International Commerce Centre

2019 ESCI Best Practices Awards Program
Smart Building – Low Energy Buildings Network

No.1 Austin Road West, Hong Kong
Content

ICC
- Background Information

Strategy
- Innovativeness
- Inspiration
- Clearness

Measure
- Practicability
- Replicability
- Cost-effectiveness
- Consistency

Performance
- Completeness
- Verifiability
- Impact
Section 1

Background Information
Sun Hung Kai Properties Limited ("SHKP") was publicly listed in 1972 and is now one of the largest property companies in Hong Kong. The Group also has complementary operations in the following property related fields: Hotels, Construction, Insurance and Mortgage services. SHKP embraces corporate social responsibility by respecting its staff, the environment and society at large. It has clear green policies for sustainable development in its operations to conserve resources for future generations.
As stated in SHKP Sustainability Report, the energy reduction target of ICC is 15% by 2021 with 2015 as base year.
Kai Shing Management Services Limited

Kai Shing Management Services Limited (Kai Shing), a member of Sun Hung Kai Properties, was established in 1978. It currently manages over a hundred million square feet of properties including A-grade commercial buildings, large-scale shopping malls, premium residences, large-scale residence estates, commerce and trade buildings, HOS estates, and clubhouse and leisure facilities management across Hong Kong, Kowloon and the New Territories. Kai Shing is one of the largest property management organizations in Hong Kong.
International Commerce Centre

Vision: Harbour Gateway
Location: Central’s extension

Part 1 Background Information
International Commerce Centre

1st in Hong Kong, 11th tallest in the world

2.5 million square feet of office space, 98% occupied

Source: CTBUH
Connectivity – Union Square

Part 1 Background Information

Key Information
- Two MTR Stations Nearby:
  - Austin Station
  - Kowloon Station
- Guangzhou-Shenzhen-Hong Kong Express Rail Link (XRL)
  - West Kowloon Station

All are within **15 minutes** walking distance from ICC
Connectivity – Guangzhou-Shenzhen-Hong Kong Express Rail Link (XRL)

Key Information

- Service commencement date: 23 September 2018
- Estimated daily traffic: 109,200 passengers
- Route Length: Approximately 26 km in Hong Kong
- Direct Links offered: 44 mainland cities
Part 1 Background Information

Connectivity - West Kowloon Cultural District (WKCD)

5 minutes walking distance from ICC
Building Information

- Location: 1 Austin Road West, Kowloon, HK
- Floors: 118-storey
- Height: 490m (1st in Hong Kong)
- Construction period: 2002-2011
- Phases of occupation:
  Zone 1 & 2 - 2008
  Zone 3 & 4 - 2010
  Zone 5 - 2011
  Hotel - 2011
- No. of Staff: 170
Building Information

The Ritz-Carlton Hong Kong (Level 102 – 118)

Office floors (Level 10 – 99)

Key Information
ICC is a multi-function building totaling 3 million s.f.:
- Office: 2.5 million s.f.
- Hotel: 0.38 million s.f.
- Observation Deck + Restaurants: 0.06 million s.f.
Highly Efficient Large Floor Plates

- The size of the ICC footprint and the efficiency of the structure produce a highly efficient plan for tenants, each floor can accommodate 1.5 times more population than normal commercial building in Central Business District.
- A number of tenant occupation could be easily adopted with uninterrupted panoramic views.
- Span depth varies from 12.6 to 16m to cater for different tenants' requirements.
- The structural floor system facilitates the multiform tenants to build internal staircases to reduce the reliance on lift systems. All the major tenants had subsequently built their internal staircases.
Shingled façade design: cut down glare and solar gain while maintaining views out of the tower; brings the sculptural form of the building to life and significantly reduces unwanted reflections.

Curtain Wall Design: The curtain wall design utilizes specially selected glass to cut down glare and solar gain while maintaining views out of the tower. The unique shingled design of the façade brings the sculptural form of the building to life and significantly reduces unwanted reflections.
95% of the building’s tenants are international investment banks that operate 24 hours by 7 days.

The combined market capitalization of the tenants’ businesses amounts to multi-billion dollars.
SECTION 2.1

HONG KONG SUSTAINABLE POLICY

INNOVATIVENESS/ INSPIRATION
HK Climate Action Plan 2030+
HK Energy Saving Plan 2025

Target Energy Intensity by 2025

(base year 2005)

40%
HK Energy End Use

Electricity Consumption By Sectors in 2016

- Residential: 27%
- Commercial: 65%
- Industrial: 5%
- Transport: 2%

Largest Source of Carbon Emission

- Electricity: 70%
- Transport: 16%
- Waste and Others: 5%

Buildings account for 90% of carbon emission

Source: Hong Kong Energy End Use Data 2018

Part 2 Strategy
New Buildings vs Existing Buildings

- Over **42,000** existing buildings in Hong Kong
- Potential reduction of **52%** in absolute electricity consumption compared to a Business-As-Usual (BAU) scenario

Source: HK3030 Market Drivers for Transformation of Green Buildings in Hong Kong (Executive Summary)
HK Roadmap in Smart City Development

• In HKSAR, Hong Kong Smart City Blueprint was released in Dec 2017.
• Making use of innovation and technology (I&T) continues to be a trend
• One of the initiatives is the use of the “Internet of Things” (IoT) in buildings.
SECTION 2.2

S.M.A.R.T ICC APPROACH

INNOVATIVENESS
Kai Shing Missions and Visions

The backbone of the company

Company Missions

- Protect the environment
- Put customers first
- Gather trade experts
- Discover the potential of Mainland China

The 6 Kai Shing Goals

- Discipline
- Constant progress
- Staff training
- Technology
- Cost control
- Eco-friendly

Part 2 Strategy
ICC Operation Model (I-C-C)

ICC management team has incorporated the **three-element management** framework: **Intelligence, Collaboration and Continuity** in operating ICC for **green management**, smart building development and support of government.

