. This would impact the indoor and outdoor air quality and help in overall user well-being.

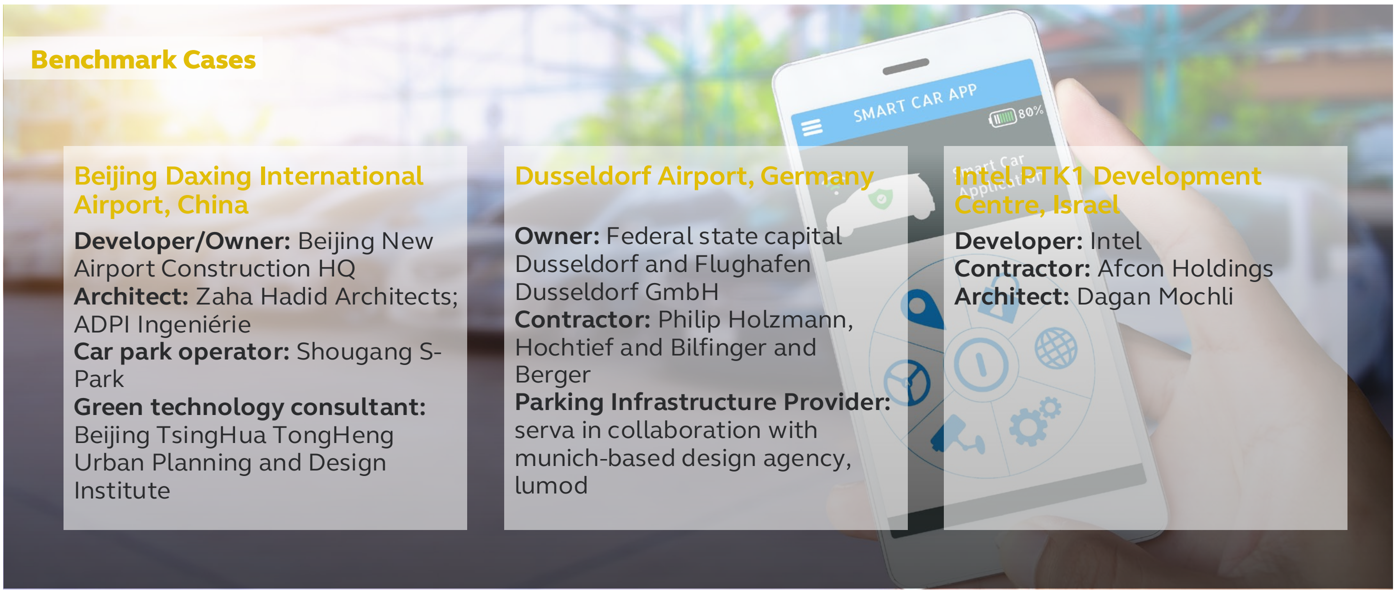
Enhancing operational efficiencies

Automated car parking systems can help to achieve approx. 50% extra car parking spaces and also optimise the design and maintenance of the parking space, due to absence of human interface. Also, mobile car space reservation and access control via smartphone application will help to respond to a driver's request for a parking spot, controlling access to vacant parking spaces.

Generating cost savings

With use smart horizontal and vertical parking systems more cars can be parked in the same space.

F.1 Smart Green Parking



Benchmark Cases

Beijing Daxing International Airport, China

Developer/Owner: Beijing New Airport Construction HQ
Architect: Zaha Hadid Architects; ADPI Ingeniérie
Car park operator: Shougang S-Park
Green technology consultant: Beijing TsingHua TongHeng Urban Planning and Design Institute

Dusseldorf Airport, Germany

Owner: Federal state capital Dusseldorf and Flughafen Dusseldorf GmbH
Contractor: Philip Holzmann, Hochtief and Bilfinger and Berger
Parking Infrastructure Provider: serva in collaboration with munich-based design agency, lumod

Intel PTK1 Development Centre, Israel

Developer: Intel
Contractor: Afcon Holdings
Architect: Dagan Mochli

Technology Requirements

- With the use of smartphone application, parking space can be reserved, paid for, and an e-ticket can be obtained. It also allows for customised pickup and retrieval times for the car as well as viewing the map of the carpark and its surroundings. Integration with existing apps and systems is also possible.
- The car is measured with a 3D laser scan where the robot adjusts to the size of the car during approach and picks it up. The transfer station has a drive-in assistant, check-in column, 360° camera system and also license plate recognition to identify registered customers automatically. A control centre is also required to coordinate operations centrally.

