



Construction Industry Institute  
HONG KONG

# **Costs and Financial Benefits of Undertaking Green Building Assessments**

## **Final Report**

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## 0 RESEARCH HIGHLIGHTS

This study has examined the costs and financial benefits of green building assessments for *new* buildings in Hong Kong. The estimates are based on studies for two building types: a high-rise, air-conditioned office building of ‘generic’ design, and a low-cost (public sector) high-rise residential building. Most often investment decisions for building projects tend to be based on capital cost; consequently, any investment in green attributes for a building is likely to depend on the added cost, i.e. the cost premium over conventional design and construction practice. To understand the cost premiums for so-called green buildings, i.e. buildings assessed and certified under a building environmental assessment method, it is necessary to understand what assessment and certification entails, and what it achieves in terms of enhancements to building qualities and performance. Similarly, the financial benefits of a green building depend on the outcome of the assessment and the persistence over time of the performance enhancements.

### 0.1 COST PREMIUMS FOR GREEN BUILDING ASSESSMENTS IN HONG KONG

The study has revealed that the *minimum* premium on total construction cost for buildings certified as ‘green’ under the Hong Kong Building Environmental Assessment Method (HK-BEAM) is likely to be of the order of 0-4%, depending on the certified performance grade achieved (e.g. HK-BEAM ‘Gold’). Costs for financing, additional design time/fees, and certification fees are excluded.

The following table summarises the minimum premiums for the two types of buildings assessed under HK-BEAM versions 1/96R (1999) and 4/04 (2004) for office buildings, and HK-BEAM versions 3/99 (1999) and 4/04 for low-cost, high-rise residential buildings. The percentages for private sector residential buildings would be about half of the values given in the table. The estimates for HK-BEAM versions 1/96R and 3/99 are historical in that both assessment methods have been replaced by version 4/04.

Projecting these estimates to particular development would not be appropriate given the variability of site conditions, building scale and design, as well as the correctness of the data used in this study. Rather, the cost premiums should be seen as indicative for the stock of new ‘green’ buildings in Hong Kong.

**Summary of minimum cost premiums for buildings assessed under HK-BEAM**

Office Building	Certified Grade and required % of available credits		
HK-BEAM 1/96R - 59 credits*	‘Good’ 55%+	‘Very Good’ 65%+	‘Excellent’ 75%+
% Premium <sup>@</sup>	0%+	< 1%	1%+
HK-BEAM 4/04 – 112+ credits*	‘Silver’ 55%+	‘Gold’ 65%+	‘Platinum’ 75%+
% Premium <sup>@</sup>	0.8%+	1.3%+	3.2%+
Residential Building			
HK-BEAM 3/99 - 75 credits*	‘Good’ 45%+	‘Very Good’ 60%+	‘Excellent’ 70%+
% Premium <sup>@</sup>	0.5%+	1.6%+	3.3%+
HK-BEAM 4/04 – 104+ credits*	‘Silver’ 55%+	‘Gold’ 65%+	‘Platinum’ 75%+
% Premium <sup>@</sup>	0.8%+	1.7%+	3.4%+
* Number of available credits varies depending on particular circumstances for a project.			
<sup>@</sup> % premium is based on construction cost, excluding ‘soft’ costs and fit-out costs.			

In the case of high-rise residential buildings the greater variability in the layout, design and usage patterns increases greatly the uncertainties in performance modelling and estimation of the outcomes from any performance enhancements. Consequently, the costs and benefits of green building assessments for this type of building has proven to be much more difficult to quantify than for air-conditioned buildings, leading to less reliable predictions and conclusions, and greater reliance on qualitative indicators.

## 0.2 CERTIFIED GREEN BUILDINGS

Green buildings are characterised as those providing the required building performance over the building *life-cycle* whilst minimising consumption of non-renewable resources and the environmental loadings to land, air and waters. However, the assessment of new buildings covers only performance aspects from the initial planning stage through to building completion. Actual performance during building use depends on what has been achieved in terms of improved design and construction quality, as confirmed by final testing and commissioning, the quality of management, operation and maintenance practices, as well as the activities of building users.

The outcome of a green building assessment is a certified grade (e.g. HK-BEAM 'Silver') depending on which performance criteria, i.e. enhancements over regulatory requirements or conventional practice, which are deemed to have been satisfied. As Table 0.1 shows, the better the grade the greater the proportion of the performance criteria (number of credits) that have been satisfied. However, within a given grade the outcome can vary depending on which particular criteria have been met, e.g. emphasis could be on indoor environmental quality as opposed to energy performance.

### 0.2.1 DETERMINATION OF COST PREMIUMS

Cost premiums over non-green designs largely depend on which assessment criteria (credits) are achieved. This is likely to be influenced by client preference and any overriding cost constraints, which in turn depend on project scale, site circumstances and the design approaches adopted. The cost premium may be high if a client has preference for particular green features, and/or circumstances are such that their inclusion adds significant cost.

In this study the likely cost premium for each HK-BEAM assessed issue (i.e. each credit) was first estimated, before estimating the overall cost premium for each certified grade based on the minimum number of credits required, e.g. 55% of available credits for 'Silver'.

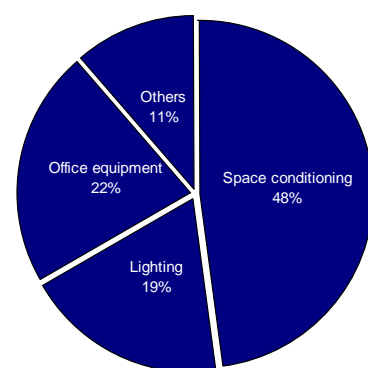
Given the wide range of performance issues covered by a HK-BEAM assessment and the fact that available cost data is limited and sometimes contradictory, further study into costs and benefits of some of the HK-BEAM credits is warranted.

#### *Performance-based Assessments*

Where assessment criteria are based on performance, it is possible to meet the criteria in different ways. For example, enhancements in energy performance (annual energy use) can be achieved through various means, such as the use of energy efficient lighting, more efficient controls, etc. Each approach will have different cost implications. An estimate of the likely minimum cost of achieving a given performance level based on a 'lowest-cost' approach is feasible, but actual cost will depend on the design choices. Furthermore, there is also a measure of synergy between certain credits such that achieving a particular credit or performance attribute will have implications on the impact and cost of related credits. This study has not attempted to examine all possible synergies in HK-BEAM assessments except when estimating the cost premium for the energy performance credits.

## 0.3 POTENTIAL FINANCIAL BENEFITS

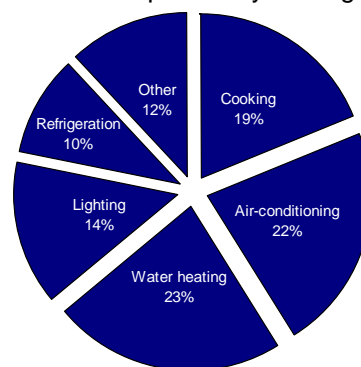
The financial benefits from green building assessments include tangible benefits, such as savings due to improvements in energy efficiency, reduced water use, materials use and waste. Intangible benefits include improvements in productivity in workplaces, better health and comfort in residential settings, reduced burdens on infrastructure, etc. These tangible benefits depend not only on which performance enhancements were confirmed by the assessment but also on the persistence over time of the measures introduced. Although this study provides quantification of some of the financial benefits, e.g. annual energy use, it needs to be appreciated that actual gains depend on the accuracy of the predictions, confirmation that installed equipment and systems meet design specifications, and that the performance is maintained during operation.



Energy end-uses in office buildings

As the figure illustrates the energy use in air-conditioned office buildings in Hong Kong is mainly electricity, with HVAC, lighting and office equipment the major end-uses. Although HVAC system performance can be strongly influenced by design, such as 'right-sizing' of systems, the selection of efficient equipment and implementation of robust control strategies, much depends on the installation and usage patterns of installed lighting and equipment. This highlights the importance of fit-out for lighting and controls, and the end-user selection and use of office equipment. It also demonstrates that improving the energy efficiency of buildings is a shared responsibility amongst building designers, operators and users.

However, as the figure opposite shows, the pattern of energy use for residential buildings is much more diverse than for air-conditioned buildings, with the majority of end uses dictated by the lifestyle and preferences of the occupant rather than factors that can be influenced through design. Opportunities to reduce energy used for air-conditioning and lighting are much less, and are usually more difficult to achieve. As residential building designs and usage patterns are much more variable, the financial benefits are not so clear cut and are more difficult to quantify.



Energy end-uses in residential sector

### Energy Costs

The cost of energy for businesses and residents in Hong Kong is of the order of 2-3% of overall business costs, and total household expenditure, respectively. There is little financial incentive to save energy. Given that the target for green buildings is to provide the required performance, saving energy by reducing the quality of services or indoor environment is a false economy if it results in negative impacts on workplace productivity and occupant comfort.