- Contain a wide variety different kinds of **sensors** to track **operational data**
- Different systems are **connected together** to form a holistic operational view of the building
- Tracked data is analyzed with **automatic response** mechanism to optimize operation
Intelligence - integration of people, place, process and technology

- Building management system (BMS)
- Power monitoring system (PMS)
- Etc.
Collaboration - Vitalizing the trade experts and recognizing the contributions from stakeholders from within and outside the building environment

**3rd Tier – Societal Level**
Government, Non-Government Organizations, Green Groups

**2nd Tier – Community Level**
Other buildings, institutions, Community partners

**1st Tier - Building Level**
Building owners, property and facility managers, building users, suppliers
 ICC Operation Model - Continuity

Continuity - Working towards a common goal of reducing environmental impacts

- Year-on-Year tracking of operating data and adjusting of strategy
- Medium to long term plan with Management System in place to gauge on building performance
- Benchmarking with similar types of properties

✓ BEAM Plus Existing Building V2.0
✓ Annual Energy Audit
✓ IoT application
Upgraded ICC Operation Model - S.M.A.R.T ICC

I-nelligence  Sustainability
C-ollaboration  M-achine Learning
C-ontinuity  A-nftificial Intelligence
R-esearch &  R-e search &
D-evelopment  Development
T raining  T raining

To sustain the building performance, the “I-C-C” operation model has been upgraded to “S.M.A.R.T I-C-C”.

Part 2 Strategy
Updated ICC Operation Model - S.M.A.R.T ICC

Sustainability

Training

Machine Learning

Intelligence

S.M.A.R.T

I-C-C

Continuity

Collaboration

Research & Development

Artificial Intelligence
SECTION 2.3

S.M.A.R.T ICC STRATEGIES

INNOVATIVENESS
Our Management System

- Assesses the policies, procedures and strategies implemented to ensure buildings operate in a sustainable manner

- ICC Innovative Systems:
  - Lift-cycle Testing and Commissioning (LCTC)
  - IoT Deployment and Big Data Analytic

- ICC Management Systems:
  - HK BEAMPLUS Existing building v2.0
  - LEED Offices
  - OHSAS 18001, ISO 50001, ISO 22301
  - Indoor Air Quality (IAQ)
Lift-cycle Testing and Commissioning (LCTC)

Design & Construction

Cx

Smart on-going Commissioning + Operation

Condition-Based Maintenance

Functional testing

through

Smart IoT Device

Big Data

Analytics

Part 2 Strategy
We have collaborated with Local University to optimize energy use in building since design stage.
Technologies Demonstrated for Existing Buildings

• The GOAL is to demonstrate energy efficiency and comfort improvement in existing buildings;
• The technologies chosen aim to overcome the hurdles in existing buildings;
• Minimize major change in equipment;
• Speedy implementation;
• Does NOT affect daily operation;
• Quick ROI
IoT Deployment and Big Data Analytic

Smart Internet-of-things (IoT)

Improve efficiency and comfort in ICC

S.M.A.R.T ICC

The Internet of Things
From connecting devices to human value

Part 2 Strategy
**IoT Deployment and Big Data Analytic**

**Extract of “HK Smart City Blueprint”**

**Strategy and Initiatives**

- **Climate Action Plan 2030+**
  - Reduce our carbon intensity by between 66% and 70% by 2030 compared with the 2005 level.
  - Phase down coal-fired electricity generation gradually and replace with natural gas and non-fossil fuel sources. Coal as a proportion of the fuel mix will be reduced from 47% as of 2016 down to about 25% in 2030.
  - Apply renewable energy on a wider and larger scale based on mature and commercially available technologies with the public sector taking the lead.
  - Further promote energy efficiency and conservation in the community with particular focus on buildings.
  - Implement other measures to achieve carbon emission reduction by phases.

**Green and Intelligent Buildings, and Energy Efficiency**

- Promote retro-commissioning and building-based smart technologies.
- Phase-out LED lamps in public lighting systems progressively under the LED Public Lighting Replacement Programme of the Highways Department starting from 2017-18 and encourage retrofitting LED lighting for existing government buildings.
- Continue to include requirements, such as green building design, provision of smart water meter system, electric vehicle charging facility and real-time parking vacancy information for new land sale sites in Kowloon Bay, with a view to developing a green and smart community.

**Extract of “SHKP Sustainability Report”**

**Innovative application of technology is a growing trend in property management.**

It is observed that SHKP has developed smartphone applications, such as the SHKP Malls App and the Intake Easy device, for its customers’ convenience. Is the Group also exploring other innovative technological solutions to enhance resource efficiency of its operations?