IOT	AI	ML	BT	5G	DV	BD

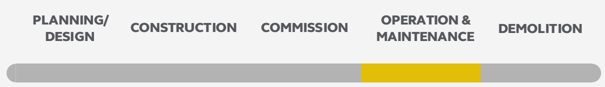
Design Requirements

- A typical vertical parking system would require 3.5 - 4.4 meters floor-to-floor. A spacious transfer station of about 4x7 m would be required in the design, from where the car is lifted by a forklift or a robot. For every 100 car parks 3-4 transfer stations and robots are needed. Every 40 parking spaces take up 709 m² of space, including robot lane.

Barriers/Constraints

- Stringent statutory processes are required to install smart parking facilities, such as approvals from Buildings Department, Transport Department, lease modifications, and Section 12 and/or 16 Planning Applications.

Application in Building Life Cycle



Building Type

NEW BUILDING	EXISTING BUILDING
✓	✓

Ease of Implementation

New Building

It is relatively easy to install and plan for smart parking systems in a new development since planning can be undertaken from the initial design stages.

Existing Building

It would be more challenging for existing buildings since this solution requires minimum height requirements, which may be hard to achieve in existing buildings.

Cost Information

CAPEX	OPEX
A parking space with 900 spaces typically costs HKD 160 million (HKD 180,000 per space).	Maintenance cost ranges from HKD 155 to 195 per space for each month.

Remarks (if any)
Above cost information is indicative and based on 2020 figures

F.2 **Intelligent People Flow**

Description

Intelligent people flow solutions aim to create a seamless user experience from the front door to destination. Through the use of IoT, AI and other advanced technologies, intelligent people flow enables elevators and doors to do the following:

- Predictive call entry: based on previous time and date usage patterns, each passenger can choose from a list of his or her most frequently selected destinations.
- Automatic call entry: each elevator terminal is equipped with an RFID sensor, when a passenger scans a pre-programmed RFID card, the system can verify the passenger's credentials and automatically call an elevator to transport that person to an authorised floor/required destination.
- Contextual operation: on floors above the lobby, a display can be programmed to show only the floors that are relevant to the passengers of those floors.
- Operated via smartphone-based service: for personal mobility, a smartphone application can control building doors and allow the user to automatically call an elevator to take them to their destination. This can eliminate the need to carry physical keys.

Benefits

Reducing environmental impacts

Intelligent people flow solutions may offer a mode which allows intelligent reduction of the elevators' energy consumption. Unrequired elevators will be placed into a low energy consumption state. Due to the reduced number of trips and improved balancing of elevators, energy will be saved.

Promoting better occupant wellbeing

Intelligent people flow can provide extra convenience, comfort and security to building users by connecting building access, elevators, and intercom systems (for homeowners and tenants) via smartphone application. Building users will have an improved ride experience, and seamless travel through a building.

Enhancing operational efficiencies

Productivity of elevators will be increased, and passenger traffic will be managed in the most efficient way possible. Even during heavy traffic conditions, the system will operate elevator groups in the most highly optimised way, improving people flow. Such a system can create up to 50% improvement in wait and destination times, and handling capacity.

Generating cost savings

As intelligent people flow technology can reduce energy consumption, it lowers energy costs. With the reduced number of elevator trips, the amount of energy saved in a day can be substantial.

F.2 **Intelligent People Flow**

Benchmark Cases

Tencent Headquarters, Shenzhen

Owner: Tencent Technology Company Limited
Architect: NBBJ; Tongji Architectural Design (Group) Co., Ltd; Shenzhen Tongji Architects
Elevator Supplier: Schindler
Main contractor: China Construction Second Engineering Bureau Ltd.

A'DAM, Amsterdam, Netherlands

Developer: Lingotto; Sander Groet; Duncan Stutterheim; Hans Brouwer
Elevator Supplier: KONE
Architect: Felix Claus en Dick Van Wageningen Architecten; Oever Zaaijer & Partners

Capital Bank Plaza, North Carolina, USA

Architect: G. Milton Small; Emery Roth & Sons
Elevator Supplier: Schindler Elevator Corporation

Technology Requirements

- Software and hardware are required. Software is necessary for access-control features, elevator-related features, building door interface, and management tools. The hardware required will be RFID card readers, and touchscreen destination operating panels.
- A smart phone app may also be used to enable personal mobility.