### 0.3.1 PERFORMANCE ENHANCEMENTS

The significant added value of the total built environment is as contributors to businesses, national assets, economic development and quality of life. A poor or depreciating built environment costs the economy and society.

The study has revealed that achieving higher performance in buildings, particularly large air-conditioned buildings, at relatively little additional construction cost depends on investment in quality processes rather than any particular green features or attributes. In line with studies conducted elsewhere this study reiterates that better integration at the early planning and design stages, improved quality assurance during construction, particularly in respect of testing and commissioning, and key provisions for operation and maintenance can improve performance outcomes.

A significant part of the design process for air-conditioned buildings is the detailed and accurate modelling of energy performance based on realistic design and use data. When such an approach is taken it is likely that the initial capital cost of building services, particularly HVAC services, can be reduced. Whilst it is appreciated that the investment cost for new buildings, particularly the cost of land, is a driver to shorten both design and construction timeframes, there is evidence to suggest that more time spent on design can result in a reduction in construction time and cost through reduced variation (change) orders and remedial work.

Whilst detailed specifications for testing and commissioning buildings exist, the outcome of the activities is generally found to be unsatisfactory. The adoption of full building commissioning as an overriding quality assurance process has the promise of improving the performance of buildings during use and thereby realising the performance gains.

### 0.4 GREEN BUILDING ASSESSMENTS IN HONG KONG

For new building developments assessment can be undertaken at various stages in the development cycle from initial planning through to final occupancy. The latest HK-BEAM assessment method for new buildings (Version 4/04) seeks to endorse good practices in the various stages, and to assess as far as practicable the impacts of the completed building, whilst certification is only confirmed upon completion. The assessment method CEPAS, recently developed by the Buildings Department is very similar to HK-BEAM in terms of coverage, but

differs in respect of scoring (weightings) and provides for certification at various stages in the development process.

With the emergence of international standards that define the framework for building environmental assessment, the wider interest in sustainability, and greater energy performance, it is opportune for the HK-BEAM Society to revise the assessment method. It is suggested that the assessment process strengthens the building development process by rewarding integrated design and detailed analysis through increased weightings and incorporating pre-certification whilst retaining confirmation of the final grade based on delivered performance. The assessment method can be strengthened by requiring minimum performance in key areas such as energy use and building commissioning.

#### *Regulatory Framework*

With the renewed emphasis on reducing carbon dioxide emissions there is a strong case for the HKSAR Government to implement the current building energy codes as part of the building regulations. Had the codes been implemented as a regulatory requirement it is estimated that air-conditioned buildings built subsequently would have been some 8% more energy efficient. On the other hand had the buildings complied with the highest targets set in HK-BEAM 1/96R (1999) the average energy performance improvements would have been around 32%. On this basis setting a target of 20% improvement in the energy efficiency of new air-conditioned buildings in line with recent UK and European legislation is not unreasonable if Hong Kong is to pay serious attention to the impact of buildings on the environment.

#### *Existing Buildings*

There is much evidence to show that Hong Kong's existing buildings do not meet the performance requirements in terms of indoor environmental quality and service quality, nor energy performance. A bold measure for Asia's World City would be to introduce compulsory building labelling in all workplaces (including schools, health care facilities, etc) that indicates to building users both the quality of the indoor environment and the building energy performance. In this connection, a study into the costs and financial benefits of green building assessments for existing air-conditioned buildings would be invaluable.

Given the relatively low cost of energy it would be appropriate to extend the study to examine the full cost of energy supply and water supply (including sewage) then consider how the performance of existing buildings can be improved through incentives, e.g. tax rebates, and penalties, e.g. energy taxes.

# 1 INTRODUCTION

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## 1.1 BACKGROUND

Clients and consultants worldwide, including those in Hong Kong, have a perception that more environmentally friendly buildings cost substantially more to build than conventional designs, with premiums of the order of 5-15% often quoted.

This study, jointly funded by the Construction Industry Institute Hong Kong (CII-HK) and the Hong Kong Polytechnic University, aimed to reduce the uncertainty about the cost of green buildings in Hong Kong by providing data as to the 'premium' above the cost of standard construction, and to outline the financial and other benefits that result from various levels of green building performance, as exemplified by an assessment under the Hong Kong Building Environmental Assessment Method (HK-BEAM)<sup>[1]</sup>. In essence, the analysis is intended to enable stakeholders to determine cost premiums and the potential benefits of obtaining a given HK-BEAM rating, such of 'Very Good' or 'Gold', etc.

The study was inspired by a report on the cost of green buildings prepared for California's Sustainable Building Task Force<sup>[2]</sup>. The California study examined projects which had undergone an assessment under the USGBC LEED scheme<sup>[3]</sup>. In addition to published data building representatives and architects were contacted to secure the costs for green buildings compared to conventional designs for those buildings. It was found that the average premium for these green buildings is slightly less than 2%, substantially lower than is commonly perceived.

This study has used actual cost data whenever possible, otherwise using estimates provided by clients, consultants and contractors who have knowledge of building and construction costs and prior involvement in green building assessments.

### 1.1.1 GREEN BUILDINGS

In the light of discussions with the Steering Committee and findings from the investigation, it became clear that the project deliverables needed to include a discussion of concepts and definitions of 'green' buildings.

Whilst some proponents describe green buildings in terms of additional 'green' features, increasingly green buildings are regarded as those that have been assessed and certified under a so-called building environmental assessment method (BEAM). Notwithstanding, as discussed later, being green and sustainable is a multi-faceted life-cycle performance issue, whereas assessments are only at a point in time in the building life-cycle. Like most BEAMs, HK-BEAM assessments cover a wide range of performance attributes, including global, regional, local and indoor issues, certifying an assessment grade according to the number of performance issues satisfied, e.g. 45% for 'Satisfactory' or 'Bronze', and up to 75% for 'Excellent' or 'Platinum'.

### 1.1.2 COSTS AND BENEFITS

In order to appreciate cost premiums for green building assessments, i.e. the cost premium for a given grade over a 'non-green' building, it is necessary to appreciate the number and nature of issues being assessed, the performance criteria for each, and the weighting/scoring method to determine the overall grade. In order to appreciate the potential benefits of certification not only is it necessary to know what performance levels have been achieved, but also the persistence of the measures over time. In this study, the focus is on the assessment of new buildings which are assessed within in the building life-cycle from initial planning through to handover.

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<sup>1</sup> HK-BEAM Society Website: <http://www.hk-beam.org/general/home.php>

<sup>2</sup> The Costs and Financial Benefits of Green Buildings. Sustainable Building Task Force. California. October 2003.

<sup>3</sup> US Green Building Council. LEED - Green Building Rating System. For New Construction & Major Renovations (LEED-NC).

Furthermore, in the consideration of costs and benefits it is apparent that the particular circumstances of a new building and client preferences for the project will have significant impact on costs. Clearly, given the variability of site conditions, building type and scale, system designs, and end usage, detailed assessment of overall cost premium is highly problematic. Similarly, change of use from the original intent means that estimates of financial benefits is also problematic. Consequently, the outcomes of studies such as this can only provide an indication of cost premiums and potential benefits as they might apply across a stock of green buildings.

## 1.2 HK-BEAM

The HK-BEAM scheme has been under development since the publication of the first two versions (1/96 and 2/96) for office buildings. HK-BEAM 1/96 (New Offices)<sup>[4]</sup> and HK-BEAM 2/96 (Existing Offices)<sup>[5]</sup> were updated in 1999 as versions 1/99R<sup>[6]</sup> and 2/99R<sup>[7]</sup>, respectively. HK-BEAM 3/99 (Residential)<sup>[8]</sup> was published in 1999. Two new 'pilot' versions of HK-BEAM were produced in 2003: HK-BEAM 4/03 'new building developments', and HK-BEAM 5/03 'existing building developments'. Both pilot versions were revised and released in December 2004 as HK-BEAM 4/04 'New Buildings'<sup>[9]</sup> and HK-BEAM 5/04 'Existing Buildings'<sup>[10]</sup>.

HK-BEAM is a significant private sector initiative in Hong Kong to promote green and sustainable buildings. Funding support for the 1996 and 1999 versions of HK-BEAM was from The Real Estate Developers Association of Hong Kong (REDA). Funding for the development of the later versions was from the HK-BEAM Society which owns and operates the scheme with support from the Business Environment Council.

To-date over a hundred major projects has undergone a HK-BEAM assessment<sup>[11]</sup>. Not only has the environmental performance been improved but the awareness and 'green' skills of construction and real estate professionals in Hong Kong have been raised.

## 1.3 TIMELINE

Starting in early 2005 the study was undertaken in stages. The focus of Stage I was on new air-conditioned office buildings, using data from assessments under HK-BEAM version 1/96R (1999). Stage II analysis focused on new high-rise residential developments using data from projects assessed under HK-BEAM 3/99 (1999). The Stage III study considered the costs and potential financial benefits of undertaking assessments under the latest version of HK-BEAM applied to both office-type buildings and high-rise residential buildings, respectively.