SHKP is committed to investing in the effective use of innovation and technology. Specifically, the Group sees the potential of the commercial application of IoT (Internet-of-Things) technology as a means to improve operational efficiency and quality. We have been supporting our subsidiaries on the introduction of technologies in property management and across other commercial aspects, such as construction, healthcare, event management and smart city development.

During the year, Kei Shing and Smartine collectively launched a smart management solution in ICC with IoT applied, allowing ICC to meet or exceed the energy-saving target set by the Government for commercial buildings. We believe this innovative system will help to set a new industry standard in smart and eco-friendly property management in Hong Kong. More information on the management solution implemented in ICC can be found in the Value Created for Customers section in this report.

**SMART BUILDING MANAGEMENT**

**SMART ENVIRONMENT**
IoT Connectivity Technologies

- **Low-Power-Wide-Area Network**
  - wireless technology for IoT environment
  - Characteristic
    - Long range
    - Low energy consumption
    - Low data rates

Apply **Narrowband IoT (NB-IoT)** together with our carrier partner
IoT Deployment and Big Data Analytic

SmarTone and Kai Shing spearhead NB-IoT enabled smart property management solution at Hong Kong’s tallest landmark ICC

2018-05-23

SmarTone and Kai Shing Management Services Limited (“Kai Shing”) jointly announce today the introduction of a Narrowband Internet-of-Things (NB-IoT) enabled smart property management solution at International Commerce Centre (ICC), bringing property management service level to new heights in this tallest landmark in Hong Kong.
Remarks: Implemented IoT projects can refer to Section 3 for details
HK BEAM Plus Certification

ICC is the 1st HK building awarded Platinum Rating under “BEAM Plus Existing Buildings V2.0”.

Existing Buildings V2.0
Final Platinum Total Score: 79.1

<table>
<thead>
<tr>
<th>Category</th>
<th>Applicable Credits</th>
<th>Achieved Credits</th>
<th>Achieved Bonus Credits</th>
<th>% of Achieved Credit</th>
<th>Category Weighting</th>
<th>Weighted Achieved Credits</th>
<th>Category Grade</th>
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<tbody>
<tr>
<td>MAN</td>
<td>23.0</td>
<td>16.0</td>
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<td>82.8%</td>
<td>24%</td>
<td>19.8</td>
<td>Platinum</td>
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<td>SA</td>
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<td>17.0</td>
<td>0.0</td>
<td>77.3%</td>
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<td>7.7</td>
<td>Platinum</td>
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<tr>
<td>MWA</td>
<td>17.0</td>
<td>10.0</td>
<td>1.0</td>
<td>64.7%</td>
<td>14%</td>
<td>9.1</td>
<td>Platinum</td>
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<tr>
<td>EU</td>
<td>39.0</td>
<td>28.0</td>
<td>2.0</td>
<td>76.9%</td>
<td>24%</td>
<td>18.5</td>
<td>Platinum</td>
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<tr>
<td>WU</td>
<td>23.0</td>
<td>11.0</td>
<td>3.0</td>
<td>60.9%</td>
<td>14%</td>
<td>8.5</td>
<td>Platinum</td>
</tr>
<tr>
<td>IEQ</td>
<td>26.0</td>
<td>11.0</td>
<td>3.0</td>
<td>53.8%</td>
<td>14%</td>
<td>7.5</td>
<td>Platinum</td>
</tr>
<tr>
<td>IA</td>
<td>Max. 10 Bonus</td>
<td>8.0</td>
<td>8.0</td>
<td>100%</td>
<td>10%</td>
<td>8.0</td>
<td>Platinum</td>
</tr>
</tbody>
</table>

Overall Score: 79.1 Platinum
LEED Offices in ICC

LEED VS General Office
Approx. 40% Energy Saving

For 66% LEED Offices
Approx. 1,750,000 sq. ft
Approx. 395,000 kg CO₂
Energy audit is an effective way to examine the energy use and performance of a building. The annual energy audit conducted in ICC is based on the Building Energy Efficiency Ordinance (BEEO) of Hong Kong Legislation Chapter 610 (Cap.610) which enacted by HKSAR. Through continuously optimizing the energy consumption facilities, the annual audit of ICC showed the reduction of Energy Utilization Index (EUI) of ICC.

<table>
<thead>
<tr>
<th>Energy Management Opportunity (EMO)</th>
<th>Energy Management Approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>EMO I</td>
<td>Housekeeping practice for saving energy</td>
</tr>
<tr>
<td>EMO II</td>
<td>Replacement of less energy efficient apparatus with the more energy efficient one with a reasonable outlay</td>
</tr>
<tr>
<td>EMO III</td>
<td>Substantial savings over a long term with capital investment</td>
</tr>
</tbody>
</table>
Whole building of ICC has been awarded “Excellent Class” under Hong Kong IAQ Certification Scheme since 2014.
SECTION 2.4

COMMUNICATION CHANNEL

INSPIRATION/ CLEARNESS
4Ts Charter Programme

4Ts Charter

Pledging to:
- set energy saving target with a timeline
- ensure transparency to track energy saving result
- encourage inhabitants to work together on the above energy saving on the above energy saving target

