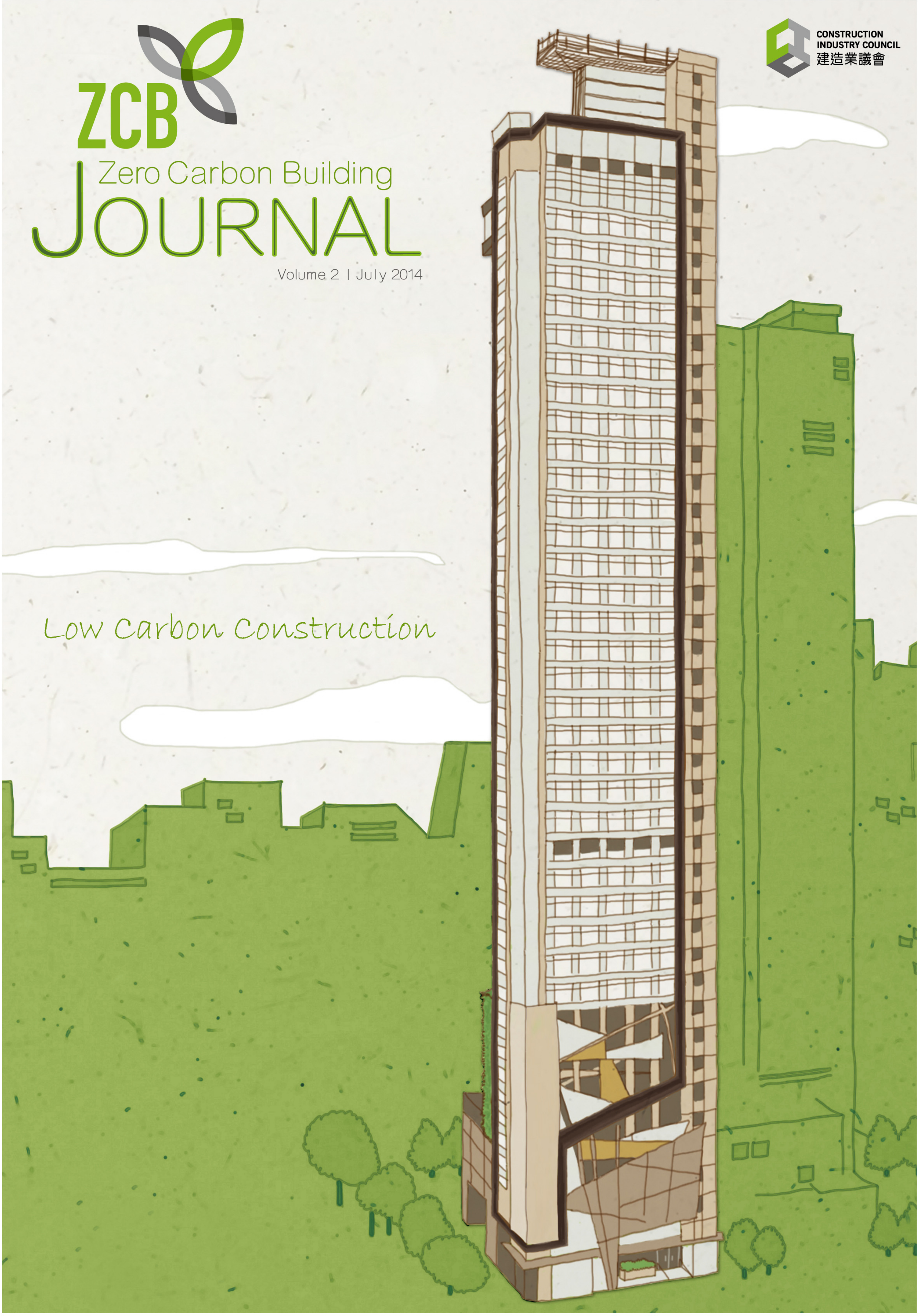
ZCB Zero Carbon Building JOURNAL

Volume 2 | July 2014

CONSTRUCTION INDUSTRY COUNCIL
建造業議會

Low Carbon Construction



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ISSN 2311-7400

Zero Carbon Building Journal is
Design and Published by
Edge Media Limited
www.edgemedia.com.hk

Printed in Hong Kong

ZCB
Zero Carbon Building
JOURNAL

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Preface

Mr LEE Shing-see, GBS, OBE, JP
Chairman, Construction Industry Council

Buildings account for the majority of the total greenhouse gas emissions in Hong Kong. The construction industry has a significant role to play in reducing greenhouse gas emissions and in helping to mitigate climate change. The key challenge for those involved in the construction industry is balancing Hong Kong's development needs with environmental protection for future generations.

The Construction Industry Council (CIC) is committed to promoting good practices in the construction industry in relation to environmental protection and sustainable construction. To this end, the CIC has embarked on a series of initiatives to meet this objective including the launching of a carbon labelling scheme for construction products, the development of the first zero carbon building in Hong Kong—ZCB, and the publication of *Zero Carbon Building Journal*.

With the aim to disseminate recent advances in regulations, research and practice in low/zero carbon buildings, including performance evaluations of technologies and projects, this journal fills a niche in the industry. It provides a common platform for discussion and sharing of information and ideas for the wider adoption of cost effective innovative designs and measures for low/zero carbon buildings. More importantly, I believe it will help instill a change in the culture and mindset across different segments of the construction industry towards sustainable development.

ZCB has established itself as an innovative and pioneering achievement in the Hong Kong construction industry. The development of ZCB and the publication of *Zero Carbon Building Journal* reflect the strategic direction of the CIC to facilitate the transition of the construction industry towards the development of a low carbon built environment and a sustainable, livable and competitive city. A proactive construction industry with forward looking strategies is critical to this process.

Mr LEE Shing-see
Chairman
Construction Industry Council

Editorial

In January 2014, the Construction Industry Council (CIC) of Hong Kong launched a Carbon Labelling Scheme for Construction Products. The scheme, based on an earlier CIC funded research project on "Establishing a Hong Kong Based Carbon Labelling Framework for Construction Materials", aims to provide an industry wide benchmark for assessing the embodied carbon of construction products. It is hoped that it would facilitate clients, designers and contractors to select low carbon construction materials and thereby reduce the carbon footprint of projects. It is a "cradle to site" scheme with ISO/TS 14067:2013 as a reference standard.

As the principal investigator of this CIC funded research, Professor Thomas Ng in his paper "Towards a Carbon Emission-Encompassed Tender for Construction Projects", proposes to incentivise contractors to cut down carbon dioxide (CO_2) emissions of a construction project through the tender process. He gives a brief overview of the CIC Carbon Labelling Scheme for Construction Products and advocates that the carbon labelling scheme can be used as a basis for assessing the carbon footprint of contractors' proposals.

An important part of implementing the scheme is setting a benchmark to compare the embodied carbon contents of different construction products. The benchmark has to be representative of the local market. Ms Judy Zhang, Dr Jack Cheng and Professor Irene Lo attempt to address this issue by proposing a framework for the development of a local carbon inventory database for construction materials.

With 90% of electricity in Hong Kong consumed by buildings, the reduction of buildings' carbon footprint has to be a top agenda item in combating climate change. The Hong Kong Government enacted the Buildings Energy Efficiency Ordinance in September 2012, which sets the minimum requirements for energy efficiency of building services installations. Ir Dominic Lau and Ir David Li explain the Ordinance and the associated Building Energy Code and Energy Audit Code in their paper "A Major Step Towards Low Carbon Buildings in Hong Kong - Full Implementation of Buildings Energy Efficiency Ordinance".

In addition to regulations, a number of green building rating schemes has been established around the world to facilitate the implementation of green and low carbon buildings. BREEAM developed by Building Research Establishment (BRE) in the United Kingdom is one of the earliest green building certification schemes. Many of the current schemes worldwide stem from BREEAM, including BEAM Plus in Hong Kong. An update of BREEAM's status is provided by Mr Martin Townsend and Mr David Leonard of BRE whilst Dr Raymond Yau, Dr Eddy Lau and Mr Michael Choi provide a comprehensive overview of the past, present and future of Hong Kong's BEAM Plus.

This Issue of the journal also brings to readers three good case studies of recently completed green buildings in Hong Kong. They are MTR's New Entrance at University Station, Hysan Place—a mixed-use development located in the centre of one of the most vibrant commercial districts in the world, and Holiday Inn Express Hong Kong Soho. The latter two cases aimed to address the challenges of the high-density and high-rise context that is Hong Kong.

While the design and construction of green and low carbon buildings are important, human behaviour is often more important than the hardware itself in reducing energy consumption. The University of New South Wales is publicising live energy data to promote behavioural changes and the response from the users on campus has so far been encouraging.

According to a European Union survey conducted in 2011, climate change ranked second amongst the 10 biggest problems in the world. It is a global issue and demands the collective effort of us all. We welcome contributions from both local and overseas researchers and practitioners to share their innovative ideas and best practices with our readers. Please send in your contributions, feedback and thoughts to us at zcb@hkcic.org.

Dr Guiyi Li
Chief Editor

Towards a Carbon Emission-Encompassed Tender for Construction Projects

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The construction industry is one of the major greenhouse gas emitters and has an indispensable role to play in terms of emissions reduction. Apart from addressing the issue from the design perspective, contractors can contribute to reducing carbon emissions by using novel construction materials, techniques and equipment. In order to encourage contractors to come up with low carbon alternatives, this paper proposes a carbon emission-encompassed tender (CEET) for construction projects. Through CEET, contractors can calculate carbon reduction by referring to the project carbon footprint under a business as usual scenario. Any additional costs required for carbon reduction can be reflected in CEET. By comparing CEET with the price of carbon, clients can make an informed decision as to whether CEET is worth pursuing. In this paper, the concept of CEET is introduced. It is followed by an introduction of the way in which carbon footprints of products are calculated. The paper concludes with highlighting the challenges facing the construction industry in the implementation of CEET.

Keywords: greenhouse gases, project carbon footprint, emissions reduction, emission-encompassed tender

Thomas Ng is a Professor in the Department of Civil Engineering, The University of Hong Kong and the Executive Director of the Centre for Infrastructure and Construction Industry Development at the same university. Over the years, Professor Ng has secured more than HK$52 million of research grants and published over 300 scholarly items. His recent research interests include carbon footprint of construction products, life cycle assessment, construction industry development and performance, project delivery systems, contractor selection and construction information technology.

Introduction

Rising greenhouse gas emissions have been recognised as the root cause of climate change and undesirable catastrophes. In order to protect our future generations, it is imperative to keep the global temperature increase to less than 2˚C, by capping atmospheric carbon dioxide (CO_2) concentrations to below 450 parts per million (Baer and Mastrandrea, 2006). Achieving this would require that global emissions be reduced to 60%-75% of the 1990 levels by 2020 (UNFCCC, 2007). Many countries have introduced pragmatic measures to control carbon emissions.

Reducing the emissions of constructed facilities is particularly important for Hong Kong (HK), as 90% of end-use consumption of electricity is from the building sector (EPD, 2011). In 2009, 37,694 million kWh of electricity was consumed—or 24.5 million tonnes of CO_2 equivalent (tCO_2e) were generated as a result of building usage (EMSD, 2010). Harvey (2006) argued that up to 80% of building energy can be reduced by bringing in best practices and novel design solutions to facilities construction. Therefore, more attention should be directed to the construction industry to help achieve the mission of carbon reduction.

Apart from addressing the problem from the up stream construction supply chain, through greater adoption of sustainable design concepts and energy efficient building services equipment, contractors may also contribute to carbon reduction as a sizeable amount of CO_2 originates from imported materials (Defra, 2008), materials transportation (Smith *et al.*, 2003), and site activity. Therefore, more stringent monitoring and control of CO_2 emitted at the project level is essential (Ecocycle Council, 2000).

Carbon offsetting has been promoted as a solution to reduce carbon emissions due to its economic and environmental efficiency (Kollmuss *et al.*, 2008). In 2008, 4,213.5 million tCO_2e of carbon, costing more than US$120 billion, was transacted in the global market (Hamilton *et al.*, 2009). Nevertheless, the construction industry is fragmented and involves many stakeholders, and carbon trading may not be easy to implement at the project level. As *"carbon has a similar priority as price"* (Fieldson *et al.*, 2009), clients shall seriously consider how to adopt the carbon trading concept in their tendering systems.

Nowadays, more and more organisations understand their responsibility to the environment, and have been introducing innovative sourcing processes to lower the carbon footprints of their purchases (Cosbey and Cameron, 1999; Sterner, 2002; Gardiner, 2007). According to Lee *et al.* (2009), green purchasing should consider vendors' environmental performance along with other traditional factors such as time, cost, quality and flexibility. Construction clients should develop proactive and strategic carbon reduction approaches, which take into account the entire construction process, to help improve contractors' environmental commitment.

In this paper, a carbon emission-encompassed tender (CEET) is proposed, to incentivise contractors who can introduce novel ideas to cut down the CO_2 emissions of a construction project. The paper begins by explaining the concept behind CEET. A mechanism for measuring the carbon footprints of construction materials at the product level is then introduced. The paper concludes with the challenges facing the construction industry to introducing the CEET concept.

Model Framework

Notwithstanding the existence of mandatory systems such as the clean development mechanism (Ruth *et al.*, 2000) and off-the-counter trading in voluntary markets, the amount of carbon emitted through the construction stage of a project may not justify the use of those mechanisms. As a result, there is a need to devise a practical system to encourage contractors to contribute to carbon reduction. One way to achieve this is by awarding contracts to those who can come up with bright ideas to reduce CO_2 emissions. Incorporating project carbon footprint as one of the determining factors in construction bid evaluation seems to be a feasible and logical step towards emissions reduction (HM Government, 2005).

Acknowledging the importance of maintaining fairness and transparency in bid evaluation, data pertinent to carbon emissions must be carefully solicited and analysed. To improve consistency and reliability, the project carbon footprint shall be systematically estimated according to an established framework that clearly depicts the major components of carbon emissions during the construction process. The suggestion by IBM (2008) to estimate the carbon footprint by considering the planning, sourcing, production and logistics along with carbon footprint recording principles (Chan and Boehmer, 2006) may help formulate a framework for construction project carbon footprint accounting.

The project carbon footprint as estimated by bidders can then be compared with that of a "business-as-usual" design and construction scenario (Kollmuss *et al.*, 2008), in order to determine the level of carbon emissions that each contractor can reduce. A monetary value which is acceptable to the client can then be assigned to the carbon saving such that contractors' commitment to CO_2 emissions reduction can be considered along with their bid price (*cf:* Fieldson *et al.*, 2009). The envisaged CEET framework is shown Figure 1.

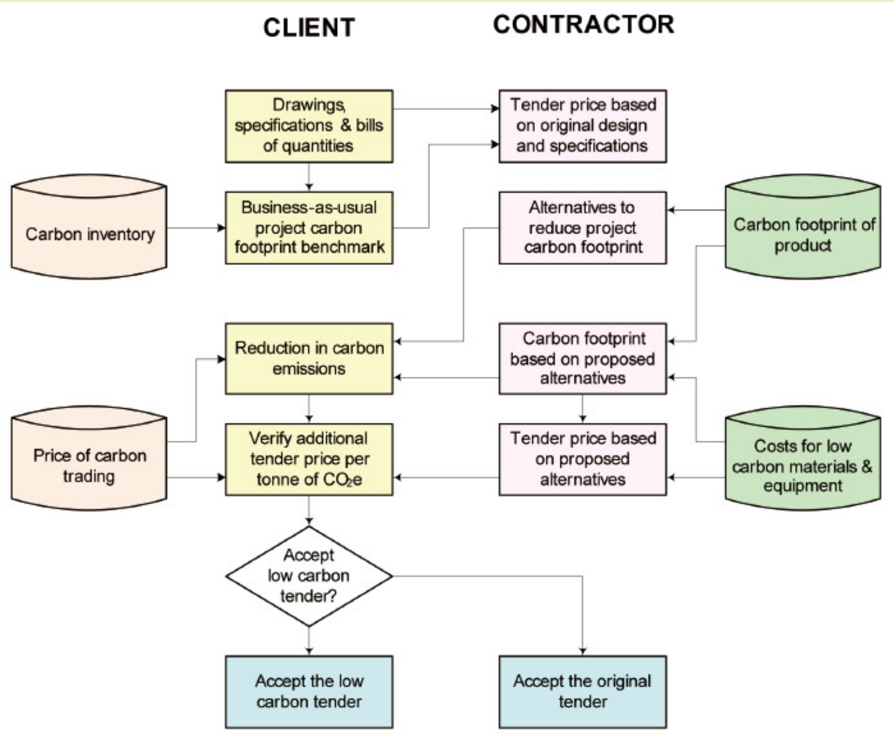


Figure 1 Conceptual framework of carbon emission-encompassed tender

The notion of CEET is analogous to that of an alternative tender, except that a project carbon footprint should first be determined by the client and/or design team, based on the developed drawings and specifications. The project carbon footprint represents the emissions in a "business-as-usual" scenario, and this can be derived by referring to typical information as identified from the Inventory of Carbon and Energy database developed by the University of Bath and/or the Institution of Civil Engineers' CESMM4 Carbon & Price Book (ICE, 2013). The project carbon footprint should be disclosed to tenderers at the tendering stage as it would serve as a baseline for subsequent comparisons.

Should a tenderer be interested in submitting a low carbon proposal, the details of alternative construction materials and/or methods, along with the magnitude of carbon reduction should be provided in CEET. Instead of using the norms as identified from established databases, the contractor should obtain and rely on the actual carbon footprint of the alternative construction materials and/or methods to calculate the emissions-conscious alternative. While the low carbon alternative may involve extra costs, the tenderer should be allowed to reflect such costs and any possible cost savings in CEET.

With the conforming tender and CEET, the client can make an informed decision to balance their carbon reduction goal and budgetary constraints. The comparison is not limited to determining how much additional cost is needed to achieve a specific amount of carbon reduction, but would also enable the client to examine whether the low carbon initiatives proposed by the tenderer represent value for money, by comparing them with the market price of carbon and the life cycle costs.

Tracking and Tracing Project Carbon Footprint

In recent years, many established standards have become available to guide the measurement of CO_2 emissions (Johnson, 2009). They include the European Union Emissions Trading Scheme (European Commission, 2007), the European Union Renewable Energy Directive (Renewable Energy Directive, 2008), and the UK Standard Assessment Procedure for Energy Rating of Dwellings 2005 (Standard Assessment Procedure, 2008).

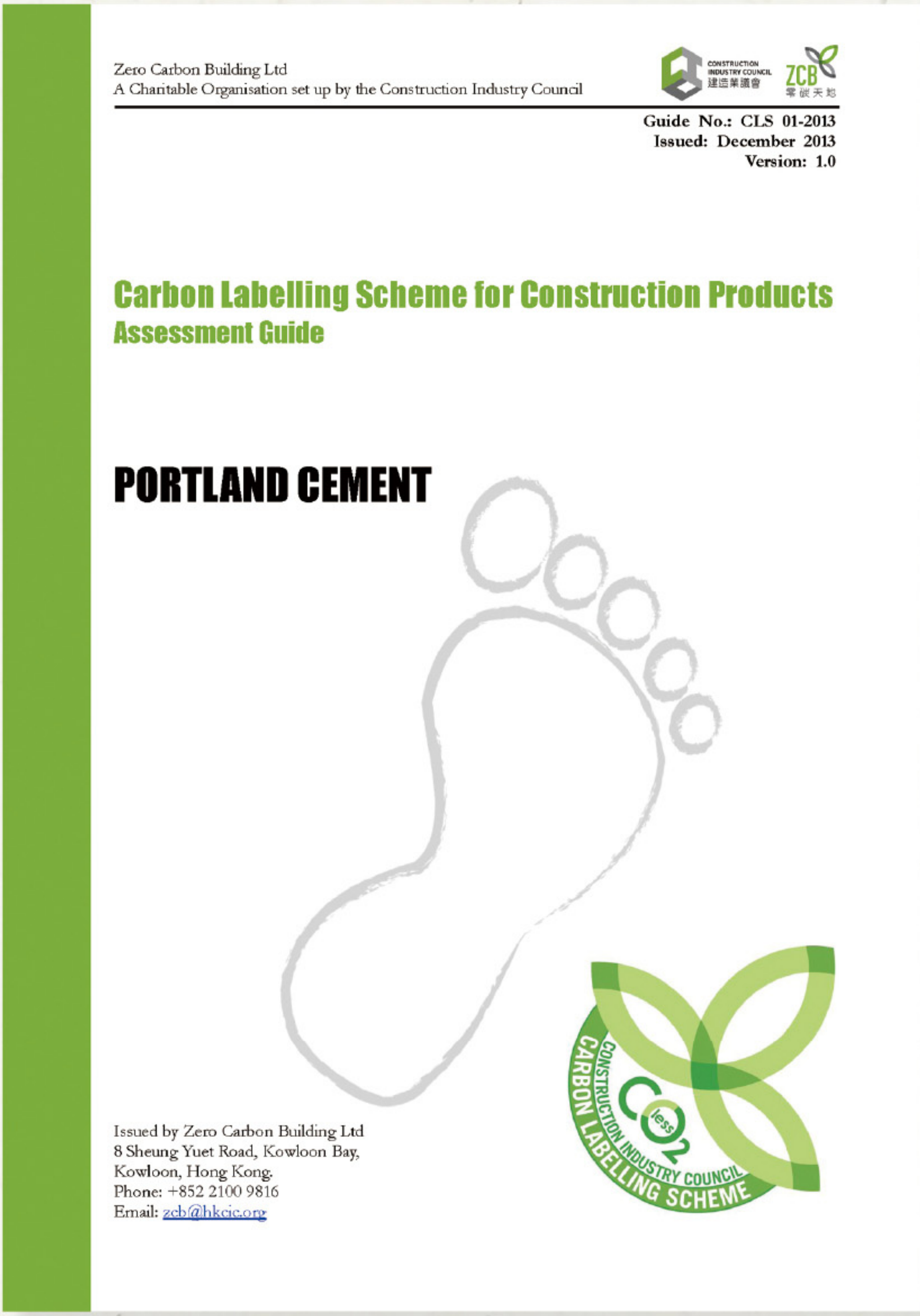
Additionally, various carbon footprint models or calculators—like the Carbon Footprint, Carbon Fund, Combat Climate Model, Grian, Resurgence, and Safe Climate are available for calculating an individual's carbon footprint based on electricity, oil, gas or coal consumption. Wiedmann and Minx (2007) proposed calculating the carbon footprint methodologically, based on the process analysis in life cycle analysis (a bottom-up approach), or according to the environmental input-output analysis using national or organisational financial statistics (a top-down approach).

Fieldson *et al.* (2009) commented that these protocols tend to focus more on organisational emissions and reporting. With the recent release of the Publicly Available Specification 2050 (PAS, 2008), and ISO/TS 14067:2013 "Greenhouse Gases – Carbon Footprint of Products – Requirements and Guidelines for Quantification and Communication" (ISO, 2013), a robust and consistent approach for assessing life cycle carbon emissions at the product level is now viable. From the perspectives of both the client and contractor, an equitable mechanism to assess the carbon footprint of product is essential, as this would allow an accurate calculation of CO_2 reduction.

With the foresight of the Construction Industry Council in HK, a carbon labelling scheme for the construction industry has been developed and launched. The first phase of development covers six construction materials: cement, reinforcing bars, structural steel, aluminium, tiles, and external glass. The second phase of development of the carbon labelling scheme is now underway, with the development of carbon assessment frameworks for another ten construction materials: concrete, precast concrete, aggregate, stainless steel, galvanised steel, cast iron, asphalt, bricks and blocks, timber products, and gypsum board.

The carbon footprint of a product is taken as the CO_2 emitted during raw material extraction and the manufacturing process, up to the point when the finished construction material is delivered to the Hong Kong border. The assessment consists of direct emissions arising from raw material combustion, combustion of kiln fuels, and combustion of non-kiln fuels. Any combustion of kiln fuels as well as those fuels used for drying and processing the raw materials should be taken into account. The combustion of non-kiln fuels which are not covered in the definition of kiln fuels, e.g. for quarrying or mining of raw materials, on-site transportation, room heating, etc. should also be accounted for. Apart from direct emissions, indirect CO_2 emissions including external production of electricity consumed by cement manufacturers, production of bought raw materials, third-party transportation, land use change and so on should also be reported.

The details of how to assess the carbon footprint of cement, reinforcing bars and structural steel are documented in guidelines prepared by the Construction Industry Council (Figure 2). The carbon labelling scheme provides transparent and reliable product carbon footprint information to both the client and contractor for assessing any carbon reduction in CEET.


Zero Carbon Building Ltd
A Charitable Organisation set up by the Construction Industry Council

Guide No.: CLS 01-2013
Issued: December 2013
Version: 1.0

Carbon Labelling Scheme for Construction Products
Assessment Guide

PORTLAND CEMENT

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CONSTRUCTION INDUSTRY COUNCIL
CARBON LABELLING SCHEME

Figure 2 Carbon footprint assessment guidelines developed by the Construction Industry Council

Benchmarking and Incentivising Regime

Under the mandatory emissions reduction regime, a project would be awarded carbon emission reduction units if the carbon reduction is "*additional to any that would occur in the absence of the project*" (UNFCCC, 1997). Therefore, projects under the clean development mechanism must be compared with a baseline to quantify the carbon reduction. An emission-based additionality test is used to establish what would have happened without the clean development mechanism project (Kollmuss *et al.*, 2008).

Similarly, voluntary markets such as the Chicago Climate Exchange operate a cap-and-trade programme, in which members are committed to annual carbon reductions as a percentage of their baseline (Estrada *et al.*, 2008). Reductions beyond the contracted level can be sold to the others (Ribón and Scott, 2007). Ruth *et al.* (2000) argued that setting a benchmark at an aggregate production level does not allow the accurate comparison of emissions reductions from a range of similar projects and they have proposed a process-step benchmarking approach.

In the absence of an agreed benchmarking approach, it would be prudent to refer to the project carbon footprint when establishing the baseline. This should ensure projects of different types, scales, standards and complexity can be compared on an equitable basis. It is encouraging to note that the Hong Kong Housing Department has developed a Carbon and Energy Estimation (CEE) model to calculate the entire life cycle of public housing projects based on a 100 year building life. Using the CEE model, the carbon emissions pertinent to the materials consumed and transportation, energy consumed in communal areas, energy consumed by occupants, carbon removals, and disposal can be systematically analysed at the project level. This should serve as a reliable and transparent basis for establishing a project's carbon footprint benchmark.

In determining whether an emission-conscious alternative is worth pursuing, one should trade-off the carbon reduction against the cost, service and quality of the proposed low carbon construction materials and methods (cf: IBM, 2008). From the client's perspective, it is necessary to leverage the reduction in project carbon footprint and any corresponding additional costs. In the voluntary market, the price for offsetting a tonne of CO_2 is governed by different offset service providers. As a result, the carbon offset prices may vary from vendor to vendor and from one project to another; plus, prices could fluctuate with the market (David Suzuki Foundation, 2009). Clients should carefully verify the suitability of using those prices in the exchange market for incentivising emission-conscious contractors. Another approach is to allow contractors to put the additional costs for using low carbon initiatives in their tender price. Then, the market price of carbon can serve as a reference for comparing the CEET price put forward by the contractor.

Challenges

To elicit the challenges of implementing CEET in HK, semi-structured interviews were conducted with various stakeholders to capture their opinions. Of the 93 experts identified, 12 agreed to take part in the interviews. The interviewees held senior positions in the government, in development, contractor and consultant firms and in a non-government organisation (NGO) (Table 1).

Table 1 Interviewee profile

Interviewee	Organisation Type	Position
A1	Government Department	Senior Engineer
A2	Government Department	Senior Engineer
A3	Government Department	Senior Architect
A4	Government Department	Senior Engineer
B1	Developer	Assistant Technical Manager
B2	Developer	Quantity Surveyor
C1	Contractor	Project Environmental Engineer
C2	Contractor	Project Engineer
C3	Contractor	Senior Quantity Surveyor
C4	Contractor	Senior Project Engineer
D1	Consultant	Senior Engineer
E1	Non-Government Organisation	Corporate Member

Obstacles

Lack of common goal: while the idea of introducing CEET is to reduce the carbon footprint of construction projects, the interviewees from government departments stressed that every stakeholder should align to this goal. Otherwise, CEET would become just another rewards scheme with no significant impact on emissions reduction at the construction stage. However, under the current cut-throat tendering mechanism, some contractors would strive to maximise their profits rather than invest energy in exploring low carbon alternatives.

Additional costs: according to the experts from the government, developers and NGO, CEET would inevitably lead to an increase in the capital cost of a construction project. The developers may not be willing to bear any excessive cost arising from CO_2 reduction. Some developers even suggested that the government should take a lead by introducing incentive schemes that motivate developers to cut the carbon emissions of their constructed facilities. According to some of the contractors interviewed, an increase in cost is the main reason clients hold back.

Immature technology: interviewees from the government and NGO believed that only a few contractors and suppliers are capable of coming up with innovative solutions to reduce project carbon footprint. From the contractor's perspective, the know-how of implementing low carbon measures could be a major obstacle, as their supervisory staff and workers will have to become acquainted with the properties of the low carbon materials and/or equipment. The limited choice of low carbon materials and/or equipment was also a concern for the contractors interviewed. The lack of knowledge could further increase their costs.

Project constraints: the contractors were less optimistic regarding CEET as they are very much handicapped by the design and specifications developed by the client and design team. As a result, low carbon alternatives that the contractors can adopt could be very limited. The contractors interviewed also pointed out that project time, cost and quality are seen as the most important aspects of a construction project and introducing any low carbon alternatives may jeopardise project success. Unless the introduction of low carbon initiatives is equitably rewarded, there is little incentive for them to take the risk.

Key Factors for Success

Transparent system: while the consultants interviewed believed that CEET can help with consolidation in the industry and improve contractors' confidence in developing low carbon construction technology, the government, developers, contractors and NGO interviewees emphasised the importance of developing a transparent system to measure carbon reduction and reward the contractor. According to the interviewees from the development companies, sufficient resources should be directed to analyse whether construction time and quality will be affected by the low carbon alternatives. Constant reviews should be carried out to ensure effective CO_2 reduction as work progresses, according to interviewees from the government.

Change in mindset: from the contractors' perspective, a fundamental change in clients' mindset is needed, so that the focus is no longer on minimising construction costs and time, but on reducing the environmental impacts and carbon footprint of a constructed facility. This was echoed by the developers and consultants interviewed, who emphasised the importance of a cultural change towards sustainable development. To achieve this necessitates close communications between the client, design team and contractor, to establish which are the most feasible and effective low carbon alternatives in the construction stage, according to contractors and the NGO.

Leadership: with more and more companies recognising the importance of corporate social responsibility and the adverse impacts of carbon emissions, some contractors are willing to contribute to emissions reduction on a voluntary basis. However, the successful introduction of CEET would call for leadership from the government and professional institutions, according to interviewees from the government, development, consultant and contractor firms. While developers are sceptical of spending extra money on low carbon construction materials and/or equipment, the government can implement CEET on a trial basis for some public works projects to explore its effectiveness.

Education and training: the government officials interviewed stressed the importance of education and training to equip construction stakeholders with low carbon measures. They also believe that it is necessary to provide training to clients and contractors, to familiarise them with the CEET concept especially the way in which a project carbon footprint is calculated, as this is still very new to many participants in the construction industry. This is echoed by the contractors interviewed, as they considered it vital to understand the philosophy behind CEET so they can accurately submit low carbon tenders.

Conclusions

In this paper, the CEET concept has been proposed to encourage contractors to identify innovative solutions to help reduce carbon emissions at the project level. To ensure the contractor is equitably rewarded, it is necessary to identify the project carbon footprint based on a business-as-usual scenario. On this basis, a baseline can be established to benchmark against the carbon saving of a low carbon alternative. Acknowledging that any reduction in project carbon footprint may add to the cost of a project, the contractor is allowed to price the low carbon materials and/or equipment proposed. The extra cost is compared with the market price of carbon to enable the client to make an informed decision.

One of the major challenges of CEET lies in how to systematically and accurately account for the carbon of low carbon construction materials. Thanks to the recently released ISO standard, a product's carbon footprint can be scientifically calculated. More importantly, the Construction Industry Council in HK recently launched the carbon labelling scheme for construction products. The scheme should provide a simple and reliable platform for clients and contractors to gauge the carbon emissions of construction materials at the product level. This should open up opportunities for realising CEET in the construction industry.

Even so, there are still a number of challenges ahead before CEET can be successfully introduced in practice. Examples include the inherent adversarial culture of the construction industry, and the lack of incentives for clients to move towards a low carbon construction philosophy. There is a need to change the current culture through substantial government support and better training, so that construction stakeholders become aware of the benefits of low carbon construction not only for their own companies through reduced life cycle costs, but also for society by helping to reduce the impacts of climate change.

Acknowledgements

The author would like to thank the Construction Industry Council and the Shenzhen Government for funding this research study through the CIC's Research Funding Grants and Shenzhen Key Lab in Carbon Emissions Enabling Technology respectively. The help of Miss Fanny P.Y. Chung in conducting the interviews and analysing the data is also gratefully acknowledged.