Stage I and Stage II study outcomes provide a historical perspective on green building assessments as they relate to buildings which have undergone assessment under older versions of HK-BEAM, whilst the Stage III study examines current and future trends on cost premiums and potential benefits under the current version.

The detailed costs and benefits data provided in this report are mainly for assessments under HK-BEAM 4/04, i.e. cost premiums and potential benefits for each applicable credit in version 4/04, whilst overall cost premiums focus on the outcomes for version 4/04 (2004) they are compared with historical data for the previous versions of HK-BEAM.

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<sup>4</sup> HK-BEAM (New Offices). An environmental assessment for new air-conditioned office premises version 1/96. 1996.  
<sup>5</sup> HK-BEAM (Existing Offices). An environmental assessment for existing air-conditioned office premises version 2/96. 1996.  
<sup>6</sup> HK-BEAM (New Offices) An. environmental assessment for new office designs version 1/96R. 1999.  
<sup>7</sup> HK-BEAM (Existing Offices). An environmental assessment for existing office buildings version 2/96R. 1999.  
<sup>8</sup> HK-BEAM (Residential). An environmental assessment for new residential buildings version 3/99. 1999.  
<sup>9</sup> HK-BEAM 'New Buildings'. An environmental assessment for new buildings version 4/04. 2004.  
<sup>10</sup> HK-BEAM 'Existing Buildings'. An environmental assessment for existing buildings version 5/04. 2004.  
<sup>11</sup> HK-BEAM assessments are listed at: <http://www.hk-beam.org/caseStudies/new.php>



## 2 GREEN BUILDING ASSESSMENTS

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The descriptions 'green' and 'sustainable' in relation to buildings, building systems and building products are common in current literature, with the terms often used interchangeably but often ill-defined. The popular press is predisposed to regard green buildings as those having certain green features, particularly those that are visible, such as greenery or photovoltaic arrays. Even building professionals speak loosely of building being green and sustainable because the architectural design includes green materials, provisions for natural ventilation, etc. The emergence of building environmental assessment methods (BEAMs) in the 1990's has dispelled such 'greenwash' by providing a measure of the environmental performance of a building through assessment and certification. Most stakeholders now regard green buildings as those that have been certified under a BEAM. Concepts of what constitutes green and sustainable in respect of buildings are outlined in several international standards, and as awareness of sustainability increases, it is likely that the focus of assessment methods will move away from 'green', with its connotation of environmental protection, to 'sustainable', which has a broader connotation and wider appeal.

### 2.1 GREEN BUILDING CONCEPTS

In 2001 ASTM International<sup>[12]</sup> defined a green building as: "a building that provides the specified building performance requirements while minimizing disturbance to and improving the functioning of local, regional, and global ecosystems both during and after its construction and specified service life", adding, "a green building optimizes efficiencies in resource management and operational performance; and, minimizes risks to human health and the environment". Conceptually, the definition can be presented as a life cycle 'efficiency' ratio:

$$\text{Life cycle eco-efficiency} = \frac{\text{Indoor Environmental Quality (IEQ) + Services + Amenities}}{\text{Resource Consumption + Environmental Loadings}}$$

In 2003 the Organisation of Economic Co-operation and Development (OECD)<sup>[13]</sup> defined green buildings as those buildings that have minimum adverse impacts on the built and natural environment, in terms of the buildings themselves, their immediate surroundings and the broader regional and global setting. According to OECD a green building is designed to minimise the total environmental impact of its materials, construction, operation and deconstruction while maximising opportunities for indoor environmental quality and performance. Furthermore, green buildings are constructed and operated in ways that enhance their impact on the building occupants whilst reducing impacts on the environment.

These notions emphasise that in order for a building to be 'green' it shall satisfy its *specified performance over its useful lifetime*, provides a focus for improving the eco-efficiency of buildings and, by emphasising performance requirements and impact on human health, also embraces economic and social dimensions of sustainability. Essentially, a building is more sustainable if it can maintain good quality indoor environments and other essential services through efficient use of energy, water and other resources, whilst reducing to the minimum possible related emissions, waste and effluent.

#### 2.1.1 LIFE-CYCLE PERFORMANCE

As illustrated by Figure 2.1 quantifying the life-cycle performance and impacts of a large air-conditioned building is very difficult. Following initial planning, design, construction, commissioning and handover phases as a 'new' building, there is much change and churn during its life as an 'existing' building, with changes to layout, redecoration, refurbishment, etc, all

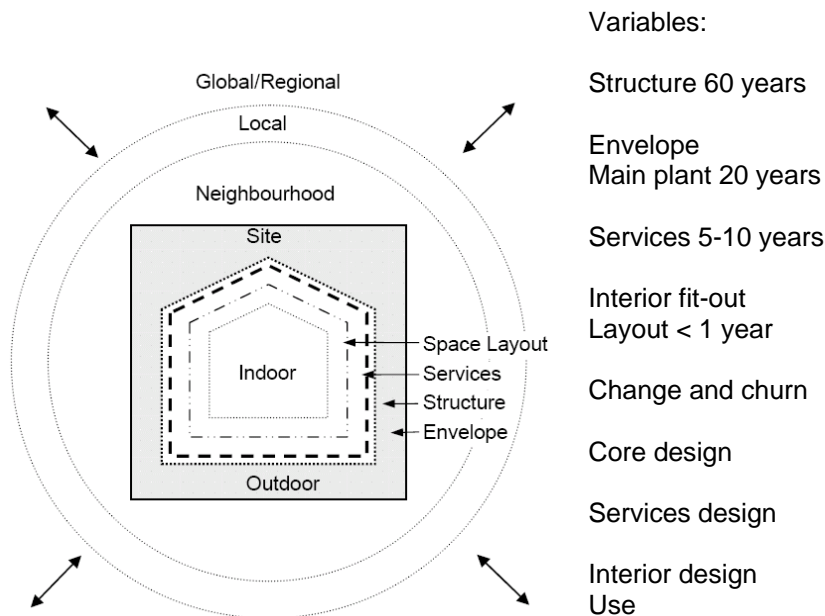
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<sup>12</sup> ASTM International. Standard Terminology for Sustainability Relative to the Performance of Buildings. Designation E 2114 – 05a. 2001.

<sup>13</sup> OECD. Environmentally Sustainable Buildings: Challenges and Policies. 2003.

impacting on performance. In an affluent city like Hong Kong retail buildings, catering establishments, recreational facilities and the like can be prone to fashion and fads as are residential buildings, where 'redecorating' and 'do-it-yourself' accounts for substantial part of construction activity.

Over the life-cycle of heavily-serviced buildings, the impact of the building structure reduces in significance when considering the cumulative impact of several generations of major equipment, changes to interior services, changes to space layouts, etc<sup>[14]</sup>. Life cycle performance depends firstly on planning, design and construction quality, then on quality of management, operation and maintenance, as well as the actions and activities of building users.



**Figure 2.1 Life cycle impacts of buildings<sup>[15]</sup>**

### 2.1.2 SUSTAINABLE BUILDING CONCEPTS

As emphasised in an ASTM standard<sup>[16]</sup>, buildings have environmental, economic, and social impacts that occur at all life-cycle stages in multiple ways and on local, regional, and global scales. The standard recognises that sustainability is an ideal and practical application relies upon balancing these impacts, seeking to:

- protect and enhance the health, safety, and welfare of building occupants, neighbours, and the public, that contribute to a positive quality of life for current and future generations;
- mitigate negative environmental impacts, and promote positive environmental impacts that affect ecosystems, biodiversity, and balances the use of renewable, non-renewable and perpetual resources; and
- optimize direct economic impacts, those associated with the life-cycle costs/benefits of materials, land, and labour directly attributable to the building, and indirect economic impacts associated with external costs/benefits that accrue to those indirectly impacted by the building.

A recently published ISO standard<sup>[17]</sup> dealing with sustainability and environmental matters, provides a framework for sustainability indicators of buildings based on the premise that sustainable construction brings about the required performance with the least unfavourable environmental impact, while encouraging economic, social and cultural improvement at a local,

<sup>14</sup> Queensland Department of Public Works. Ecologically Sustainable Design in Office Fitout. June 2000.

<sup>15</sup> Burnett J. Creating Valuable Buildings. RICS Conference, Hong Kong, May 2006.

<sup>16</sup> ASTM International. Standard Guide for General Principles of Sustainability Relative to Buildings. E 2432-05. 2005.

<sup>17</sup> ISO/TS 21929-1. First edition. Sustainability in building construction — Sustainability indicators — Part 1: Framework for the development of indicators for buildings. 2006.

regional and global level. The inclusion of social and economic issues is an emerging trend in the development of BEAMs<sup>[18]</sup>.