Public Seminar for Best Practices Sharing

- ICC was invited to share energy saving achievement via the implemented MVAC strategies on Sun Hung Kai Properties (shkp) ‘s Internal Sharing Session for Kai Shing, Hong Yip and SHK Real Estate Management
<table>
<thead>
<tr>
<th>Seminars / Sharing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experience sharing of winners of Energy Saving Championship Scheme 2016</td>
</tr>
<tr>
<td>Experience Sharing Seminar with winning teams of Energy Saving Championship Scheme 2016</td>
</tr>
<tr>
<td>Environmental Forum on Green and Healthy Buildings</td>
</tr>
<tr>
<td>Technical Visit to International Commerce Centre – BEAM Plus for Existing Buildings (EB) v2.0 Comprehensive Scheme A – Final Platinum</td>
</tr>
<tr>
<td>Energy Saving Sharing Session for Kai Shing, Hong Yip and SHK Real Estate Management Sharing on 9th Oct, 2018</td>
</tr>
<tr>
<td>Experience Sharing Session – Energy Saving Championship Scheme 2017</td>
</tr>
<tr>
<td>University Visit - HKU, PolyU, City, THEi, Penn State, etc.</td>
</tr>
<tr>
<td>Sky-high experience at Sky 100 for primary &amp; secondary schools</td>
</tr>
</tbody>
</table>
Public Seminar for Best Practices Sharing

Organized by BEAM Society Limited
Technical Visit to International Commerce Centre – BEAM Plus for Existing Buildings (EB) v2.0
Comprehensive Scheme A – Final Podium

Date: 12 May 2018 (Saturday)
Time: 10:30am – 12:30noon (Registration starts at 11:30am)
Venue: International Commerce Centre

Language: Cantonese supplemented with English as appropriate

Fee:
- HK$70 (BEAM Pro & BEAM Affiliate)
- HK$170 (Others)

CPD Entitlement: 2.5 CPD hours for BEAM Pro and BEAM Affiliate

Enquiry:
Email: bema@hkecc.org.hk
Tel: (852) 3130 3576

Thank you for your support. The event is full house now.
Best Practices Applied in Other Projects

ICC has been work with PolyU for *Lift-cycle Testing and Commissioning (LCTC)* work to optimize the chiller plant system and the collected data & design approach is widely adopted in other buildings for optimize the energy efficiency of chiller plant system and achieve energy saving.
Communication Chanel (External)

ICC Website

Tenant’s Corner

ICC Notice

ICC Publications
Helpdesk System & Customer Relationship Management (CRM) System
Communication Chanel (External)

L3 & L8 e-directories to display building information and performance

Part 2 Strategy
Communication Channel (Internal)

SuperE Management System (SEM)

Autodesk Viewer System
Section 3
Measure
ICC makes use of IoT technology to improve energy efficiency and building comfort.

- Smart Lighting System
- Smart Lift Control System
- Real-time Indoor Air Quality Monitoring System
- Optimal Control of Central Cooling & Air Conditioning System
- Air Handler Reborn Project
- Renewable Energy System (Feed-in Tariff)
- Demand Response Programme
From a single digital building, to multiple digital buildings using digital services.

From Smart Buildings transform to Smart City.
Smart Lighting System

Smart Control for Lighting Pattern & Energy Use Tracing

- Optimize energy consumption via different lighting sense
- Capture Date, Time & Sensor Level
- FTP Raw Data Files
- Regroup the Date for Analysis

Daylight Harvesting Reprot

Power Distribution Report
Smart Lift Control System

86 lifts (40 double-deck)

Destination Control System
Shorten both travelling and waiting time

Port
Security for access control & passenger reports by Touch-less system
Smart Lift Control System

Based on the capability of the lift system to capture key information about traffic patterns of occupants, the availability of lifts will be adjusted to reduce wastage of energy while the facility is idle.

### Lift Traffic Analysis

<table>
<thead>
<tr>
<th>Time Period</th>
<th>Total # Calls</th>
<th>AWT [sec]</th>
<th>ADT [sec]</th>
<th>Call Distribution: Waiting Time (as %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Day</td>
<td>08:00h-20:00h</td>
<td>31217</td>
<td>5.9</td>
<td>&lt;30sec: 95.9%, &gt;30-60sec: 4.1%, &gt;60-90sec: 0.0%, &gt;90-120sec: 0.0%, &gt;120sec: 0.0%</td>
</tr>
<tr>
<td>Morning peak</td>
<td>08:00h-10:00h</td>
<td>9043</td>
<td>8.5</td>
<td>&lt;30sec: 92.1%, &gt;30-60sec: 7.8%, &gt;60-90sec: 0.1%, &gt;90-120sec: 0.0%, &gt;120sec: 0.0%</td>
</tr>
<tr>
<td>Lunch peak</td>
<td>12:00h-14:00h</td>
<td>7142</td>
<td>5.7</td>
<td>&lt;30sec: 97.2%, &gt;30-60sec: 2.8%, &gt;60-90sec: 0.0%, &gt;90-120sec: 0.0%, &gt;120sec: 0.0%</td>
</tr>
<tr>
<td>Evening peak</td>
<td>18:00h-20:00h</td>
<td>2801</td>
<td>5.3</td>
<td>&lt;30sec: 97.3%, &gt;30-60sec: 2.7%, &gt;60-90sec: 0.0%, &gt;90-120sec: 0.0%, &gt;120sec: 0.0%</td>
</tr>
</tbody>
</table>
Future Development of Internet of Elevators and Escalators (IoEE.) in ICC

- Allows proactive on events and to define whom should be informed automatically on equipment status changes
- Real-time insights in day-to-day operations and mid-term planning needs, with full transparency on status and maintenance activities notifications.
Energy Management System

Use Smart Energy System to record, collect, analyze the power usage data to provide a full picture of each trade, each floor and each time period about energy consumption.