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The Importance of Developing a Local Carbon Inventory Database Towards Low Carbon Construction in Hong Kong

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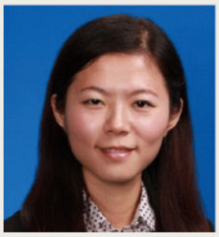
According to World Wide Fund (WWF), the construction sector was the second largest contributor to the Hong Kong carbon footprint. Around 85% of this carbon footprint was embodied in imported goods and services from upstream material inputs to Hong Kong. Therefore, it is crucial to study the embodied carbon of construction materials and select low carbon materials in order to achieve a low carbon built environment. This paper reviews current major carbon inventory databases worldwide and their impacts on the local industry. A local carbon inventory database specific to the Hong Kong construction industry can provide a basis for the development of carbon labels, selection of green materials, promotion of low carbon manufacturing of materials, and low carbon design and construction, thereby helping to construct a low carbon Hong Kong. Therefore, The Hong Kong University of Science and Technology (HKUST) started to develop a local carbon database for commonly used construction materials in Hong Kong, namely ECO-CM (Embodied Carbon Of Construction Material). A "Cradle-to-Site" system boundary is used in the ECO-CM database to improve the accuracy and completeness of the results. The life cycle methodology framework used in the development of the ECO-CM database is presented and briefly described in this paper.

Keywords: cradle-to-site, carbon inventory database, construction materials, low carbon construction



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Introduction

Hong Kong is one of the world's most densely populated cities and its construction sector is one of the important pillar industries that establish the foundation for the city's stable and sustainable development. Buildings in Hong Kong consume about 90% of the city's total electricity consumption, which accounts for about 60% of the overall greenhouse gas (GHG) emissions (GHG Protocol, 2012a). According to the *Hong Kong Ecological Footprint Report 2010* released by WWF, 4 million tonnes of carbon dioxide were emitted in Hong Kong and the construction sector was the second largest contributor to the Hong Kong carbon footprint in 2007 (WWF, 2011). In response to the Hong Kong government's carbon intensity reduction target of 50%–60% by 2020, compared with the 2005 level, different industries are proactively adopting various low carbon practices. The construction industry plays an indispensable role in this trend.

Being a service economy without many major manufacturing industries, the Hong Kong construction sector largely depends on the import of different construction materials. According to the statistics from the Hong Kong Census and Statistics Department (HKCSD) for example, about half of all cement products are imported, while all wood-based products (e.g. plywood, lumber, fibreboard, and particle board) are imported from overseas. The consumption of other major commonly used construction materials in Hong Kong, such as steel and aggregate, also relies on imports.

Of the carbon footprint associated with the construction sector in Hong Kong, around 85% was embodied carbon in imported goods (i.e. construction materials) and services, from upstream material inputs to Hong Kong (WWF, 2011). The recent continuous growth of the construction gross volume, together with the Ten Major Infrastructure Projects in Hong Kong[1], enormously boost the local consumption of construction materials. With the concern for increased material consumption, the impact of embodied carbon in materials that increase the overall carbon footprint of a single building should also be considered.

It has been shown in some cases that the carbon footprint embodied in materials can be as significant as the emissions after the construction stage is completed and the building is in use (Fernandez, 2008; Fridley *et al*., 2008). In addition, a case study that focused on the construction stage of a building in Hong Kong indicated that the embodied carbon footprint of construction materials could contribute 82%–87% of the total GHG emissions in the building construction stage (Yan *et al*., 2010). If low carbon construction materials are prudently selected in the initial design and construction stages of projects, the total carbon footprint of the whole constructed facility could be efficiently controlled and mitigated.

The reduction of embodied carbon in imported construction materials will lead to a significant decrease in buildings' overall carbon footprint, thus facilitating Hong Kong's transition towards low carbon construction. Yet, Hong Kong currently does not have an authoritative, independent and publicly acceptable database or inventory providing the carbon footprint values of locally used construction materials. With the intention to lower the carbon footprint of the Hong Kong construction sector, local construction industry stakeholders are calling for a recognised inventory or evaluation system to indicate the performance (in terms of carbon footprint) of commonly used construction materials.

Review of Major Embodied Carbon Databases

The embodied carbon of a construction material has been defined as the total carbon released over its life cycle, which would include at least raw material extraction, product manufacturing and transportation (Hammond and Jones, 2008). There have been various studies on the embodied carbon of materials. Table 1 summarises basic information on some major life cycle carbon inventories around the world, evaluating the direct and indirect impacts of material production processes, using a life cycle assessment technique. These inventories influence the local industry in various ways, including facilitating the application of low carbon technology and transforming the industry towards low carbon manufacturing and practices.

Ecoinvent

Ecoinvent is one of the best known and most commonly used life cycle inventories worldwide. It was built by the Swiss Centre for Life Cycle Inventories and has been developed for two decades. Known as the leading provider of life cycle data and services, Ecoinvent supports various industries (including the construction sector) in enhancing the environmental performance of products, processes, and services.

Table 1 Different life cycle carbon inventories of construction materials

Region	Name of the Database	Developer	System Boundary
Switzerland	Ecoinvent	Swiss Centre for Life Cycle Inventories	Gate-to-Gate
Europe	ELCD (European reference Life Cycle Database)	European Union (EU)	Cradle-to-Gate
China	CLCD (Chinese reference Life Cycle Database)	Sichuan University, China	Cradle-to-Gate
United Kingdom	ICE (Inventory of Carbon and Energy)	University of Bath, United Kingdom (UK)	Cradle-to-Gate
Japan	Carbon Footprint of Product (CFP) Database	Japan Environmental Management Association for Industry	Cradle-to-Gate

[1] The then Chief Executive Donald Tsang announced in "The 2007-2008 Policy Address" that the HKSAR government would push ahead with 10 large-scale infrastructure projects to promote economic development, improve the living environment in Hong Kong and create employment opportunities. Details can be found at: http://www.policyaddress.gov.hk/07-08/eng/policy.html

Ecoinvent contains about 125 specific building materials and processes (Kellenberger *et al*., 2007). The scope of Ecoinvent is "gate-to-gate" for building materials and the emission of each GHG is given separately (Kellenberger *et al*., 2007; GHG Protocol, 2012b).

Ecoinvent has directly or indirectly improved the sustainability and environmental performance of the construction industry through authorising its data usage in green building design software or sustainable building assessment tools, such as the Swiss Eco-bau for performing life cycle impacts analysis of a building, and a German calculation tool (LEGEP software) for integrated design of sustainable buildings.

ELCD

The European reference Life Cycle Database (ELCD), comprises life cycle inventory (LCI) data from front-running EU-level business associations and other sources for key materials, energy carriers, transport, and waste management. One of the major topics covered in ELCD is materials production, which includes the manufacture of construction materials such as glass, ceramics, cement, concrete, and wood. ELCD sets the scope of construction material as "cradle-to-gate" (ELCD, 2010). It collects data from various sources including academic research, industry statistics, government publications, and other LCA databases.

As the key element in the European Platform for Life Cycle Assessment (EPLCA), ELCD assists users in collecting data for product life cycle and corporate GHG inventories. With the data service provided by ELCD, the EPLCA serves as an effective platform to support businesses and public authorities in the implementation of sustainable consumption and production, thereby facilitating the development of a green economy in Europe.

CLCD

Chinese researchers are developing a LCI database similar to ELCD—the Chinese reference Life Cycle Database (CLCD). CLCD is an expandable life cycle model of major industries in China, which includes 600 products such as electricity, coal, other fossil fuels and transport (Liu *et al*., 2010; GHG Protocol, 2012c). To date, the CLCD has been developed as a national LCI database based on a consistent core life cycle model representing a combination of various technologies in the Chinese market.

CLCD claims to be the only publicly available comprehensive carbon inventory database in China currently with more than 1000 users. Beijing Research Center of Urban System Engineering is among the users of CLCD, utilising the data provided to support its research on low carbon community development and urban management, including carbon footprint auditing, analysis and community reporting. In addition, the developer of CLCD has collaborated with the China Building Material Test & Certification Centre in implementing projects on construction material testing and certification from a life cycle perspective.

ICE

The University of Bath, UK, developed the Inventory of Carbon & Energy (ICE), which includes the embodied energy and carbon of a large number of building materials (Hammond and Jones, 2011). The ICE database contains data for over 200 materials, grouped into over 30 main material categories (such as cement, concrete, glass, timber, plastics, and steel). ICE's scope is "Cradle-to-Gate". As a very comprehensive inventory focusing on the embodied energy and carbon footprint of building materials, ICE has been well received in the construction industry. In total, the ICE database has been downloaded by over 15,000 professionals from around the world, and it appears in countless reports, journals, books, lectures, carbon footprint calculators and more. It is believed that ICE has become a leading embodied carbon resource.

Japan CFP Database

The Japan Environmental Management Association for Industry (JEMAI) has operated a Japan Carbon Footprint of Products (CFP) scheme and built a database with a "Cradle-to-Gate" system boundary. The CFP database results are presented in terms of CO_2-e, representing total GHG emissions (JEMAI, 2012). A major contribution of the CFP database is to support the implementation of the CFP scheme, which labels the carbon footprints of products complying with ISO 14067, to enhance credibility and transparency of the low carbon performance of applied products and their manufacturers.

According to the CFP programme website, 21 products from large corporations such as Canon, Samsung Electronics, and Fuji Xerox, have been certified and labelled with the corresponding CFP. This indicates that the CFP scheme together with its CFP database have proactively encouraged industry stakeholders (e.g. producers and consumers) to increase their awareness of carbon footprints and to take actions in low carbon manufacturing and purchasing.

The Need for Local Databases

After reviewing the current major life cycle databases or carbon footprint inventories, it is found that the databases support researchers, local industry practitioners and business decision makers to examine the carbon footprint and environmental performance of a product or service, as well as identify significant GHG emission sources and potential carbon reduction opportunities. For these tasks, it is crucial to have accurate and representative data that can truly and comprehensively reflect a product's life cycle.

A question may be raised: "While there are several existing major carbon inventory databases, why are different countries still dedicated to developing their own inventories instead of referring to data in the existing databases? And why does Hong Kong need to develop a new database?" Since the manufacturing process, fuel mix and raw material sources may be different in various regions and countries, the values of embodied carbon are closely related to different regional conditions. It is particularly important to obtain region-specific data of the manufacturing process and its upstream and downstream stages. Therefore, the life cycle carbon inventory databases in other regions cannot be directly used for Hong Kong and hence a local database needs to be developed. The following section will discuss the importance and potential impacts of a local carbon inventory database for the Hong Kong construction industry.

Potential Impacts of a Local Carbon Database for Hong Kong

In general, a local carbon inventory database for construction materials can fill the gap for assessing and reducing the carbon footprint of the built environment in Hong Kong. Like the other regional databases mentioned in the previous section, a Hong Kong-based carbon database can provide several benefits to the local construction industry, including but not limited to the following:

Development of Carbon Labels

The Construction Industry Council (CIC) has recently launched a Carbon Labelling Scheme for Construction Products for the Hong Kong construction industry. The scheme aims to provide verifiable and accurate information on the carbon footprints of construction products for client bodies, designers, contractors and end users, enabling them to select low carbon materials. Each material submission is certified with a grade between A to E based on benchmarks of the corresponding product category. Local carbon footprint data is crucial and desirable in determining the benchmarks of the labelling scheme for each product category and to ensure the grading of materials correctly reflects the real technology level and environmental performance of the local industry. In this context, the development of a local database can meet the urgent need of the CIC Carbon Labelling Scheme. In addition, the assessment approach developed in this study could serve as a reference for carbon measurements and auditing in the application of carbon labels.

Low Carbon Procurement

In Hong Kong, the green building evaluation system (i.e. BEAM Plus) has gained popularity with the incentive of granting gross floor area (GFA) concessions. The increased use of low carbon materials in the whole building project may help in obtaining additional credits in the BEAM Plus evaluation. With such considerations, developers and contractors are pleased to invest more on procurement of low carbon materials. A carbon inventory database can provide a publicly available platform for presenting the current carbon footprint benchmark of the Hong Kong market, which serves as a reference for selecting low carbon materials for green procurement.

Low Carbon Manufacturing

If procurement decisions are affected by low carbon initiatives, then schemes such as the CIC Carbon Labelling Scheme, can stimulate the demand for and supply of low carbon construction materials in the local market. Manufacturers and suppliers will be driven to pay more attention to the environmental performance and carbon footprints of their products to increase competitiveness as well as build a corporate image based on climate change mitigation. The development of a local carbon inventory comprises the embodied carbon for each material, and also develops guidelines for reviewing GHG emission sources in material production. This helps material manufacturers to measure their effectiveness in reducing carbon emissions, equips them with best practices in GHG management, and enables them to strive for technology advancement as well as energy reduction. This promotes low carbon manufacturing of construction materials and indirectly encourages the development of green construction materials.

Low Carbon Design and Construction

Architects are faced with a new challenge to ensure that the new buildings they design and the existing buildings they refurbish produce less carbon emissions than at present. In some regions, low carbon designs are included in tender evaluations as credits in addition to the criteria of cost and quality. Apart from measures of utilising energy efficient techniques or equipment that rely on occupants' behaviour, the use of low carbon materials is desirable to reduce the embodied carbon of buildings at an early stage.

The carbon inventory lays the foundation for applying low carbon materials in the design and construction stage. On the basis of the available local carbon footprint data provided by the database, architects and engineers can estimate the embodied carbon of each component (e.g. concrete and steel), as well as the whole building. They can then use this information to optimise the structural configuration, to minimise the embodied carbon of the building and facilitate the design of low carbon buildings, if the carbon footprint data is integrated with suitable evaluation methods and assessment systems.

Prefabrication and modular designs have been applied in public housing works for several years by the Hong Kong Housing Authority in order to increase efficiency and reduce manpower requirements onsite. If the prefabricated components or modular design are integrated with the use of low carbon materials, carbon footprint reduction can be achieved in the pre-construction stage together with productivity enhancements during construction, doubling the benefits. Moreover, a government department taking the lead to use low carbon materials in public works may encourage other stakeholders to follow suit in private projects.

The establishment of a local carbon inventory database provides a measureable and comparable indicator of the embodied carbon of materials. This stimulates industry stakeholders, from senior management to construction workers, to boost awareness of using low carbon materials from the design stage to the construction stage and even in tender evaluation. With the integration of low carbon design and construction, it is believed that the construction industry's carbon footprint can be reduced from the very beginning of the building life cycle.

Development of ECO-CM

Considering the importance of and need for a local carbon inventory database, a research team at HKUST initiated a research project to develop a local embodied carbon database, focusing on construction materials that are commonly used in the Hong Kong construction industry. The database is called Embodied Carbon Of Construction Materials (ECO-CM). The following sections will briefly describe the methodology framework and its steps for the development of the ECO-CM database.

Methodology Framework

ECO-CM was developed using the life cycle assessment (LCA) technique, which is a holistic methodology for identifying the inputs, outputs, and potential environmental impacts (e.g. eutrophication, toxicity, and climate change) over the product life cycle. A series of international standard guidelines related to LCA and carbon footprint auditing, such as ISO 14040:2006 (ISO, 2006a), ISO 14044:2006 (ISO, 2006b), Publicly Available Specification (PAS) 2050:2008 (Defra, 2008), and ISO/TS 14067:2013 (ISO, 2013), were referred to in developing the methodology framework for this project, focusing on the single impact category of climate change.

In the ECO-CM database, the calculation of material embodied carbon is examined over the "Cradle-to-Site" life cycle system boundary, which covers a partial product life cycle from resource extraction ("cradle") until the product has reached the point of use (i.e. the border of Hong Kong). Product transportation is considered in ECO-CM because most construction materials used in Hong Kong are produced by overseas manufacturers. Consideration of emissions from product transportation could improve the accuracy and completeness of the results. However, the use phase is not considered in ECO-CM because construction materials often have a long service life of up to 50-70 years.

As shown in Figure 1, the generic methodology framework consists of four main stages: (1) Background study, (2) System boundary setting, (3) Data collection and calculation, and (4) Analysis and reporting.

To develop a region-specific inventory, the manufacturing processes of the materials produced in local and nearby areas should be examined in the background study. The GHG emission sources over the specified life cycle are then identified, and the standard GHG emission calculation guidelines are reviewed. Based on the information obtained from the background study, detailed system boundaries describing the life cycle stages within the predefined scope, are portrayed for each material. In the data collection and calculation stage, questionnaires specific to local and nearby manufacturers are designed and distributed to collect first-hand data. In addition, face-to-face interviews are conducted as needed. This data collection stage is the key to the whole study because the availability, quality and completeness of the data could influence the accuracy and reliability of the final results. In the data collection, iterative reviews and revision of the questionnaires are conducted in response to industry feedback. GHG emissions of the building materials are then calculated with reference to the relevant guidelines and standards. Finally, the results are analysed, compared, and reported, summarising the whole study.

This methodology is modified based on the basic framework of LCA studies, with consideration of local factors, which serves as a reference for the investigation of other construction materials. Specific modifications can be made according to situations that occur during the investigation.

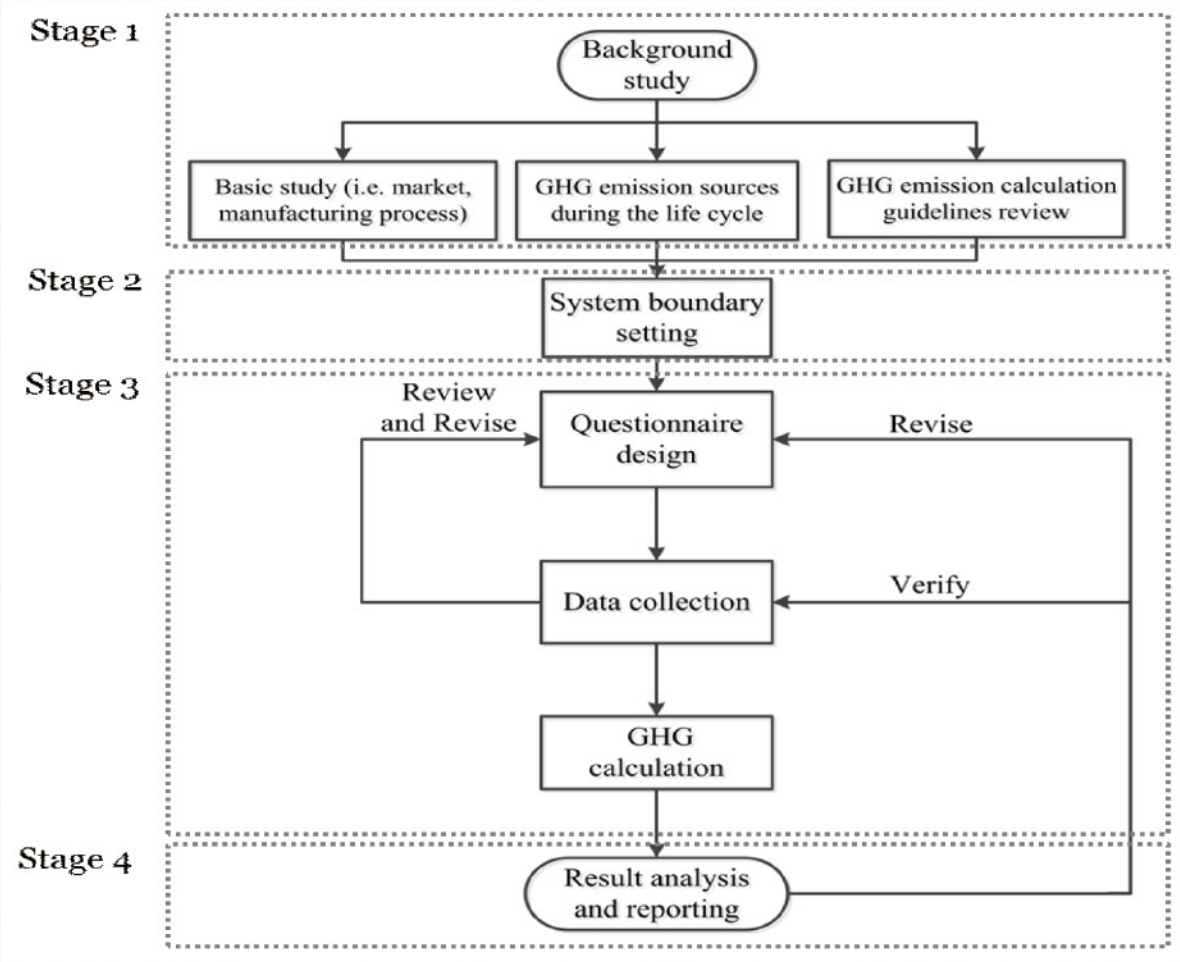

Figure 1 Methodology framework developed for life cycle carbon measurement

Figure 2 A snapshot of ECO-CM

Snapshot of ECO-CM

Following the above methodology framework, the HKUST research team has conducted studies on construction materials such as portland cement, ready-mixed concrete, plywood, timber, and aggregate. The results and findings have been published in some international journals and conferences.

With ongoing development of the ECO-CM database, first-hand data will be collected to produce results on embodied carbon of different materials. Parts of the results will be available online (as shown in Figure 2) as a reference source for the local construction industry, academia and consultant agencies. The HKUST team intends to further extend the life cycle study of construction materials used in Hong Kong and build a comprehensive database/inventory which covers other environmental impacts.

Conclusions

Low carbon building and construction has become an important consideration in the Hong Kong construction sector. Local industry practitioners are increasingly willing to contribute to the sustainable development of the city by implementing green practices such as using low carbon materials. This paper presents the importance and potential impacts of a local embodied carbon database for construction materials in Hong Kong. A well-developed carbon inventory database can benefit the local construction industry through carbon label benchmarking, low carbon material procurement, stimulating the demand for low carbon construction material manufacturing, and low carbon building design and construction. Together with other initiatives, such as the CIC Carbon Labelling Scheme, this database will help drive the Hong Kong construction industry towards a low carbon and sustainable future.

In view of this, the HKUST research team initiated a project to develop a local carbon inventory database for construction materials called ECO-CM. The database is a Hong Kong-based database that considers a "Cradle-to-Site" system boundary, from raw material acquisition, till the finished materials are transported to the border of Hong Kong. The key steps of the methodology framework for the development of ECO-CM were briefly described in this paper. They can be a reference for interested stakeholders when conducting carbon assessments of their own materials. In order to elicit real region-specific performance, first hand data from material manufacturers and suppliers are collected, and used in the calculation of ECO-CM. With more accurate and locally specific estimates of the embodied carbon of construction materials, ECO-CM intends to serve as an independent and comprehensive sharing platform for low carbon construction materials.

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BREEAM:
Driving Sustainable Buildings Globally

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Since its launch in 1990, BREEAM has become known around the world as a mark of quality for sustainable construction. Some of the key elements that have made BREEAM so influential are discussed. The assessment process is summarised with how to become involved in the scheme.

Keywords: BREEAM, sustainable building design, assessment, certification

Martin Townsend has a diverse professional background ranging from advising UK Ministers, as a regulator in his time at the Environment Agency, to working on many construction sites. Martin joined BRE Global as Director in 2008 to drive BREEAM forward not just in the UK market, but also internationally. He works closely with the construction industry bringing sustainability issues alive for companies right across the social, economic and environmental agenda. Martin offers both a UK and an international perspective on construction and has addressed and briefed Ministers of State and several other major fora on the environment and sustainable construction in particular.

David Leonard is BREEAM New Construction Manager at BRE Global, responsible for managing a team of sustainability experts who maintain and operate BREEAM schemes globally, thereby influencing sustainability on thousands of new build projects. He has been involved in the BREEAM certification of numerous major projects including Heathrow Terminal 2 in London, Franshion Green Building Exhibition Centre in Changsha, and Roland Garros Stadium Modernisation in Paris. David was recently recognised in Building Magazine's 'Rising Stars of Sustainability' for 2014.

Introduction

BREEAM is a global standard for best practice in sustainable building design, construction and operation, which encourages designers, clients and others to implement low carbon design.

To date, BREEAM assessments of some 270,000 buildings worldwide have been certified, with more than 1,000,000 registered for certification. With these assessments covering buildings in more than 60 countries, BREEAM has established itself as the world's foremost environmental assessment method and rating system for buildings. This article discusses BREEAM's approach to driving improved sustainability in development projects. It provides brief overviews of new versions covering more parts of the building life cycle and elements of the built environment, and presents case studies of recently BREEAM assessed buildings.

Figure 1 Tour Majunga is a 44 storey office building, with capacity for more than 6,000 occupants in La Defense – the modern high-rise and office tower business district of Paris.

The building achieved BREEAM Excellent and was the highest scoring building in Europe in 2011.

Tour Majunga's impressive array of features include access on each floor to a 50m² loggia on the south side of the building, which provides all occupants with ready access to outdoor space.

The BREEAM Approach

BREEAM assesses buildings against scientifically-based criteria covering a wide range of environmental and broader sustainability issues. The buildings are rated and certificated on a scale of "Pass", "Good", "Very Good", "Excellent" and "Outstanding".

As well as recognising and promoting buildings with sustainability credentials, BREEAM aims to improve sustainability in those buildings and in the built environment as a whole. The BREEAM standard sets sustainability benchmarks and targets that stay ahead of regulatory requirements in order to encourage developers and project teams to push beyond regulations. It also rewards the use of innovative strategies for achieving these targets.

Figure 2 The Houghton Primary Care Centre was the first healthcare building in the UK to achieve a BREEAM Outstanding (post-construction stage) rating.

Figure 3 MediaCityUK in Manchester achieved a BREEAM Communities Excellent rating.

BREEAM is underpinned by a set of key principles. These include the robustness of the science on which it is based, the scheme's strict impartiality, its holistic approach, and the flexibility that enables it to be applied almost anywhere in the world. These principles help to ensure that construction professionals use BREEAM to deliver the sustainability benefits they seek, and that the market recognises the value of BREEAM rated buildings. Another important principle is the continual drive to improve and develop BREEAM, with the help of feedback from assessors, clients and experts, and in light of technical and regulatory advances.

Scientifically Robust

BREEAM is operated by BRE Global, a BRE Group company[1]. BRE has been at the forefront of scientific research and development in the built environment sectors for more than 90 years, and in recent decades has taken a leading role in sustainability. This experience, expertise and ongoing research provide the robust science that underpins BREEAM.

The scheme's scientific rigour gives industry professionals confidence that BREEAM brings genuine sustainability improvements. "BREEAM has a strong reputation as an environmental standard," says Stuart Rimmer, Construction Project Director with the Peel Group, the client on the MediaCityUK project as shown in Figure 3. "Using the scheme on development projects gives us confidence that we are designing and constructing sustainably, and gives our clients and tenants confidence that the green credentials claimed for our developments are accurate. People know and trust the BREEAM standard – if you get a BREEAM Excellent, for example, there is no doubt or argument about what you have achieved."

Impartial

The BREEAM assessment process is based on an international network of more than 2600 trained and licensed, independent BREEAM Assessors. They conduct impartial building assessments that are then submitted to BRE Global for quality assurance and third-party certification. This approach ensures that BREEAM rated buildings are as sustainable as they claim and that the highest scoring buildings represent some of the best examples of sustainable design and construction.

[1] BRE Group comprises: BRE, BRE Global and BRE Ventures.

The use of independent assessors reflects the impartial ethos of the BRE Group. The group is owned by BRE Trust, a charitable company that aims to advance knowledge, innovation and communication in all matters concerning the built environment. This ownership structure has enabled the group to be maintained as a national asset, independent of specific commercial interests. All profits made by its subsidiary companies are passed to the trust for use to further its charitable aims.

Holistic

A BREEAM assessment encompasses sustainability in its widest sense—not just energy use and carbon emissions. A broad range of issues grouped into nine categories: energy, water consumption, health and wellbeing, pollution, transport, materials, waste, ecology and management, are assessed with BREEAM credits available for each.

Within these categories, issues such as acoustic performance, construction site impacts and the responsible sourcing of materials are addressed. For example, issues covered in the area of health and wellbeing include microbial contamination, to ensure that building services are designed to reduce the risk of legionellosis in operation.

Applicable Worldwide

BREEAM can be used worldwide. The BREEAM International New Construction scheme has been specifically developed to enable assessments of office, retail and industrial buildings, as well as residential developments. The scheme can also be adapted on a case-by-case basis for assessments of other building types via the BREEAM Bespoke criteria development process. In addition, there are a growing number of country-specific BREEAM schemes operated by National Scheme Operators (NSOs).

There are currently NSOs affiliated with BREEAM in:

The Netherlands – the Dutch Green Building Council operates BREEAM NL
Spain – the Instituto Tecnológico de Galicia operates BREEAM ES
Norway – the Norwegian Green Building Council operates BREEAM NOR
Sweden – the Swedish Green Building Council operates BREEAM SE
Germany – the German Institute for Sustainable Real Estate (DIFNI) operates BREEAM DE
Austria – DIFNI operates BREEAM AT
Switzerland – DIFNI is adapting BREEAM CH
Luxembourg – DIFNI is adapting BREEAM LU

Schemes operated by NSOs can take any format as long as they comply with a set of overarching requirements specified in BRE Global's "Code for a Sustainable Built Environment " as shown in Figure 4. They can be developed from scratch by adapting current BREEAM schemes to the local context, or by developing existing local schemes. The Code for a sustainable Built Environment is an overall framework for the environmental, social and economic assessment of the built environment.

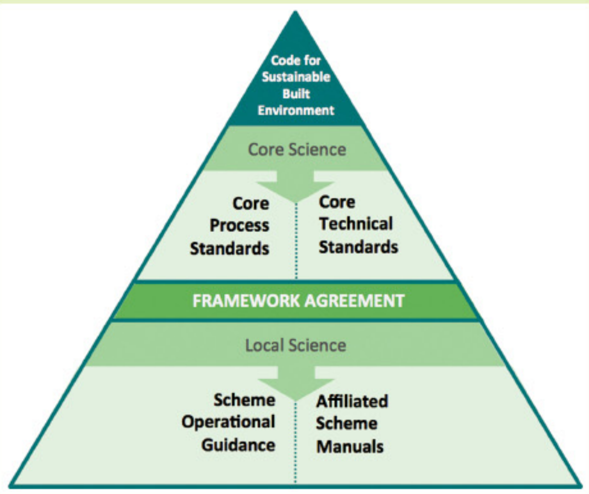

Figure 4 Code for a Sustainable Built Environment

A key feature of the framework is the ability to allow organisations in other countries to adapt BREEAM to their local context and affiliate their processes, products and tools with BREEAM across all life cycle stages of buildings and infrastructure. At the same time, it ensures that the key governing standards are consistently applied, but in a market focused way.

The flexibility that has enabled BREEAM's global spread is also reflected in other aspects, such as its "weighting" system. The relative importance of different sustainability issues is quantified in the BREEAM methodology through the weightings given for each BREEAM category. These weightings vary by country or region to reflect differences in climate, regulations and culture, etc. For example, the water category contributes 3.5 % of the total assessment score for projects in Finland, 6% of the assessment score in Latvia and a very substantial 21.5% for projects in the Kingdom of Saudi Arabia. Weightings for Latvia and Saudia Arabia are compared in Table 1.

BREEAM Assessment Category	BREEAM Weightings in the Kingdom of Saudi Arabia	BREEAM Weightings in Latvia
Management	9.5%	12.5%
Health and Wellbeing	11%	14.5%
H & W Hazards	0.5%	1%
Energy	15%	20%
Transport	8.5%	6%
Water	8%	8%
Materials	10%	13%
Waste	8%	8%
Land Use & Ecology	8%	8%
Pollution	5%	5%
Pol Surface Water Run-off	3%	3%

Table 1 A comparison of BREEAM assessment category weightings in Saudi Arabia and Latvia

The BREEAM Process

Anyone wishing to have a built asset BREEAM assessed and certificated will first decide which scheme applies to their project, for most of which there are international (as well as UK) versions:

BREEAM Communities – for the planning stage of communities
BREEAM New Construction – for the design and construction of new buildings (non-domestic)
Code for Sustainable Homes (UK only) – for the design and construction of domestic buildings
BREEAM In-Use – for an in-use assessment of an existing building
BREEAM Refurbishment – for refurbishment and renovation

The next step is to contact a BREEAM assessor (listed on www.greenbooklive.com) who will take the client through the remaining steps of registering for an assessment and to ultimately getting the building certificated.

BREEAM assessments consist of two stages:

- **Design stage** or interim assessment, which typically represents a building's performance before operations on site, and will ideally be carried out at the schematic design or detailed design stages;

- **Post construction** assessment and certification, which represents the as-built performance of a building and will be carried out before occupation.

BREEAM assessors determine the BREEAM rating using the appropriate assessment tools and calculators. An indication of performance against the BREEAM scheme can also be determined using a BREEAM Pre-Assessment Estimator (available on www.breeam.org).

BREEAM credits, which are added together to provide an overall rating, are awarded for issues grouped under the nine assessment categories. The number of credits awarded is determined by the assessor in accordance with the criteria given for each issue in the schemes' technical manuals.