### 2.1.3 SOCIAL DIMENSIONS

Social exclusion should be avoided by providing for easy accessibility and movement within buildings for the physically impaired and the elderly<sup>[19]</sup>, and should extend beyond the current provisions in Hong Kong's building regulations. Physical design features, both internal and external, surveillance and public lighting, can help to deter crime and contribute to the safety and security of building users and bystanders<sup>[20]</sup>.

The ASTM standard<sup>[16]</sup> highlights that those who are potentially affected by a building should be provided with information and the means to contribute to decision making. The involvement of end users in the planning and design stages is lauded as being beneficial, but for some organisations it also means being a good neighbour in the communities in which they do business<sup>[21]</sup>. This includes locating buildings in deprived areas in order to provide economic stimulus through job and business opportunities, helping promote community development, and contributing to the improvement of areas around buildings.

Relationships between buildings, when viewed as neighbours, depend on the types of buildings involved. New buildings, particularly those that are part of an urban redevelopment, can be 'good' or 'bad' neighbours, depending on the extent to which the design takes into account the associations between the building and neighbouring properties, public open spaces or urban greenery. The potential impacts on neighbours and neighbouring properties that are usually covered in BEAMs include:

- wind amplification, provision of breezeways, biotope, etc;
- overshadowing and views;
- light pollution; and
- pedestrian, vehicular access, etc.

Collaborative planning with local officials and neighbourhood interest groups on issues of common interest such as urban design, transportation and security, serves a community need. In this regard the UK government has introduced a number of instruments under the planning system to require developers to consider more closely the environmental, social and economic impact a building may have on an area<sup>[22]</sup>. In Hong Kong buildings should interface with urban planning and address concerns about the visual impact of building masses, connections with people and places, creation of spaces for movement, urban amenities and public realm, and the process of improving the overall townscape<sup>[23]</sup>.

### 2.1.4 ECONOMIC DIMENSIONS

A building has both direct and indirect economic impacts through its development, use and disposal. Direct economic impacts are those associated with the life-cycle costs and benefits of land, materials, labour, etc. External costs and benefits accrue to those indirectly impacted by the building, including environmental costs associated with infrastructure, loss of biodiversity, etc. and social benefits, such as job creation. Whilst the focus for new buildings is usually on minimising first cost and rarely involves life-cycle costing, there is a growing appreciation that what really counts is value, particularly in respect of workplaces, schools and hospitals<sup>[24]</sup>. The significant added value of the total built environment is as contributors to businesses, national assets,

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<sup>18</sup> Cole R J. Building Environmental Assessment Methods: A Measure of Success. International Electronic Journal of Construction. The Future of Sustainable Construction, May, 1-8, 2003.

<sup>19</sup> Design for Accessibility: A Cultural Administrator's Handbook. National Assembly of State Arts Agencies. US. 2003.

<sup>20</sup> National Crime Prevention Council, Singapore. Crime Prevention Through Environmental Design Guidebook. October 2003.

<sup>21</sup> Public Buildings Service, US General Services Administration. Planning with communities. 2000.

<sup>22</sup> British Council for Offices. Planning and Sustainability Briefing Paper. February 2006.

<sup>23</sup> Hong Kong Planning and Standards Guidelines. Chapter 11. Urban Planning Guidelines. July 2006. [http://www.pland.gov.hk/tech\\_doc/hkpsg/english/](http://www.pland.gov.hk/tech_doc/hkpsg/english/)

<sup>24</sup> Davies R Ed. Green Value. Green buildings, growing assets. Royal Institution of Chartered Surveyors. 2006.

economic development and quality of life<sup>[25]</sup>. A poor or depreciating built environment costs both the economy and society.

Whilst the costs associated with design and construction is relatively well understood, valuing the benefits of high-performance buildings is difficult, as the benefits are hard to quantify so tend to be under-valued, or even ignored<sup>[26]</sup>. The type of value created is summarised in Table 1, but appreciation will depend on 'who pays' and 'who benefits', with different perspectives for different stakeholders - investors, developers, users (tenants/occupiers, management and maintenance staff, and visitors), society/government, and neighbours. Real estate developers can be divided into three groups:

- Investor/Developer - the group who develop real estate for sale to investors;
- Owner/Operator - the group who develop real estate for rental and management; and
- Owner/Occupier - the group who develop real estate for their core business as users.

Each is likely to have a different perspective on investing in green building attributes and whether or not the additional cost makes good business sense.

**Table 2.1 Types of value created** (extract from Eclipse Research Consultants<sup>[26]</sup>)

Type of value created	Examples of indicators or metrics
Exchange value	Book value. Return on capital. Rental Yield.
Use value	Measures associated with occupancy: such as satisfaction, motivation, and teamwork. Measures of productivity and profitability.
Image value	Public relations opportunities. Brand awareness and prestige .
Social value	Sense of community and neighbourly behaviour. Reduced crime and vandalism.
Environmental value	Environmental impact. Whole life value.
Cultural value	Press coverage. Critical reviews.

## 2.2 CERTIFIED GREEN BUILDINGS

Since the early 1990's, BEAMs have been developed in around twenty countries to provide a more holistic assessment of building performance than previously. Some are well-established<sup>[27,28,29,30]</sup> and some have been introduced more recently<sup>[31,32,33,34]</sup>. Schemes may cover both new and existing buildings, and an assessment method may be specific to a particular building type, or even part of a building, e.g. core and shell.

These schemes almost invariably operate on a voluntary basis, consequently the rigours of assessments depends on what the market is likely to accept so, unless supported by significant financial incentives, scheme developers must strike a balance between difficulty and acceptability. Consequently, the assessment of new buildings tends to focus on what the project team can achieve over and above typical practice.

Assessment methods for new buildings include a variety of assessment criteria, some are performance-based, and some are prescriptive, i.e. the inclusion of particular features, as well as

<sup>25</sup> Pearce D. The Social and Economic Value of Construction. The Construction Industry's Contribution to Sustainable Development. nCRISP the Construction Industry Research and Innovation Strategy Panel. 2003.

<sup>26</sup> Eclipse Research Consultants. Better designed buildings: improving the valuation of intangibles. June 2005.

<sup>27</sup> Baldwin R, Yates A, Howard N, Rao S. Building Research Establishment. BREEAM 98 for Offices.

<sup>28</sup> HK-BEAM Society. <http://www.hk-beam.org.hk/>.

<sup>29</sup> US Green Building Council. <http://www.usgbc.org/>. LEED.

<sup>30</sup> Green Globes. <http://www2.energyefficiency.org/design/homeca.asp>

<sup>31</sup> Architecture and Building Research Institute, Ministry of the Interior. Taiwan. <http://www.abri.gov.tw/english/techplan/index.aspx?DBID=4>

<sup>32</sup> Institute of Building Environment and Energy Conservation, Japan. CASBEE – Comprehensive Assessment System for Building Environmental Efficiency. 2003.

<sup>33</sup> Green Building Council of Australia. Green Star Environmental Rating System for Buildings.

<http://www.gbcaus.org/greenstar/page.asp?id=117>

<sup>34</sup> Building and Construction Authority, Singapore. Green Mark for Buildings. <http://www.bca.gov.sg/>

provisions for management, operation and maintenance. The range and number of issues assessed within a BEAM is significant when judging the outcome of an assessment. Some BEAMs are intended to provide a relatively simple assessment, especially in the first phase of implementation in order to gain acceptability in a market. However, the international trend is for a more comprehensive assessment, especially where the buildings targeted for assessment are large and complex.

In most building assessments methods the focus of *specified performance* has been mainly on the assessment of indoor environmental quality (IEQ), expressed in terms of thermal comfort, indoor air quality, lighting quality, acoustics and noise, and hygiene. Coverage of other aspects of building performance and provision of amenities has tended to be rather limited, but as 'sustainability' comes more to the fore, additional economic and social issues are being included. Given the potential impact on productivity in workplaces and the overall quality of life of citizens, IEQ is clearly germane to the economic and social performance of buildings of all types.