Power Monitoring System (PMS) & Building Energy Management System (BEMS)

- Load Profile
- Load Monitoring
- Energy Analysis
- Forecast Peak Demand
Smart IAQ Management

Needs for Smart IAQ management

- Fit-out works are a fact of life in Hong Kong office buildings, which may induce dust and odour to indoor environment
- The enhanced working environment lowers the absenteeism while boosts the workforce productivity.
- Closely monitor the indoor air quality during fit-out works can minimize impact for occupancies
With the use of IoT, AHUs are connected for real-time environmental monitoring for **relative humidity, total volatile organic compounds (TVOC), ozone and PM2.5 level**.

Demand control ventilation is adopted in the office area while IAQ sensors are embedded into the return air duct of AHU.
Real-time Indoor Air Quality Dashboard
Real-time Indoor Air Quality Monitoring System

- IoT connects between occupants, building and building landlord.
- Real-time IAQ monitoring allows heath-focus environment for building occupants. Immediate remedial actions could be taken in case the measured IAQ parameters fall below the acceptable levels.

DCV is adopted, controlling outdoor air supply based on the real-time occupancy conditions.

Outdoor air control is optimized without sacrificing IAQ while energy-saving could be achieved.

Part 3 Measure
IoT PROJECT 1
OPTIMAL CONTROL OF CENTRAL COOLING
AND AIR CONDITIONING SYSTEM

Collaboration with Academia
Life Cycle Commissioning Works

**Retro-commissioning**

- Planning Stage 1
- On-going Commissioning
- Investigation Stage 2
- Implementation Stage 3

**Life Cycle-commissioning**

**Steps towards Energy Efficient Buildings**

- Operation Stage and T&C Stage
  - Push systems approach the best
- Construction Stage
  - Ensure systems operate as good as intent
  - Construct/install systems correctly
- Design Stage
  - Optimize designs and selections
  - Make designs proper and correct

**Part 3 Measure**
Optimal AC Control Strategies

- Revised Chiller Sequencing Control
- Optimized design configuration of PCHWP for HX
- Optimized cooling tower control
- Optimized HX control logic
- Optimized chiller water supply temperature
- Optimized control of secondary pump for AHU
- Peak demand limiting strategy
- Optimized control of AHU supply air static pressure
Energy Performance Enhancement Work

- Optimize the temperature reset of control strategy for AHU
- Keep review and fine-tune
- 1+1 chiller or 2+1 chiller program based on seasonal change
- Peak demand limiting strategy for chiller start up
- Revised chiller sequencing control
- Keep review and update based on annually chiller performance assessment

- On-going
Optimize Chiller Sequence Control

Original Control: If cooling load <1000 RT, then operating chiller 2->1

Revised Control: If cooling load <1500 RT, then operating chiller 2->1

The COP of chillers is improved by 3.7%
The multilinear regression model used in the chiller sequencing control also have to be updated using the most recent operation data.

\[ Q_{ex,max} = c_0 + c_1 \cdot P_{ev} + c_2 \cdot P_{cd} \]

where, \( c_0, c_1, c_2 \) are regression coefficients based on operating history data. The coefficients shall be updated periodically.

<table>
<thead>
<tr>
<th>Chiller #</th>
<th>( c_0 )</th>
<th>( c_1 )</th>
<th>( c_2 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3679.002</td>
<td>25.518</td>
<td>-3.462</td>
</tr>
<tr>
<td>2</td>
<td>3632.291</td>
<td>35.282</td>
<td>-5.607</td>
</tr>
<tr>
<td>3</td>
<td>2583.231</td>
<td>38.515</td>
<td>-5.073</td>
</tr>
<tr>
<td>4</td>
<td>10457.785</td>
<td>6.401</td>
<td>-3.741</td>
</tr>
<tr>
<td>5</td>
<td>3582.208</td>
<td>29.722</td>
<td>-4.199</td>
</tr>
<tr>
<td>6</td>
<td>4396.750</td>
<td>17.025</td>
<td>-2.367</td>
</tr>
</tbody>
</table>

The estimated saving is about 3%
Further Improved Chiller Sequencing Control

COP is high if chiller vane opening is above 40%
Further Improved Chiller Sequencing Control

Table 1 Percentage of time of different chiller number in the two years

<table>
<thead>
<tr>
<th>Chiller number</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
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<tbody>
<tr>
<td>2014</td>
<td>0.10%</td>
<td>59.80%</td>
<td>25.50%</td>
<td>14.40%</td>
<td>0.30%</td>
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<tr>
<td>2015</td>
<td>0.30%</td>
<td>59.50%</td>
<td>26.20%</td>
<td>14.10%</td>
<td>0</td>
</tr>
<tr>
<td>2016</td>
<td>0.40%</td>
<td>43.10%</td>
<td>31.70%</td>
<td>12.70%</td>
<td>12.10%</td>
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<tr>
<td>2017</td>
<td>0.10%</td>
<td>66.40%</td>
<td>21.80%</td>
<td>11.70%</td>
<td>0</td>
</tr>
<tr>
<td>2018</td>
<td>0.00%</td>
<td>65.50%</td>
<td>22.20%</td>
<td>12.30%</td>
<td>0</td>
</tr>
</tbody>
</table>

\[ Q_{ev,max} = c_0 + c_1 \cdot P_{ev} + c_2 \cdot P_{cd} \]