The percentage of credits achieved is calculated for each category and multiplied by the corresponding category weighting. These category scores are then added together to give the overall BREEAM score (additional innovation credits may be available for innovative sustainability strategies). This score is then compared to the BREEAM rating benchmark levels as shown in Table 2, and provided any required minimum standards have been met, the relevant BREEAM rating is achieved. An example of a BREEAM assessor's calculation is provided in Table 3.

BREEAM Rating	% Score
Outstanding	≥ 85
Excellent	≥ 70
Very Good	≥ 55
Good	≥ 45
Pass	≥ 30
Unclassified	< 30

Table 2 BREEAM ratings

Category	Credits Achieved	Credits Available	% of Credits Achieved	Category Weighting	Category Score
Management	10	22	45%	0.12	5.45%
Health & Wellbeing	8	10	80.00%	0.15	12.00%
Energy	16	30	53.33%	0.19	10.13%
Transport	5	9	55.56%	0.08	4.44%
Water	5	9	55.56	0.06	3.33%
Materials	6	12	50.00%	0.125	6.25%
Waste	3	7	42.86%	0.075	3.21%
Land Use & Ecology	5	10	50.00%	0.10	5.00%
Pollution	5	13	38.50%	0.10	3.85%
Innovation	2	10	20%	0.10	2%
Final BREEAM Score			**55.66%**		
BREEAM Rating			**Very Good**		

Table 3 Example BREEAM score and rating calculation

Market Recognition of Quality and Value

A BREEAM rating can make a building more marketable to tenants and purchasers because it is recognised as a mark of quality for sustainable construction and for its potential for reducing operational costs. "Sustainability reduces running costs – energy use, waste disposal, etc," says Stuart Rimmer of Peel Group. "We retain many of the assets we build and take a close interest in their life costs. There is also a lot of pressure from potential tenants to design and construct sustainable buildings with lower running costs – if we don't provide them with the sort of building they want, they will go somewhere else."

Achieving the standards required by BREEAM requires careful planning, design, specification and detailing, and a good working relationship between the client and project team. These are also the qualities that produce better buildings and better conditions for building users. The greater efficiency and quality associated with sustainability are also helping to make such buildings more commercially feasible. There is growing evidence, for example, that certified and rated buildings provide increased rates of return for investors, and increased rental rates and sales premiums for developers and owners. For example, a study carried out by Maastricht University and published by the Royal Institution of Chartered Surveyors (RICS) in 2012, titled "Supply, Demand and the Value of Green Buildings", provides empirical evidence of the value of buildings with certificated BREEAM assessments. The study examined a sample of office buildings in London, using data from transactions over the 2000–2009 period, and found that these buildings achieved a 21% premium on transaction prices and an 18% premium on rents[2].

Updates and New Schemes

BREEAM is continually being updated and improved in line with advances in technology, evolving legislation, feedback from users, and consultations with professionals and experts in the construction industry. The current global standard for new build projects, BREEAM International New Construction, was launched in 2013 and the next update is due in 2015-16.

In addition, BREEAM continues to be expanded to include other aspects of the building life cycle and other elements of the built environment. Since its launch, BREEAM has extended its original focus on individual new buildings at the construction stage to encompass other life cycle stages. For example, in addition to the New Construction scheme, BREEAM certification schemes for "Refurbishment" and "In-Use" are now used internationally to encourage improvements in the sustainability performance of existing buildings.

BREEAM In-Use enables building managers, investors, owners and occupiers to reduce the running costs and improve the environmental performance of existing non-domestic buildings. It comprises three parts: (1) Part 1 which deals with the building asset itself; (2) Part 2 covers the management of the building; and (3) Part 3 focuses on occupier management and activities within the building.

BREEAM In-Use International has already been applied in more than 25 countries and is the most widely used assessment scheme for existing buildings in Europe. Features of the scheme include two energy calculator tools for assessing asset and operational energy performance, which can account for local climatic conditions. These generate comparable ratings for all assets in a portfolio, regardless of the building type,

[2] Chegut, A., Eicholtz, P. and Kok, N. (2012) *Demand and the Value of Green Building*, Royal Institution of Chartered Surveyors, March 2012, UK.

age or location. This is particularly useful to organisations that have assets in more than one country as it enables direct comparisons of operational building performance across the portfolio.

Figure 5 Cité Europe in Calais is one of many Unibail-Rodamco supermarkets to have been BREEAM assessed in France. Cité Europe was the first mall in Europe to achieve certification under the BREEAM In-Use International scheme.

"BREEAM In-Use matches with the Group's culture and management to improve the performance of our assets on a daily basis," says Christophe Garot of Unibail-Rodamco.

The sustainability debate now extends beyond the envelope of the building, to the community and wider built environment. For this reason the BREEAM Communities scheme has been introduced in recent years, and the BREEAM Infrastructure scheme is currently in development.

BREEAM Communities is an assessment method that helps professionals to design places that people want to live and work in, are good for the environment, and are economically sustainable. Updated in 2012, BREEAM Communities has a simple bespoke process through which it can be applied internationally. This enables projects in any country to tailor the scheme's technical manual to their unique local situation.

Looking Ahead

By its very nature, sustainability is all encompassing—not limited to any particular sets of products, buildings or issues. Assessment and certification systems must be widened accordingly if the momentum for a more sustainable built environment is to be maintained.

While BREEAM has already been expanded into a scheme that can be used on almost any type of building in any location and the range of issues addressed has also increased, more environmental, social and economic aspects need to be considered. The challenge is to broaden the scheme without increasing its complexity. Expansion must go hand-in-hand with efforts to make assessments more accessible and transparent. Support and feedback from the industry will continue to be vital in this process.

The eventual goal is to make sustainability mainstream and routine. BREEAM has been a key driving force for sustainability in the built environment and will continue to play a significant role in meeting the future global challenges of sustainable development.

Getting Involved

Many building services engineers and building professionals of all kinds are variously involved in BREEAM. For example they can:

- Attend awareness training courses to increase their knowledge of built environment sustainability;
- Obtain professional qualifications, for example, become a BREEAM Accredited Professional (AP). BREEAM APs can have important roles in projects seeking BREEAM ratings;
- Become licensed BREEAM Assessors – this involves completing a three-day training course followed by an exam. The resulting BREEAM International Licence also allows them to carry out assessments using the BREEAM New Construction scheme; and
- Initiate or participate in the process that leads to their organisation to become a National Scheme Operator.

BREEAM Case Studies

Le Hive, Paris

Le Hive is Schneider Electric's global headquarters and is occupied by around 1,850 employees. It was the first building to be certified under the BREEAM In-Use International pilot scheme, achieving an "Excellent" rating for asset performance, and "Outstanding" for both building management and occupier management.

Le Hive's name is an acronym from the French for hall of innovation and energy showcase. The retrofit of the seven-storey building reflects Schneider Electric's position as an energy management specialist, incorporating comprehensive energy monitoring, and was carried out largely by the company's own in-house experts.

Figure 6 Le Hive, Schneider Electric's global headquarters

The building is highly energy efficient. It offers many services for employees including rest lounges, a fitness centre, an electrical car service and family days. The occupant comfort level is monitored, and regular awareness events and surveys involve employees in the continuous improvement of the building's management. Numerous actions have been taken to minimise environmental impacts, care for green areas and enhance biodiversity. For example, there are 10 bee hives producing honey on the green roof.

A spokesperson for Schneider Electric said, "BREEAM highlights our energy efficiency solutions and our sustainability policy, and is a boost for our building solution business. We reduced our energy consumption by 50% and have already reached the French 2020 greenhouse reduction target for buildings. And we have improved employee comfort and productivity. We choose BREEAM because it challenges us to achieve excellence – we want Le Hive to be recognised as a model of sustainability – and for its international recognition in the real estate sector."

Wuhan Tiandi Riverview Plaza in China

Wuhan Tiandi Riverview Plaza as shown in Figure 7 is a mixed-use development consisting of a shopping centre and three office towers. The sustainability credentials of the retail area design have been assessed using BREEAM International Bespoke. This resulted in the award of a design stage BREEAM rating of "Very Good", making Wuhan Tiandi the first Chinese development to be awarded interim BREEAM certification.

Covering about 4.2ha, the Wuhan Tiandi Riverview Plaza site is located in the central area of Wuhan, adjacent to Tangtze River. The development includes outdoor spaces for leisure located on the roof, including a botanical garden, alfresco dining area, children's playground and cinema terrace. To maximise occupant comfort in internal areas, there are skylights to provide natural daylight to the atrium spaces.

Figure 7 Wuhan Tiandi Riverview Plaza

The BREEAM International Bespoke assessment methodology enabled Wuhan Tiandi Riverview Plaza to use Chinese building standards. This allowed the project to demonstrate compliance with BREEAM assessment criteria by implementing local best practice standards. This avoided the additional burden of meeting UK, US or other international standards.

BEAM Plus – Past, Present and Future

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First initiated in 1996, Building Environmental Assessment Method (BEAM) is Hong Kong's locally produced green building rating tool. From 1996 to 2013, it underwent a number of revisions and expansions. The general directions of changes were: from specific to wider applicability; from prescriptive to more performance-based; from a narrow scope to increased comprehensiveness; from emphasising indoor environmental quality only to demanding a balanced achievement in a larger number of aspects; and last but not least, from relying on active systems to encouraging passive design. There was a steady growth of project numbers from 1996 to 2010. From 2011 onwards, the increase in numbers has been particularly sharp due to government's policy incentive. Up to the end of April 2014, BEAM had certified more than 14 million m^2 of gross floor area of more than 350 properties and also more floor area on a per capita basis than most other voluntary schemes in the world. Its success is attributable to strong initial commitment of key industry players, wide industry involvement that is crucial to securing buy-in, as well as strong support from the government. Looking to the future, the Hong Kong Green Building Council (HKGBC) and BEAM Society Limited will continue to strive to increase the penetration of BEAM Plus by working on neighbourhoods and existing buildings, broadening BEAM practitioner training, and continually updating the standards to meet the needs of the industry.

Keywords: Building Environmental Assessment Method, green building rating tool, passive design

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Introduction

Hong Kong is famous for its high-rise, high-density buildings. The design and operation of these buildings play a significant role in the region's environmental footprint as well as the lives and wellbeing of its citizens. Globally, buildings account for about one third of the world's greenhouse gas emissions. However, in service-based economies such as Hong Kong, the figure is close to 60%. In 1995, two local property developers – Hongkong Land and Swire Properties, conceived an idea of developing a Building Environmental Assessment Method (BEAM)[1]. Being good corporate citizens, they believed that the industry should take the lead rather than depend on legislation, which was yet to be developed. Such a belief led to a unique success story. This paper looks at how the BEAM rating tool has developed and matured over the years, its present status and future outlook.

An Early Start

It is generally accepted that the era of green building rating tools commenced in 1990 with the introduction of the UK's Building Research Establishment Environmental Assessment Method (BREEAM) (see Figure 1). This was followed by the Hong Kong BEAM and the French HQE standards, both of which were launched in 1996, although the French system

[1] For the sake of simplicity, the short form "BEAM" is used throughout this paper although before 2009, the full name of the scheme was "HK-BEAM"

only began certification in 2005. The Hong Kong scheme, which began operation in 1996, was largely based on the BREEAM Version 1/93 (Prior, 1993), with modifications to suit the characteristics of office buildings in Hong Kong. The performance categories followed the UK protocol, i.e. Global, Local and Indoor issues. The BEAM booklets in 1996 comprised two versions, one covering new office buildings (CET, 1996a) and the other for existing office buildings (CET, 1996b). The primary aim of this rating tool was to reduce the environmental impact of buildings using the best available techniques and within reasonable additional cost. The major issues addressed were ozone depletion, recycling, greenhouse gas emissions and indoor air quality. The scheme at that stage consisted of only 56 credits. Initial funding for development of the tool was provided by the Real Estate Developers Association. An independent steering committee with wide industry representation was responsible for overseeing the development.

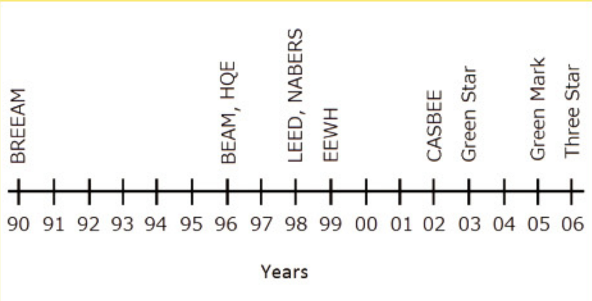

Figure 1 Launch dates of major green building rating tools that are still in use today

The Pioneer High-rise Residential Scheme

Following the first version, it was decided to extend the scheme to high-rise residential buildings—the first assessment system of its kind in the world (HK-BS, 2005). The second generation of BEAM was launched in 1999, featuring an additional rating tool for new residential buildings (CET, 1999a; CET 1999b; CET, 1999c). The two office building standards were updated at the same time. The revisions made included the removal of Overall Thermal Transfer Value (OTTV) assessment and the transfer of the original credits to the electricity use of air-conditioning. This was because in deep plan office buildings, internal heat gain rather than envelope load usually dominated the cooling load. Focusing on overall kWh/m^2/year instead of OTTV also allowed flexibility in design, by allowing a trade-off between the envelope performance and the energy efficiency of air-conditioning systems.

The Global, Local and Indoor issues were also expanded. There was a broadening of the scope to encompass other greenhouse gas related aspects such as limitation of private car parking spaces and encouraging natural clothes drying facilities. Areas specific to the needs of Hong Kong were also covered, including the proper location of domestic air-conditioning units and proper noise control in a high-density living environment. The value of environmental management planning and ecological impact assessment were also recognised. For the residential scheme, there were 86 credits. Compared with the 1996 rating tool, this represented a substantial increase in comprehensiveness.

Building up Wider Ownership

The 1996 to 1999 versions of the rating tools were owned by the Centre of Environmental Technology Ltd. (CET)—a company established in 1991 by the Private Sector Committee on the Environment (PSCE) to pool resources and provide practical assistance to industries. In 2000, the PSCE and the CET were merged to form the Business Environment Council, an organisation with members from large corporations, small and medium enterprises, business associations, etc. Later, it became clear that the council's membership had not encompassed enough key players such as building professionals, contractors, material suppliers, property and facility managers. The industries realised that more progress would be made through embracing these important stakeholders in the ownership and governance of BEAM. In 2002, the original BEAM steering committee was formalised into the BEAM Society, which was a separate entity open to individual and corporate members from all building-related disciplines. This had been the key to getting buy-in for the rating tools, not only in constructing buildings, but also in operating them.

Enhancing Versatility

With the success of assessment in new and existing offices and residential buildings, other projects including schools, hotels and shopping malls were proposed for assessment. Encouraged by market demand, the third generation of the BEAM rating tool (HK-BS, 2003a; HK-BS, 2003b) was compiled and issued in May 2003. This represented a significant upgrade by broadening the types of buildings that could be assessed. In fact, the schemes were renamed "Existing Buildings" and "New Buildings" without restriction to offices and residential types. Furthermore, the number of best practice criteria was increased to over 100, covering areas specific to the high-rise and high-density environment of Hong Kong, including off-site prefabrication and mechanised construction, embodied energy of structural materials, and mitigation of the urban heat island effect.

The assessment credits were grouped into six categories: Site Aspects (SA), Materials Aspects (MA), Energy Use (EU), Water Use (WU), Indoor Environmental Quality (IEQ), Innovations and Performance Enhancements. This laid down a foundation framework for the BEAM standard, which is still being followed in the present-day version. The overall assessment grades were changed from "Excellent", "Very Good", "Good" and "Fair" to "Platinum", "Gold", and "Silver" rating used by LEED, along with a "Bronze" rating that paralleled LEED's Certified Level. Aside from the overall total score, there was a minimum score requirement on IEQ, reflecting the special importance of this aspect in a sub-tropical high-density city. These major changes mirrored trends in the assessment methods that were appearing worldwide, while reflecting Hong Kong's unique situation.

More importantly, the energy assessment criterion was migrated from kWh/m^2/year to percentage gain using the energy budget approach, which could be applied to a much wider range of buildings. In the old version, separate assessments were conducted for HVAC loads and lighting loads. On the contrary, the new version was based on the aggregated annual energy use of all the systems. This enhanced design flexibility. The assessment was very similar to the method used in performance-based building energy code (PBEC), but PBEC was a pass/fail assessment whereas BEAM quantified the level of improvement and included an assessment of the peak electricity demand. The method could also be applied to mixed-use buildings, which were dealt with by an area weighting method. This placed the tool in a good position to assess multi-use complex buildings in this compact city. This third generation represented a major step in enhancing the tool's versatility.

Increasing Comprehensiveness

After pilot-project testing, further review and development, in December 2004 a set of fine-tuned versions known as the 4/04 Version for New Buildings and 5/04 Version for Existing Buildings (HK-BS, 2004a; HK-BS, 2004b) emerged. These versions extended the coverage to issues that further defined building quality and sustainability, including enhanced hygiene requirements (after the lessons learned from the SARS outbreak), security and amenities provisions, universal access and cultural heritage. In this way, BEAM provided users with a single label that demonstrated overall building performance.

Enhancing the Chosen Scheme

While BEAM was a private sector initiative, the government was also enthusiastic in promoting green building. In 2001, the government pledged to develop a comprehensive environmental performance assessment scheme (CEPAS) for green buildings. The tool was developed and published in 2006 (BD, 2006). Noting the co-existence of the two schemes in Hong Kong, the government requested the former Provisional Construction Industry Co-ordination Board (PCICB) (replaced by the Construction Industry Council, CIC, in 2007) to conduct a holistic review and to determine the way forward. In December 2006, the PCICB recommended the adoption of BEAM as the integrated model for green building assessment in Hong Kong, and recommended that the desirable features of CEPAS be incorporated into BEAM. The BEAM Society took up the development work, and in November 2009 produced a revamped version of the rating tool, now known as BEAM Plus. The major changes were:

1. A new type of credits—prerequisite credits, was added in the scheme. All participating buildings should first fulfil these credits, in order to proceed to the remaining part of the assessment. The purpose was to clearly define the base line for every green building;

2. In view of the increased importance of microclimate in a high-density city, Air Ventilation Assessment (AVA) was added to the rating tool to encourage developers to optimise the layout of their buildings;

3. To reduce carbon emissions, regionally manufactured materials were encouraged;

4. To encourage good architectural planning and passive design, a new credit known as "energy efficient building layout" was added. This included building orientation, site permeability, solar shading, OTTV and vertical daylight factors;

5. The introduction of multiplier type weighting factors to precisely enforce the relative importance of the five aspects: SA, MA, EU, WU and IEQ. In particular, EU was given a higher weighting factor (35%) in response to global concerns of climate change and carbon emissions. In the past versions, the relative importance of EU (as counted by the number of credits) was around 25%-28%;

6. The imposition of minimum score requirements on EU and SA. In the past, only IEQ had such a requirement; and

7. For renewable energy system installations, the assessment scale was adjusted and an alternative way of assessment based on the percentage of building footprint covered was added to provide more incentives for applicants to pursue these credits.

In 2007-2008, the CIC discussed with concerned industry stakeholders the formation of an independent entity to promote green building. Eventually, the Hong Kong Green Building Council (HKGBC) was established in November 2009. This is an independent member-based NGO charged with the four duties of advocacy (to promote green building and make suggestions to the government), assessment (to operate the green building rating system), accreditation (to qualify professionals) and award (to provide recognition to outstanding performers). Both BEAM Society and the CIC are founding members of the HKGBC. The other two founding members are the Business Environment Council and the Professional Green Building Council.

In April 2010, the HKGBC endorsed the BEAM Plus scheme (HKGBC/BS, 2010a; HKGBC/BS, 2010b) as the officially recognised green building rating tool in Hong Kong. In August 2010, project registration for the scheme commenced. The scheme operation was taken up by HKGBC while the actual assessment work was entrusted by HKGBC to BEAM Society. BEAM Society in turn assigned the work to qualified BEAM Assessors who were openly recruited from the industry. In case of appeal on the assessment results, the first appeal would be handled by the BEAM Society, while the final appeal would be processed by the HKGBC. This model is still being followed today.

Period of Rapid Growth

One year after the promulgation of BEAM Plus, the HKSAR Government decided to give the green building movement a bigger push. Starting from 1 April 2011, participation in BEAM Plus shall be one of the prerequisites for private developments to obtain gross floor area (GFA) concessions for green/amenity features and non-mandatory plant rooms. As a result, there has been a sharp increase in the number of registered projects per year, from an average of 16 projects from 1996 to 2010, to an average of 150 in the BEAM Plus era from 2011 to 2013 (see Figure 2).

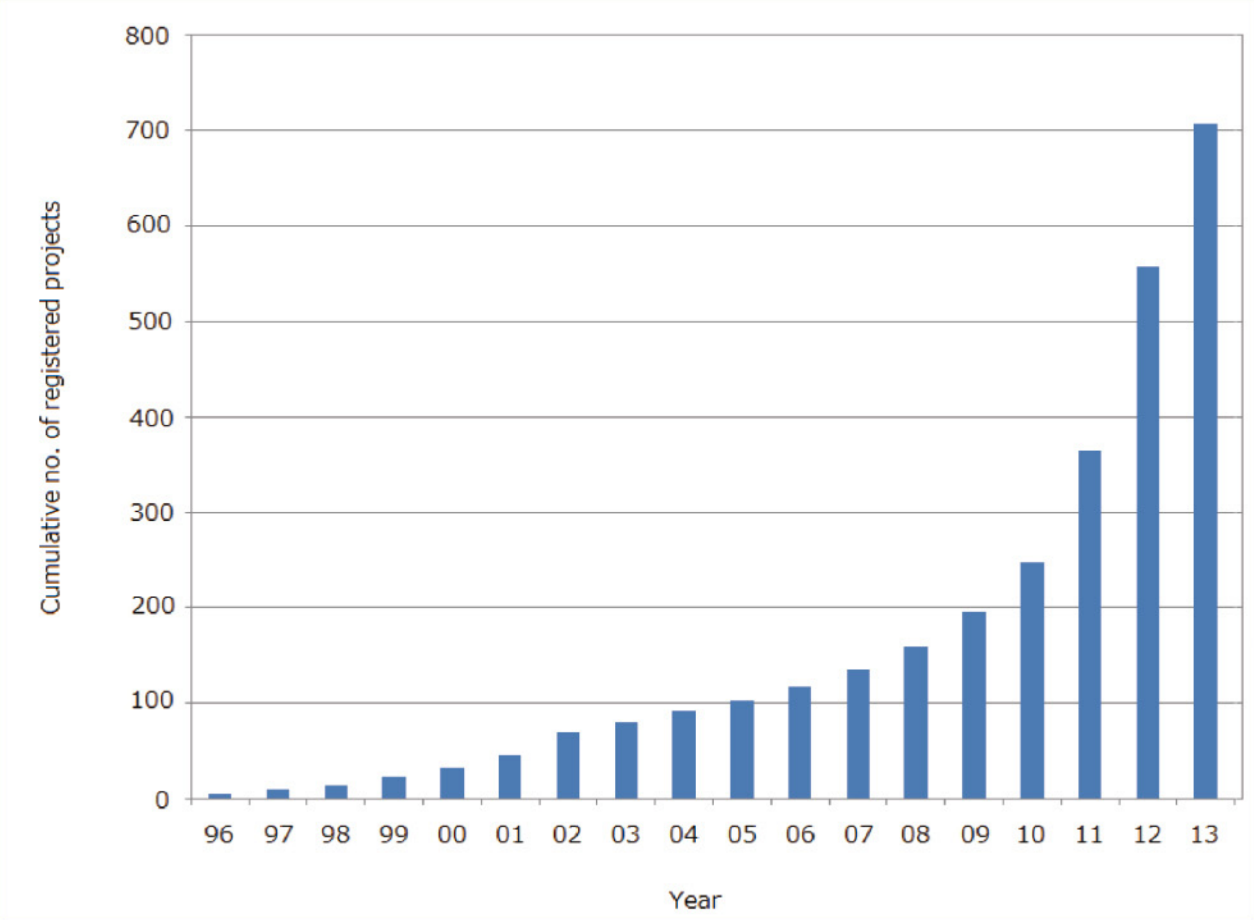

Figure 2 Project growth from 1996 to 2013

The following statistics are obtained from a desktop review of the Buildings Department (BD)'s Monthly Digests and HKGBC's BEAM Plus project registration database:

No. of private development projects registered with BEAM Plus from 1.4.11 to 28.2.14	394
No. of project submissions to BD during the same period	690
Ratio of the above	0.57

Table 1 Ratio analysis for private development projects

The ratio in Table 1 is a rough indication of the market penetration rate of BEAM Plus in the past three years. Although one may think that the high penetration rate is due to BD's policy to incorporate BEAM Plus as a prerequisite for granting GFA concessions, it should be noted that not all BEAM Plus registered projects would apply for GFA concessions. Participation in BEAM Plus is only one of the prerequisites. The other prerequisites include compliance with BD's Sustainable Building Design (SBD) and compliance with BD's acceptance criteria for the individual green/amenity features. In fact, there are many cases in which projects are registered with BEAM Plus but GFA concessions are not pursued. In such cases, the motivation to pursue BEAM Plus labelling is non-GFA related. Other reasons, such as corporate citizenship, energy saving considerations, the drive to be distinguished from other competitors, or the wish to integrate sustainable development thinking into the heart of a business, may contribute to the high penetration rate of BEAM Plus.

Encouraging Passive Design

With widespread use of BEAM Plus in the industry, there was feedback from the industry that criticised the inadequate weight of passive design in the rating tool. Passive design is a major design approach for buildings, as it enables a building to respond to the local climate and reduce reliance on active systems. This in turn will reduce energy consumption. The ultimate goal of passive design is to completely eliminate the use of active systems while maintaining occupant comfort. Although it is unlikely that such a goal can be achieved in Hong Kong's hot and humid climate, passive design should still be encouraged, especially for residential buildings, in order to rationalise the building design strategy and improve building performance.

In 2009, when BEAM Plus was first launched, a basic methodology for passive design (i.e. energy efficient building layout) was included to address the aforementioned demand. In order to fully assess and quantify the influence of passive design on building sustainability, a holistic and scientific passive design assessment methodology had to be developed. In 2011, the BEAM Society commissioned Ove Arup and Partners Hong Kong to carry out the research study. The Chinese University of Hong Kong and Ronald Lu & Partners (Hong Kong) acted as sub-consultants in the study.

The study found that BEAM Plus had certain considerations of passive design, but the score weighting was not adequate compared to most other green building rating tools in the world, especially in the EU category. Therefore, the consultant proposed different strategies, which allowed designers and engineers to quantify the benefits from passive design in residential buildings. Details of the design strategies are illustrated in Figure 3 and Figure 4.

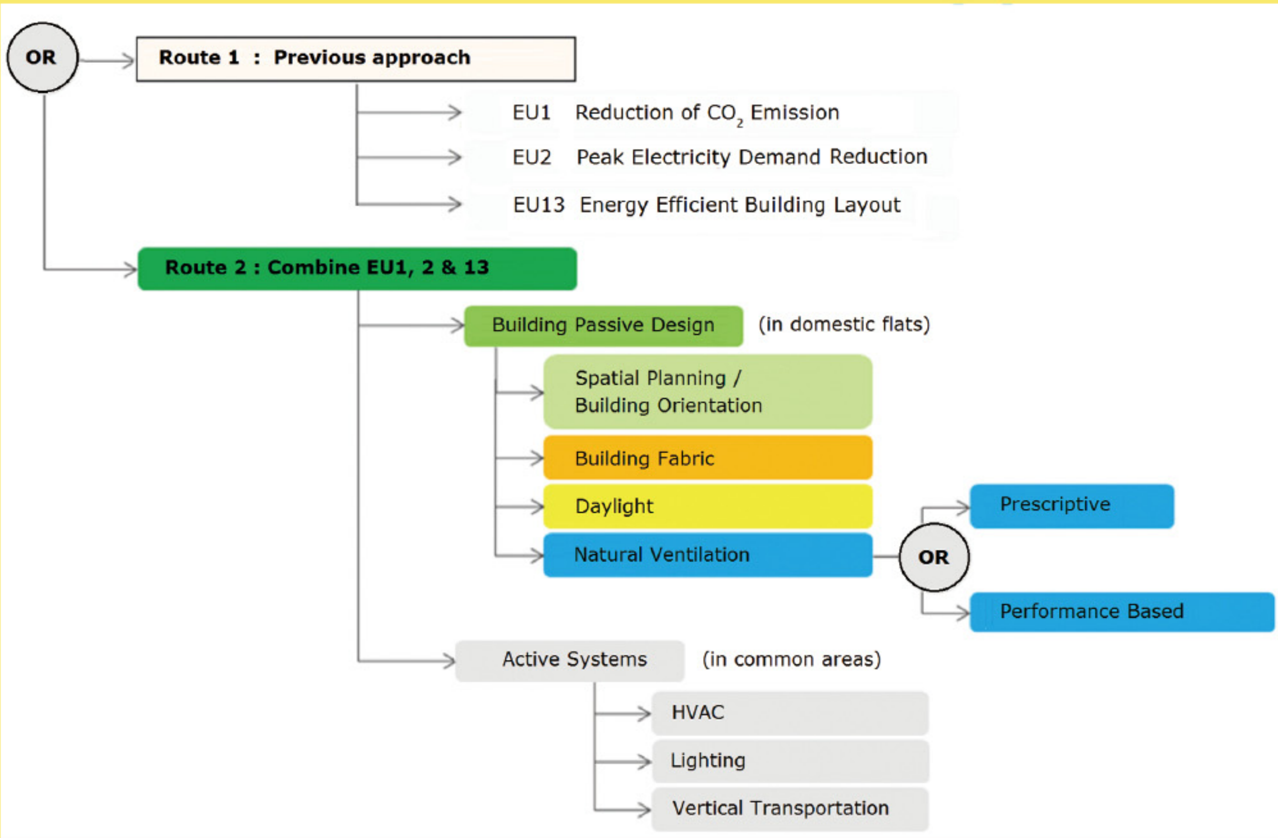

Figure 3 Alternative EU route that utilises passive design

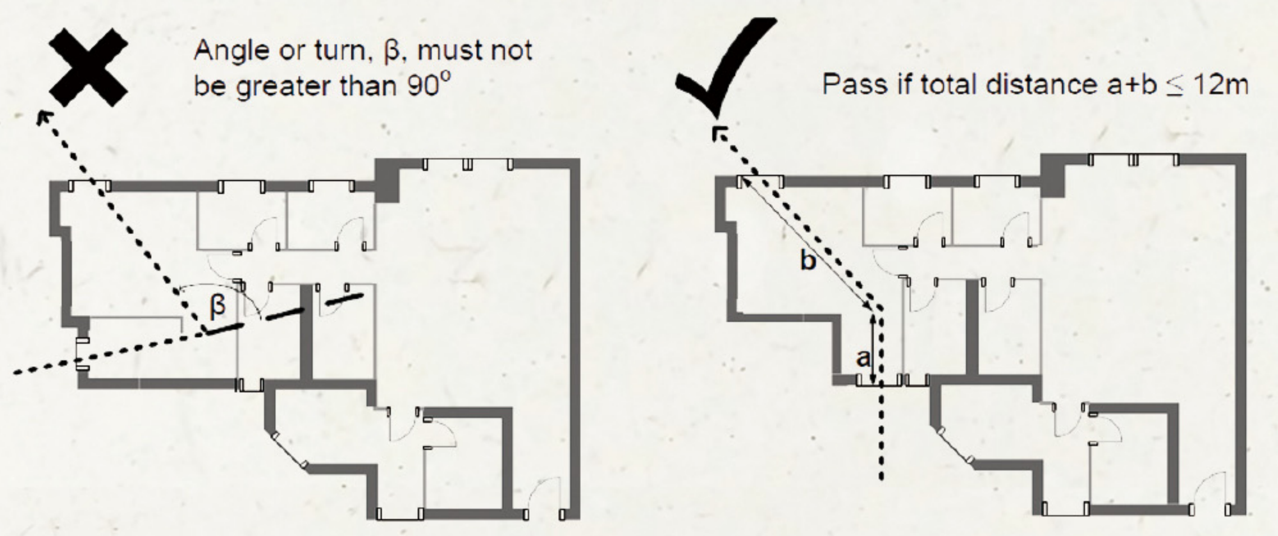

Figure 4 Example of prescriptive approach to natural ventilation

In order to test the suitability of these recommended changes for Hong Kong buildings, sensitivity tests were carried out. It was found that the typical passive design strategies used in Hong Kong were recognised by the assessment methodology. This was a great breakthrough, as the approaches quantified the benefits of using passive design in reducing energy use. An engagement exercise was also carried out in October 2011 with participation by over one hundred industry stakeholders. The approach was generally considered satisfactory by the stakeholders and the revised BEAM Plus, known as Version 1.2, was launched in July 2012 (HKGBC/BSL, 2012a; HKGBC/BSL, 2012b).

This revision to BEAM Plus also took into account government regulations concerning natural lighting and ventilation, such as Practice Note for Authorised Persons (PNAP) APP-130. This practice note demonstrates the government's effort to recognise alternative performance standards on the provision of natural lighting and ventilation in habitable rooms and domestic kitchens. The revised BEAM Plus adopted this PNAP as the baseline for performance assessment, i.e. only performance exceeding such baseline would be rewarded.