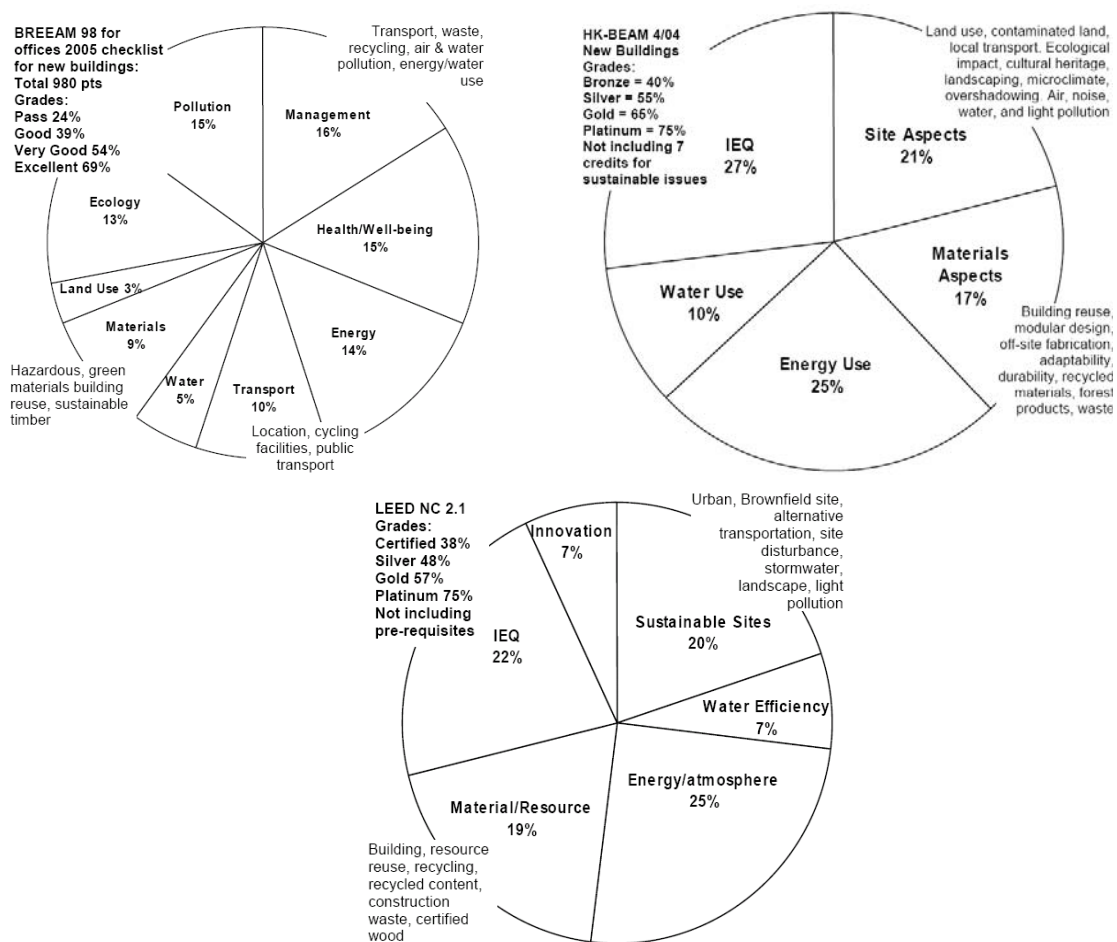


Fig. 2.2 Categories and grade requirements under various BEAMs (from Burnett et al<sup>[35]</sup>)

As Fig. 2.2 shows although performance issues may be grouped in different categories, BEAMs generally include assessment of a wide range of external environmental impacts, at the site, local, regional and global levels. Whilst depletion of the ozone layer, deforestation, pollution of water sources, etc are of concern, global warming and climate change, CO<sub>2</sub> emissions in particular, has become a major focus, and with it renewed efforts to reduce energy consumption through various energy efficiency measures. However, energy efficiency and IEQ are but 'two sides of the same coin', and inappropriate measures to reduce energy consumption, to the extent that it has a significant negative impact on user comfort and health, can be counter productive.

<sup>35</sup> Burnett J, Chau C K, Lee W L. Green Buildings: How Green the Label? HKIE Transactions. Vol. 12, No. 4, 1-8, 2005.

Usually a BEAM will have several grades or levels of performance, depending on the number of points or credits achieved. The outcome of an assessment is a grade (Platinum, Gold, or Excellent, Very good, or 4-star, 3-star, etc) defined within the assessment method, and based on either the sum of points<sup>[27]</sup> or credits<sup>[29]</sup> obtained, or on a more complex calculation incorporating weighting factors<sup>[31]</sup>. Fig. 2.2 provides an outline of the performance categories and grade requirements the requirements for BREEAM'98, LEED-NC 2.1 and HK-BEAM 4/04 (for air-conditioned office buildings).

### 2.2.1 PERFORMANCE ENHANCEMENTS

The performance enhancements relative to prevailing practice of a building certified to a particular grade under a BEAM depends on the range of environmental issues included in the assessment, the standards of performance demanded, the rigour of demonstrating compliance, the relative weighting or scoring of each issue, and the aggregate score required for a the grade<sup>[35]</sup>:

#### *Coverage, weightings and grade achieved:*

An assessment may be limited to relatively few issues, or be as comprehensive as practice permits. The range of issues will depend on the stages of the development process (from initial planning to final handover) that are covered in the assessment. The weightings, i.e. the way in which individual issues are scored and then aggregated are significant in determining the certified grade. The better the grade the greater the number of issues satisfied in the assessment.

#### *Performance requirements:*

Performance criteria will be set against a baseline or benchmark, such as compliance with the minimum requirements of building regulations. The criteria may be performance-based, such as predictions of annual energy use, prescriptive, i.e. providing specific features such as energy meters, or provisions that will allow efficient building management such as commissioning and operator training.

#### *Assessment and certification:*

Assessment for compliance may be based on actual measurements or modelled performance, specifications or check-lists, or confirmation that certain features have been provided. The extent to which compliance can be verified, the degree to which assessments are objective and the consistency are also important.

Some BEAMs assess new buildings at the design stage. However, if final assessment and certification takes place at this stage, assessment of the construction phase and final commissioning can only be based on specifications and contractual arrangements. Whether or not these commitments are fulfilled depends on the abilities and commitments of the client, contractors, and commissioning agents.

### 2.2.2 HOW GREEN AND SUSTAINABLE

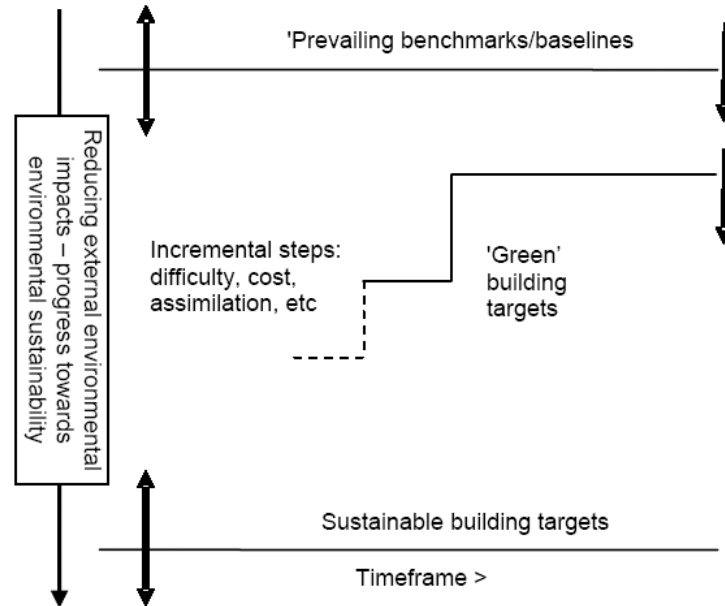
It is not feasible to quantify or rate the greenness of a given eco-label (e.g. LEED-NC 'Gold') in absolute terms. As Figure 2.3 illustrates the absolute levels of environmental performance of the current baseline/benchmarks, as well as the targets for environmental sustainability, are mostly unknowns (as indicated by double-headed arrows). Conceptually, Figure 2.3 can apply to a particular performance issue (e.g. annual energy consumption), a building, or even the building stock as a whole. As standards rise, or more buildings become 'greener', the baseline/benchmark rises (prevailing/overall standards rise), so that over time the green (BEAM) standards should be raised further (incrementally, as indicated by the staircase, and the single-headed arrows).

Furthermore, given the variability in the range of performance issues that are included, and differences in performance standards, it is very difficult to rank eco-labels between different BEAMs. However, the greenness of a particular BEAM eco-label is distinguished by the extent to which performance standards are raised relative to the standards of environmental performance (i.e. the distinct baseline/benchmarks) that prevail in the jurisdiction in which the BEAM applies.

#### *Assessment Outcomes*

Unless a BEAM specifies minimum requirements in a given performance category, it is possible for buildings to have the same assessment grade yet comply with different performance criteria.

Generally clients and project teams tend to seek a good grade but within budgetary constraints. This has led to the tendency of 'point-mongering' based on achieving a target grade, rather than adopting an integrated design approach where improvements in overall performance is a more likely outcome <sup>[Error! Bookmark not defined.]</sup>.



**Fig. 2.3 Green and sustainable performance relative to benchmarks** (from Burnett)

## 3 COST AND BENEFITS OF GREEN BUILDINGS

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There is a tendency to promote green buildings on the basis of the totality of issues included in an assessment method and to conclude that green developments are fundamentally better, healthier, less expensive to run, more socially responsible, more attractive to occupiers and the public, and ultimately have the potential to be more profitable. This forgets that a certified green building may have covered little more than half of the total points or credits (e.g. 55% for Silver), and that some of the 'green' performance may not persist during use.