Coefficients are reviewed regularly and was updated in Feb 2019
Optimize Temperature Reset Control Strategy for AHU

- Find the optimal supply air temp set point
- (Original) By supply air fan speed
- (New) Calculate cooling load of individual AHU by real-time cooling load through air side sensors
- Prevent the downstream effect during low cooling demand season, therefore guarantees indoor thermal comfort.
- Annual energy saving: 250,000 kWh

**Original Control**

<table>
<thead>
<tr>
<th>Increase set-point</th>
<th>Decrease set-point</th>
</tr>
</thead>
<tbody>
<tr>
<td>AHU VSD &lt; 60% for 700s (+0.5 DegC)</td>
<td>AHU VSD &gt; 70% for 300s (-0.5 DegC)</td>
</tr>
</tbody>
</table>

**Modified Control**

\[
CL = M_{c_l} \cdot (\rho_{c_l} \cdot h_{c_l} - \rho_{c_0} \cdot h_{c_0})
\]
Peak demand affects electricity cost and thus, there is room of electricity cost savings.

Applied area: all AHUs start at 8:00am simultaneously which would result in a peak in demand curve with high probability.

A deep analysis on the impact of morning peak demand was conducted to evaluate the possibility of reducing electricity cost, as well as energy consumption.

Chiller current and load profile in CLP online meter.
IoT PROJECT 2
AIR HANDLER REBORN PROJECT

Collaboration with Industrial Partner
On-going Commissioning Works for AHUs

Retro-commissioning

AHU reborn

- Reliability
- Performance
- Resilient
- Energy Efficiency
- Lifetime
- O&M
- On-going Cx
- Big Data analytics

Part 3 Measure
On-going Commissioning Works for AHUs

- Reliability improvement
- Improve energy efficiency
- Performance improvement
- **On-going commissioning**
- Predictive maintenance
- Get CONNECTED
- Data analytics
- Lift cycle improvement

---

Part 3 Measure
Air Handler Reborn Project

IoT Based Energy Monitoring System

- Provide continuous retro-commissioning for the HVAC system
- Better optimization of energy saving and comfort
- Further saving real-time energy costs by weather forecast
- Help condition-based maintenance by machine learning algorithms
- Achieve energy conservation by enhanced operation control strategies based on past operational pattern and real-time data
- Real-time data visualization and big data analysis (trends of cooling load and energy profiles) allow the identification of needs and improvement opportunities across time and seasonal changes.
IoT Based Energy Monitoring System

- AHUs are connected by IoT devices, SMART pressure independent control valve.
- Real-time data monitoring includes air volume, chilled water delta temperature & flow rate, cooling energy and power consumption.
- Day-to-day energy consumption of air-side system is monitored closely.
Air Handler Reborn Project

Energy Efficiency Dashboard

SMART BUILDING Big Data

17 January 2019 (THU)

Energy Efficiency Intensity

Total Energy

01 236 kWh

02 57 kWh

FINDINGS

Part 3 Measure
Big Data Analytics

### Energy Saving Categories:

- Eliminate excess flow
- Adjust AHU operating hours by learning usage profile
- Supply temp reset
- Pump optimization
- Improve chilled water supply temp & system remedial
- Improve control logic by self learning
- Miscellaneous
Big Data Analytics for On-going Commissioning

- To identify energy saving opportunities & implement on-going commissioning
Air Handler Reborn Project

Big Data Analytics for On-going Commissioning

- Retro-commissioning the system based on the load trend analytics.
- By simulation algorithm, we optimize the flow control to achieve energy saving but not affecting the comfort level (return air temperature)
Air Handler Reborn Project

Big Data Analytics for On-going Commissioning

- Each zone has its own profile/characteristic
- Optimization for each zone based on the zone weekly profile & characteristic
- Maximize energy saving is achieved responding to the zone characteristic
Air Handler Reborn Project

Big Data Analytics for On-going Commissioning

Continuous Improvement through Analytics

monthly Performance Analytics of each floor

Performance Monitoring

- On-going energy saving monitoring;
- On-going Commissioning;
- Proactive maintenance action;
- Quick fault detection and diagnostics;
Air Handler Reborn Project

Big Data Analytics for On-going Commissioning

- Real time data collection
- Feedback improvement
- Analytics and Decision @ datacenter
- Analytics through preset algorithm
- Deep Learning through Neural Networks (testing)

AHU

AFDD @ smart IoT device

Automatic Fault Detection and Diagnostic

Part 3 Measure
Air Handler Reborn Project

Automatic Fault Detection and Diagnostic

- Smart IoT devices with built-in automated fault detection and diagnostic process are employed.
- Some algorithms include:
  - Detection of AHU/valve status/fault
  - Detection of actuator modulating status/fault
  - Detection of temperature sensor status/fault
  - Comparison of air/chilled water temperature for consistency
- Passive diagnostic process helps identify the failure in order to improve ACTION time.
- Proactive diagnostic process helps diagnose and isolate faulty operations.
Air Handler Reborn Project