In sustainable building design, passive strategy should be the primary course of action, while active systems should be regarded as supplementary measures to achieve occupant comfort. While more credits allocated to passive design would give it a deserved recognition, as long as passive design is assessed through an "alternative" rather than the main route, the difficulty in fostering the use of passive design still remains. The proposed methodology for passive design should, eventually, transition from an alternative method to the mainstream method. Inevitably, incremental changes are necessary for incorporating the wider use of passive design in BEAM Plus, with the ultimate aim of influencing all building developers to adopt passive design as the first design strategy in achieving sustainability.

Expanding to Interiors

While the incorporation of passive design in 2012 was a great improvement to the building design approach, the HKGBC and BEAM Society were not complacent with this achievement. In 2013, the two organisations launched a new rating tool for building interiors—BEAM Plus Interiors (BI) (HKGBC/BSL, 2013). Non-domestic tenants and occupiers now have a blueprint for creating environmentally friendly and healthy interiors. The BI tool complements the two organisations' already successful BEAM Plus New Buildings by certifying an area of facility design not adequately covered by the previous tools. In the coming years, BI is expected to become a new design standard because spaces that meet its criteria will be environments where people will want to work in. Figure 5 gives a brief summary of the whole history of BEAM Plus developments from 1996 to the emergence of BI.

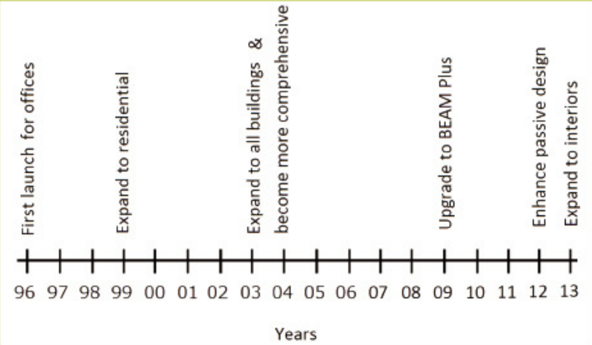

Figure 5 Timeline of BEAM developments in Hong Kong

Beam Achievements

From 1996 to the end of April 2014, BEAM (both HK-BEAM and BEAM Plus) had certified (including provisionally certified) more than 14 million m² of GFA of more than 350 properties. Hong Kong has a population of about 7.2 million. On a per-capita basis, the BEAM-certified area is nearly 2m² per person. For other green building labelling schemes in the world, the cumulative certified GFA seldom exceeds 1m² per capita, except those schemes with mandatory implementation. This reflects the fact that the BEAM system has a remarkably long history and has produced substantial achievements despite its voluntary nature. Today, buildings that have been certified by BEAM or BEAM Plus can be widely seen throughout the territory. Examples include HSBC Headquarters Building, Standard Chartered Bank Building, Bank of China Tower, Central Plaza, Two International Finance Centre, International Commerce Centre, Hysan Place, The Peak Galleria, Kai Tak Cruise Terminal, and the CIC Zero Carbon Building, to name a few. The scheme has encouraged greener designs and construction practices. More importantly, it has stimulated innovative and outstanding designs. One notable example is Sing Yin Secondary School (certified as Platinum according to BEAM 4/04). This school has obtained the "2013 Greenest School on Earth" award from the Center for Green Schools of the U.S. Green Building Council. This demonstrates that Hong Kong's green building design is globally recognised.

A snapshot of HKGBC's BEAM Plus Project Directory (Figure 6) also shows that many current building development projects are participating in the scheme. It is certain that in the near future, the scheme will continue to produce more certified buildings.

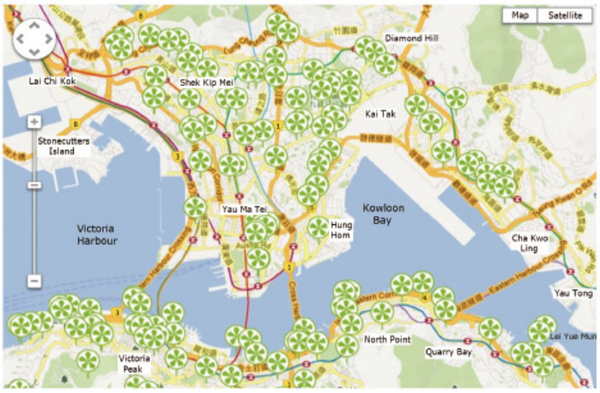

Figure 6 A snapshot of the BEAM Plus Project Directory

Some key facts about recent BEAM Plus achievements:

- Up to the end of April 2014, the number of projects registered with BEAM Plus had exceeded 500. The vast majority of these projects are new buildings. About 44% of the projects are residential, 25% are commercial, 17% are government, institution or community (GIC), 11% are mixed use and 2% are industrial;
- Nearly 140 projects have undergone design-stage assessments with Provisional Assessment certificates issued. Of these, 27 have achieved Platinum rating, with four of these having undergone post-construction stage assessment and obtained Final Assessment certificates;
- Of the Platinum-rated projects, about 52% are GIC projects, 30% are residential projects, 15% are commercial projects, and 4% are industrial projects;
- Within the Platinum-rated residential projects, the ratio of public/quasi-public housing projects to private housing projects is 50:50;
- On average, Platinum projects delivered about 30% annual energy savings against building energy code; Gold projects delivered about 19%; Silver delivered about 17%; Bronze delivered about 13%. The total annual energy saving that will be yielded from all these buildings is estimated to be equal to the annual electricity consumption of about 30,000 households, or 95,000 tonnes of carbon dioxide emissions; and

- From 2010 to the end of April 2014, more than 2,300 industry practitioners were trained in the BEAM Plus rating tool and have been accredited as BEAM Professionals.

Future Developments

The two organisations recognise that simply putting a number of individually certified green buildings together is no guarantee that the resulting district would be a green, healthy and efficient neighbourhood. What a single building can achieve in terms of "green" would be limited. By expanding focus to the public realm and gaining synergies from a mixed-use development, it is possible to achieve what single buildings cannot. For example, in a high-density city, liveability can be enhanced if there is a vibrant street life. In terms of resource sharing, in a certain building, there may be surplus electricity, cooling supply, recycled grey water or compost derived from food waste, whilst an adjacent building may require these resources. If the developers of large land parcels have green thinking in mind and apply suitable rating tools in the design of their land development projects, it is possible that more sustainable and liveable neighbourhoods can be created through green-rated districts or sub-district developments. In fact, the trend of changing focus from green buildings to green neighbourhoods is a worldwide one. In line with this trend, the HKGBC is conducting a study on the development of a new rating tool for neighbourhood development. The study is expected to be completed near the end of 2014, and it is expected that an interim version of the neighbourhood rating tool will be published.

Much of the focus of the discussion in this paper has been on driving sustainability in new building developments. However, the majority of building stocks in Hong Kong are existing buildings. Improving the energy efficiency and environmental performance of existing buildings will be a crucial step in making significant changes to address climate change.

From December 2012 to May 2013, the HKGBC conducted a special review of its green building rating tool—BEAM Plus Existing Buildings (EB). Based on 14 case studies of existing buildings, the study identified those credits that might need modifications, as well as collated a number of stakeholder opinions concerning the scheme. These issues include: an overwhelming emphasis on buildings' inherent characteristics, occupant areas outside the applicant's control, too much reliance on scientific analysis, disturbance to building operation during re-commissioning, inadequate scope of coverage, and the required standards not being achievable for aged buildings. In response to the results of the study, BEAM Society commissioned a consultancy study in January 2014 to revamp the BEAM Plus EB. It is expected that the new tool, which is planned to be launched in 2015, will embrace an alternative path through which stepwise improvement efforts of aged buildings could be recognised, when some physical constraints render such buildings incapable of meeting the full scheme's requirements in one go. This would help the gradual upgrading of Hong Kong's existing building stocks to a greener standard.

Looking ahead, the two organisations have already started to set the directions for future upgrades of BEAM Plus New Buildings. It is expected that the tool will continue to become more comprehensive by incorporating more sustainability elements. The standards would be suitably raised to keep pace with industry progress. Other recently developed HKGBC tools such as green building product labelling will be incorporated where appropriate. The main principle is that the tool will continue to be consensus-based, and a high degree of transparency will be maintained throughout the revision process. This means that working groups with wide industry representation will be formed to guide the revision process. Stakeholder engagement exercises will also be organised, to solicit views from developers, building design professionals and other relevant parties.

On the practitioner side, an arrangement has been made to extend the green building qualifications from qualified members of professional institutes to other related personnel including young graduates, technical officers, site and estate supervisors. The HKGBC and BEAM Society have recently launched the BEAM Affiliate qualification for such practitioners, with the first training session to be held in June 2014. The broadening of green building training and qualification is expected to give extra momentum to the green building movement.

Conclusions

This paper provided an overview of the past, present and future of Hong Kong's locally produced green building rating system. From 1996 to the end of April 2014, the BEAM rating tool has certified more than 14 million m^2 of GFA, of more than 350 properties. With 18 years experience of operation and fine-tuning, BEAM Plus can serve as a good role model of green building rating tool for high-rise, high-density building developments in a sub-tropical climate.

In the local context, the scheme has transformed the way we construct and operate buildings. The HKGBC and BEAM Society are poised to increase the penetration of this scheme by developing a new neighbourhood rating tool and revamping BEAM Plus EB, broadening training to BEAM Affiliates, and continually updating the New Buildings standard.

As the green building movement continues forward, the impacts will be significant—greenhouse gas emissions are reduced, the environment is improved, and the quality of life of our citizens is enhanced. Whilst we are glad to see these achievements, we recognise that these are just the first of many steps that are still needed to cope with sustainability issues.

Acknowledgements

The authors would like to thank the Secretariats of the HKGBC and BEAM Society Limited and the Business Environment Council for providing information to compile this paper.

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A Major Step Towards Low Carbon Buildings in Hong Kong – Full Implementation of Buildings Energy Efficiency Ordinance

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Taking a major step towards low carbon buildings with the aim of raising their energy efficiency performance, the Buildings Energy Efficiency Ordinance (Cap. 610) (BEEO) (HKSAR Government, 2010) came into full operation on 21 September 2012. The BEEO governs energy efficiency standards of building services installations in buildings, requiring compliance with the Building Energy Code (BEC) (EMSD, 2014a; EMSD, 2014b) for new construction and major retrofitting works. It also requires an energy audit of central building services installations in commercial buildings in accordance with the Energy Audit Code (EAC) (EMSD, 2013a; EMSD, 2013b). This article introduces the legislative framework of the BEEO with brief highlights of the engineering requirements in the codes, and the benefits that are brought about by the mandatory approach.

Keywords: Building Energy Code, Buildings Energy Efficiency Ordinance, Certificate of Compliance Registration, energy audit, Energy Audit Code, form of compliance, major retrofitting works

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Ir David Li is an engineer with EMSD. He has over 20 years experience in building services design and project management of a wide variety of government premises. In recent years, Ir Li has been actively involved in providing technical support in the development of the BEEO, including serving the Technical Taskforce (with trade participation) and guiding its Working Groups in drafting and finalising the codes and their guidelines under the BEEO, devising engineering technical information input for certification of code compliance, the assessment of REA applications, and the promotion of the BEEO and its codes and guidelines to stakeholders and the public.

Introduction

As an international metropolis, Hong Kong (HK) is characterised by numerous high rise buildings that form the spaces needed for our work, living and recreation. They account for a significant portion of our carbon footprint. Energy use has been identified globally as the culprit of climate change. Buildings in HK are a major energy consumer—consuming some 90% of HK's electricity. To combat climate change, the reduction of our buildings' carbon footprint will likely top our agenda in the years to come. An aspiration is towards a vision of low carbon building with state of the art energy-efficient passive and active building designs, which would generate green business opportunities for environmental industries and nurture a low carbon economy essential for sustainable development.

With this vision, the Electrical and Mechanical Services Department (EMSD) of the Government of HK Special Administrative Region (HKSAR) is tasked to vigorously promote building energy efficiency to various sectors of the community. To target a reduction in building energy consumption, the BEEO was enacted in late 2010 and has been in full operation since 21 September 2012, with EMSD as the enforcing department. The BEEO governs building services installations including lighting installations, air-conditioning installations, electrical installations, and lift and escalator installations. The BEEO establishes both the energy efficiency standards of a building for its design, and the means of evaluating its energy efficiency performance in operation. For building design, the BEC governs the design standards for energy efficiency of building services

Figure 1 The BEEO website

installations, whereas for building operation, the EAC governs the necessary steps in conducting energy audits of central building services installations—building services installations not solely serving an individual unit of the building.

EMSD maintains a dedicated website at http://www.beeo.emsd.gov.hk/ for the BEEO. It consists of the most up-to-date information about the BEEO, codes, technical guidelines, forms and technical circulars etc.

BEEO Scope of Coverage

Types of Buildings

The BEEO governs most types of buildings, in respect of BEC compliance in both private and government sectors. These include buildings for commercial use (e.g. offices, shopping complexes etc.), hotels, municipal buildings, community buildings, educational buildings, hospitals, railway stations and airport passenger terminal usages etc. For industrial buildings, residential buildings and composite buildings, common areas and the portion not for residential or industrial use are governed. Residential units are not governed to avoid undue disturbance to the general public. Industrial units, which strive to remain competitive through efficiency gains are not governed, to avoid undue disturbance to industrial operations that may require specific energy inputs.

Newly Constructed and Existing Buildings

The building services installations in a newly constructed building, i.e. a building for which consent to commencement of building works for superstructure construction is given after 21 September 2012, should comply with the BEC design requirements. Compliance is applicable to all subsequent retrofitting works irrespective of whether or not they are regarded as major retrofitting works.

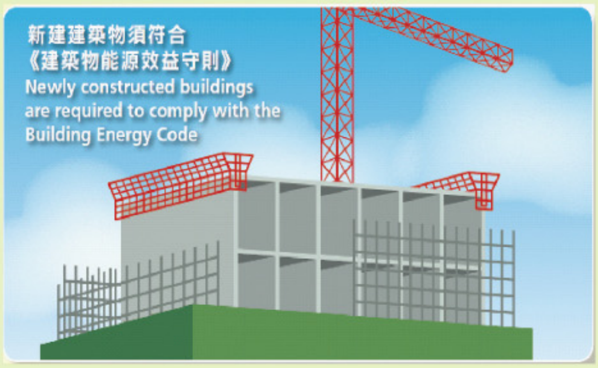


Figure 2 BEEO applicable to newly constructed buildings

As for an existing building, i.e. a building for which consent to the commencement of building works for superstructure construction was given on or before 21 September 2012, the BEC requirements must be complied with only for major retrofitting works.

Figure 3 BEEO applicable to major retrofitting works

Major Retrofitting Works

Major retrofitting works under the BEEO refer to:

- The addition or replacement of a building services installation in retrofitting works covering an aggregated floor area of 500m^2 or above (under the same series of works within 12 months) in a common area or a unit; or

- The addition or replacement of a main component of the central building services installations (including a chiller at rating 350kW or above, or a complete electrical circuit at rating 400A or above, or motor drive and mechanical drive of a lift or an escalator).

Energy Audit

The BEEO requires carrying out an energy audit for central building services installations in commercial buildings, and commercial portions of composite buildings every ten years, in accordance with steps specified in the EAC. After the audit, the building's energy utilisation index (EUI, in MJ/m^2/annum and kWh/m^2/annum) that reflects the building's energy intensity or energy performance is to be identified and exhibited.

Figure 4 BEEO applicable to energy audit in commercial buildings

BEEO Compliance Hierarchy

The BEEO prescribes the responsibilities of the developer, owner or responsible person of a building or a unit of the building, and the Registered Energy Assessor (REA), with requirements for submission and certification to demonstrate the compliance at different stages of the building—from design to occupation approval and subsequently during operation. Under the BEEO are two subsidiary regulations, one on REA and the other on the fees for the submissions.

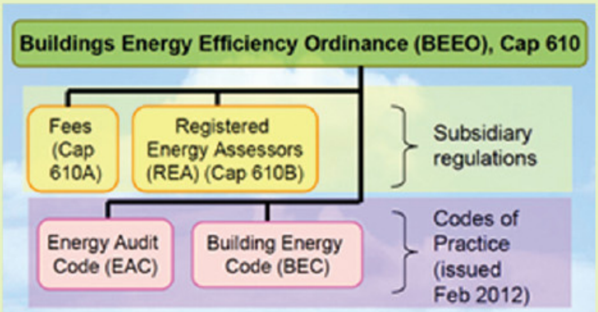


Figure 5 BEEO compliance hierarchy

BEC Requirements at Design Conditions

The BEC requirements are energy efficiency standards at corresponding design conditions and not actual operational settings such as lighting levels, air-conditioning room temperatures etc. These are left to the discretion of building operators to suit the operational needs of individual buildings and installations.

Newly Constructed Buildings

The developer of a building at building design stage i.e. within two months after obtaining the aforesaid consent to the commencement of building works issued by HKSAR Government's Building Authority, is required to submit to EMSD a "stage one declaration". This declaration is to be certified by an REA to declare that the building services installations to be provided by the developer are designed and will be installed and completed in accordance with the BEC.

Subsequently, at the occupation approval stage, i.e. within four months after obtaining an "occupation permit" issued by the Building Authority when the building is ready for occupation, the developer is further required to:

- Submit to EMSD a "stage two declaration" certified by an REA to declare that the building services installations provided by the developer in the building at or before the time when the declaration is made have been designed, installed and completed in accordance with the BEC; and

- Apply for a Certificate of Compliance Registration (COCR) from EMSD for the building.

The declarations are to be on specified forms and be accompanied by supporting documents specified in the forms. Based on the merits of the declarations, EMSD will issue a COCR to the developer. EMSD maintains a register of COCRs for the public's inspection.

The aforesaid COCR for newly constructed buildings is subject to renewal every ten years. For renewal the owner of the building is required to:

- Engage an REA to certify that:
  - The design (but not the operational performance) in regards to energy efficiency of the central building services installations (no need to include the installation only serving an individual unit) is maintained at a level not lower than the standard in the BEC version applicable to the COCR (issued by EMSD ten years ago for the building);
  - If major retrofitting works have been undertaken for certain portions of the central building services installations, the design of the installation is maintained to a standard not lower than the latest BEC version applied to this part of the installation.
- Submit an application to EMSD for renewal.

Major Retrofitting Works

For all prescribed buildings under the BEEO irrespective of newly constructed or existing buildings, within two months after completion of major retrofitting works, the owner of the central building services installations in the building and the responsible person of a unit or a common area in the building are required to:

- Engage an REA to certify that the replaced or additional installations in the major retrofitting works comply with the latest BEC; and
- Obtain a Form of Compliance (FOC) from the REA for the said works.

In the course of building operation with a COCR (i.e. a newly constructed building), the owner of the central building services installations (usually the owner of the building) and the responsible person (usually the owner or tenant) of a unit or a common area in the building, are required to ensure that when a building services installation is replaced or added (irrespective of whether it falls into the scope of major retrofitting works or not), its design shall comply with the standard not lower than that applied in the original BEC applicable for this installation.

Energy Audit

The owner of a commercial building, or a portion of a composite building that is for commercial use must carry out an energy audit in accordance with the EAC at least once every ten years.

The first energy audit for central building services installations of a building issued with a COCR, i.e. a newly constructed building, is to be carried out within ten years after the issuance of a COCR.

For existing buildings, the first energy audit for the central building services installations is to be carried out within four years from 21 September 2012, as prescribed in schedule 5 of the BEEO in four batches according to building age—the newer the earlier. The principle is that information, such as energy bills, technical data on building services installations, design drawings, operational records etc., should be more readily available in a newer building such that the first mandatory energy audit can be conducted with minimum difficulty.

The second batch buildings—buildings with occupation permits issued between 1978 and 1987, have a 20 September 2014 deadline for carrying out energy audits. For the first batch of buildings, the deadline was 20 September 2013.

The owner of the building is required to:

- Engage an REA to conduct the energy audit;
- Obtain from the REA an Energy Audit Form and an energy audit report with recommendations on energy management opportunities (EMO) identified in the audit; and
- Exhibit the valid Energy Audit Form showing the building's EUI in a prominent position at the main entrance of the building.

Figure 6 Energy Audit Form at main entrance

The disclosure of the EUI is expected to have a benchmarking effect on building operators to improve the building's energy efficiency, as the building's energy performance can be easily compared with that of similar buildings. The implementation of EMO will not be mandatory as there is a wide variety of EMO which differs in terms of scope and cost. Nevertheless, the REA's analysis and recommendations of the EMO identified in the energy audit report will facilitate the implementation of some if not all of the EMO, as the energy savings from EMO is itself a key incentive.

Registered Energy Assessor (REA)

The BEEO opens up a new role for professional engineers who, upon appointment by the developer, owner or responsible person, have the obligation to:

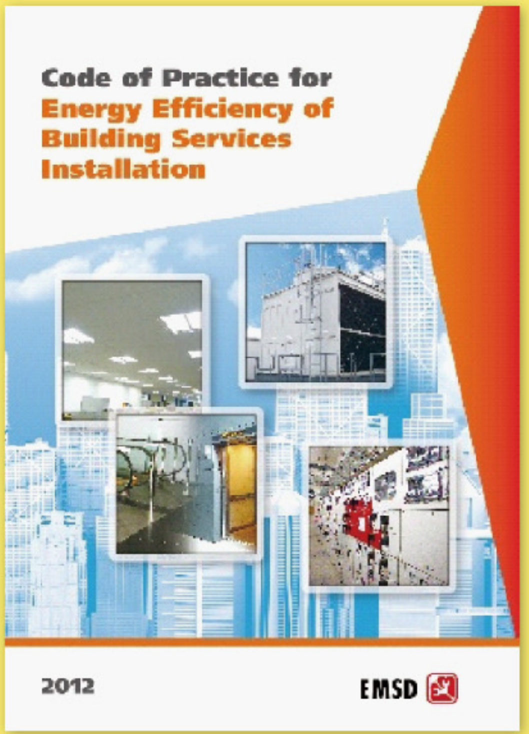
- Certify compliance with the BEC for applications of COCR or issuance of FOC;
- Issue FOC to the relevant owner or responsible person of a building or a unit in a building;
- Carry out an energy audit and issue the Energy Audit Form and energy audit report to the building owner; and
- Send a copy of the FOC, Energy Audit Form and energy audit report to EMSD as a record.

EMSD maintains a register of the REAs. The application for registration as an REA is opened up to Registered Professional Engineers (RPE) under the Engineers Registration Ordinance. It is also opened up to corporate members of the Hong Kong Institution of Engineers (MHKIE) or equivalent in electrical, mechanical, building services or environmental disciplines, who possess the knowledge and relevant post-qualification experience (two years for RPE and three years for MHKIE) in the application of energy efficiency in buildings.

Penalties

Penalties for non-compliance under the BEEO are mainly in the form of monetary fines imposed on developers, building owners, responsible persons or REAs. Imprisonment is only applicable to a person who is liable for obstructing an authorised officer in exercising the power under the BEEO, or who provides any false or misleading information/documents required under the BEEO.

BEC Technical Requirements



To provide an overview, the key technical requirements of the BEC (Rev. 1) issued under the BEEO are summarised as follows:

Lighting Installation

- Maximum allowable lighting power density (LPD) (e.g. 13W/m^2 for office space, 17W/m^2 for retail);
- Minimum allowable number of lighting control points (i.e. switching devices) for office space;
- Lighting control points to which the BEEO is applicable to be independent from those for lighting to which the BEEO is not applicable; and
- Is not applicable to lighting exterior to the building, lighting that is not fixed, signage lighting and lighting solely for decoration.

Figure 7 Lighting installation

Figure 8 Air-conditioning installation

Air-Conditioning Installation

- Load calculation per specified outdoor and indoor conditions (e.g. maximum of 35°C outdoor DB);
- Allowable air distribution system fan power per unit volume flow (e.g. maximum 1.6W/L/s for CAV);
- Allowable percentage power of full load, of power drawn by motor of variable flow fan at 50% design flow (maximum 55% of full load);
- Air distribution ductwork leakage limit;
- Piping system to cater for variable flow;
- Allowable piping system frictional loss (e.g. maximum 400Pa/m for over 50mm diameter);
- Allowable coefficient of performance of chiller and unitary air-conditioner (e.g. minimum 4.7 for water-cooled screw chiller at 500kW–1000kW cooling);
- Minimum allowable thickness of thermal insulation for pipework and ductwork;
- Energy metering (e.g. for chiller at 350kW cooling) to measure power and energy input/output; and
- Energy efficient system control, including temperature control, off-hours control, zone control.

Electrical Installation

- Allowable power distribution loss (e.g. maximum allowable circuit copper loss);
- Allowable motor efficiency (e.g. minimum efficiency of 87% for 2-pole motor with rated output power at 5.5kW to less than 7.5kW);
- Allowable motor sizing ratio (maximum 125%);
- Allowable design total power factor (minimum 0.85 for circuit at or above 400A);
- Allowable design total harmonic distortion of current (e.g. maximum 12% for designed circuit current at 400A to below 800A);
- Balancing of single-phase loads (maximum allowable unbalance at 10%); and
- Metering and monitoring facilities requirements (e.g. sub-main circuit at or above 400A to facilitate measuring V, A, kWh, kVA, TPF & THD).

Lift and Escalator Installation

- Allowable running active electrical power of motor drive (e.g. maximum 36.1kW for traction drive lift at 2.5m/s to below 3m/s rated speed and 1,350kg to below 1,600kg rated load);
- Allowable lift decoration load (e.g. maximum 50% of rated load or 600kg, whichever is lower, for lift with rated load less than 1,800kg);
- Shutting off ventilation/air-conditioning of lift car during idling;
- Minimum allowable total power factor;
- Maximum allowable total harmonic distortion; and
- Metering and monitoring facilities requirements.

Figure 9 Electrical Installation

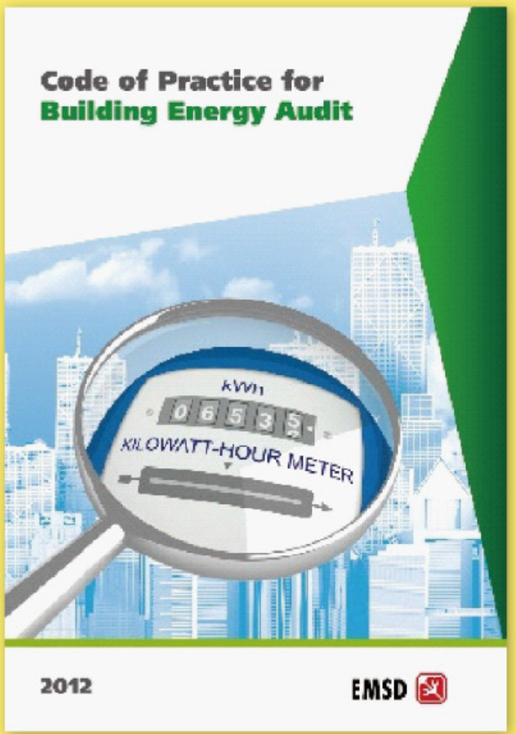
Figure 10 Lift and escalator installation

Performance-based Approach

The performance-based approach provides an alternative approach to complying with the BEC. This approach focuses on estimating the total energy consumption of a building using building energy simulation software. With this approach, the energy savings from energy efficient equipment and renewable energy installations can be evaluated and made known to the building owner at the building design stage, for consideration of cost and environmental benefits.

The performance-based approach also facilitates certain relaxation from some of the above BEC requirements, which are prescriptive in nature. For example, a lighting installation with a combination of look-out and look-down sensors to adjust the intensity of electric lighting based on the available daylight and the presence of occupants, can be allowed to have a LPD higher than the prescribed requirement. This is subject to the building's design energy not exceeding its energy budget as dictated by compliance with all the prescriptive requirements of the code.

EAC Technical Requirements



To provide an overview, the key technical requirements of the EAC (Rev. 1) issued under the BEEO are summarised as follows:

Key Steps of the Energy Audit

(i) Collection of information
(ii) Review of energy consuming equipment
(iii) Identification of EMO
(iv) Cost benefit analysis
(v) Recommendations
(vi) Compile an energy audit report

Contents of Energy Audit Report

- Executive summary (Form EE-EAes)
- Energy audit scope
- Description of building characteristics and equipment/systems
- Energy consumption and performance evaluation
- Indication of key characteristics of air-conditioning equipment/systems
- Indication of total lighting power of lighting installation

- Analysis of historical energy consumption of the building
- Indication of the building's EUI (on Energy Audit Form to be displayed)
- Indication of the energy supply from central building services installations to the building's units
- Findings from review and site inspection of energy consuming equipment, focusing on identification of potential EMO
- Evaluation of potential EMO
- Recommendations of EMO and further studies

A snapshot of the executive summary form EE-EAes (V.1) is shown below. In addition to information on building type, usage and operation, there are other technical data to be input into the form, which include the characteristics of the building services installations, such as overall lighting power density, chiller capacities and performance, flow rates and performance of the supply of cool air and chilled water etc. It is anticipated that with the available technical data, a building's overall energy performance can be compared with buildings similar in characteristics and operations. For a property management organisation, the collected data can facilitate comparisons within the organisation's portfolio of buildings, based on which strategic measures can be developed for benchmarking and collective improvement.

(B) Building Characteristics (EAC Clause 8.1)

(I) Building Type, Usage & Operation (Tick where applicable and insert N/A for non-applicable items.)

1) Type of building

(a) Please choose the type (tick one item only) of building of the building entity[^2] audited :

☐ Commercial building ☐ Commercial portion of composite (commercial & residential) building ☐ Commercial portion of composite (commercial & industrial)[^3] building

(b) Please indicate the portion of the building entity being common area[^4] : ____ %

(c) Please indicate the no. of blocks[^2] of the building entity : ____ no. of blocks

2) Total internal floor area[^5] of the building entity (m^2) :	
3) No. of floors [^6] of the building entity :	
4) Major type of building façade (tick one item) :	☐ Curtain wall ☐ Non-curtain wall
5) Date(s) of issue of occupation approval (dd/mm/yyyy) [^7] :	

6) Type of central air-conditioning[^8] provided :

☐ Cool air ☐ Chilled water ☐ Condenser water only ☐ Not applicable

7) Summary of operation characteristics of categorized major usages of CBSI-served areas :

(Below is a summary of the categorized usages in item 8). Item 8) should be completed first, based on which the following summary information can be provided.) (EXCEL version of Form EE-EAes has the built-in function to automatically add the corresponding % area figures in item 8) and insert in the relevant yellow shaded cells in item7).)

Major usage / Operation characteristics	%tage area of total of building entity [^9^27E]	%tage AC area of total of building entity [^10^27E]	Average weekly operating hours (hrs/week) [^11^12]	Daily average no. of occupants[^12]
(a) Office				
(b) Shopping & leisure				
(c) Back of house area				
(d) Restaurant				
(e) Car park				N/A
(f) Others[^13]				
Total[^14^27E]			N/A	
Daily average occupant density (m^2 per person) [^15^27E]				

Table 1 Snapshot of Executive Summary form EE-EAes(V.1) showing information requiring input in respect of building type, usage and operation

Technical Guidelines

To supplement the BEC and the EAC, corresponding technical guidelines, "TG-BEC" (EMSD, 2014a; EMSD, 2014b) and "TG-EAC" (EMSD, 2013a; EMSD, 2013b), were also issued to assist in the understanding of the BEC and EAC requirements against the legislative background of the BEEO.

Benefits of Mandatory Approach

The HKSAR Government's approach to the mandatory implementation of BEC and energy audit is in line with international efforts to address the barriers to energy efficiency (APERC, 2010; ENB, 2010; Liu *et al.*, 2010). It has the following notable benefits:

- Removes the obstacle of split incentive—where the energy savings from an energy efficient installation may be enjoyed by its user but not the owner who had paid for the installation;
- Brings sub-standard designs up to the mandatory level;
- Ensures more quality building services designs by qualified professionals, as only REAs can process certification under the BEEO;
- Creates market forces that drive service providers to offer and consumers to use more energy efficient products and deliverables with a level of performance that exceeds minimum mandatory standards;
- Creates a paradigm shift for customer expectations, from meeting a minimum level of energy efficiency to actually expecting a deliverable or product exceeding the energy efficiency level specified in the mandatory standards;
- Encourages EMO implementation based on findings in energy audits;
- Provides the energy data for developing a benchmarking tool for HK buildings; and
- Reinforces the government's role as a leader in pursuit of energy efficiency, paving the way for promulgation of further energy efficiency programmes for society.

It is estimated that the BEEO, having had addressed the barriers to energy efficiency, can generate an energy saving in newly constructed buildings in the order of 2.8 billion kWh in the first 10 years.

Review of Code Requirements

The HKSAR Government is also tasked with regularly reviewing the minimum energy efficiency standards under the BEC, with reference to the latest international standards, advances in relevant technologies, and data on building services installations submitted under the BEEO. Having enforced the BEEO and the BEC for a year, EMSD carried out a review of the LPD standards in late 2013. A new version, the BEC (Rev. 1) incorporating certain tightening of LPD was launched in February 2014. In this new version, the LPD standards are in general tightened 10%–15%, an example being 15 W/m^2 to 13 W/m^2 for office space. And before this review was the review for the EAC in mid 2013, which resulted in the launch in August 2013 of the EAC (Rev. 1) to provide guidance on the exemption from energy audit of small scale central building services installations.