IOT | AI | ML | BT | 5G | DV | BD

Design Requirements

- No specific design requirements.

Barriers/Constraints

- No specific barriers/constraints.

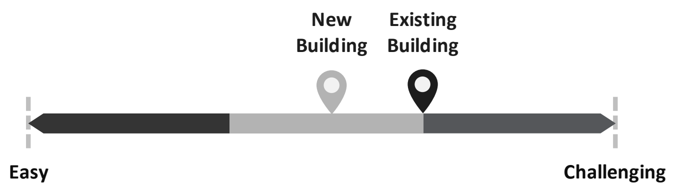
Application in Building Life Cycle

PLANNING/ DESIGN | CONSTRUCTION | COMMISSION | OPERATION & MAINTENANCE | DEMOLITION

Building Type

NEW BUILDING	EXISTING BUILDING
✓	✓

Ease of Implementation



New Building

Implementation of intelligent people flow is moderately easy in a new building, if ample planning is undertaken during the initial design stages.

Existing Building

It can be moderately challenging since this solution is unique to each building and will require a study to determine the building's needs. Retrofitting to existing structures may be required.

Cost Information

CAPEX
The installation cost of a smart elevator ranges from HKD 500,700 to 600,000, depending on the location and site environment.

Remarks (if any)
Above cost information is indicative and based on 2020 figures

F.3 Autonomous Vehicles

Description

Autonomous vehicles are small pods meant for public transportation, travelling short to medium distances. Autonomous vehicles are generally sized for individual or small group travel, typically carrying not more than ten passengers per vehicle. They are on-demand transport which allows quick point-to-point travel, bypassing all unnecessary stops. Autonomous vehicles can be used separately or attached (same destination or route) depending on the design of the pod that will be used.

Autonomous vehicles are electrically powered and can be charged at a fixed charging point while awaiting usage.

For implementation of autonomous vehicles, a designated defined area (such as a large community/ development area) with a dedicated lane is required.

Benefits

Reducing environmental impacts

Autonomous vehicles do not require use fossil fuels and thereby provide a clean mode of transportation. They reduce energy consumption and with re-designed computerised systems, they can also choose the most fuel-efficient routes and travel faster.

Promoting better occupant wellbeing

With the use of driverless vehicles, potential accidents caused by humans lowers significantly making it safer and reliable mode of transportation.

Enhancing operational efficiencies

Autonomous vehicles can provide quick point-to-point travel and can replace shuttle bus services typically operated by larger developments.

Generating cost savings

By adopting autonomous vehicles, potential cost savings can generate from reduced manual labour and cancellation of shuttle bus services.

F.3 Autonomous Vehicles

Benchmark Cases

West Kowloon Cultural District, Hong Kong

Owner: West Kowloon Cultural District Authority
Autonomous Vehicle Provider: NAVYA

Masdar City, Abu Dhabi

Developer: Masdar, a subsidiary of the Mubadala Development Company
Autonomous Vehicle Provider: NAVYA

Nanyang Technological University , Singapore

Autonomous Vehicle Provider: NTU Singapore and Volvo in partnership with Land Transport Authority

Technology Requirements

- Typically, an autonomous vehicle has the following features:
  - Light Detection and Ranging (LIDAR) sensors to detect objects
  - Cameras to detect objects
  - GPS for navigation
  - A smartphone application for user interface, such as booking autonomous vehicles on demand

IOT	AI	ML	BT	5G	DV	BD

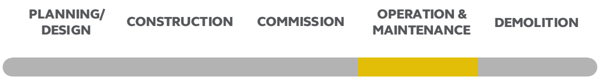
Design Requirements

- The dimensions of autonomous vehicles differ but typically have a width of 2 to 2.2 meters. This requires the vehicles to have a lane width of at least 4.5 meters, meaning 9 meters for traffic in both directions. The minimum turning radius is 4.5-5 meters.
- As for parking, space is required to house the autonomous vehicles overnight, carry out maintenance, cleaning and to charge/replace the battery. A cartridge system can be used, meaning that one battery is being charged and the other is being used in the vehicle. Typically, autonomous vehicles are 2 by 4 – 6 meters, so about 11 square meters is required to house one unit.

Barriers/Constraints

- Legislation for autonomous vehicles is currently under development. Transport Department currently grants trials for autonomous vehicles on a case-by-case basis. Hence, also due to safety concerns, pilot trials to full implementation may be a lengthy process.
- However, under the current Hong Kong Smart City Blueprint, autonomous vehicles have been identified as priority initiative and guidance notes on application of relevant permits and trials are available, including Transport Department's Guidance Notes on the Trials of Autonomous Vehicles (December 2019).