Cloud Technologies

• Emerging Cloud technologies are used for data acquisition, analytics, storage; which benefit in faster setup, flexible resources and economies of scale
• Enable us to do data-mining in cross databases
• Enable us to share data in various applications to enhances our services
Air Handler Reborn Project

Energy Saving & Payback

**Weekly** Energy Saving of one AHU in August 2018

809 kWh
HK$970

**Annual** Saving for All Office Floors

65 Floors
> 3,005,000 kWh
HK$3.75 million

ROI = 1.3 Years
Summary of Air Handler Reborn Project

- Retro-commissioning of HVAC system beyond chiller plant is not easy, but we did it
- Result achieved in the area deployed:
  - Cut Peak kW by 40%;
  - Estimated energy saving over 3 million HK dollar after applying to all office floors;
  - ROI 1.3 years;
- Emerging technologies were used:
  - IoT technologies
  - Cloud technologies
  - Big-Data analytics
- Provide a retro-commissioning model for existing buildings
- Not only retro-Commissioning, but an on-going Cx solution
- Energy saving, but not compromise in human comfort
- Quick deployment and result model through emerging technologies
PROJECT 3
DEMAND RESPONSE PROGRAMME

Collaboration with Power Company and NGOs
ICC joined the Bi-lateral Demand Response (BDR) programme launched by Power Company - CLP for reduce electricity demand during CLP peak demand hours and achieved 463 kWh saving as well as acquired an incentive cost of HK$6,685.
Low Carbon Programme

Part 3 Measure
PROJECT 4
RENEWABLE ENERGY

Collaboration with Power Company
Renewable Energy System

HK Government launches Feed-in Tariff Rate

Key Information
Under the post-2018 Scheme of Control Agreements (SCAs) with the two power companies, Feed-in Tariff (FiT) is one important new initiatives to promote the development of distributed Renewable Energy (RE).

FiT will help encourage the private sector to consider investing in RE as the power generated could be sold to the power companies (HK Electric and CLP) at a rate higher than the normal electricity tariff rate to help recover the costs of investment in the RE systems and generation.
Renewable Energy System

Feed-in Tariff

Estimated 20,000 kWh Energy Generated Annually in ICC
Section 4
Performance
Key Energy Saving Performance Highlights

1,000,000 kWh energy consumption is saved due to the modification on the secondary water loops of Zone 3 & 4

2,360,000 kWh, (about 5.1% of annual energy consumption of chillers and cooling towers) of the cooling system can be saving due to the change from single speed to variable speed using VFD.

607,000 kWh, (about 2.8% of annual energy consumption of chillers and cooling towers) of the cooling system will be wasted when the lowest frequency is limited at 37 Hz.

3,500,000 kWh, (about 7%) of the total energy consumption of HVAC system) can be saved using PolyU control strategies based on the original design.
Key Energy Saving Performance Highlights

**Saving by Design Optimization (Improving the system configuration and selection)** – compared with the original design. *About 3.5 M per year*

**Saving by Control Optimization** – compared with the case when the HVAC system operates correctly as the original design intent. *3.5M per year*

**Saving by continuous commissioning and optimization:**  
*About 3.0 M per year*

*The Annual Total Energy Saving is about 10.0M kWh*
Energy Saving Performance

Over 26% Saved (>14 million kWh)
(2018 VS baseline year of 2012)
Energy Saving Performance

Energy Audit is conducted annually. The Energy Audit Form EE-5 obtained with Energy Utilization Index (kWh/m²/annum) from Registered Energy Assessor (REA) should display the Form at building main entrance.
Key Energy Saving Performance Highlights

Attained an energy credit rating of 37 out of 40 (equivalent to low CO₂ emissions)

Achievable Credits:
ENE 31 Energy consumption start date
ENE 32 Energy consumption end date
ENE 33 Electricity consumption
ENE 49, 52, 55, 58 & 61 Non-standard energy consumption floor area

In SHKP Sustainability Report, energy saving target of 15% by 2021 (as VS 2015), 9.74% saving was achieved for whole year of 2018
Energy Saving Performance

Regular Building Energy Performance Assessment Reports are conducted by PolyU. In the report, energy consumption data of the whole building and the historical operating data of the HVAC system are analyzed. The energy performance of the overall HVAC system and the individual sub-systems (e.g. chiller, cooling tower system, chilled water distribution system, air-side system) are assessed respectively.

Building Energy Performance Assessment of ICC:

The first half-year Report of 2018

This report aims at providing an assessment of the monthly energy performance of ICC in the first half-year of 2018. In this report, the energy consumption data of the whole building and the historical operating data of the HVAC system are analyzed. The energy performance of the overall HVAC system and the individual sub-systems (e.g. chiller, cooling tower system, chilled water distribution system, air-side system) are assessed respectively.