Green Business Opportunities

In the absence of the mandatory approach, enhanced energy efficient products and technologies can have their market uptake and penetration but at a slower pace. The mandatory approach, with its benefits mentioned above, is a catalyst for green business opportunities. Looking back, it can be seen that EMSD's various energy efficiency initiatives have contributed to the uptake and popularity of T5 fluorescent tubes, electronic ballasts, compact fluorescent light bulbs, Grade 1 Label air-conditioners, water-cooled air-conditioning, energy audits etc. It is the Government's role to continue to provide and nurture the environment for these and the forthcoming green business opportunities, the mandatory approach being the needed one at the right time.

Conclusion

With the implementation of the BEEO, HK has taken a very major step forward towards a low carbon economy characterised by low carbon buildings. This mandatory approach will reinforce the roothold of the minimum energy efficiency standards in the BEC and the minimum energy audit requirements in the EAC, and pave the way for further enhancement of the standards. EMSD will review and tighten the standards over time. This will further facilitate continuous improvement to bring us closer to a low carbon economy.

Acknowledgements

Sincere thanks are extended to members of the Technical Taskforce on Mandatory Implementation of the BEC and its working groups in offering their expert advice and support in the development of the BEC and EAC.

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Holiday Inn Express Hong Kong SoHo: A Hotel With Multiple Green Awards, Triple Platinum and Three Stars

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Holiday Inn Express Hong Kong SoHo is a site-specific, 36-storey, 274-room business hotel, combining green design practices, construction, and operation to create a functional sustainable built environment. As the hotel is located on a confined site; advanced planning was necessary. Building Information Modelling (BIM) software was used to enhance construction logistics. For quality control, over 50% of building components for hotel floors were prefabricated in regional factories. A full scale mock-up was created to improve design and constructability. With a tight construction schedule, a 4-day cycle was achieved with a effective design planning programme, construction technology, mock-ups and careful selection of equipment and materials. A perfect safety record from the Hong Kong Labour Department was also achieved.

Efficient building services engineering design and commissioning managed to save energy, prolong life-cycle, and reduce maintenance costs and operational manpower. Rainwater recycling and utilization of solar energy were deployed. Eco-friendly innovations such as Peltier headboards, permanent magnet fan coil units and energy optimization solution for the centralized air-conditioning system increase the comfort level of guests while reducing energy consumption. A PowerBox™ system was fitted for comprehensive energy data monitoring and management to enable optimum performance of the hotel. Since the grand opening at the end of November 2012, the hotel's annual energy consumption has been recorded at 209kWh/m². This is about 50% lower than the energy consumption benchmark for hotels set by EMSD in 2007.

The Holiday Inn Express Hong Kong SoHo is the first high-rise building in the world that achieved four platinum or equivalent ratings in green building assessments: BEAM Plus by the Hong Kong Green Building Council (HKGBC), Three-Star by China Green Building Council, LEED by the US Green Building Council, as well as Green Mark by the Building & Construction Authority in Singapore. Additional merits include: Merit in Quality Building Award 2014; 2013 HICAP Sustainable Hotel Awards – Sustainable Project Design; Merit in Green Building Awards 2012 awarded by HKGBC; and Distinction in Intelligent Hotel Building 2012 awarded by Asian Institute of Intelligent Buildings.

Keywords: green building, green hotel, energy optimization solution, iFCU™, PowerBox™, Starfon™

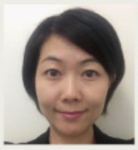
Ir Conrad Wong has over 25 years of construction project management experience. He is the Vice Chairman of Yau Lee Holdings Limited, the Managing Director of Yau Lee Construction Company Limited and Yau Lee Wah Concrete Precast Products Company Ltd., the Vice Chairman of REC Engineering Company Limited as well as the Chief Executive Officer of VHSoft Technologies Company Limited.

Ir Wong is active in public and community services. He has been appointed as the Chairman of the Hong Kong Green Building Council, the Chairman of Occupational Health and Safety Council, the Deputy Chairman of Vocational Training Council, a Member of the Antiquities Advisory Board, a Member of MPF Industry Schemes Committee as well as the Director of the World Green Building Council. In the past, Conrad served as the President of the Hong Kong Construction Association, the President of the International Federation of Asia and West Pacific Contractors' Associations, the Chairman of Pneumoconiosis Compensation Fund Board and Member of the Construction Industry Council.

Antonio Chan is currently the Executive Director of REC Engineering Group and is responsible for operations in the Hong Kong region composed of REC Engineering Co. Ltd., REC Engineering Contracting Co. Ltd., REC M&E Engineering (Shanghai) Co. Ltd., REC Engineering (Singapore) Pte. Ltd., Tin Sing Chemical Engineers Ltd., and REC Green Technologies Co. Ltd.

Antonio has been in the industry for more than 30 years and has worked in various professions including as a consultant, contractor and as a developer. He has worked in Hong Kong, China Mainland as well as the United Kingdom.

In Holiday Inn Express Hong Kong SoHo, Antonio led REC who was responsible for the MEP Design and Build and also RGT offering green technology solutions to facilitate the energy efficient and sustainable development of the project.



Carmen Wong is currently the General Manager of REC Green Technologies Co., Ltd. and is responsible for operation of REC Green Technologies Co. Ltd. Carmen has been working at Yau Lee Holdings for more than 15 years in research and development in building projects. R&D green technology products have been successfully applied to Holiday Inn Express Hong Kong SoHo. The most successful of these is the iFCU™ Retrofit Kit creating a new energy efficient fan coil unit.

K.W. Wong is currently a Senior Engineer at REC Green Technologies Co. Ltd. He has been involved in green building projects and energy efficiency projects for several years. He is experienced in China Green Building Label (3-Star) and was responsible for the application of 3-Star for Holiday Inn Express Hong Kong SoHo.

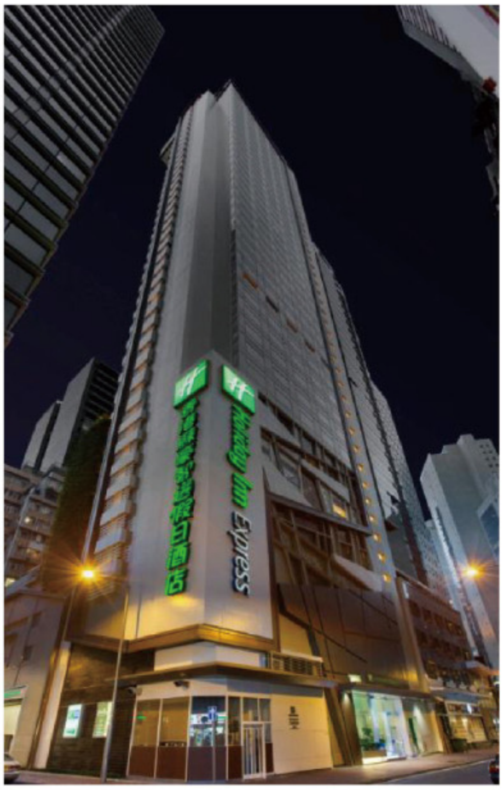


Figure 1 Holiday Inn Express Hong Kong (SoHo)

Introduction

Since 2005, Yau Lee Holdings Limited has a vision of "Becoming a Green Integrated Corporation". With previous experience in hotel building, Yau Lee decided to design and build Holiday Inn Express Hong Kong SoHo, its second hotel development. From the outset, the aim was to design, construct and operate the greenest high rise building in the world. Therefore, green building assessment tools and criteria were studied and incorporated in the building design.

Table 1 shows the scopes of some reputable green building assessment tools. It shows that the assessment criteria of site, energy, water, material and indoor environment are common to all of the assessment tools. The following sections of the paper will describe the hotel building according to this set of criteria.

Table 1 Scope of various green building assessments

Green Building Assessment	HK BEAM Plus	China 3-Star Green Building Label	US LEED	Singapore Green Mark
Scope of Site	Site Aspects (SA)	Land Saving	Sustainable Site	Environmental Protection
Scope of Energy	Energy Use (EU)	Energy Saving	Energy and Atmosphere	Energy Efficiency
Scope of Water	Water Use (WU)	Water Saving	Water Efficiency	Water Efficiency
Scope of Material	Material Aspects (MA)	Material Saving	Material and Resources	(also included in Environmental Protection)
Scope of Indoor Environment	Indoor Environmental Quality (IEQ)	Indoor Environmental Quality	Indoor Environment Quality	Indoor Environmental Quality
Other Scope	Innovations and Additions (IA)	Operation and Management	Innovation and Design Process	Other Green Features and Innovation

Site

Building Envelope

According to the Energy Efficiency Office (2013), space conditioning accounted for 30.5% of the total electricity consumption in Hong Kong in 2011, as shown in Figure 2. Good passive design of the building envelope can reduce the energy consumption from air-conditioning systems in summer, which is a major portion of annual energy consumption. Figure 4 and Figure 5 show the building orientation and the materials of the building envelope respectively. The eastern facade is connected with an adjacent building. The western facade is insulated with precast walls and an open staircase. The northern and southern facades are insulated with low-emissivity double glazed curtain walls. Insulated façades ensure the heat gain/loss through the building envelope is minimized.

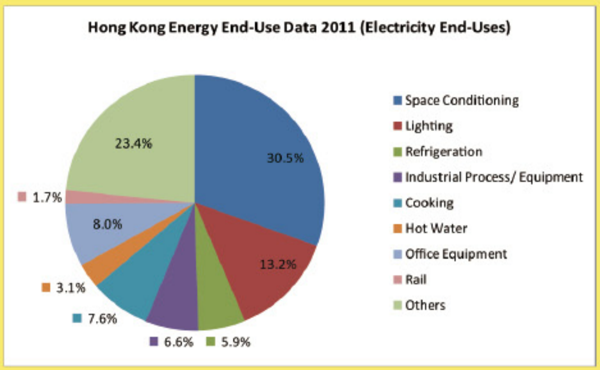


Figure 2 The end usage of electricity in Hong Kong in 2011

Figure 3 Holiday Inn Express Hong Kong SoHo

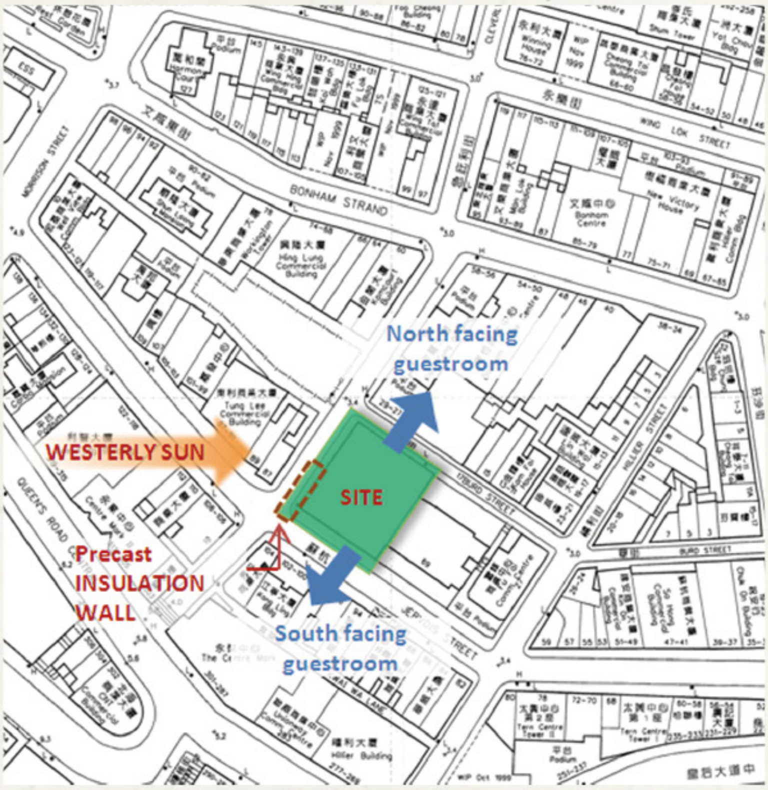


Figure 4 Building Orientation

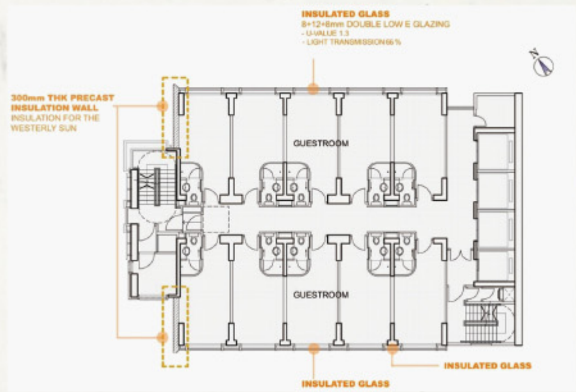


Figure 5 Building envelope materials

Greening

The greening criteria is included in all four green building assessments. For example, 2 credits are given under the HK BEAM Plus assessment for providing appropriate planting on site equivalent to at least 40% of the site area (HKGBC/BSL 2012), 1 credit is awarded under the 3-Star Green Building Label (Hong Kong version) for providing appropriate planting on site equivalent to at least 30% of the site area (China Green Building Council, 2010). Therefore, greening was considered in the early planning stage and a landscape master plan was drafted and discussed in the design stage. The area of vegetation was carefully considered, taking into consideration the variety and quantity of planting on site.

Greening was introduced at different levels of the building. The building incorporated 47.5% greenery in total, including a signature vertical green wall and a green rooftop. The lawns introduced on the 39/F, R/F and UR/F can significantly reduce the surface temperature in summer. Moreover, it can also reduce roof runoff. The lawn on R/F not only acts as a buffer to screen the chillers and cooling towers but also provides a comfortable open space for users. The vertical green wall, planters and lawn on 2/F enhance the quality of the environment in the restaurant area and the outdoor environment, providing an “oasis in the city”. They can also improve the microclimate, through absorbing heat and reducing the hard surface temperature.

The planted species, as shown in Table 2, have adapted to the local climate. Hong Kong Herbarium (2003) suggests that they are common in Hong Kong. They are resistant to drought, require limited fertilization and require little maintenance.

Table 2 Selected plant species in the building

No	Scientific Name	Common Name	Type	Planting Location
1	Nephrolepis auriculata (L.) Trimem	Tuberous Sword Fern	Herb	Vertical Green Wall (see Figure 6)
2	Asparagus densiflorus (Kunth) Jessop cv. Sprengeri	Springers Asparagus	Subshrub	Vertical Green Wall and Green Roof
3	Axonopus compressus (Sw.) P. Beauv.	Carpet Grass	Perennial Procumbent Herb	Green Roof (see Figure 7)
4	Melia azedarach L.	China-berry; Persian Lilac	Tree	6/F Podium (see Figure 8)

Figure 6
The signature vertical green wall at 2/F

Figure 7
Part of the green area on the roof

Figure 8
The tree planted on 6/F

Energy

Eco-friendly Hotel and its High Efficiency Building Services Systems

Chiller with High Coefficient of Performance

Two high efficiency water-cooled chillers are used in the hotel building. According to EMSD (2012), the coefficient of performance (COP) for screw type water-cooled chillers with cooling capacity from 500kW–1,000kW should not be less than 4.7. The cooling capacity of the hotel chiller is 684.2kW and the COP is 5.48. It has twin compressors and a primary pump, and saves a total of 373,846kWh/year, which is much higher than the statutory requirement. A comparison is shown in Table 3.

Figure 9 Water cooled variable speed chiller with twin compressors

Table 3 A comparison between the hotel chiller and the requirements in the Building Energy Code 2012

	Building Energy Code 2012 (BEC)		Chiller in the Hotel Building
Mode of Cooling	Water-cooled	Water-cooled	Water-cooled
Type of Compressor	Screw type	Screw type	Screw type
Cooling Capacity [kW]	50 – 1,000	> 1,000	684.2
Power Consumption [kW]	N/A	N/A	124.8
COP (cooling)	4.7	5.2	5.48

Energy Optimization Solution for the Centralized Air-Conditioning System

An Energy Optimization Solution (EOS) has been designed and implemented to optimize the energy consumption for the centralized air-conditioning system. It responds to the real time system load and the external weather conditions to continually monitor and control different system components. The chiller system has achieved a 27% energy reduction. There are various control strategies in the energy optimization solution, and the corresponding energy savings are shown in Table 4. The energy consumption of the centralized air-conditioning system is reduced by 172,700 kWh/annum.

Figure 10 Energy Optimization Solution (EOS)

Figure 11 The chiller is controlled by EOS coutrol algorithms

Table 4 Energy saving of the energy optimization solution for the building's centralized air-conditioning system

No	Control Strategies	Energy Saving [kWh/annum]
1	Cooling tower fan speed control and sequence control	125,000
2	Chiller sequence control	4,700
3	Chilled water pump sequence and speed control	29,000
4	Chilled water temperature optimization	8,000
5	Primary air unit (PAU) fan speed control	6,000
	Sub-total =	172,700

Intelligent Fan Coil Unit (iFCU™)

The building's centralized air-conditioning system includes a patented permanent magnet fan coil unit—Intelligent Fan Coil Unit (iFCU™). Unlike the conventional fan coil unit (CFCU), which makes use of electrical energy to generate a magnetic field for driving the motors, the iFCU™ makes use of a permanent magnet for driving the motors, to reduce power loss and enhance efficiency. The energy-free magnetic field from the permanent magnet results in energy savings. In addition, the absence of carbon brushes in the iFCU™ can reduce both friction and heat generation resulting from axial rotation of the motor. A comparison of FCU, with 600cfm, between the energy consumption of CFCU and that of iFCU™ is shown in Table 5. The energy consumption of iFCU™ is 40%–80% lower.

Table 6 shows the estimation of average energy saving from using iFCU™ over CFCU. With 274 rooms in the hotel and 274 identical FCUs operating continuously over 24 hours, it is estimated that adopting iFCU™ over CFCU could save 155,440kWh per annum.

Figure 12 Intelligent Fan Coil Unit (iFCU™)

Table 5 Comparison between the energy consumption of CFCU and iFCU™

Fan Speed	CFCU Input Power [W]	iFCU™ Input Power [W]	Energy Saving per FCU [W]	Percentage of Energy Saving [%]
High	112	67	45	40
Mid	98	33	65	66
Low	85	17	68	80

Note: The above data refers to FCU with 600cfm

Table 6 Average energy saving using iFCU™

Fan Speed	Energy Saving per FCU [W]	Daily Operating Duration [hour/day]	Annually Operating Duration [day/annum]	Energy Saving [kWh/annum]
High	45	3	365	49.3
Mid	65	3	365	71.2
Low	68	18	365	446.8
			Energy Saving per iFCU™ =	567.3
			Energy Saving for 274 no. iFCU™ =	155,440.2

Water to Water Heat Pump

Heat pumps are systems that can extract thermal energy from a lower temperature medium, and force that energy to a higher temperature medium. Therefore, heat pumps can produce chilling and heating simultaneously. The Energy Efficiency Office (2010) states that most heat pumps produce more than 1kW of chilling work on one medium plus more than 1kW of heating work on another medium, when 1kW of energy is consumed. With such high energy efficiency, heat pumps can enhance energy saving.

With the need for hot water for showers and the need for chilled water for the centralized air-conditioning system, four heat pumps were adopted for the building. Compared to conventional water boilers with 80% average efficiency where 0.8kW of heating work is done on water when 1kW is consumed by the boiler, the heat pumps employed in the building have a coefficient of performance (COP) equal to 3. This means that 3kW of chilling work is done on chilled water plus 3kW of heating work is done on hot water when 1kW is consumed by the heat pump. The estimated energy saving through using heat pumps for the hot water system is 667,680.2kWh/annum as shown in Table 7.

Figure 13 Heat pump

The chilling work done by the heat pumps on the chilled water is not included in Table 7, as it achieves energy saving for the air-conditioning system, specifically the chiller. By rough estimation, the energy saving of the chiller due to the chilled water produced by the heat pumps is 84,025kWh/annum.

Table 7 Energy saving through using heat pumps for hot water systems

Hot Water System	Boilers	Heat Pumps
Energy Consumption of Boilers/ Heat Pumps [kWh/annum]	886,987.5	212,699.7
Energy Consumption of Pump Systems [kWh/annum]	2,643.4	9,251.0
Sub-total [kWh/annum]	889,630.9	221,950.7
	Energy Saving [kWh/annum] =	667,680.3 (75.1%)

PowerBox™ – On-line energy management, monitoring and analysis software

An energy monitoring system "PowerBox™" was installed to monitor the energy consumption of the hotel building, as shown in Figure 14. The recorded data helps the implementation of energy optimization solutions (EOS) for the building. It also helps to quantify the energy saving for each of the EOS.

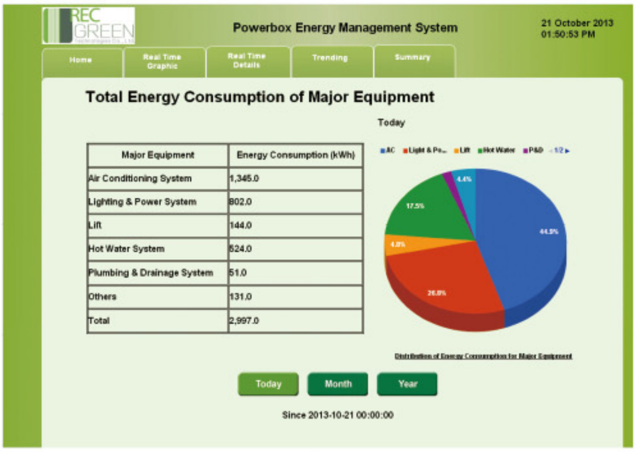


Figure 14 PowerBox™, On-line energy management, management, mouitoring and analysis software

Lift Counterweight Optimization

Figure 15 Adjustable lift counterweights are installed in the lift systems

Lift counterweights are normally designed and set at a constant value, at a certain percentage of the handling capacity of the lift car. This practice applies to almost all buildings. However, the passenger loading profile varies from building to building. Lam *et al.* (2006) suggest that the optimal counterweights in residential buildings is 35% of the lift car handling capacity—this value results in the lift system consuming the least energy.

The building's lift system utilizes adjustable lift counterweight systems. By analysing PowerBox™ data and adjusting the lift counterweights, the lift system's energy use is reduced by 15,930kWh/annum.

Use of Renewable Energy

Solar Hot Water System

There are 24 solar hot water panels installed on the building rooftop, as shown in Figure 16. The solar energy is used to directly heat potable water instead of generating electricity, as the latter process would involve energy loss during the conversion to electricity. The energy harvested from the solar hot water system is estimated at 70,570kWh/annum.

Figure 16 Solar hot water panels and solar buffer tanks

Water

Recycling of Rainwater and Condensate Water

Two recycle water tanks, each with a 5,000L capacity, as shown in Figure 17, have been installed inside the building to store rainwater and the condensate water from the air-conditioning system. The rainwater and the condensate water are recycled and used to irrigate the building's greenery. The amount of collected recycled water is greater than the total demand of the greenery. Therefore, irrigation of greenery relies only on recycled water.

Figure 17 Recycle water tank and a rainwater inlet on the green roof

Low Flow Sanitary Fittings

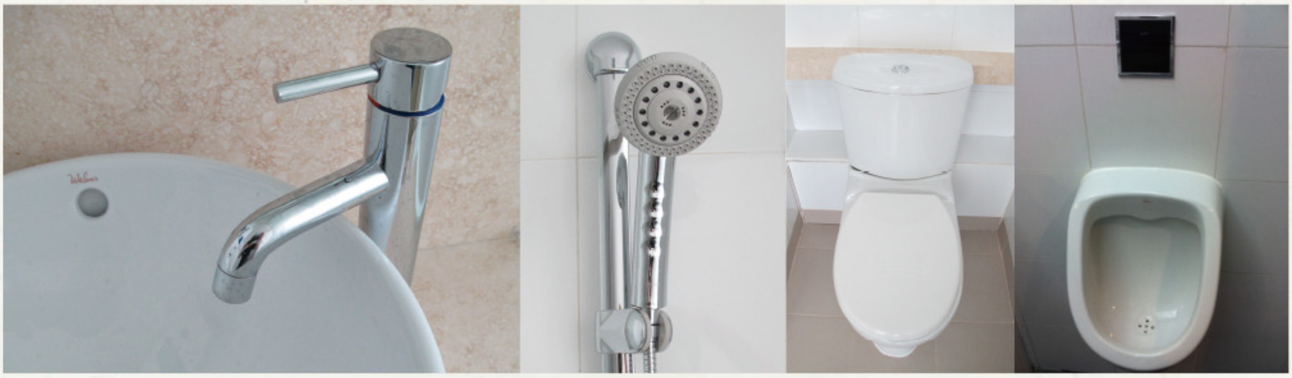


Figure 18 Low flow sanitary fittings

Low flow sanitary fittings as shown in Figure 18 are installed in the building. The faucets and shower heads use potable water. Table 8 shows their designed water flow rate. Aerators are installed in all the faucets and shower heads to achieve the design values. When water passes through the aerators, air bubbles are injected into the water stream, creating the same volume flow with less water. As a result, the water flow rates of the faucets and the shower heads are reduced by 51.4% and 47.5% respectively.

Using seawater instead of potable water for flushing is a common practice in Hong Kong. This saves a substantial amount of potable water. Seawater is used to flush the hotel's water closets and urinals. Low flow urinals and dual flush water closets, provide low flush and high flush options. These low flow sanitary fittings do not reduce potable water consumption but will reduce the loading on the building drainage system and the municipal drainage system.

Table 8 Design flow rates of sanitary fittings

Sanitary Fittings	Baseline Water Flow Rate [L/s]	Design Water Flow Rate [L/s]	Reduction [%]
Faucets	0.138	0.067	51.4
Shower Heads	0.158	0.083	47.5
Water Closets	7.5L per flush	*6L per flush	20
Urinals	4.5L per flush	3.78L per flush	16

*Dual flush (3L/6L) water closets are employed in the hotel building, and the high flush volume is used for comparison

Construction Process and Building Technologies

Simulation of Wind Loading

A wind tunnel modelling study of the hotel was conducted at the CLP Power Wing/Wave Tunnel Facility in HKUST. This is shown in Figure 19. A 1:400 scale model of the hotel was built for the simulation of the wind loads affecting the site. With the information obtained, we were able to fine tune the use of rebar and concrete. Hence the building structure could be designed in the most efficient way. The use of rebar was reduced by 45 tonnes and grade 40 concrete was used instead of grade 60.

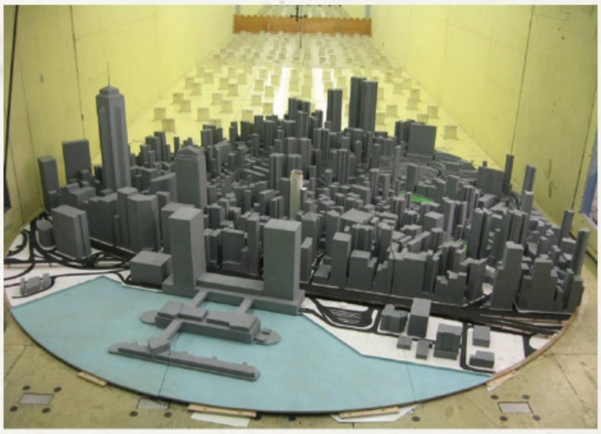


Figure 19 Wind tunnel modelling study

Building Information Modelling

The construction schedule for the hotel was tight. A 4-day cycle was targeted. Using BIM software for underground utilities outside the building and typical floor construction, three-dimensional and real-time data helped establish a clear and detailed construction schedule. This enhanced productivity in both the design and construction stages. Early planning was made possible with reduction of on-site coordination time. To further save time, a combined formwork system was adopted for 50% of building elements, such as the staircase and end wall façade, which were prefabricated off-site. A 4-day floor cycle was successfully achieved.

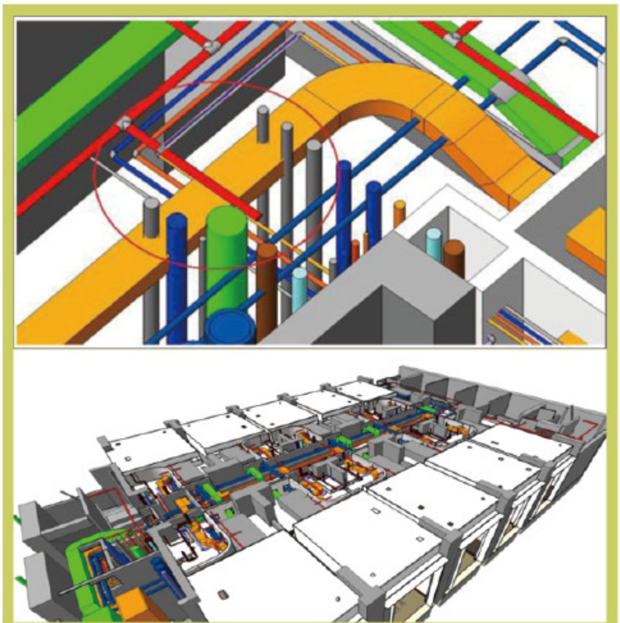


Figure 20 BIM was used for construction

Standardized Design and Prefabricated Construction

With the time constraints and the confined site area, approximately 50% of the building elements were standardized and prefabricated prior to site delivery. Materials were used more efficiently and on-site wastage was greatly reduced. Doing so also improved construction precision and quality while reducing wastage of materials. The standardized building elements included the tower's external walls, staircases (Figure 21), and guest room elements (Figure 22).

Figure 21 A precast staircase

Figure 22 Standardized curtain walls of guest rooms

Materials

Choice of Materials

The materials used at the site were chosen after careful consideration. The goal was to be green and efficient at the same time. Materials used included:

- Low Volatile Organic Compounds (VOC) products;
- Double-coated Low-E glass;
- Forest Stewardship Councils (FSC) certified timber: reused timber or timber from a sustainable forest was used in the hotel's formwork, falsework, furniture, and doors;
- Starfon™- to lower the heat island effect while preserving natural resources with resistance to termites, other insects, water and stains.

Recycled Material Use: Starfon™

Acquired from the US, the patented Starfon™ was used for the first time in the construction of the hotel lobby and the building facade. Starfon™ is an eco-friendly building material. It adopts an innovative and patented extruded cementitious composite technology with selection of materials such as cementitious binders, recycled glass or other inorganic fillers. During the curing process of the substrate, additional input of heat is not required. Various combinations of UV curable inks and coatings can be added to the product. Compared with other coating methods, such as aqueous coatings and varnish, UV coating is a clean technology that eliminates the emissions of VOC and reduce energy consumption.

Starfon™ products range from marble, printed image, wood, monotone, fiber optics and metals. In accordance with BS EN 12467:2004, ASTM C1185-08 and all related coating tests, the products possess good mechanical properties, good durability and are resistant to fire, chemical and dangerous substances.

The uses of Starfon™ in the building are shown in Figure 23.

Figure 23 Use of Starfon™

Indoor Environment

Daylighting

Daylight can enhance indoor environments. Large glazed windows and doors were adopted in the building design to facilitate daylight penetration. Corridors of the guest floors are naturally lit therefore daytime artificial lighting energy is conserved. Low emissivity (low-E) double-coated glass is used in the insulated glass units (IGU) of the curtain walls, to permit visible light while the heat flows in and out of the building are efficiently controlled. Details of the IGU are shown in Table 9. The estimated energy saving through using IGU with low-E double-coating in the building envelope is 3% while views from guestrooms are maintained.

Figure 24 Large glazed windows are used in the corridors

Figure 25 Large glazed windows are used in the Multi-function Room

Table 9 Comparison between IGU & IGU with low-E double-coating

Glass Type	Lighting Transmission	Shading Coefficient	U-Value [W/m²K]
IGU with double low-E coating	66%	0.42	1.3
IGU	78%	0.79	2.7

Demand Control Fresh Air Supply and Motorized Curtain System Interlinked with Keycard Control

The demand fresh air control and motorized curtain system are interlinked with keycards inside guestrooms. Whenever a guest leaves the room, the curtains are automatically drawn together to reduce the fresh air and solar heat gain during unoccupied periods as shown in Figure 26.

The motorized curtains are also programmed to be drawn together at 11pm to prevent light pollution however when a guest steps inside the room, the curtains are opened automatically to reveal a lovely view.