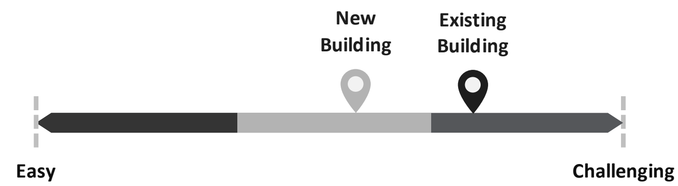
Application in Building Life Cycle



Building Type

NEW BUILDING	EXISTING BUILDING
✓	✓

Ease of Implementation



New Building

Provided a dedicated lane and adequate space has been planned during design stage, it is moderately easy to implement.

Existing Building

It is more challenging to implement in an existing development, as it would require changes to the master planning as sufficient space is needed.

Cost Information

CAPEX	OPEX
Unit cost of an autonomous vehicle with a 15-person capacity is approximately HKD 2 million. However, this varies depending on the capacity required and product supplier.	Maintenance cost of an autonomous vehicle with a 15-person capacity is approximately HKD 84,000 per month. However, this varies depending on the capacity required and operator.

Remarks (if any)
Above cost information is indicative and based on 2020 figures

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Consultant Team

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Arcadis Consultancy Hong Kong Limited

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Construction Industry Council

HKGBC Steering Committee of Hong Kong Smart Green Building Design Best Practice Guidebook:
Dr Benny CHOW (Convenor) – Aedas Ltd.
Dr Paul HO – City University of Hong Kong
Ir Raymond CHAN – New World Development Co., Ltd.
Ir Dr Vincent CHENG – Ove Arup & Partners Hong Kong Ltd.
Ir Ivan LAW – Lik Kai Engineering Co., Ltd.
Ms Jasmine LEE – Schneider Electric (Hong Kong) Ltd.
Mr Kevin NG – Henderson Land Development Co., Ltd.
Mr Andy YEUNG – Hongkong Land (Property Management) Ltd.
Mr Kenneth YUEN – Schneider Electric (Hong Kong) Ltd.
Sr WONG Bay – The University of Hong Kong

HKGBC Industry Standards & Practices Committee (ISPC):
Mr Donald CHOI (HKGBC Director cum ISPC Chairman) – Chinachem Group
Mr Eric POON (HKGBC Director cum ISPC Vice Chairman) – Urban Renewal Authority
Ir Dr Vincent CHENG (HKGBC Director) – Ove Arup & Partners Hong Kong Ltd.
Ir Eric CHEUNG (HKGBC Director) – CLP Power Hong Kong Ltd.
Dr Paul HO (HKGBC Director) – City University of Hong Kong
Mr Tony IP (HKGBC Director) – Tony Ip Green Architects Ltd.
Mr LI Ho-kin (HKGBC Director)
Dr Raymond YAU (HKGBC Director) – Swire Properties Ltd.
Mr Andy YEUNG (HKGBC Director) – Hongkong Land (Property Management) Ltd.
Mr Dave CHAN – ATAL Building Services Engineering Ltd.
Mr Eugene CHING – The Hong Kong Institute of Architects
Mr Ivan CHIU – Gammon Construction Ltd.
Dr Benny CHOW – Aedas Ltd.
Mr Jimmy LAM – Hong Kong Baptist University
Ir Ivan LAW – Lik Kai Engineering Company Ltd.
Mr Samson LEONG – Intertek Testing Services Hong Kong Ltd.
Ms SO Ching – The Association of Architectural Practices Ltd.
Miss Jasmine LEE – Schneider Electric (Hong Kong) Ltd.

Mr Alexander PONG – Shiu Wing Steel Ltd.

Advisors:
Mr Laurence KWAN – Architectural Services Department
Mr Arthur LEE – Electrical & Mechanical Services Department
Ms Rachel LEUNG – Hong Kong Housing Authority
Mr Gary YIP – Water Supplies Department

Ex - HKGBC Industry Standards & Practices Committee (ISPC):
Ir Antonio CHAN – REC Engineering Co. Ltd.
Ir Raymond CHAN – New World Development Company Ltd.
Ir Victor CHEUNG – J.Roger Preston Ltd.
Mr Stephen LEE – MTR Corporation Ltd.
Mr LEUNG Man-kit – Ronald Lu & Partners (Hong Kong) Ltd.
Mr Kevin NG – Henderson Land Development Company Ltd.
Ir Edward PONG – Shiu Wing Steel Ltd.
Sr Frankie SO
Sr WONG Bay – The University of Hong Kong
Mr Jonathan YAU – Cundall Hong Kong Ltd.
Mr Kenneth YUEN – Schneider Electric (Hong Kong) Ltd.