1. Energy Consumption of whole building

Table 1: Energy consumption data for the first half-year of 2018 and 2017

<table>
<thead>
<tr>
<th>Month</th>
<th>2018</th>
<th>2017</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan</td>
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<td>Feb</td>
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<tr>
<td>Dec</td>
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<td></td>
</tr>
</tbody>
</table>

Table 2: Energy Consumption of Sub-systems in the first half-year of 2018 and 2017

<table>
<thead>
<tr>
<th>Sub-system</th>
<th>2018</th>
<th>2017</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chiller</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cooling Tower</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chilled Water Distribution System</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Air-side System</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The total energy consumption of the whole building is further broken down into the individual consumption of different systems, which provides more details about the energy usage and energy savings, as shown in Table 2. All energy consumers of ICC are classified into three categories.
Development and validation of an effective and robust chiller sequence control strategy using data-driven models


Over 20 Publications had been generated based on on-site implementations of new technologies
Research Title: Direct chiller power limiting for peak demand limiting control in buildings—Methodology and on-site validation

Published by: Kui Shan, Shengwei Wang, Rui Tanga  
- Department of Building Services Engineering, The Hong Kong Polytechnic University, Kowloon, Hong Kong  
- Research Institute for Sustainable Urban Development, The Hong Kong Polytechnic University, Kowloon, Hong Kong
Development and validation of an effective and robust chiller sequence control strategy using data-driven models

Published by:
Kui Shan, Shengwei Wang, Dian-ce Gao, Fu Xiao
Department of Building Services Engineering, The Hong Kong Polytechnic University, Kowloon, Hong Kong
• **Over 20 Undergraduate students** participated in their final year projects.

• **Over 6 PhD students** have been trained based on practical and innovative project

<table>
<thead>
<tr>
<th>Number</th>
<th>Name</th>
<th>Thesis title</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Ma Zhenjun</td>
<td>Online supervisory and optimal control of complex building central chilling systems</td>
<td>2008</td>
</tr>
<tr>
<td>2</td>
<td>Sun Yongjun</td>
<td>Online optimal control of multiple-chiller systems in large buildings</td>
<td>2010</td>
</tr>
<tr>
<td>3</td>
<td>Sun Zhongwei</td>
<td>Ventilation control and ventilation performance of multi-zone air conditioning systems</td>
<td>2010</td>
</tr>
<tr>
<td>4</td>
<td>Gao Dican-ce</td>
<td>Diagnosis and robust control of complex building central chilling systems for enhanced energy performance</td>
<td>2012</td>
</tr>
<tr>
<td>5</td>
<td>SHAN Kui</td>
<td>Sensitivity and uncertainty analysis, and robust optimal control strategies for air-conditioning systems with low quality measurements</td>
<td>2013</td>
</tr>
<tr>
<td>6</td>
<td>Fan Chen</td>
<td>Development of data mining-based big data analysis methodologies for building energy management</td>
<td>2016</td>
</tr>
</tbody>
</table>
Publications

We shared our Best Practices in various institutes
BUILDING THE BUSINESS CASE:
Health, Wellbeing and Productivity in Green Offices

<table>
<thead>
<tr>
<th>REPORTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Building the Business Case: Health, Wellbeing and Productivity in Green Offices</td>
</tr>
<tr>
<td>Health, Wellbeing &amp; Productivity in Offices: The Next Chapter for Green Building</td>
</tr>
<tr>
<td>Doing Right by Planet and People: The Business Case for Health and Wellbeing in Green Building</td>
</tr>
</tbody>
</table>

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World Green Building Council’s Better Places for People
Awards and Recognitions

RICS - Sustainability Achievement of the Year 2018

HKGBC BEAM Plus EB V2.0 Comprehensive Scheme - Final Platinum

Asia Pacific Intelligent Green Building Alliance (APIGBA) “Excellent Intelligence Green Building - Performance Award”
Awards and Recognitions

- ASHRAE Technology Award 2014 Honorable Mention
- Hong Kong Awards for Environmental Excellence (HKAEE) Gold Award
- World Wide Fund - Low Carbon Office Operation Programme (LOOP)
- Hong Kong Awards for Industries Productivity and Quality Award 2014

Part 4 Performance
Awards and Recognitions

ICC Awarded Hong Kong Energy Saving Championship Scheme 2016 – 2017

Energy Saving Championship Scheme 2017 - Hanson Supreme Grand Award (Group 1)

Energy Saving Championship Scheme 2017 - Hanson Grand Award

Part 4 Performance
Awards and Recognitions

CLP Smart Energy Award 2018

IFMA Asia-Pacific Facility Management Awards 2018

Green Organization Certification - EnergyWi$e & Carbon Reduction Certificate

HK Q-Mark Scheme Certificate

CTBUH Performance Award 2014

BIFM Awards - Impact on the Environment (High Commended)

CIBSE Building Performance Awards 2015
Awards and Recognitions

Corporate Environmental Leadership Awards 2016

2016 Corporate Citizenship Award - Silver Award

2017 Green Pioneer - Green Office & Eco - Healthy Workplace Awards Labelling Scheme

2017 Energywi$e Label

Indoor Air Quality Certificate (Excellent Class-whole building)

Caring Company Certificate

HSBC - Green Achievement Award 2016
Conclusion

Highlighted Green Initiatives – Energy Use

• **Management System:**
  • Energy Management Policy
  • Energy Management Plan
  • Appointment of Energy Warden

• **Energy sub-metering and BMS and data logging system**

• **Carry out Energy Audit more frequently (Bi-yearly cycle instead of 10 years)**

• **Comprehensive data analysis:**
  • Energy Use intensity (EUI)
  • Abnormal Usage and Peak Analysis
  • Energy Saving Opportunities
  • Continuous self-Improvement in energy use
  • Assist in setting short term long term energy / carbon reduction targets

• **Building retro commissioning and ongoing commissioning**

*Part 4 Performance*
Conclusion
The End