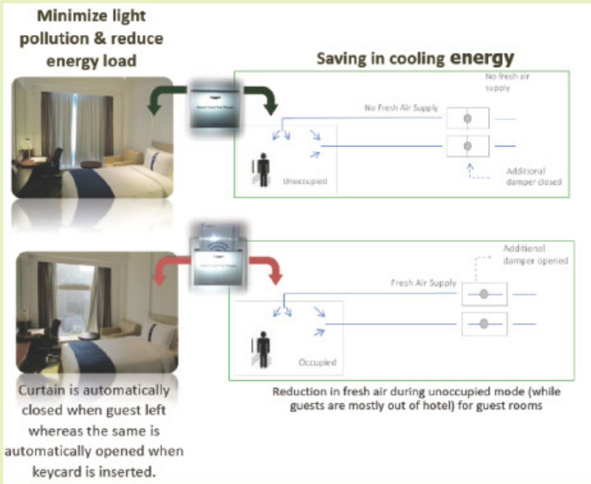


Figure 26 Fresh air supply and motorized curtain system interlinked with keycard

Access for Disabled Persons

Six hotel guestrooms were designed according to the Design Manual – Barrier Free Access 2008. The guestroom layouts, including the bathrooms and the shower compartments, meet the recommended design requirements to enable a wheelchair user to move easily without assistance. Moreover, the guestroom furniture is accessible and used in a convenient manner. Figure 27 and Figure 28 show the layout of a guestroom with barrier free access.

Figure 27 Guestroom with barrier free access

Figure 28 Wheelchair users can easily move from the living area to the bathroom area without assistance

Other Scope

Innovative Features

Peltier Headboards

Conventional air-conditioning devices cool down the whole guestroom. Guests prefer to be covered by a thick blanket to keep warm whilst the room temperature setting is kept at a relatively low value. This is a tremendous waste of energy. By using Peltier headboards, a guestroom's temperature setting can be raised from the normal 23°C–27°C, thus saving considerable energy from the air-conditioning system throughout the night. A photo of Peltier Headboards is shown in Figure 29.

Solar Hot Water Cladding (SHWC)

Yau Lee has developed a product named "Solar Hot Water Cladding" as shown in Figure 30. It is aluminium cladding with water tubing installed in the back, connected to a water re-circulating system. Potable water flowing through the water tubing is heated and then cools down the building envelopes.

The building adopted an integrated central hot water supply system which consists of the SHWC, the solar hot water system and the heat pumps. The SHWC together with the solar hot water system can save energy by preheating the water before it passes to the heat pumps.

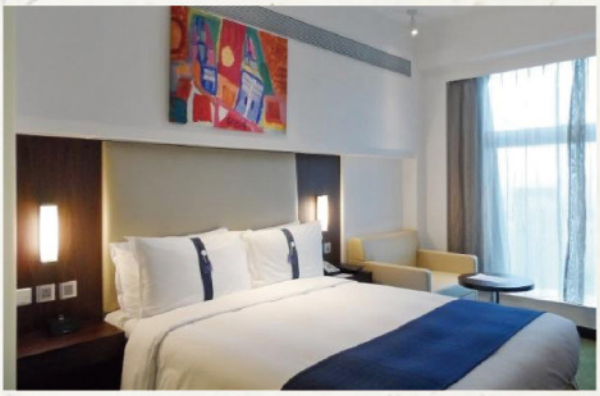


Figure 29 Peltier Headboards

Pattern Recognition Energy Saving Solution (PRESS)

A Pattern Recognition Energy Saving Solution, featuring pattern recognition software and electronic interfacing devices, is connected to the existing CCTV cameras. It turns off unnecessary lighting and air-conditioning in corridors when no one is in the area.

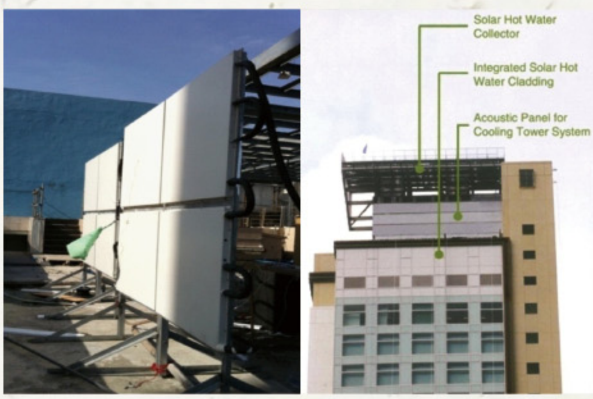


Figure 30 Solar hot water cladding

Figure 31 Concept of Pattern Recognition Energy Saving Solution (PRESS)

Operation and Maintenance Features and Cost Effectiveness

The cost for maintenance of the above features was HKD$0.26M during the first year of operations. Yet, these features cut energy costs by around HKD$1.9M, hence they are cost effective.

Corporate Social Responsibility (CSR)

To share our vision of sustainability with the public, green tours for guests and technical visits for industry are organized to promote the hotel's eco-friendly facilities and solutions. As of September 2013, over a hundred technical visits had been conducted for local and overseas government departments, developers, design consultants, hotel operators and stakeholders. Education leaflets are also available at the hotel lobby and in all guestrooms. A green corner has been set up to introduce green features.

Through collaboration with a local charitable NGO—Nesbitt Centre, we established a means of contributing to the cultural side of the community. The centre is dedicated to adults with learning disabilities. An art project was set up to encourage its students to create paintings that were inspired by their trips through the streets of Hong Kong's Sheung Wan district. Copies of the paintings have now become part of the hotel decor, with one in each guestroom.

Figure 32 Technical visit for the industry

Figure 33 Green tours for guests

Figure 34 An art project with a local charitable NGO - Nesbitt Centre

Conclusion

In conclusion, Holiday Inn Express Hong Kong SoHo is a green integrated corporation that has achieved reduced carbon emissions, water conservation, energy optimization and minimal use of natural resources. With a number of innovative ideas on energy optimization solutions and sustainable practices, the hotel is a pioneering attempt to inspire not only Hong Kong, but also Mainland China, and the world. All the green technologies and solutions adopted in the project can be applied in any building. Committed to raising public awareness and to encourage the construction industry to adopt green practices and build in a green way, the developer would like to turn sustainability into a norm, protect the earth, and benefit generations to come by building a quality tomorrow.

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Sustainable Redevelopment Model for High-density Commercial District in Hong Kong – Key Step Towards Sustainable Urban Transformation

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In Hong Kong, the lack of space results in buildings being constructed close to each other and making it one of the most densely populated cities in the world. This brings environmental and social challenges when it comes to designing sustainably for new developments. To this end, Hysan Development (Hysan) set clear targets for Hysan Place—a mixed-use commercial building built in Causeway Bay, one of Hong Kong's most vibrant commercial districts. The project was to answer some of the environmental issues and challenges associated with high-density and high-rise development, which had received less attention in the past. Furthermore, the building aimed to go beyond its site boundary and help improve the urban environment of the district, which would be a necessary first step to achieve sustainable urban transformation in Hong Kong. For Hysan Place to succeed, a tailor-made sustainability framework was adopted for the project, which covered sustainable urban environment, green features, active system optimisation, passive design, as well as material and waste. This paper provides an in-depth view of the project and explores the possibility of sustainable development in such a built-up environment.

Keywords: high-density urban context, high-rise development, sustainable urban transformation, sustainability framework

Dr Vincent Cheng is a Director of Arup and the Leader of Building Sustainability Group of Arup East Asia Region. He is specialised in sustainable master planning, low/Zero carbon design, LEED & BEAM Plus certification, life-cycle analysis and Air Ventilation Assessment (AVA). He has been involved in more than 60 LEED and BEAM Plus projects in Hong Kong and the Region, including the most recent award-winning CIC ZCB, the first Zero Carbon Building in Hong Kong and Hysan Place, a LEED and BEAM Plus certified Platinum commercial building. Since 2008, Dr Cheng has been servicing the Hong Kong Professional Green Building Council as a council member and is currently sitting in the advisory committee of School of Energy and Environment, the City University of Hong Kong.

Sunny Chan leads Hysan's project management affairs from new developments to all major asset enhancement projects. Mr Chan holds a Bachelor of Engineering (Honours) Degree in Building Services Engineering and is qualified as a member of the Hong Kong Institution of Engineers and the Chartered Institution of Building Services Engineers, United Kingdom. He is also a Member (Energy Use) of the Green Building Faculty nominated by the Hong Kong Green Building Council. Mr Chan has extensive design and project management experience for award-winning and landmark sustainable building projects, ranging from residential and serviced apartments, shopping malls, to Grade "A" office buildings and luxury integrated resort hotels.

Gary Leung handles the building services and environmental sustainability aspects of Hysan's new developments and major asset enhancement projects. He holds a Master of Science Degree in Building Services Engineering and is qualified as a member of the Hong Kong Institution of Engineers, the Chartered Institution of Building Services Engineers, United Kingdom and also Beam Professional of Hong Kong Green Building Council. Mr Leung has extensive design, construction and project management experience from prestigious building projects, ranging from residential and serviced apartments, shopping malls, to super high-rise office buildings and luxury hotels.

Introduction

Hong Kong has a population of about 7.2 million (Census and Statistics Dept., 2013), all living within a total area of 1,100km^2. The average population density in Hong Kong is around 6,500per km^2. However, with the hilly topography in most areas of Hong Kong, only 25% of the land is habitable (Ng, 2009). Insufficient land supply and high demand are factors that contribute to high land prices. To account for the high land cost, property developers are building taller and bulkier buildings to maximise the plot ratio. This, in turn, led to the population density rising up to 29,412km^2 in the core urban areas (Demographia 2014). Although a densely packed urban area provides efficient commercial operations and convenience, it brings challenges to various aspects of sustainability design for a new development. Seeking ways to successfully implement sustainability in new buildings is the first and key step towards sustainable urban transformation in terms of a community and a city.

In the past, Hong Kong as a whole paid little attention to what is now considered sustainable urban planning. Most buildings constructed in the past decades were built for financial benefits and contributed little towards the community's sustainability. In recent years, more attention has been paid towards sustainability in Hong Kong, but the international trend has already been shifting towards sustainability as a more city-wide and even regional concept (Berek, 2002). This has put Hong Kong under the spotlight. Property developers are urged to employ sustainability concepts to redevelopment projects and play a key role in the process of urban transformation (Berek, 2002).

Although more attention has been paid to sustainability in the past few years, this attention has mainly focused on physical redevelopment with an unstructured sustainable development framework (Lee, 2008). In particular, when the redevelopment is located in a dense urban core, the typical sustainable development framework needs to be adapted and there is a need to prioritise among various sustainability aspects. As stated by McCormick *et al*. (2013), the efficiency of sustainability strategies requires an understanding of human behaviour and consumption to adapt the built environment not just with individual buildings but across the neighbourhood. Therefore, in order to fit into the framework for sustainable urban transformation in a high density city like Hong Kong, the building should aim to: 1) overcome the constraints and adverse impact from the surrounding high-density building context; 2) go beyond the site boundary and take the sustainability of the entire neighbourhood into consideration; and 3) drive the market and community towards sustainability. With more buildings approaching the end of their life cycles, there are new business opportunities, for future redevelopments which can fit into the process of sustainable urban transformation.

Figure 1 Hysan Place is located in one of Hong Kong's densest urban environment, which brings challenges to sustainable and low/zero carbon development.

In line with this view, the sustainable redevelopment of Hysan Place is investigated as a new prototype to gain insights into a sustainability framework for mixed-use buildings in Hong Kong's densest neighbourhood. Hysan Place is a shopping mall and office building located at No. 500 Hennessy Road, Causeway Bay. It was developed by Hysan Development Company Limited at the former site of Hennessy Centre. Hysan Place was designed by an integrated team including architects Kohn Pedersen Fox (KPF), Dennis Lau & Ng Chun Man (DLN), environmental and sustainability consultant Ove Arup & Partners Hong Kong Ltd. (Arup) and building services engineer Parsons Brinckerhoff (PB). With the client and sustainability consultant taking the lead, it was the first building in Hong Kong to be awarded the highest Platinum level under the Leadership in Energy and Environmental Design Core and Shell (LEED-CS) Program by the U.S. Green Building Council. The project was also awarded the highest rating of Platinum under the Hong Kong's BEAM Plus (New Building).

Challenges to Sustainability

High Density Urban Context

Hysan Place faced a number of environmental and social challenges due to its location. Causeway Bay is one of the most vibrant commercial districts in Hong Kong. Residents enjoy efficient transport connections and other conveniences in daily life, but also suffer from buildings constructed in close proximity to each other, a lack of open space, air pollution and the urban heat island effect. The most significant problems and challenges can be summarised as follows:

Air Pollution

The high concentration of buildings prevents wind movement through the area, leading to poor air circulation. Moreover, the heavy traffic on Hennessey Road brings large amounts of vehicular emissions. Both of these factors create a scenario whereby polluted air cannot disperse easily. While it is bad for public health, it also has an adverse impact on business opportunities.

Heat Island Effect

The congested layout in Causeway Bay sharpens the heat island effect and elevates local temperatures. In addition, the massive building block absorbs heat and releases it back to the pedestrian zone, making it even hotter.

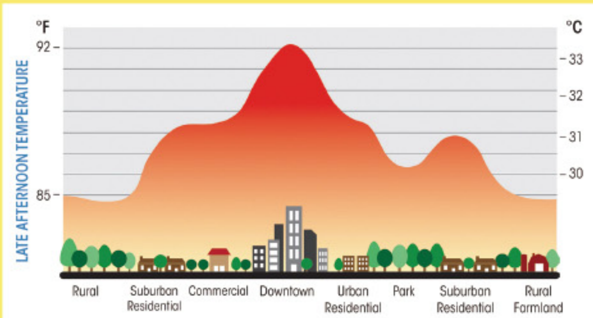

Figure 2 Buildings and concrete absorb solar radiation, resulting in the emission of long-wave radiation that heats the air in urban areas. Buildings also consume large amounts of energy, and emit this energy as waste heat, adding to the urban heat island effect.

This creates a hot, stagnant, contaminated and over-crowded environment and threatens the comfort and health of pedestrians and building users.

These challenges to sustainability suggest a need for specific sustainability initiatives. The redevelopment of Hysan Place provides a unique opportunity to implement the building sustainability concept specifically for high density urban areas. Comprehensive studies were conducted and mock-ups were created during the planning stage for this 40-storey mixed-use office and retail building to:

- Provide new opportunities to bring positive natural resources to the community;
- Improve the environment for the well-being of the public and building users.

Sustainability Strategies and Framework

The development aimed to address a set of challenges prioritised as follows:

Community: to adopt district scale measures assisted by Area Ventilation Assessment (AVA), urban heat island analysis and sustainable planning to:

i) Enhance spatial connectivity of the neighbourhood by providing building setback and low building density at ground level, maximising the liveable and open space for the entire community.

ii) Fully utilise available natural resources of wind, daylight and other elements to provide an accessible and comfortable external environment for the community;

Building: to create an advanced sustainable building design integrating both passive and active systems to best utilise natural resources and reduce building energy consumption;

Users and occupants: to provide the flexibility to lower energy consumption as well as improve the indoor environment and thermal comfort.

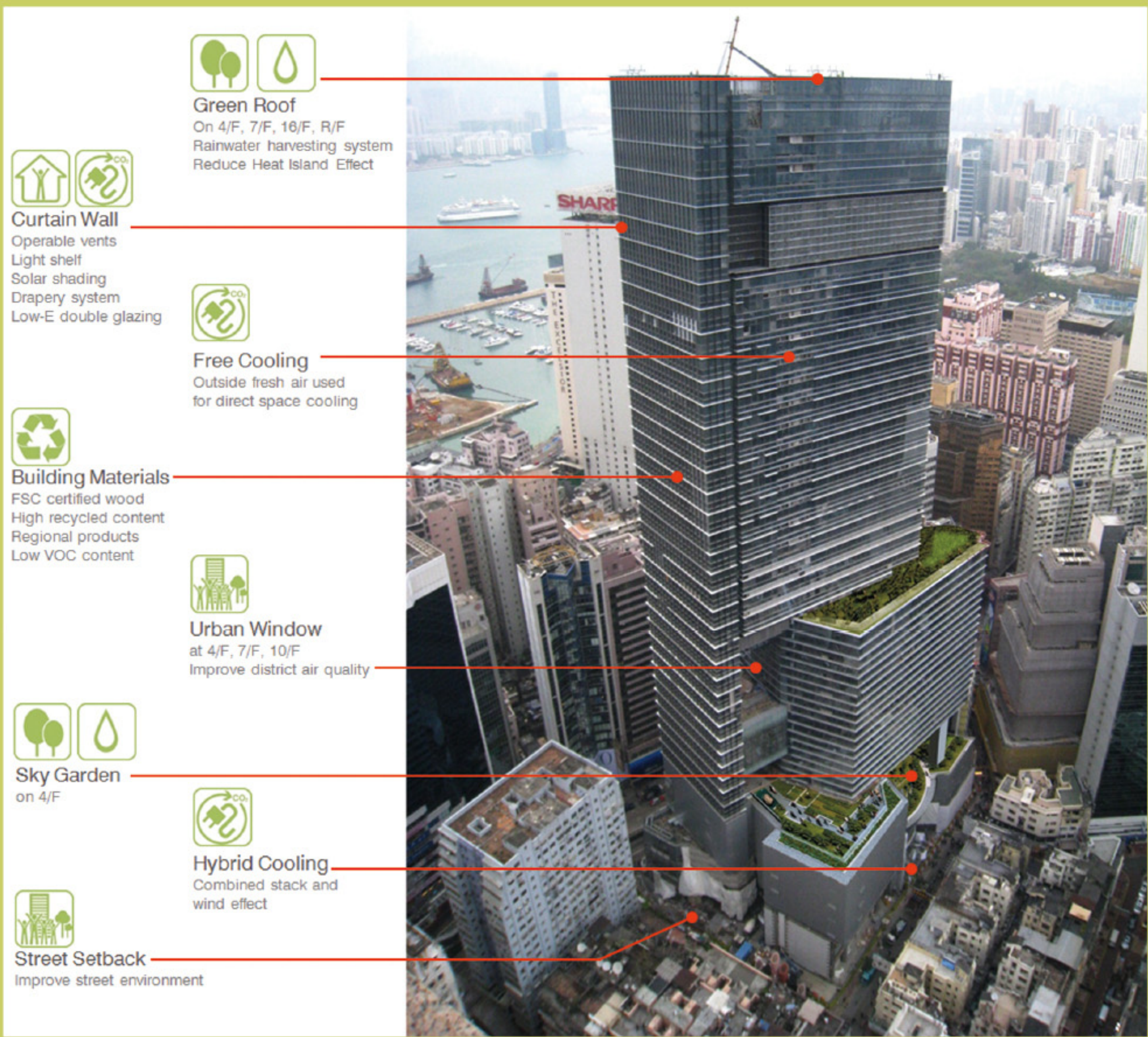

Figure 3 The key sustainable features of the development aim to address the challenges from a hierarchical perspective for the community, building and occupants.

Sustainable Urban Environment

Urban Windows

In Hong Kong, high-rise buildings near the coastline often have impermeable design to maximise views and plot ratios. This causes the adjacent buildings and inland areas to suffer from limited daylight, insufficient ventilation, poor air quality and the urban heat island effect. This is well known as the "wall effect" from Hong Kong's distinctive development pattern.

In order to tackle this problem, the most visible sustainable building features of Hysan Place are the design of urban windows—3 major openings at different heights of the building allowing efficient air flow through the neighbourhood, as well as reducing the "wall effect". They also provide an excellent setting for sky gardens and resting areas, which help to reduce the heat island effect with their lush greenery.

Figure 4 The most visible sustainable features of Hysan Place are the design of Urban Windows—3 major openings at different heights of the building, allowing efficient air flow through the neighbourhood, as well as reducing the "wall effect".

The urban windows design was integrated as a result of the Air Ventilation Assessment (AVA)—a quantitative study to assess the impact of wind in the heavily built-up environment. The initial AVA results indicated that the air circulation at pedestrian level and for residential units nearby was unsatisfactory due to the congested building layout in Causeway Bay. Therefore, a permeable building design was proposed and optimised to form the urban windows concept based on local wind availability.

Computational Fluid Dynamics (CFD) modelling was used to simulate the airflow induced by urban window designs and of their performance under prevailing wind directions. Due to the location of Hysan Place in the heart of Causeway Bay, the urban window design can significantly help ease the stagnant wind conditions and create a desirable environment for those who make use of the building, as well as for those living and working nearby. AVA showed that urban winds can contribute to an average ventilation improvement of 7% in the local environment and significant ventilation enhancement in the abutting Russell Street/Time Square (33.3%) and Tang Lung Street (62.5%).

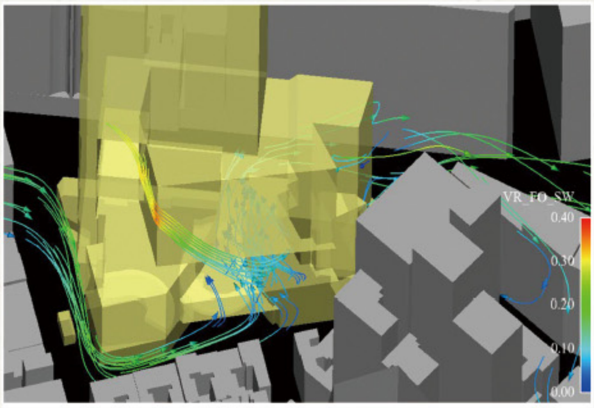

Figure 5 The urban window design improves the permeability of the design and helps to ease the stagnant wind conditions and create a desirable environment for those who make use of the building as well as those living and working nearby.

Building and Streetscape Interface

Typical zoning in Hong Kong results in little open space at ground level, which creates an adverse impact on air ventilation. The former Hennessy Centre was a product of the zoning in place at its inception. It had a three-storey podium with full site coverage and a tower with a smaller floor plate above this plinth. In an attempt to reduce the building density at ground level for Hysan Place, an open space zoning incentive was put into place, which allowed a taller podium defined by a "sky exposure plane" in exchange for a minimum of 8% open space at ground level. This additional open space helps soften the man-made environment and further enhances ventilation at pedestrian level.

Green Building Features and Facilities - Accessible Green Roof/ Urban Farm and Sky Garden

The urban heat island effect needs to be mitigated through many different measures. Apart from ventilation, greenery also plays an important role in easing the effect and provides users with a comfortable outdoor space. However, for a high-rise building with a limited site area, this is not an easy task.

In order to provide more green area for the development, a vegetated sky garden design was integrated with the urban window, which provides an open space for public users. A total vegetated area of about 2,048m^2 is achieved for Hysan Place, which equals to 47% of the site area. The greenery includes planting in sky gardens, vertical greening and a green roof.

The green roof was developed into an urban farm. The organic farm provides lush year-round vegetation in the form of vegetables and fruits. The "outdoor green areas" of the refuge floor (16/F) of Hysan Place was also developed into an experimental artificial wetland. The wetland has the function of treating waste water into becoming reclaimed water. While it provides further greenery, it is being tested to see if it can fulfil the mission of recycling grey water generated by wash basins at office units within the building. An internal office courtyard is also provided at the 37/F and 38/F with a green wall and good sunlight penetration. Meanwhile, three types of high efficiency irrigation systems including drip line, irrigation mat and sprinklers are adopted to ensure minimum water usage for the large greenery area. Considering a typical development only has 20% greenery, the 47% coverage in this high-rise building demonstrates Hysan's commitment to develop it into a truly green building to enhance the sustainability of the community in general.

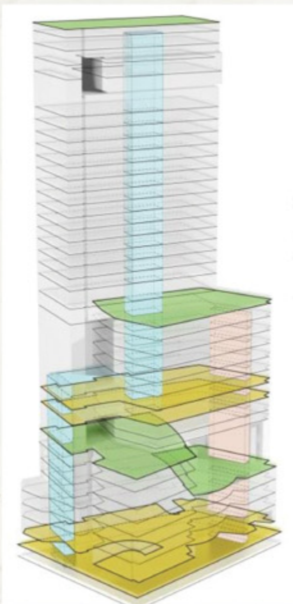

Figure 6 Hysan Place make full use of its podium, void and roof to achieve a total vegetated area of approximately 2,048m², which equals to 47% of the site area.

Health and Comfort Interiors – Integrated Building Envelope

Having tackled the exterior, the next step was to focus on the building envelope—the integrated system that separates the internal and external environments. In order to optimise the management of airflow, daylight and heat between the exterior and the interior, a highly integrated and multifunctional high performance curtain wall system was deployed for Hysan Place with the following components:

Light shelf: a customised light shelf with profiled reflective ceiling reflects daylight deep into the interior of each office while offering a panorama of Victoria Harbour along the north side of each office floor. It further reduces glare and excessive lighting at perimeter zones of the office and minimises contrast with the interiors.

Drapery system: installation of sheer screen and black-out screen at lower and upper parts of curtain wall units allows flexible use of drapes in different daylight conditions for occupants' comfort.

Solar shading devices and low-emissivity double-glazing: angled vertical fins were added to the west façade to block direct sunlight from the late afternoon summer sun, (angled slightly northwest), while maintaining views to the harbour. Horizontal fins were also added to function as external light shelves. Both devices were found to improve overall shading, especially on summer days.

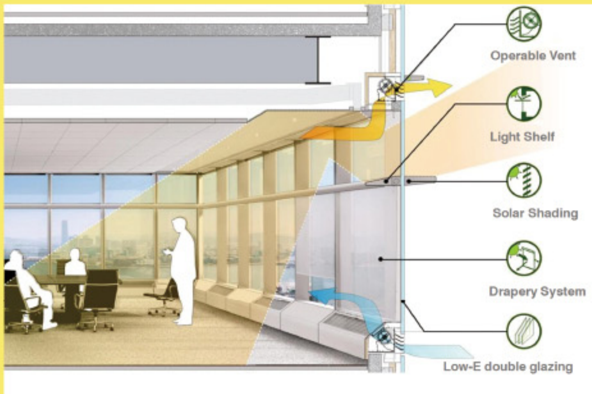

Figure 7 The integrated envelope is designed with carefully angled shading fins and light shelves to avoid direct summer sun and maximise views to the harbour.

Energy Saving and Carbon Emission Reduction – Optimisation of Energy Consumption

In Hong Kong, buildings account for 60% of carbon emissions and 90% of electricity use. Focusing on making buildings more energy efficient is the key to seizing the opportunity of meeting Hong Kong's carbon reduction target without entering the current fuel mix debate. Various passive design strategies and active systems have been designed to achieve a target saving of over 40% energy savings compared to a conventional retail and office mixed-use building. The energy saving strategy includes the following items:

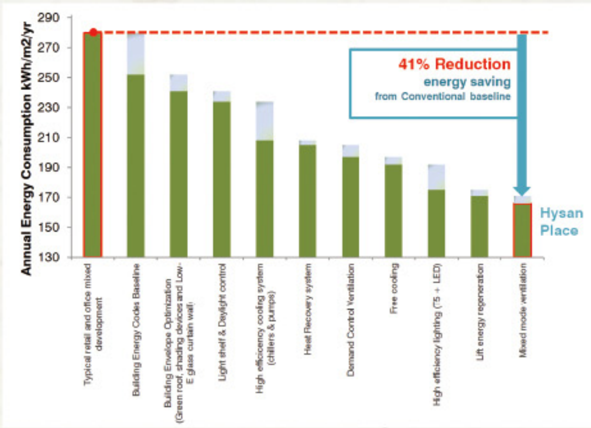

Figure 8 Various passive design strategies and active system optimisation have been designed to achieve a target saving of over 40% energy savings compared to the conventional retail and office mixed use building.

High efficiency cooling system: Hysan Place adopts chillers with variable speed drive (VSD) and an oil free magnetic bearing driven chiller, which provide superior performance, especially in various part-load conditions. Coupled with optimised chiller sequencing algorithm, a control strategy for variable primary flow (VPF) and variable speed pumps, the whole chiller plant provides a significant saving in cooling energy when compared to a conventional system.

Mixed mode ventilation and free cooling: combines natural ventilation (via operable vents) and mechanical ventilation/air-conditioning to enhance occupant comfort on office floors. Once the vents are opened, unnecessary air-conditioning to individual perimeter zones will be automatically switched off to minimise energy wastage. The effective area benefiting from natural ventilation would be the 5m deep space adjacent to the facade.

Figure 9 The building combines natural ventilation (via operable vents) and mechanical ventilation/air-conditioning to provide and enhance occupants' comfort and energy efficiency on office floors.

A free cooling system or economy cycle optimises the use of air handling units and air ducts. Outside fresh air is used for direct space cooling without using additional cooling during suitable outdoor conditions to ensure a good thermal comfort level for occupants.

Table 1 Operation strategy for mix-mode ventilation and free cooling

		Under Automatic Control	
Outdoor Conditions	Operation Mode	Operable Vents (except 33, 37-38/F)	AHUs
21°C - 23°C or above	Normal	Close	Normal
16°C - 20°C and RH <75%	Mode 1	Open	• Free Cooling • Variable Air Flow
15°C or below	Mode 2	Open or Partially Open (avoid over-cooling)	• Free Cooling • Variable Air Flow

Efficient lighting: an efficient lighting system reduces lighting power density. An energy efficient fitout was adopted in the project to maintain the required lighting level with less luminaries to save energy. Due to the higher diffusion or a wider lighting coverage, the actual measured lux level in Hysan Place is 398.55 lux, with lighting power density not exceeding $9W/m^2$. This is a significant reduction compared with $13W/m^2$ in the Building Energy Code (BEC) 2012. The low lighting power density design accompanied by the use of task lighting provide good lighting quality while reducing the overall energy consumption and operational cost.

Passive low energy design – Side core configuration: various tower massing schemes and core configurations were evaluated to determine the ideal layout for both the office and retail components. Sunlight simulations were conducted to compare central core and southern core configurations. While both provide similar natural daylighting, shifting the core towards the south can mitigate the problem of high solar gain at the south facade and improve the performance of the overall envelope.

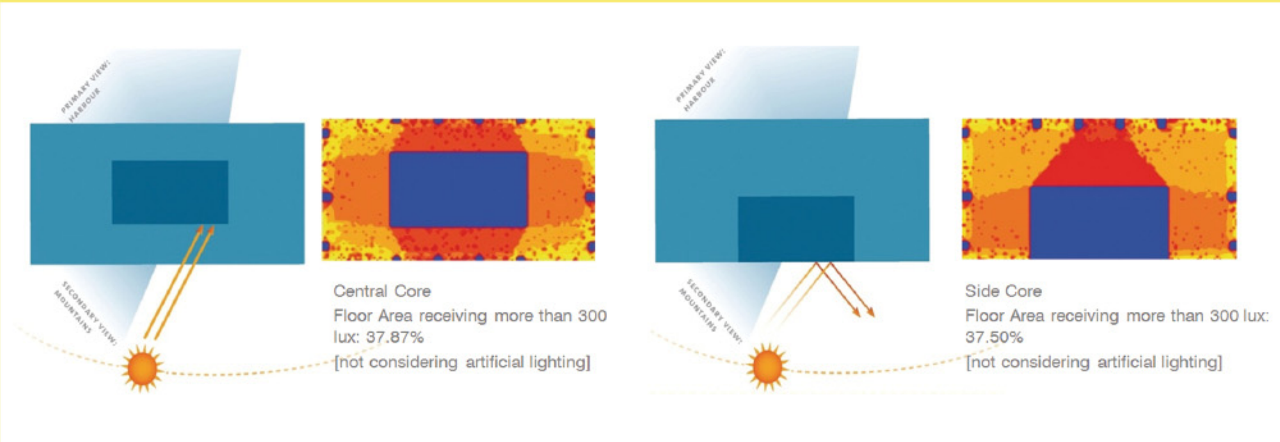

Figure 10 Shifting the core to south can mitigate the problem of high solar gain at the south facade and improve the performance of the overall envelope.

On the other hand, with the help of solar analysis, views of the harbour to the north and views of Central to the west were maintained for the office floors, with a general orientation that minimises sun exposure on the east and west facades. The placement of the tower to the north of the site left larger south facing floor plates for the retail area below, ensuring flexibility for long term use and reuse.

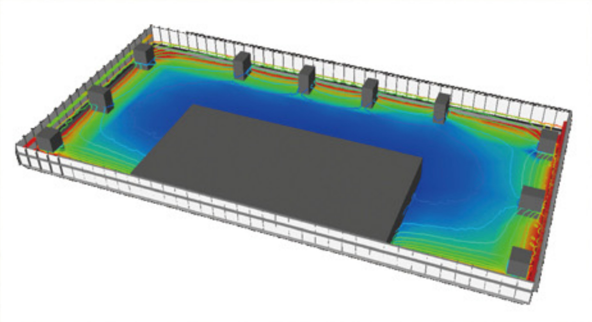

Figure 11 Simulation-assisted orientation configuration aimed to minimise sun exposure on the east and west facades.

Efficient Use of Materials and Water

Sustainable building strategies also included efficient use of other resources such as materials and water. Green construction has the potential to transform buildings from consumers of resources to producers—with resources like water, energy, and materials, or even green space (Rode *et al.*, 2011). Hysan Place adopted different measures for more efficient use of materials and water:

FSC certified wood: at least 55% of timber formwork, fibre-reinforced plastic (FRP) doors and timber products were Forest Stewardship Council (FSC) certified.

High recycled content: at least 30% of building materials used recycled content 4%-5% in reinforcement steel bars and concrete, 25% in glass for retail and office curtain walls, 80% in raised floors, and 100% in recycled timber flooring in the retail front of houses and toilets.

Regional materials: at least 45% of overall building materials were of regional content (manufactured within 800km from the site) to reduce the environmental impacts arising from transportation.