### 3.1 PERCEIVED COST PREMIUMS FOR GREEN BUILDINGS

Perceptions of costs and benefits for building green (as demonstrated by certification under a BEAM) will vary between stakeholders. According to surveys conducted in the US, those who are not familiar with building green the perceived premium may up to 15% of construction cost, whilst those who have engaged in the procurement of green buildings are likely to estimate the premiums in the 0-5% range. These conclusions seem to reflect Hong Kong opinions as determined from a survey amongst local stakeholders<sup>[36]</sup>. It may be that green 'features' that incur substantial cost premium are included to demonstrate 'green' even though environmentally friendly alternatives are available at much lower cost. Under boom conditions, green construction premiums may be higher when contractors' order books are full and there is a reluctance to bid for projects which are seen to be more demanding and great risks to profit margins.

Investors/Developers of speculative developments will be interested to know if any cost premium is warranted, e.g. through an increase in sale value, and may also be concerned that 'green and sustainable' features do not place a building outside the mainstream market. Developers who retain ownership will be interested in whether building green offers an increased rental return, and together with Owner/Occupiers should be more interested in life cycle costs and benefits. Notwithstanding, governments and other large organisations who maintain separate capital and operating budgets may find this a barrier to implementation, so that considerations of first costs will still tend to dominate decision making.

Soft costs include professional fees, management fees and cost of financing. For green buildings, it is expected that additional design effort will be required, and which may be significant for design teams who have limited experience of green building techniques and technologies, but which reduce as experience of green building design increases. As it is rare for green building projects to keep accounts of cost premiums, and consultancy fees charged to clients may not fully reflect actual costs.

A significant additional design effort is required for computer modelling, especially where sophisticated software tools are used for whole building energy analysis. World-wide the use of such tools appears to be generally lacking, and Hong Kong is no exception. Currently, few HK-BEAM assessed projects have used detailed energy simulations during the design phase.

#### 3.1.1 COST ESTIMATES

A number of studies have been undertaken in the US to determine the cost of building green, mainly focusing on LEED 'eco-labels'. The California study estimated that the additional initial cost (premium) for 'Silver' was of the order of 1-2%, although a study for the US General Services Agency (GSA)<sup>[37]</sup> questions the findings, suggesting that initial costs can be higher, and also criticises the standards being set in LEED-NC as being somewhat low when set against

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<sup>36</sup> Chau C K, Lee W L, Tse M S. Rewards for building green. International Conference Rethinking Sustainable Construction. Florida USA. 2006.

<sup>37</sup> Steven Winter Associates, Inc. LEED® Cost Study. Final Report to US General Services Administration, October 2004.



conventional practice. Syphers et al<sup>[38]</sup> quote typical incremental cost of meeting LEED-NC certification (Fig. 3.1), which reflect the upper limits, but also note that most new state construction in California should be able to achieve LEED ‘Silver’ within standard design and construction practice. A Langdon database of US building costs<sup>[39]</sup> showed that the initial cost of LEED assessed buildings and non-assessed buildings was indistinguishable, demonstrating the difficulty in assigning a premium for building green. From the limited data available it appears that similar cost premiums apply to assessments under BREEAM in the UK<sup>[40]</sup>, although direct comparison is difficult as the two assessment method differ in many respects.



**Fig. 3.1 Cost premiums for LEED-NC certifications** (from Syphers et al<sup>[38]</sup>)

Table 3.1 indicates the percentage increase in capital cost for an air-conditioned office building assessed using BREEAM 2004<sup>[41]</sup>. The increases in capital costs shown in this table were calculated by applying selections of the BREEAM requirements to a base case building. The cheapest way of reaching the required rating was favoured. Although it only applies to BREEAM assessments the data also illustrates how the building location can impact on cost premiums.

**Table 3.1 Cost premiums for BREEAM assessments (from**

Location	BREEAM score (and rating) for the base case	% increase for pass	% increase for good	% increase for very good	% increase for excellent
Poor location	20.3 (unclassified)	0%	0.2%	5.7%	–
Typical location	34.6 (pass)	–	0%	0.2%	7.0%
Good location	37.1 (pass)	–	0%	0.1%	3.3%

It is noted that the estimates reported are for a variety of building types, large and small and should not be used to estimate costs premiums for any particular building, because:

- costs are historic and include some non-green costs associated with prestige buildings;
- costs are reducing as design teams and builders become more familiar with requirements;
- costs may rise as BEAM standards change;
- additional cost very much depends on the credits which are targeted; and
- costs are limited and the benefits are maximised if implementation starts at the earliest stages of planning and design.

## 3.2 PERCEIVED BENEFITS OF CERTIFIED GREEN BUILDINGS

Tangible benefits to building owners are those that have the potential to be quantified, such as energy, water and materials savings. Intangibles include such aspects as corporate reputation, productivity in workplaces, reduced morbidity through improved indoor air quality, etc. Society will see benefits through reduced building related illnesses, reduced loadings on infrastructure,

<sup>38</sup> Syphers G, Baum M, Bouton D, Sullens W. Kemark. Managing the Cost of Green Buildings. October 2003.

<sup>39</sup> Matthiessen L F, Morris P. Costing Green: A Comprehensive Cost Database and Budgeting Methodology. Davis Langdon, July 2004.

<sup>40</sup> Bartlett E, Howard N. Informing the decision makers on the cost and value of green building. Building Research & Information, Vol. 28, No. 5/6, 315-324, 2000.

<sup>41</sup> BRE Information paper IP 4/05. Costing sustainability: How much does it cost to achieve BREEAM and EcoHomes ratings? 2005.

improvements to neighbourhoods, etc.

The literature often highlights the benefits (or value) of building green without taking account of exactly what a green building assessment (certification) actually provides in terms of added value. For example, in the Sustainable Building Pathway<sup>[42]</sup>, developed by some 50 senior executives from industry and government in Australia, added value largely included the following:

- gains derived by building occupants from good IEQ, including better staff productivity and a general sense of well-being;
- gains derived by investors from higher occupancy levels and lower tenant turnover;
- gains derived by landlords and owners from lower lifecycle costs; and
- gains derived by all market players from branding and from being seen as acting responsibly to protect and conserve the environment.

The Pathway reports that consumer demand for green products is growing strongly, and many companies are adopting green practices to satisfy customers, shareholders and staff expectations. It is reckoned that the key driver of this improved value is that green buildings strive not only for resource efficiency but also for improved IEQ, as this translates into better worker productivity through reduced absenteeism and employee turnover, better concentration and energy, and higher morale and loyalty. Thus, it is suggested, tenants of green buildings are less likely to move and will pay higher rent once they have found a building that employees actually like. Conversely, US studies have found that the main reason businesses relocate is employee complaints about the building: hot and cold spots from traditional air conditioning systems, poor lighting and stuffy air (i.e. poor air quality). Lower tenant churn rates and increased occupancy translates into significant added value for the building owner.

By way of reference to “rigorous international research that demonstrates a strong correlation between IEQ and worker health and productivity”, the Pathway document goes on to state that “Green buildings have also been found to offer significant gains in productivity because of their better internal environment with less absenteeism and greater efficiency of work tasks”.

A study by McGraw Hill<sup>[43]</sup> surveyed a representative sample of architects, engineers, contractors and building owners regarding their involvement, habits and perceptions about green buildings. When asked to predict the impact of completed green building projects the respondents reported the following:

- average expected decrease of operating costs between 8% and 9% (owners were more inclined to expect decreases);
- average increase in building values expected around 7.5%;
- on average, ROI expected to improve 6.6%;
- occupancy expected to increase by 3.5%; and
- rents expected to rise by 3% on average.

According to analysis of international and Australian data the Green Building Council of Australia reported<sup>[44]</sup> that green buildings deliver lower annual operating costs and more efficient asset management. Local case studies demonstrate a 60% reduction in water and energy consumption which can reduce annual operating costs from \$120/m<sup>2</sup> to \$60/m<sup>2</sup>. According to the Council there is also evidence that green buildings deliver:

- increased occupant productivity (1 - 25% increase) and well-being;
- less staff churn;
- higher relative investment returns (minimum 14% ROI);
- a marketing advantage (free promotion);
- higher market value for asset (10% increase);

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<sup>42</sup> Building Commission, Victoria. Sustainable Building Pathway. 2006. <http://www.buildingcommission.com.au/>

<sup>43</sup> McGraw Hill Construction. Green Building SmartMarket Report. 2006.

<sup>44</sup> Green Building Council of Australia. The Dollars and Sense of Green Buildings. Building the Business Case for Green Commercial Buildings in Australia. 2006.

- higher rents (5 -10% increase); and
- a range of other benefits.

### *Barriers*

Similar to other studies, the Green Building Council of Australia report<sup>[44]</sup> also identifies a number of barriers to the mainstream uptake of green building principles and practices, including:

- a general lack of knowledge and skills about green buildings;
- a lack of value attached to the long term benefits of green buildings and too great a focus on short term low cost construction;
- a lack of government support and leadership at all levels, including insufficient incentives and inconsistent and uncoordinated regulation;
- the lack of appropriate green and reusable materials; and
- the confusion created by the plethora of rating tools.