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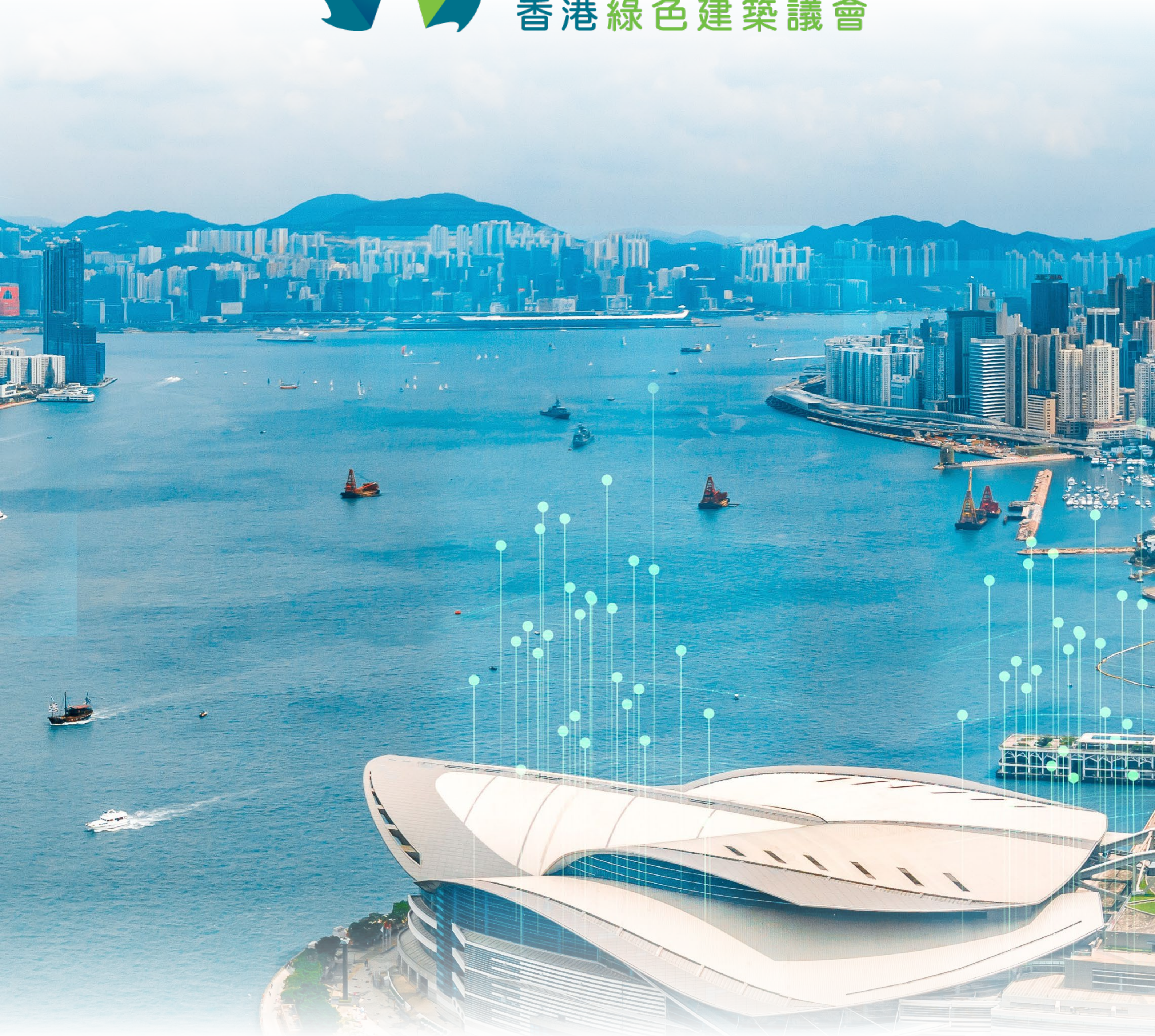

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T: +852 3994 8888

E: enquiry@hkgbc.org.hk

W: www.hkgbc.org.hk