Low emitting and low volatile organic compound (VOC) materials: the use of low-VOC materials to reduce the quantity of indoor air contaminants that are odorous, irritating and harmful to the comfort and well-being of installers and occupants.

Reuse of existing basement wall: the existing basement wall of the old Hennessy Centre was reused as part of the basement wall of the new Hysan Place to reduce construction materials used.

Rainwater harvesting system: the system makes use of rainwater collected at the green roofs, exterior walls and ground level for non-potable and safe use purposes. It is estimated that the reduction of potable water for irrigation by rainwater harvesting would be around 2,500m^3/year.

Urban Responsibility

In order to further extend building and social sustainability and connect with the community, Hysan Place also had different sustainability initiatives in place to benefit the neighbourhood beyond the site boundary. The initiatives were implemented during the construction and operation stages:

- Recycle excavation materials: including several major pieces of granite which have been transformed into sculptures in the Lee Gardens area;
- Socket outlet for electrical vehicles at car park; and
- Light pollution control by avoiding heavily illuminated billboards.

Green Partnerships with Tenants and Other Stakeholders

Hysan encouraged Hysan Place's office and retail tenants to adopt green initiatives when decorating their interiors. Office tenant KPMG and retail tenant DFS Galleria obtained Platinum and Gold LEED certifications for their office and shop interior designs and fitout respectively. With the help of Hysan's expertise, more tenants are applying for such certifications.

The urban farm on Hysan Place's rooftop became a multi-purpose green facility. As an organic farm, it became an educational tool for neighbouring stakeholders, including schoolchildren and underprivileged members of the community, to learn about farming within an urban setting. It also provided a good foundation to help advance Hysan's promotion of a sustainable lifestyle involving a good work-life balance. More than 600 participants took part in its activities in its first year of operation.

Biodiversity

The urban farm, artificial wetland and other green areas of Hysan Place help support a range of plants and other living organisms in an area that would otherwise be relatively hostile to their survival.

Conclusions

Urban transformation is a dynamic and complex process. In order to contribute to sustainable urban transformation, buildings not only need to optimise their own performance, but has to ensure its sustainability framework fit into the broader landscape of the entire community. With so many existing buildings approaching the end of their life cycles, it is an appropriate time and opportunity to kick-start Hong Kong's sustainable urban transformation.

In the densely populated areas typical of Hong Kong, there are obvious challenges for sustainable development. The sustainable development of Hysan Place hopes to have paved the way and pioneered the possibilities for a high-rise building in a highly dense and commercialised area, neighbourhood and community. This paper investigated how Hysan Place addressed the constraints brought on by its unfavourable geographic location in terms of sustainable development and took steps to go beyond the site boundary. These efforts can be summarised as follows:

- Clearly identified the constraints and needs for the building as well as the neighbourhood;
- Balanced consideration of commercial gain and corporate responsibility towards the environment; and
- Tailor-made the sustainability strategies to address constraints and achieve a good balance with a collaborative and integrated design, as well as successful construction and operation with the cooperation of Hysan, the architect, engineers and other consultants.

Since its official opening in August 2012, continuous measurements have been conducted to ensure the design initiatives are effectively implemented. These enhancement measures include:

- Regularly obtaining feedback from users and building operators;
- Measuring and monitoring thermal comfort and indoor air quality (IAQ);
- Evaluation and verifications to provide ongoing accountability of building energy consumption over time; and
- Review of control strategies to ensure occupants' habits and needs are met.

It is believed that the successful development of Hysan Place with the sustainability of the community in mind can serve as a pioneering example for redevelopment as part of the sustainable urban transformation process in Hong Kong.

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In Touch With Nature – The New Entrance of University Station, MTR

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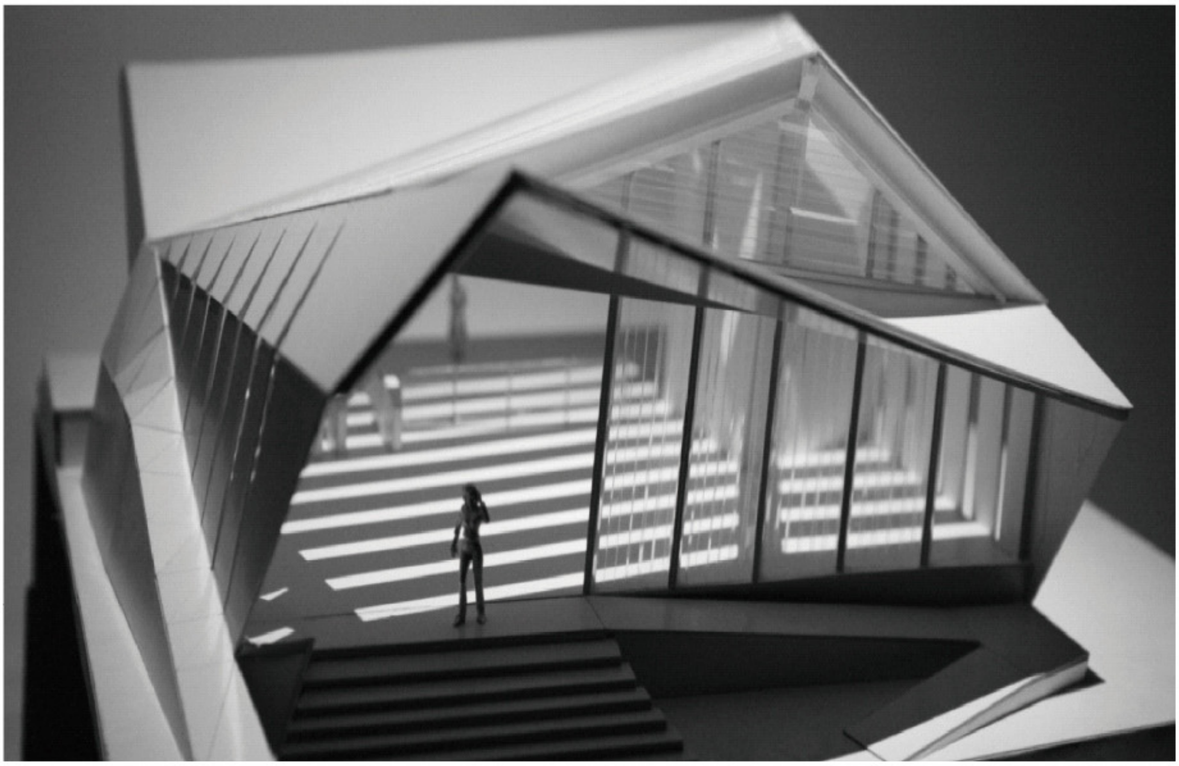
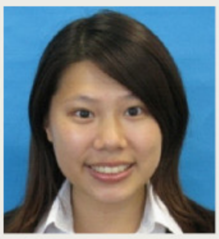


The new entrance to the MTR's East Rail University Station is a showcase of the corporation's commitment to contribute to lowering carbon emissions in upgrading their existing facilities. The rural and institutional setting of the new entrance also provides a perfect backdrop for a sustainable design that echoes the "In Touch with Nature" theme adopted for the East Rail Line.

This article discusses the key planning and design considerations for the new entrance, particularly aspects relating to sustainability and environmental friendliness. The unique nature of this entrance also enabled the team to incorporate many innovative design features, which may not always be practical to adopt in other MTR stations.

Keywords: planning, environmental management, sustainability, commitment

Patrick Chow joined MTR Corporation in 1995 for trackwork construction of Lantau and Airport Railway, subsequently for West Rail Line and Kaohsiung Mass Rapid Transit. He is currently a Senior Construction Engineer in the Operations Projects Department responsible for various interfacing works with the 5 new lines (WIL, SIL, SCL, XRL and KTE), also interfacing works with property developments and other parties.



Sharon Tsang graduated from the University of Cambridge and received her Master Degree in Civil, Structural and Environmental Engineering in 2010. She joined the MTR Corporation in the same year as a graduate engineer and was mainly involved in the design and construction management of South Island Line (East). She is currently working in the Civil & Planning Department undertaking feasibility studies of new rail extensions and pedestrian link projects.

Introduction

The public perceives the MTR Corporation as a mass transportation service provider in Hong Kong, yet it is also committed to protecting Hong Kong's environment, with responsible management of all impacts arising from its activities.

In its environmental provisions, the corporation is committed to:

a) Comply with all relevant environmental laws or, in the absence of legislation, seek out and observe accepted best international practices as appropriate;

Figure 1 Bird's eye view of the new University Station entrance

b) Employ a corporate-wide Environmental Management System (EMS) to continuously monitor and manage environmental impacts and conduct regular reviews on the range of environmental issues that require monitoring;

c) Conduct Environmental Impact Assessments for new projects, where required by law and suggested by best practice, and implement the recommendations;

d) Ensure that contractors and partners will implement any recommendations to achieve acceptable environmental standards, and train and encourage suppliers to adopt environmentally acceptable practices in the products and services provided;

e) Educate and train staff in environmental matters and raise their level of environmental awareness;

f) Educate passengers, legislators, opinion makers and the general public on the environmental benefits of railways;

g) Set environmental performance goals, arrange regular third-party environmental audits, and publish the results with the aim of continuous improvement; and

h) Promote the use of railway as the public transport backbone in Hong Kong through enhancements to station accessibility and network connectivity.

In late 2009, the Campus Development Office of the Chinese University of Hong Kong (CUHK) approached the corporation to discuss the feasibility of providing a new entrance at the northern end of the existing University

Station platform (Lo Wu bound). This would connect to the new campus facilities, which CUHK had agreed with the Government of Hong Kong Special Administration Region to build under its Campus Master Plan (2021), to accommodate a 35% increase in full-time students once the "3-3-4" normative curriculum programme started in August 2012[1].

The corporation responded proactively and considered that the proposed new entrance would not only provide better accessibility and connectivity to the new groups of academic buildings being constructed by CUHK in the vicinity of the northern side of the existing station, but would also enhance passenger convenience, and ease crowding during peak periods by creating an additional route.

After a feasibility study, the project to implement this new station entrance at the northern end of the Lo Wu bound platform, with an extension of the canopy to the existing platform at University Station was subsequently approved by the corporation's management in January 2011.

Planning and Scheme Design

The location and layout of the new entrance was planned in collaboration with CUHK to enhance "walkability" between University Station and the new campus, which will be connected by footpaths, walkways and escalators at various levels to form an integrated pedestrian-friendly Campus Master Plan. This reduces reliance on internal shuttle buses and other road-based transport currently used by students and staff. This grade-separated pedestrian access plan is sustainable and has significant environmental benefits compared to the use of motor vehicles within the campus.

The conceptual design of the new entrance was defined as part of the station improvement programme "In Touch with Nature" for stations along the East Rail Line. It would draw inspiration from the natural landscape for incorporation into the new station outlook. Earth tones and nature motifs such as trees and waves give a rustic look to the structure and appearance of the new station for the next generation of the asset life.

After careful consideration, the new entrance would have a futuristic look and environmental friendly features. The design of the new entrance responds to the context of the site, which is surrounded and overlooked by adjacent academic buildings. The asymmetrical sloping roofs with parallel slits create a unique feature—the fifth facade of the building when seen from higher levels. The final composition of each plane is of equal importance, as the atypical form of the building provides new inspiration and unspoken encouragement to the creativity of the university community.

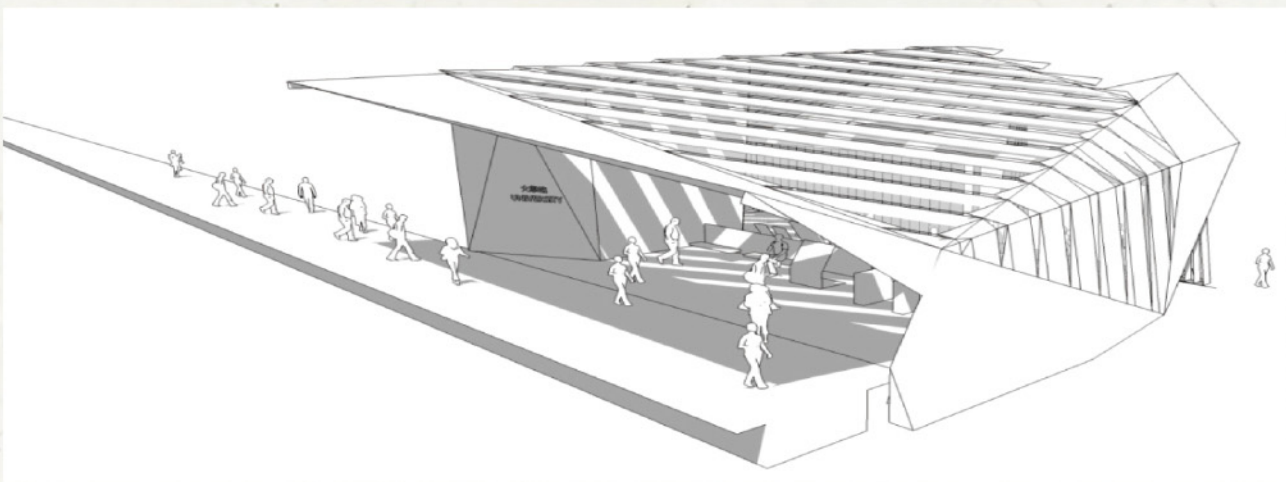


Figure 2 The proposed scheme involved a new entrance and a 110m platform canopy extension to provide full weather coverage for passengers using the new entrance

[1] The 3-3-4 scheme is the new academic structure for senior secondary education and higher education in Hong Kong, starting from 2012, HKDSF has replaced HKCEE (O'Level) and HKALE (A' Level).

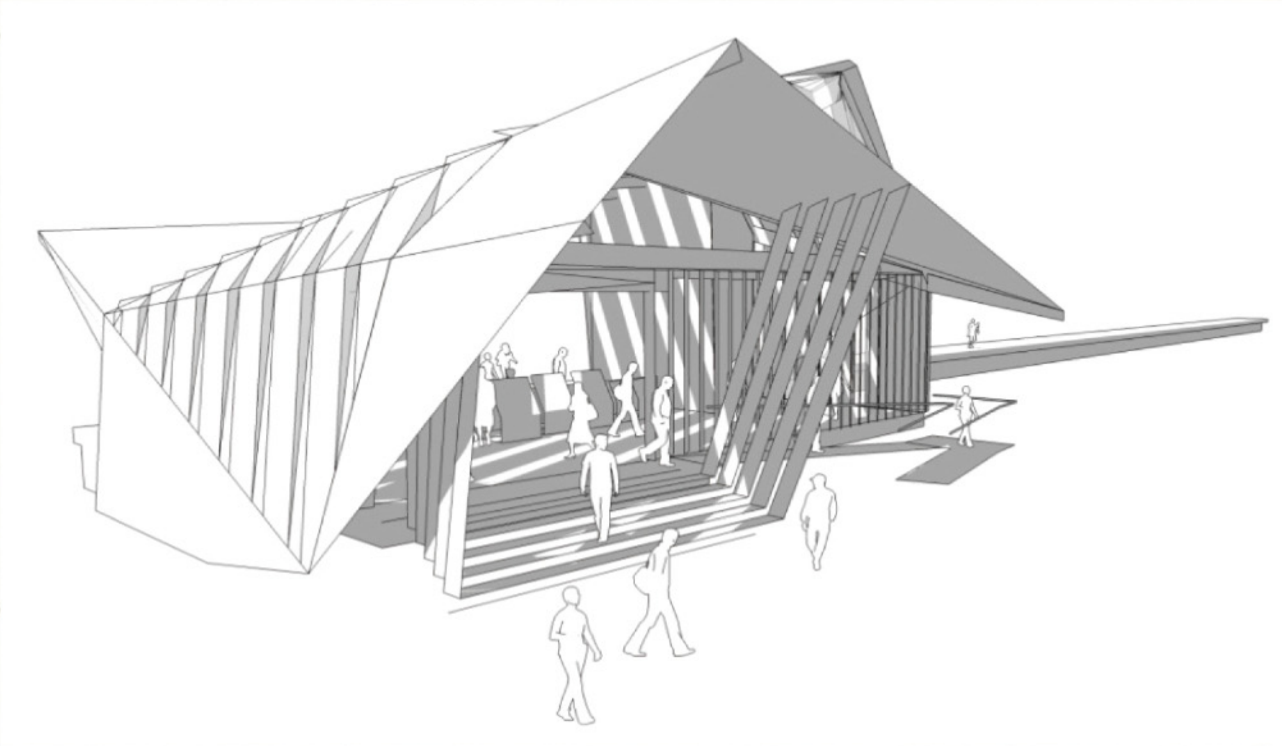


Figure 3 The configuration of the entrance is illuminated by natural light passing through skylight slits

Key Features

To accommodate the distinctive architectural elements, the new entrance would be an open design with louvres allowing natural cross ventilation and creating a comfortable environment for students and other passengers heading to and from the university. Finger-like skylights and vertical strip windows maximise natural lighting from sunrise to sunset.

The entrance incorporated a host of green features, such as:

- Natural lighting and natural ventilation;
- Energy efficient LED lighting system;
- Low emissivity (Low-e) glass;
- Environmental friendly building materials;
- Sustainable landscape design; and
- Enhanced "walkable" access and integrated connectivity.

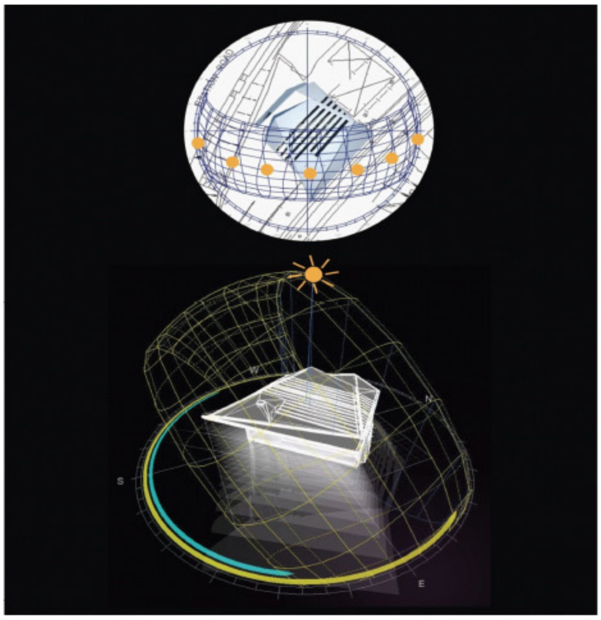


Figure 4 Solar angles were carefully studied for placement and orientation of the skylight glazing

Natural Lighting

The new entrance was designed with minimal glazing on the north facade and larger areas of glazing strips on the south facade. A larger area of glazing on the south facade would receive adequate daylight while keeping direct radiation and heat to a minimum. The aim was to maximise visual comfort and reduce energy use.

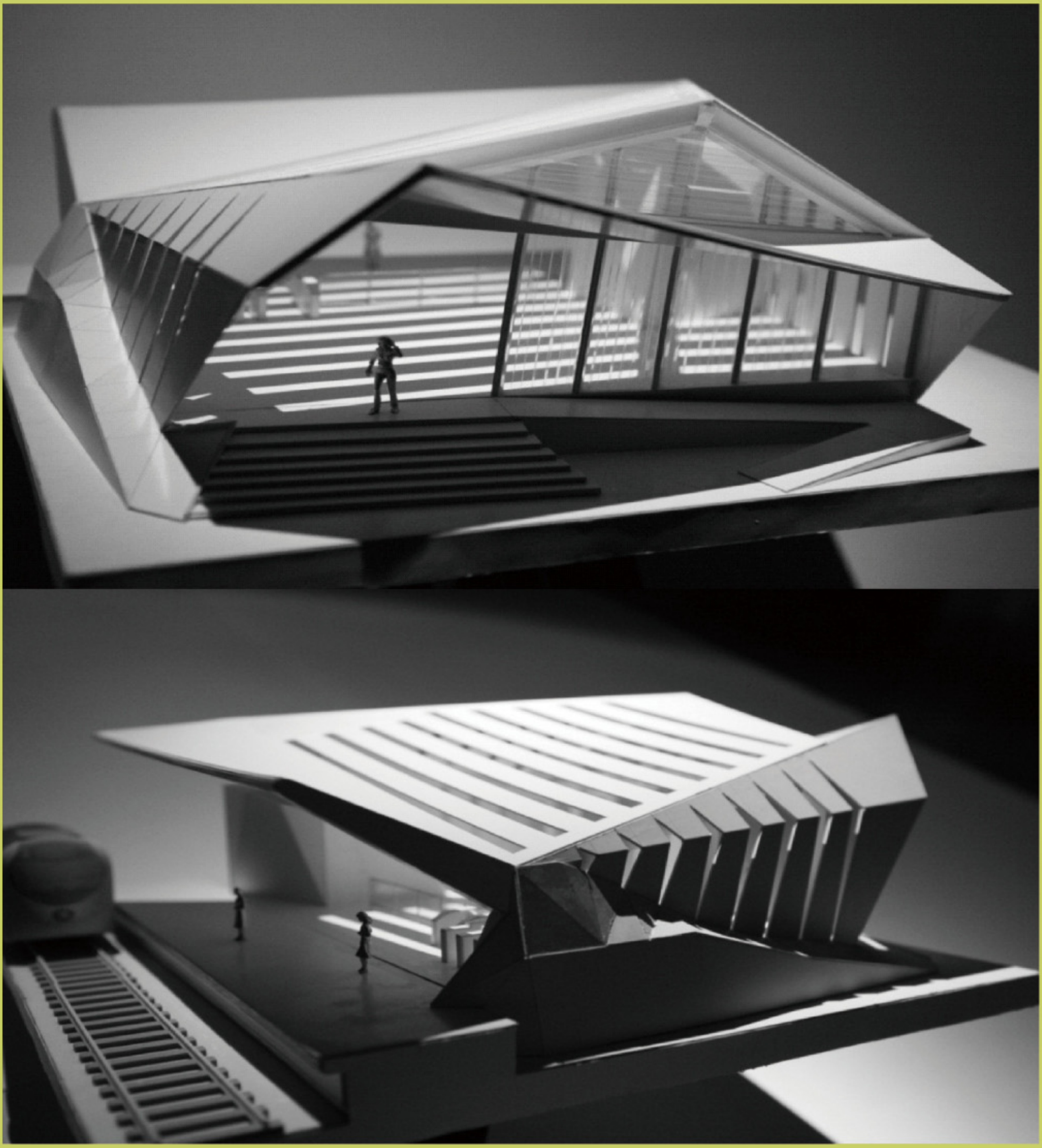


Figure 5 Modelling of the new entrance to visualise the concept

The orientation of windows at the new entrance selectively admits natural sunlight to produce shadows at different times of the day and year through:

- Placing the glazing side by side with the light coloured reflectors and wall;
- Slanting the sides of the inner openings to make them larger than the outer openings; and
- Careful placement of station signage and fixtures so as not to create blind spots from the light source.

Figure 6 As-built appearance of the entrance

Natural Ventilation

Ventilation played a major role in the entrance design as no stagnate interior air is allowed. The benefits of natural ventilation include improved indoor air quality (IAQ), energy savings, and reduced greenhouse gas emissions.

The process of replacing air without forced ventilation must involve providing high indoor airflow and controlling temperature by introducing outside air to keep the interior air circulating.

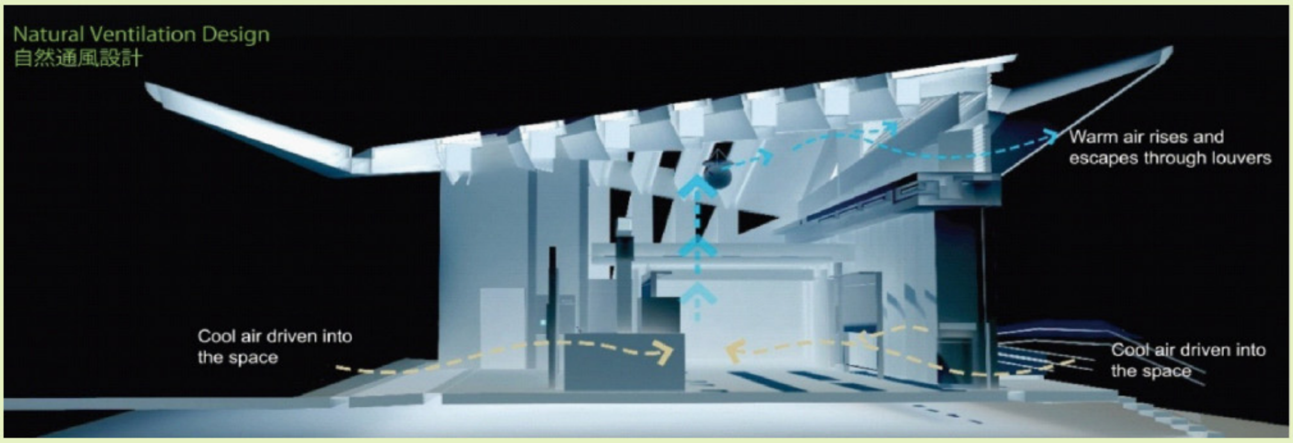


Figure 7 Building design concept to enhance airflow

Warm air in the building is allowed to rise and flow out via upper openings (the stack effect), enabling cool air from the outside to be naturally drawn into the building through openings in the lower areas.

Light-Emitting Diode (LED) Lighting

Unlike most fluorescent lamps and spot lights, LED lighting is energy efficient with low secondary waste heat emissions. With the exception of emergency lighting, the new entrance has LED T8 tube illumination to maintain a general railway station requirement of 150 lux for the concourse area, and 200 lux at the platform edge. The overall saving in electricity consumption in the new entrance compartment is estimated to be 30%.

Figures 8 and 9 Full illumination by LED lighting and e-lighting

Low Emissivity Glass (Low-E Glass)

Different types and grades of glass and different window treatments can also affect the amount of light transmission through the skylight system.

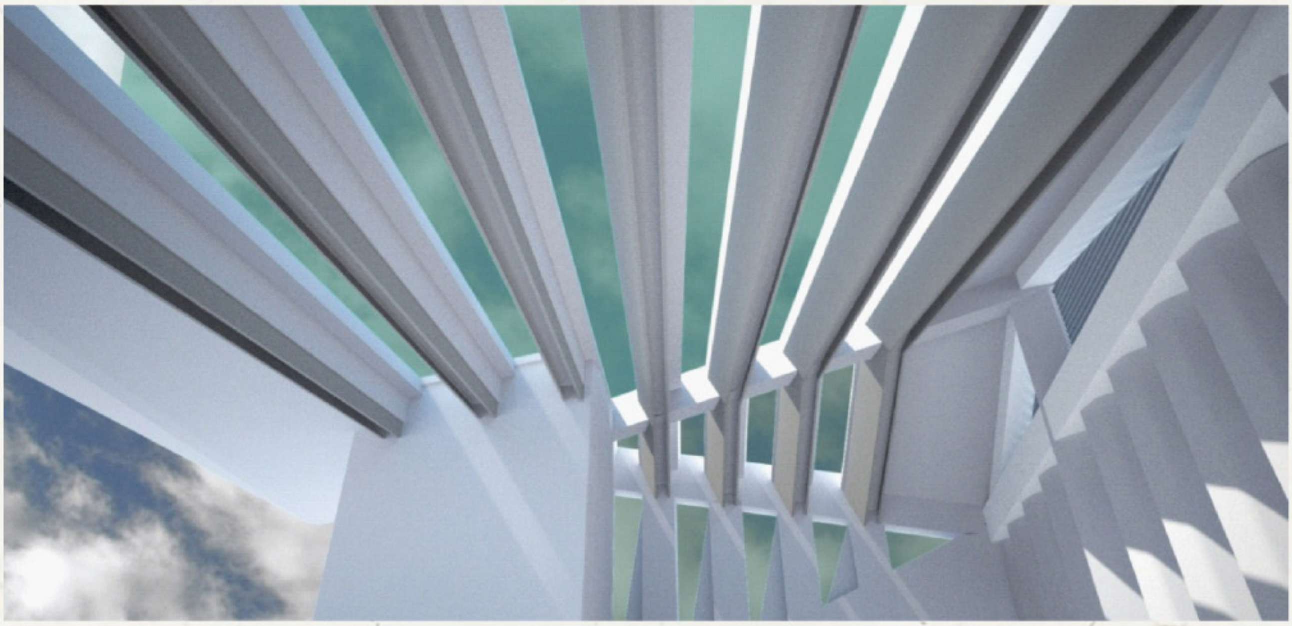


Figure 10 Skylight compilation

A low-e glazing surface would emit low levels of radiant heat energy with temperatures of approximately 40°C–60°C.

Figure 11 The resulting natural illumination of the entrance

Thin film coatings applied to the glass reflects radiant energy and keep radiant heat on the same side of the glass from which it originates, while letting visible light pass through. This results in more efficient glazing as radiant heat originating from within the entrance in winter is reflected back inside, while infrared heat radiation from the sun during summer is reflected away, keeping the entrance cooler.

Sustainable Materials

The construction of the new entrance applied sustainability considerations to reduce emissions of carbon dioxide (CO_2) and toxic compounds during construction and throughout the life of the building. The use of certified wood and steel materials as well as low-emission paints and sealants were among key considerations in planning construction works.

Certified Wood

Using Forest Stewardship Council certified (FSC certified) wood that is available from local suppliers is one way to promote environmental sustainability. This reduces the energy needed and pollution produced during transportation.

Steel Sourcing

There was a requirement that steel materials used in this project must originate from within 800km of the site and include recycled content. This would ensure that CO_2 emissions were minimised from long-distance transportation of materials.

Low Emission Materials

Adhesives and sealants: no adhesives and sealants that contain mercury or lead were selected. Where choices were available, water-based systems were preferred to those with solvents.

Paints and coatings: most conventional paints contain and emit Volatile Organic Compounds (VOC) that contribute to air pollution. One aspect of creating sustainable buildings is reducing these emissions in order to create a healthier environment. All paints were checked on Material Safety Data Sheets (MSDS), to ensure they are "natural" and non-toxic.

Landscape Design

The new station entrance has been designed to provide a pleasant environment through maximising daylight penetration and natural airflow. Landscaping, plus benches created from re-used sleepers, planters with bamboo and ivy, grasscrete with a rainwater harvesting system, and bicycle parking near the entrance created a unique backdrop for the campus environment.

Figure 12 The landscaping combination between the new entrance and Emergency Vehicle Access (EVA)

Timber Benches

The reuse of old and discarded wooden railway sleepers as benches in the entrance's open area served as an example of "up-cycling". The otherwise unwanted items became new items contributing to the environment.

Figure 13 Three sleeper benches are placed in the open area to provide a zone for the elderly or others in need of a rest

Planters and Plants

The stones of the planters alongside the Emergency Vehicle Access (EVA) were salvaged from a redundant material storage yard to gave the stone copings a new life in which they blend in with the environment. Bamboo and other greenery were chosen because they are evergreens—they stay green year round.

Grasscrete

The selection of grasscrete is the easiest way to reduce the heat island effect and manage runoff, while also forming uninterrupted access to the EVA with low life-cycle cost.

Figure 14 Grasscrete at the sides of the EVA

Rainwater Harvesting System

The unique pitched roof of the new entrance forms a watershed to collect rainwater for the water tank incorporated at the side of the station. This rainwater is sufficient for irrigating the surrounding greenery for two weeks.