The last point has been observed in the US and Canada where two or more green building or energy efficiency rating systems are in use.

It is clear from these business orientated reports that the perceived benefits of green building assessments tend to relate to the promise of improved performance, perhaps through simply examining the issues covered in the assessment methods, rather than the outcomes of the assessments, i.e. the improvements actually achieved.

## **3.3 RELATIVE COSTS FOR OFFICE BUILDINGS**

When considering cost premiums and potential benefits of building green it is germane to the discussion and analysis to consider the costs of providing buildings as a facility in relation to business and occupancy costs.

### *Business Costs*

The cost of operating a business or other enterprise - salaries, overheads, rents - in an office building obviously varies with country and location. The relative costs of procuring a building – land, design, construction, commissioning – varies with location, site complexity, etc. Based on a broad cost database, ball-part ratios for better quality buildings in OECD countries are reported<sup>[45]</sup> to be of the order 1:1.3:13, i.e. business costs some thirteen times the construction costs, and ten times O&M costs. The cost of running an office based business in the US<sup>[46]</sup> breaks down to the facilities (5%), operations (4%), technology (10%) and people (81%). Staffing costs dominate, but it is noted that IT costs have become much more significant. Similar ratios apply to offices in Hong Kong. With occupancy costs around US\$95/ft<sup>2</sup>/annum<sup>[47]</sup> for office space in Hong Kong's CBD, the cost of one workstation of 10m<sup>2</sup> is around HK\$80,000 pa. Based on a HK\$250,000 pa salary, the staff cost is 75%, occupancy cost 25%.

### *Building Costs*

In fourth quarter 2005 the approximate total building costs<sup>[48]</sup> in Hong Kong for a standard office building with air-conditioning ducting and light fittings to tenant areas was HK\$10,600/m<sup>2</sup>, including services at HK\$2,550/m<sup>2</sup> (average). Fit-out costs are estimated as HK\$5,170/m<sup>2</sup>, which includes furniture, partitioning, electrical work, minor alteration to air-conditioning, fire services and suspended ceiling to suit layout, but excludes telephones, data cabling, and office equipment. Fig. 3.2 shows a breakdown of costs assuming a mix of 'general' and 'executive' offices. Land costs, which overshadow total building costs by a factor of 3-4, are not included. Over 20 years the occupancy costs are around HK\$1.6 million, business costs HK\$6.4 million/10m<sup>2</sup> compared to the construction cost of around HK\$0.16 million/10m<sup>2</sup>.

The point made here is that with design costs at 10% (maximum) of construction costs investment in design qualities that improve IEQ and services that support business activities can have a

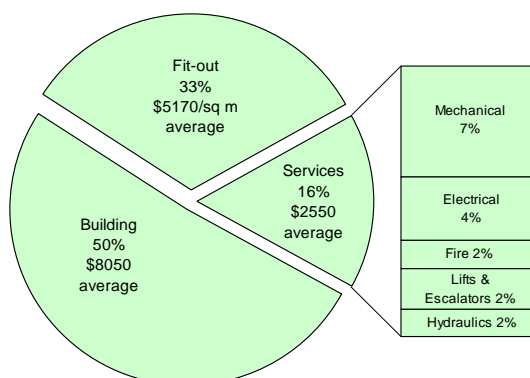
<sup>45</sup> R. Saxon. Be Valuable. A guide to creating value in the built environment. Constructing Excellence, 2005.

<sup>46</sup> BOSTI Associates. [www.bosti.com/benefits.htm](http://www.bosti.com/benefits.htm)

<sup>47</sup> King Sturge. Office Rents Survey Quarter 2, 2005. <http://www.kingsturge.com/>

<sup>48</sup> Davis Langdon & Seah Hong Kong Limited. Construction Cost Handbook (China & Hong Kong 2006)

significant impact on the much larger business cost.



**Fig. 3.2 Construction and fit-out costs for a standard office building in Hong Kong<sup>[48]</sup>**

### Energy Costs

Assuming a lighting power density of 25 W/m<sup>2</sup>, equipment power density 25 W/m<sup>2</sup>, for a workstation area of 10 m<sup>2</sup>, operating for 10 hours per weekday, 5 days a week for 50 weeks with an electricity cost of HK\$1 per kWh, the energy cost is about HK\$1 250 pa. From a recent audit<sup>[49]</sup> of operation and maintenance practices, the average monthly cost for air-conditioning O&M was HK\$17.3/m<sup>2</sup>/month, with energy accounting for 87%, i.e. HK\$15/m<sup>2</sup>/month. From a previous survey<sup>[50]</sup> air-conditioning energy accounts for around three-quarters of landlord energy use, so energy costs for landlord services average about HK\$20/m<sup>2</sup>/month, which is 40% of average management costs (HK\$53), and about 25% of the average rent (HK\$209). On this basis, any air-conditioning energy charges direct to tenants (excluding any owner's profit) is HK\$1800/10m<sup>2</sup>. If air-conditioning is charged separately the total energy cost is around HK\$3 000 pa/10m<sup>2</sup> or 1-2% of business costs.

This analysis highlights the problem that for office buildings tenant's energy costs is partially hidden and represents a small part of business costs, whereas for building owners energy costs can be a significant proportion of O&M costs for HVAC systems, if not the rental income.

## 3.4 RELATIVE COST FOR RESIDENTIAL BUILDINGS

In Hong Kong apartments are graded according to size (Table 3.2) with the smaller sizes dominating both public (subsidised) and private sector housing<sup>[51]</sup>.

**Table 3.2 Hong Kong housing stock year end 2005 (units by size)**

Class (m <sup>2</sup> )	Private	Vacant	Public	Total
A (<40)	338290	10661	609000	957951
B (40-69.9)	474389	34677	412000	921066
C (70-99.9)	108237	10666	0	118903
D (100-159.9)	48948	4865	0	53813
E (>160)	19843	2670	0	22513
	989707	63539	1021000	2074246

<sup>49</sup> Lai, J. H. H., Yik, F. W. H., Jones, P. Operation and Maintenance Expenditure and Rental Income of Commercial Buildings in Hong Kong. Energy and Buildings (under review).

<sup>50</sup> Lee, W. L., Yik, F. W. Burnett, J. A Method to Assess the Energy Performance of Existing Commercial Complexes. Indoor Built. Environment, Vol. 12, 311–327. 2003.

<sup>51</sup> Rating & Valuation Department. Hong Kong Property Review. 2006.

### Occupancy Costs

As shown by Table 3.3 despite the downturn in 1997 residential property costs in Hong Kong remain relatively high.

**Table 3.3 Private sector property costs by grade (HK\$/m<sup>2</sup> March 2007<sup>[52]</sup>)**

A			B			C			D		
HK	Kln	NT	HK	Kln	NT	HK	Kln	NT	HK	Kln	NT
44 731	31 446	28 305	51 509	38 915	30 409	72 531	60 912	40 383	85 150	73 919	51 888

As of June 2006 private sector rents in the three main areas of Hong Kong are as shown in Table 3.4. Home owners pay government rates and rent. Rates are one of Hong Kong's indirect taxes levied on properties. Rates are charged at a percentage of the rateable value which is the estimated annual rental value of a property at a designated valuation reference date, assuming that the property was then vacant and to let. For the current Financial Year 2006-2007, the rates percentage charge is 5%. Owners of properties in Hong Kong are also liable to pay Government rent under their land leases, typically around 3% of rateable value.

**Table 3.4 Private sector rents in Hong Kong (HK\$/m<sup>2</sup> June 2006)**

Class (m <sup>2</sup> )	Hong Kong	Kowloon	New Territories
A (<40)	215	155	118
B (40-69.9)	215	161	109
C (70-99.9)	242	208	133
D (100-159.9)	301	234	179
E (>160)	353	185	162

Rents for public housing in 2005 were of the order of HK\$ 40/m<sup>2</sup> per month for units of size up to 40m<sup>2</sup> and averaged around HK\$ 50/m<sup>2</sup> for the larger grade C units<sup>[53]</sup>.

### Energy Costs

Energy costs (including water and sewage charges) as a percentage of total household expenditure<sup>[54]</sup> for low income groups and middle income groups, which represents the bulk of consumers, are given in Table 3.5. The CPI(A), CPI(B) and CPI(C) are compiled based on the expenditure patterns of households in the relatively low, medium and relatively high expenditure ranges, respectively.