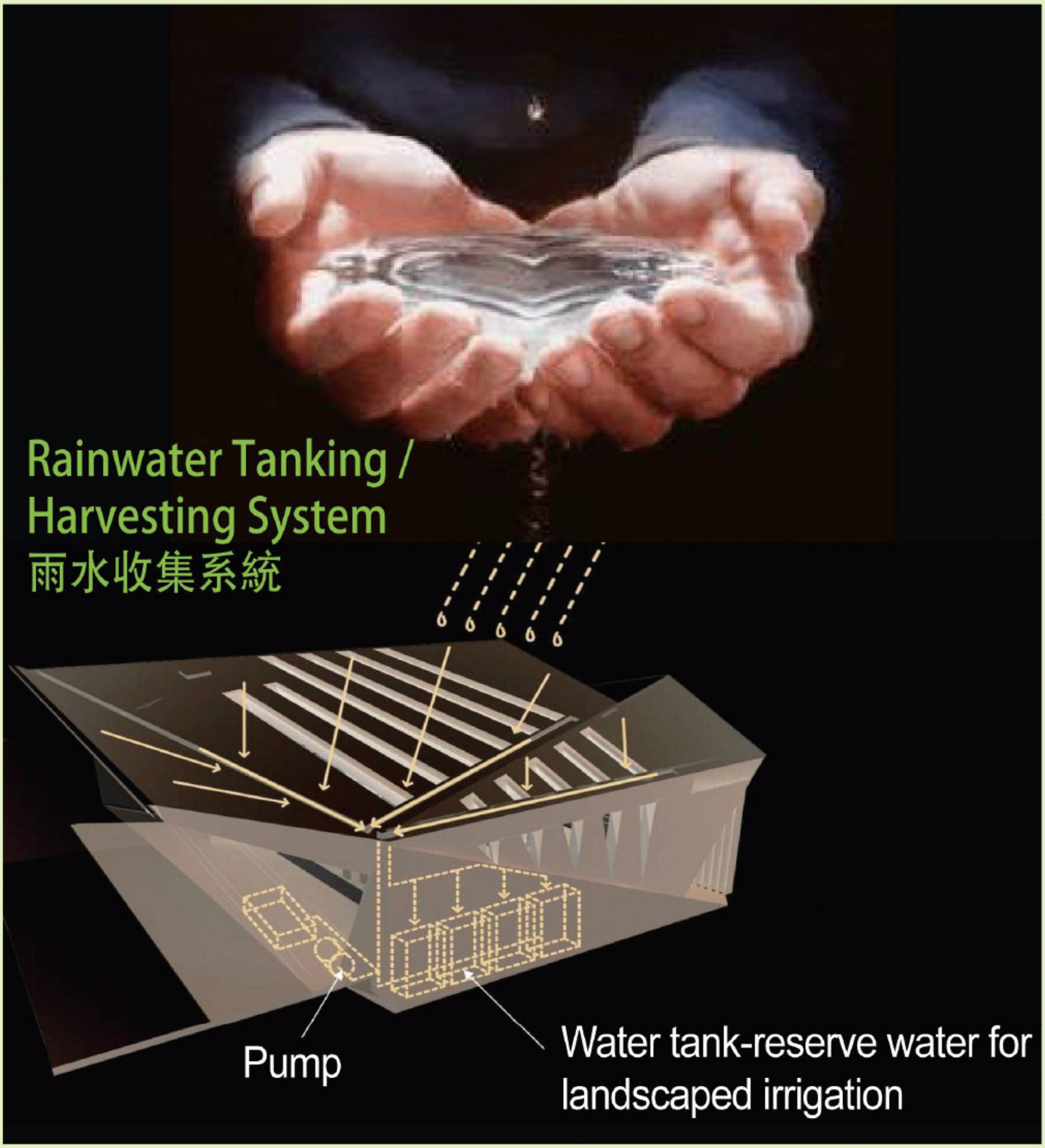


Figure 15 Rainwater harvesting

Bicycle Parking

Bicycle racks adjacent to the station entrance provide park-and-ride facilities. Cycling has virtually zero carbon footprint, and the racks enable secure and convenient parking of bicycles.

Figure 16 Bicycle parking in the vicinity of the new entrance

Conclusion

The MTR University station opened its new entrance on 28 September 2012, complementing the green campus and the new teaching buildings of CUHK. Students and campus staff can head from the new entrance to the central campus through an enhanced walking environment, which is much shorter and takes less time than previously. Beside receiving numerous compliments from the media and the public, the new entrance and its landscaping have been awarded a Silver rating from Leadership in Energy and Environmental Design (LEED). It fulfils the corporation's commitment to protect Hong Kong's environment with responsible management of all impacts arising from its activities.

The University of New South Wales Experience on Publicising Live Energy Data

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This paper reports preliminary descriptive data on patterns of user-engagement with the live energy project at the University of New South Wales (UNSW). The live energy project is an initiative from the Facilities Management Unit to publicise the University's energy use by means of live energy dashboards available on the Internet. This initiative seeks to inform the UNSW community on the energy use of its buildings, and consequently, encourage a thrifty attitude towards energy use by building occupants, either students, academics, staff, and visitors. Since the beginning of the project, the interest in the live energy dashboards has grown as measured by the number of page views, which is currently circa 8,000 views per month. Even though further work is required to determine the impact of the live feedback on energy consumption and users' behaviour (given that building occupants do not have a direct incentive for reducing energy use or increasing energy efficiency), the results of the 'living laboratory' in terms of user-engagement are so far encouraging.

Keywords: live energy data, energy efficiency, user behaviour

Jose Bilbao is a Postdoctoral Research Fellow at UNSW Australia. The focus of his research has been on the development of hybrid photovoltaic-thermal systems and low carbon, low energy buildings. He is an expert in the thermal and electrical modelling of renewable energy systems and buildings, and has several years of experience as an energy efficiency consultant, working in complex systems and buildings.

Ben Newell is an Associate Professor and Australian Research Council Future Fellow in the School of Psychology at UNSW Australia. His main research interests are in cognitive psychology (judgment, decision making, memory) and recent projects have begun to apply principles of cognition to understanding behaviour in environmental problems – especially climate change. He receives funding from the Australian Research Council and has one current grant co-funded by the Australian Federal Government Department of the Environment.

Anjanie Bhagat is a provisional psychologist currently completing her Master of Psychology (Organisational). She is writing her thesis on how to motivate individuals to reduce their electricity consumption, and is broadly interested in applied psychology research in workplace settings.

Introduction

The University of New South Wales (UNSW) has a long history of sustainability and energy efficiency initiatives. Since the early 2000s, the Energy Management Unit has been in charge of all energy and water related matters, including planning, budgeting, and forecasting of energy use and cost, the inclusion of energy efficiencies and renewable energies. The Kensington Campus is the main Campus of UNSW, with 38ha, around 490,000m^2 of Gross Floor Area, and a floating population of over 30,000 students, staff, and visitors. This study is based on the experiences of and efforts by the Energy Management Unit on this Campus on publicising energy data in an effort to sensitise building occupants' (students, staff, researchers, and academics) behaviour towards energy use and CO_2 emissions.

The Kensington Campus is in effect a micro grid within the Sydney region. The campus currently has five High Voltage electricity feeders and more than 22 substations, all owned and managed by the university. A similar scheme is true also for gas and water systems, where a couple of main connection points on the campus boundary provide water and gas to all buildings through an internal reticulation system, also owned and managed by the university. This presents several opportunities and challenges.

With more than 50 buildings on campus, there are many opportunities for energy savings, but also substantial time, energy, and resources are directed to maintaining and operating this infrastructure. One of the more important parts of this infrastructure is the sub-metering system that has been deployed through the years on the campus. Currently, the

Energy Management Unit collects, stores, and manages electricity, gas and water use data with the EMAC system (Energy Management And Control System) from over 700 meters around the campus. With an ever-evolving campus and buildings, the network of smart meters is expected to grow and expand with time.

The university processes the data from the meters to:

- Effectively control the energy provision across UNSW properties;
- Produce utility consumption and cost reports for cost recovery from commercial and other tenants on campus;
- Monitor UNSW's electricity, gas and water consumption and trends;
- Maximise the efficiency of energy and water consumption on campus;
- Prepare consumption and cost reports; and
- Manage energy and water audits.

This valuable information is currently available only to a small group of university staff in the Energy Management Unit. This means that energy and water consumption information is not transparent to or easily accessible by UNSW staff and students, who could play a direct role in reducing energy consumption.

On the other hand, Fischer (2008) shows that it is possible to achieve energy savings of up to 15% when users are provided with direct and live information about energy consumption, depending on the type and time of the feedback (see also Vine, Buyers and Morris, 2013); although the level of savings might decrease with time as shown by Van Dam *et al.* (2010). Even though these studies focus on residential areas where occupants have a direct option and incentive to save energy, there is also support for the fact that savings can be achieved and sustained through time in an office or commercial environment (see Darby 2006 and Bator *et al.* 2014). Even if the savings are only 1%, it could result in important cost reductions for UNSW.

Therefore, it might be possible that energy and water savings could be achieved by providing timely feedback to the building occupants. In this way, UNSW sustainability and resourcing objectives will be supported by improving the transparency of the energy consumption, informing the community on how they are using the university's resources, and encouraging them to save energy and water. As indicated in recent forums with staff and students, there is an appetite to be part of this change.

Given the above, in mid-2012 the Energy Management Unit started a project to develop a web based system (so it can be accessed by anyone at any time) to display live energy data to students and staff using UNSW's buildings. The project entered its beta phase during September 2012, with a final launch on June 2013. Since then, the Live Energy Dashboards for most of the buildings in the Kensington Campus have been available on the Facilities Management website (http://www.facilities.unsw.edu.au/campus-development/sustainability-campus/greensense-live-energy-project). Additionally, some of the dashboards are displayed on screens in lobbies and corridors of some buildings in the Kensington Campus: the Tyree Energy Technologies Building (TETB), the Australian Graduate School of Management Building (AGSM), the Samuels Building, and the Lowy Building.

However, even though there are potential energy and water savings as shown in the literature, it is not yet clear that the occupants will change their behaviour (or how many, in order to have a measurable impact) if they don't have a direct incentive (economic, comfort, or even sense of achievement) by having a thrifty attitude towards energy. So, does it work when users don't pay the bills or don't have a direct incentive? Recent evidence suggests that this is the case (Ferraro and Price, 2013) although the reductions in energy use are rather short lived.

Project Goals and Objectives

The project's main purpose was to create a live energy communication tool available to the wider university community. By creating this tool, the Energy Management Unit was looking to achieve three objectives:

- Increase the transparency of the building operations regarding energy and water consumption;

- Achieve energy savings by making a building's occupants aware of the building's electricity, gas and water use, and set a benchmark line based on season and weather to compare with current use; and

- Aid the Energy Management unit in monitoring building performance.

The buildings' occupants will not be able to operate or control important plant equipment (generators, pumps, fans, etc.); however, the increased awareness of energy use will give them the opportunity to contribute by altering their consumption (turn off computers, lights, lab equipment that is not being used, etc.) and inform the facilities manager of possible inefficient operations (equipment running 24/7 when it is not needed, leaks, etc.), or ideas to save energy.

By making the building energy use data available to the occupants and community, the aim is to encourage a thrifty attitude. Although it is difficult to measure attitude changes in this context and across the several buildings on the campus, facilities management can compare usage pre and post implementation to see if the community and occupants are taking a proactive approach to saving. This could potentially open up other energy saving initiatives. Another way to quantify the success of the initiative is by measuring the number of visits to the dashboards, which should relate to the amount of interest within the UNSW community for the live energy data.

Greensense Dashboards

In order to bring this project to life, UNSW partnered with Greensense (www.greensense.com.au), an Australian company that focuses on the creation of monitoring software for energy and sustainability data. Greensense has an out of the box solution based on dashboards that can display live data with active web applets. The dashboards can be customised for each building or site and as per client's requirements. The flexibility and usability of the dashboards offered a good match to the requirements and expectations of the Energy Management Unit.

Technically, the Greensense live application and the dashboards are a cloud system. UNSW sends data from a group of selected meters to the Greensense servers every 15 minutes. The meter readings are then processed in the cloud by Greensense and then displayed in the dashboards. The process is transparent for UNSW, and beside some isolated data transfer problems, the system performs as expected with little to no maintenance required.

Different views of the Kensington Campus dashboard are shown in Figure 1 below. The dashboards currently display electricity, gas, and water data via different tabs that can be controlled by the user when accessing the dashboard through the internet, or as rolling pages in the "kiosk mode" when the dashboards are shown in public displays. The dashboards also normally show the current ambient temperature trend, the amount of green energy being used and generated (when available), green tips, and a benchmark of the current energy use based on historical averages. This last tool (or widget), called "Right Now", is one of the more important feedbacks for users as it clearly shows how the building is performing.

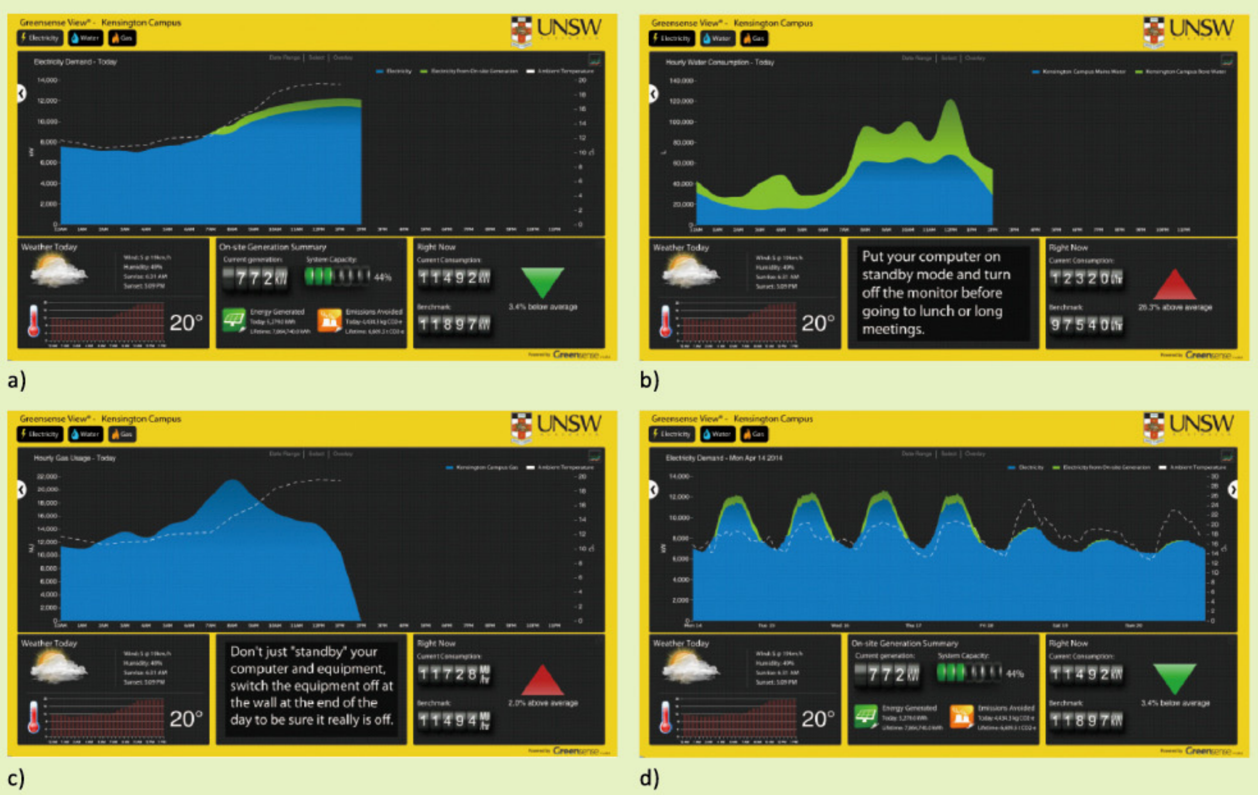

Figure 1 Example of the Kensington Campus Dashboard a) current electricity use, b) current water use, c) current gas use, and d) the weekly view for the electricity use

However, the "Right Now" widget, although a good starting point is not perfect, as currently the values shown are not normalised based on the ambient temperature or humidity levels. This type of correction (based on cooling/heating degrees per hour or other similar method) could improve the widget and make it more meaningful. Of course, the users do not need to know these details, but better accuracy on the display will help in avoiding false positives or negatives. UNSW is working with Greensense on ways of improving this widget.

On the same lines, it is possible to configure the dashboards to show a benchmark line calculated using historical trends, as shown in Figure 2. This feature is currently not shown by default on the kiosk mode of the dashboards, so occupants can't compare the current use with the expected use beside the "Right Now" widget mentioned above. UNSW is studying to make this feature more prominent, or redesigning some of the dashboard areas, to give better feedback to occupants.

A particular area where the dashboards excel is in the graphical representation on how renewable sources can help in reducing the use of grid electricity, as seen in Figure 3. The green portion of the graph shows the energy generated by the rooftop PV system of the Tyree Building. This is a great example of how renewable energies (in this case photovoltaic) can be used to reduce the peak demand of a building.

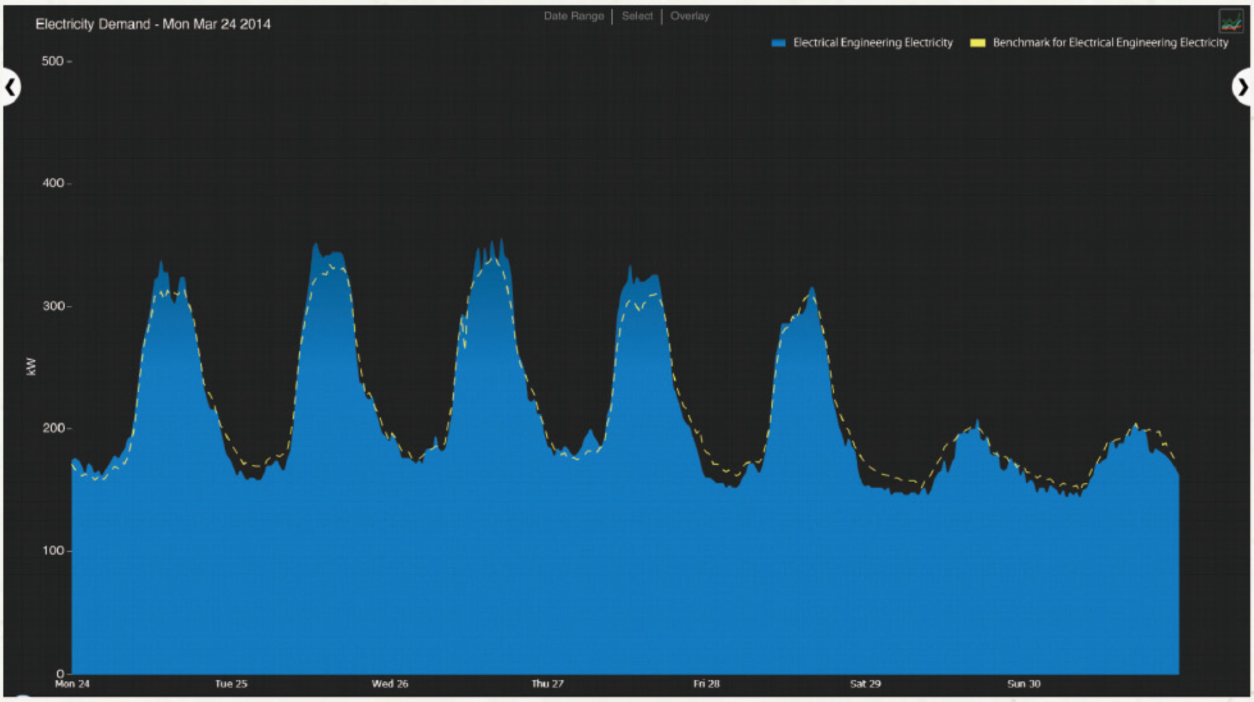

Figure 2 Screenshot of the electricity dashboard for the Electrical Engineering Building showing the benchmark line

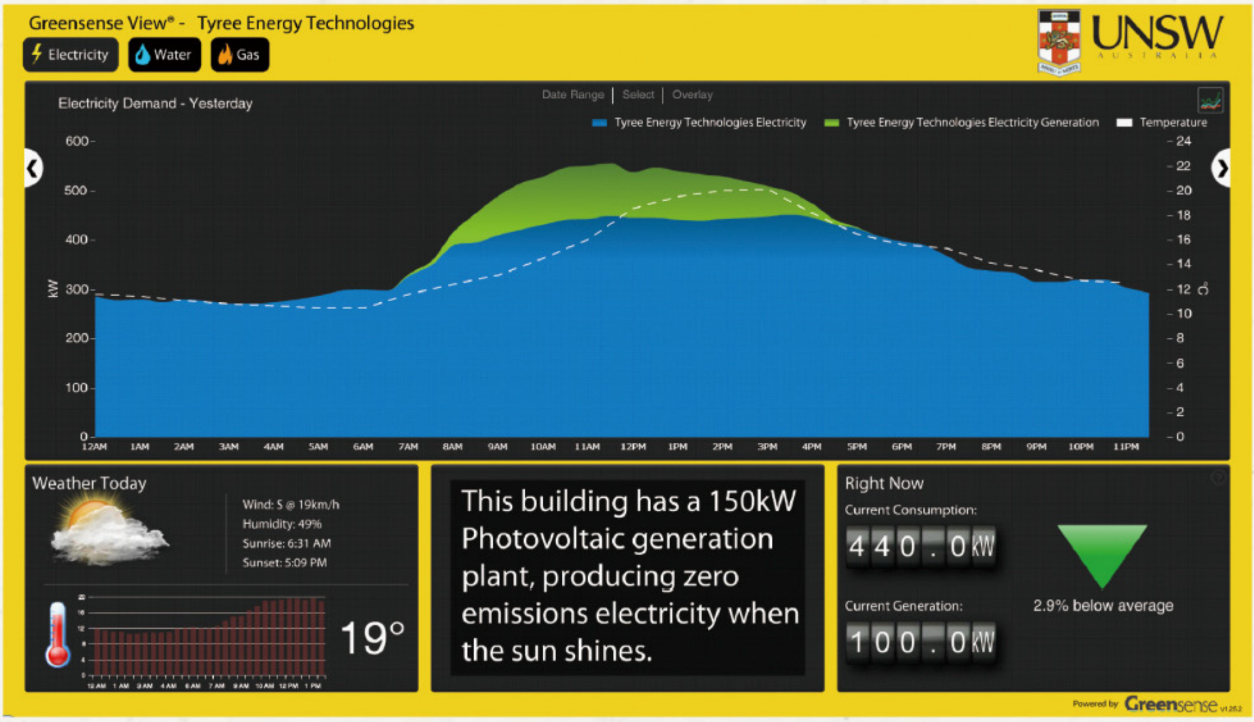

Figure 3 Tyree Building Electricity Dashboard showing the contribution of the renewable energy generated from the roof PV system into the building

On the other hand, the Tyree building has several types of spaces—from offices, to lecture rooms, to open plan areas, to several research laboratories, equipment and systems that require 24/7 operation, with the corresponding impacts on the energy use of the HVAC system, essential services, and emergency systems. These high energy use areas explain the high base load of the building, which is a surprise for most of the occupants who see the dashboard for the first time. Most of the staff and students believe that the university's buildings use little or no energy at night, but they are complex buildings with spaces that have a high energy demand (like research laboratories) and long operating hours. This realisation has a great effect on some of the occupants (mostly researchers), as they can relate some of the high use after hours to equipment that they might leave ON at night, sometimes unnecessarily.

Early Results

Because of the current dynamic status of the Kensington Campus and the short time that the Live Energy data has been publicised, it hasn't been possible to identify a direct correlation between the Live Energy Dashboards and building occupants' behaviour, or reductions in energy consumption. The best evidence gathered so far of the potential impact of the project is the amount of monthly page views of the dashboards since the project started, as shown in Figure 4.

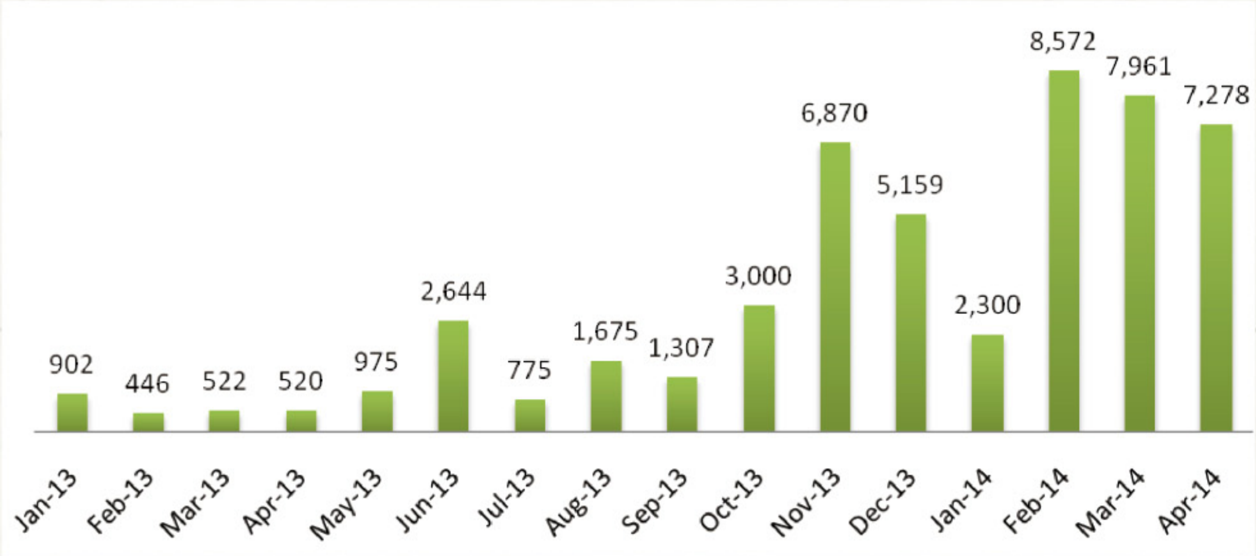

Figure 4 Total pageviews for all the Dashboards

As can be seen, during the trial period of the dashboard the monthly page views were under 1,000, with an important increase during June 2013 due to the official launch of the project, which included a small marketing campaign with staff and students. However, after the initial increase in page views the general interest decreased in the following months. At this stage, none of the dashboards were displayed in any of the buildings' screens in lobbies or public spaces. This changed in October 2013, when the first dashboard was displayed in the Tyree Building. This had a profound effect on the exposure and visibility of the project and the Tyree dashboard in particular, as it received more than 3,600 visits during November 2013. This interest was followed by other buildings' occupants, independent of whether the dashboards were displayed in the lobbies of their buildings. A more detailed result of the monthly pageviews for different buildings is shown in Figure 5. Furthermore, the dip in page views during December 2013 and January 2014 coincided with the university's Christmas shutdown period and the off session period respectively. However, when the first semester 2014 started in February, the number of page views (and interest in the Live Energy Dashboards) returned to the levels of late 2013 and has been maintained since. This seems to suggest that students are the main driving force behind the number of page views.

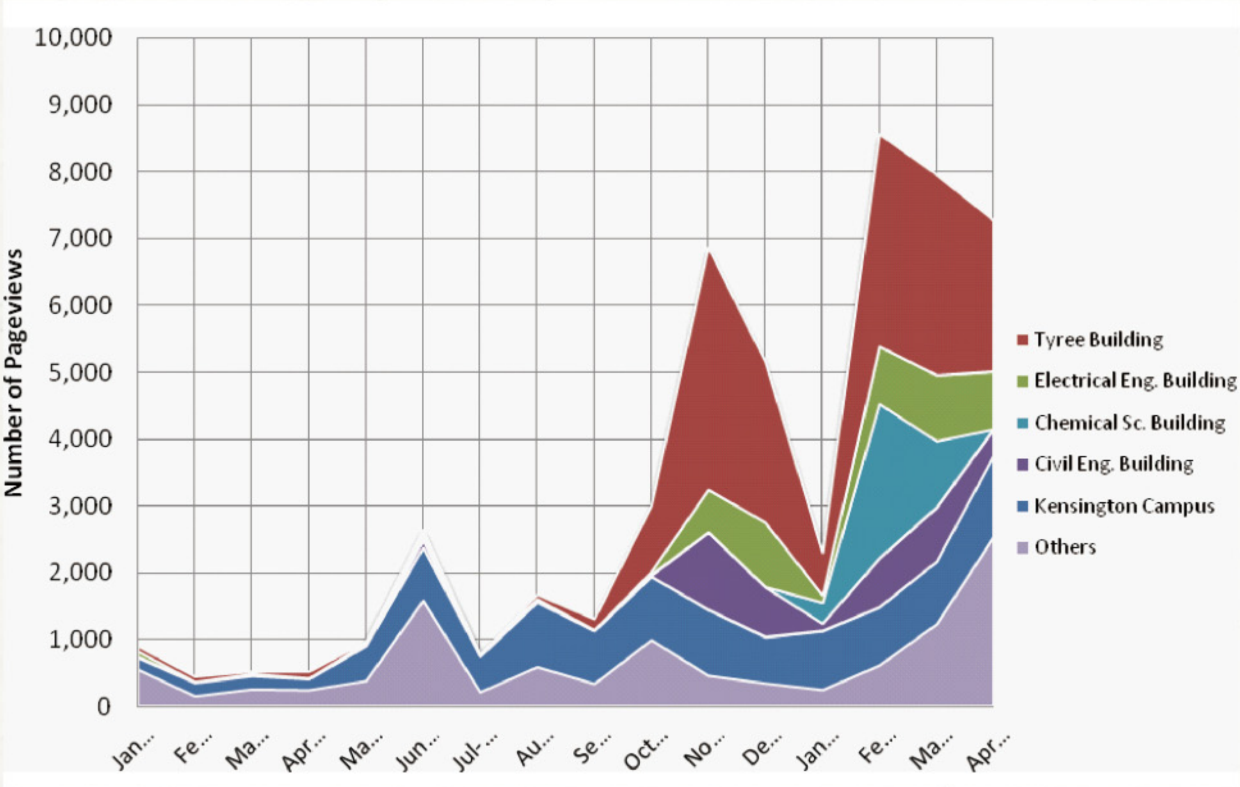

Figure 5 Evolution of page views through the project's life

Interestingly, of all the students, it seems that engineering students have shown the highest level of interest so far, as the four most visited building dashboards (i.e. not including the Kensington Campus) are from engineering buildings[1] and they account for 58% of the total page views so far (see Figure 6). It is not clear why there is an underrepresentation of other faculties in their interest in the dashboards. It could be because engineering students are more interested due to the format of the feedback from the dashboards, or are more receptive to energy efficiency issues in general. Future work will focus on studying these relationships and the reasoning behind them.

Even though there have been strong results in the form of page views for the engineering buildings, this cannot be correlated to changes (increases or reductions) in energy use or users' behaviour, mainly because of other changes within the buildings (major renovations, changes in major HVAC plant, an increase in energy intensive research equipment, etc.) that cannot be isolated using the data available or with a high degree of confidence.

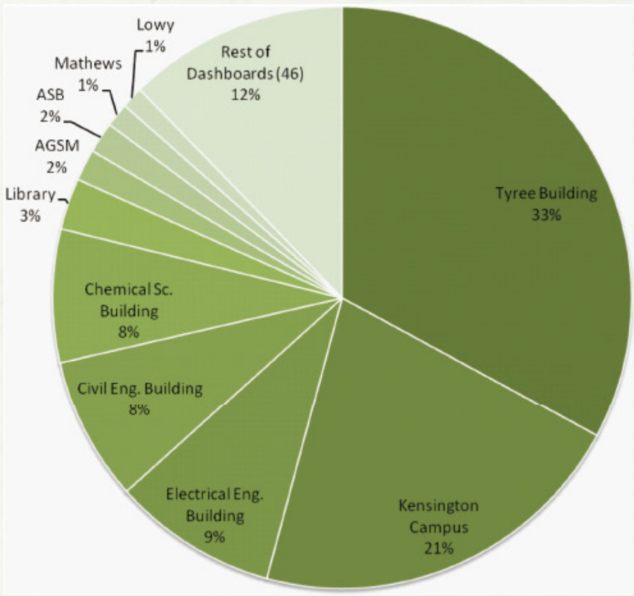

Figure 6 Percentage of page visits

[1] The Tyree building is the home of two Engineering Schools, two Energy related Research Centres and the administrative offices of the Low Carbon Living Cooperative Research Centre.

Discussion and Conclusions

This article began by establishing the positive correlation between feedback on live energy use and reduction in energy (and therefore costs associated with energy consumption) observed in residential cases, and the potential for obtaining similar results in cases where no pecuniary incentives exist. However, in the case of building occupants and particularly university buildings, there are two other factors to take into consideration: the level and granularity of the feedback and the impact of occupant control on the load. In a home environment the loads are more directly related to the occupant's behaviour, so behavioural changes are more visible through the feedback mechanism, which then reinforces changes. This is a virtuous circle, and is recompensed at the end of month with a reduction in energy costs. Because in a university environment both factors (load control and level of feedback) are less direct, it will be necessary to improve both in order to correctly measure the impact of live feedback on energy use and occupants' behaviour.

UNSW is working towards this goal, by turning the university into a "living laboratory". Firstly, a research study will be carried out later in 2014 by researchers from the UNSW School of Psychology. The project will run over a 4-5 week period and look more closely at providing different types of feedback to an experimental group. One of the on-campus residential colleges will be targeted with a campaign plus feedback intervention, during which time efforts will be made to increase awareness and use of the Live Energy Dashboard in addition to providing residents with specific feedback about their electricity use. The college's feedback will compare their overall electricity use to an expected target (based on historical patterns, temperature, humidity etc.), but will also allow residents to see how they are comparing to other on-campus colleges on a per person basis. Previous research provides evidence supporting the effectiveness of both historical and comparative feedback (Fischer, 2008; Allcott, 2011; Vine, Buys and Morris, 2013), and this study in particular will evaluate how effective a combination of the two is at improving overall energy efficiency.

Secondly, UNSW is integrating the Live Energy Dashboards with a PC power management system. In this way, an additional level of feedback will be presented to the occupants in the form of how many desktop computers are left ON or how much energy the computers are using. This will increase the granularity of the feedback, whilst presenting the occupants with information regarding loads they can control directly. Additionally, different dashboards with targeted feedback might also be tested in the future.

Despite the complications of correlating the effect of the live energy dashboards on occupants' behaviours, and consequently on energy use, a critical mass has only been achieved during the last six months. The interest in the project and the dashboards is undoubted, as shown by the number of page views, and incidental evidence such as general curiosity and data requests from students and academics. It is expected that further work and additions to the project will allow for a better understanding and measure of the effects of the live energy feedback.

Acknowledgments

The authors would like to thank Greensense and Facilities Management at UNSW for their help and data provided for this article.

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