**Table 3.5 Energy (and water) costs as a percentage of monthly household expenditure**

Income Group	Electricity %	Towngas %	LPG/other Fuel %	Energy cost HK\$	Water & sewage %	Housing %
CPI(A) \$4.1-15.8k pm	2.60	1.34	0.32	175-665	0.52	29.17
CPI(B) \$15.8-28.2k pm	1.88	0.96	0.16	470-830	0.37	27.70
CPI(C) \$28.2-61.5k pm	1.46	0.62	0.10	615-1340	0.27	26.66

Clearly, energy costs are of the order of 3% of household expenditure, and even less as a percentage of household income. In relation to the cost of financing or renting a home in Hong Kong energy costs are not significant items of household expenditure other than for perhaps those in the low income group residing in public housing.

<sup>52</sup> Census and Statistics Department. Hong Kong Property Review, Monthly Supplement. March 2007.

<sup>53</sup> Hong Kong Housing Authority Annual Report 2006.

<sup>54</sup> Census and Statistics Department. Monthly Report on the Consumer Price Index. January 2007.

## 4 GREEN BUILDING ASSESSMENTS IN HONG KONG

There are several assessment schemes in Hong Kong promoted by HKSAR Government departments which certify particular aspects of the environmental performance of buildings. Most notably are EMSD's energy efficiency registration scheme<sup>[55]</sup>, and EPD's indoor air quality certification scheme<sup>[56]</sup>. Furthermore, in order to promote 'green and innovative buildings' the government issued several joint practice notes describing the incentives available to developers<sup>[57]</sup>.

HK-BEAM has been in use since 1996 to provide a comprehensive assessment of performance. With over one hundred major new and existing commercial developments and new high-rise residential developments have been assessed or are under assessment (Table 4.1).

**Table 4.1 Assessments under various versions of HK-BEAM**

HK-BEAM Version	Commercial/Other		Residential	
	Finalised	Provisional	Finalised	Provisional
1/96 1996	6	-	-	-
2/96 1996	11	-	-	-
1/96R 1999	26	-	-	-
2/96R 1999	18	-	-	-
3/99 1999	-	-	13	3
4/03 2003	1	4	1	4
5/03 2003	2	1	-	1
4/04 2004	-	18	-	8
5/04 2005	2	-	-	-
Totals	66	24	14	16

The Buildings Department's Comprehensive Environmental Assessment Scheme (CEPAS)<sup>[58]</sup> has recently been finalised, but its application is limited to trials undertaken by the CEPAS consultant. Whilst there is a considerable overlap between CEPAS and HK-BEAM assessment criteria<sup>[59]</sup>, the scoring system to establish the levels of award differ.

### 4.1 ASSESSMENTS UNDER HK-BEAM 1/96R (NEW OFFICES)

Assessments under HK-BEAM 1/96<sup>[4]</sup> and 1/96R<sup>[6]</sup> groups the various environmental issues covered under 'Global Issues and Use of Resources', 'Building and Local Issues', and 'Indoor Issues. The 1/96 version was the first attempt to develop an assessment tool for Hong Kong. The outcome was a localised version of BREEAM<sup>[27]</sup>, and somewhat limited by the resources, experience and data available locally at that time. Appendix A1 compares the assessment criteria found in the two versions. A number of changes were made in version 1/96R, including:



Versions 1/96 & 1/96R

- dropping OTTV as assessment criteria but with the number of energy use credits increased;

<sup>55</sup> Electrical & Mechanical Services Department. Energy Efficiency Registration Scheme for Buildings. [http://www.emsd.gov.hk/emsd/eng/pee/eersb\\_pub.shtml](http://www.emsd.gov.hk/emsd/eng/pee/eersb_pub.shtml)

<sup>56</sup> Environmental Protection Department. IAQ Certification Scheme. <http://www.iaq.gov.hk/>

<sup>57</sup> Joint Practice Notes on protection and improvement of the built and natural environment by Buildings Department, Lands Department and Planning Department. [http://www.bd.gov.hk/english/documents/index\\_joint.html](http://www.bd.gov.hk/english/documents/index_joint.html)

<sup>58</sup> Buildings Department. [http://www.bd.gov.hk/english/documents/index\\_CEPAS.html](http://www.bd.gov.hk/english/documents/index_CEPAS.html)

<sup>59</sup> PCICB Secretariat. Comparison between CEPAS and HK-BEAM. Working Document BP/005. June 2006.

- additional credit regarding use of ozone depleting substances;
- additional credits under recycled materials;
- reduced number of credits for metering and monitoring;
- additional credits under hazardous materials;
- daylighting criteria changed; and
- total number of credits increased from 56 to 59.

#### 4.1.1 CREDITS UNDER HK-BEAM 1/96R

Credits are awarded where standards or defined performance criteria are satisfied. Version 1/96R includes 59 credits. To achieve 'Satisfactory' rating required 40% or more of the available credits, 'Good' required 55% or more, 'Very Good' 65% or 39 or more, and achieving 'Excellent' required at least 75% or 44 of the available credits. The Fig. 4.1 shows the average scores for the 18 buildings used in this cost-benefit study which were assessed under HK-BEAM 1/96R. The compliance with global and indoor issues was somewhat better than for the local issues.

Appendix A2 lists the assessed issues and credits allocated in HK-BEAM 1/96R (in comparison with the issues and credits in HK-BEAM 4/04 as applied to office buildings).

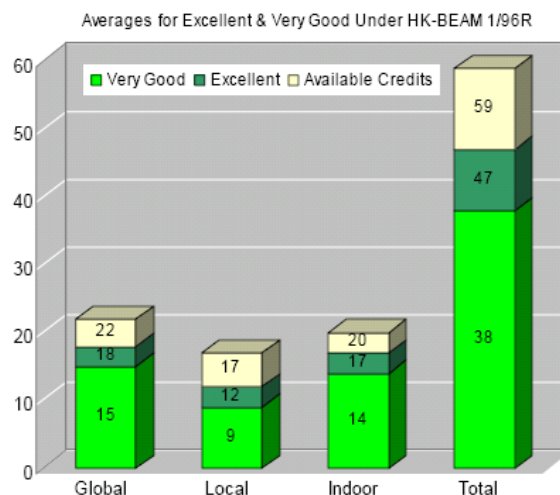
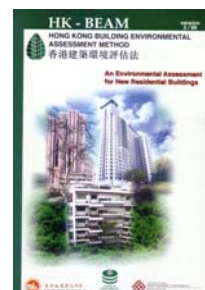


Fig. 4.1 Average credit scores for HK-BEAM 1/96R assessments

## 4.2 ASSESSMENTS UNDER HK-BEAM 3/99 (RESIDENTIAL)

This 1999 version<sup>[8]</sup> of HK-BEAM was the first assessment tool for residential buildings in Hong Kong, and one of the first attempts world-wide to assess high-rise residential buildings. The method was developed within a similar framework as HK-BEAM 1/96R (New Offices).

Assessment groups the various environmental issues covered under; 'Site Planning and Layout', 'Building and Premises Design', 'Materials Use and Specifications', 'Construction Practice', and 'Commissioning'. However, in the summary table credits are listed under; 'Global Issues and Use of Resources', 'Building and Local Issues', and 'Indoor Issues. The numbering sequence of credits used in the Stage I report followed that used in the 3/99 checklist.



Version 3/99

#### 4.2.1 CREDITS UNDER HK-BEAM 3/99

HK-BEAM version 3/99 includes 80 credits, including 2 'conditional' credits, up to 5 bonus credits (that count towards the award, but not the total credits), and an 'additional' credit. The 80 credits

break down to 31 'global', 29 'local', and 20 'indoor'. However, as some credits are deemed 'not applicable' (NA) for some projects (e.g. where an EIA is mandatory the credits were excluded, 'contaminated land' was NA to all but one project, and 'greywater recycling for flushing' NA for most projects) the number of credits applicable to the various projects varied between 71 and 79 with an average around 75.

Version 3/99 certifies a particular grade of performance if the total number of credits earned lies within a predefined range. The 'Fair' grade is awarded if 30-44% of the total number of applicable credits (71-79) is satisfied, a 'Good' grade if 45-59% are satisfied, a 'Very Good' grade if 60-69% are satisfied, and 'Excellent' grade if 70% or more are met. For consistency, the Stage II study assumed clients attempt to earn the minimum total number of credits for attaining a particular grade of performance, e.g. 60% for a 'Very Good' grade, etc.

Appendix A3 lists the credits in HK-BEAM 3/99 (in comparison with the credits under HK-BEAM 4/04 that apply to residential buildings).

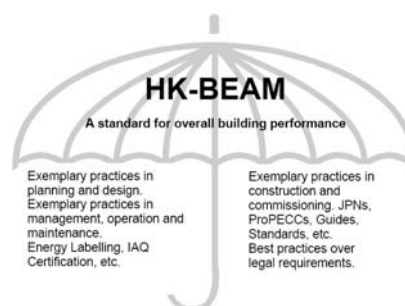
### 4.3 ASSESSMENTS UNDER HK-BEAM 'NEW BUILDINGS' 4/04

HK-BEAM 4/04<sup>[9]</sup> defines performance criteria for a range of sustainability issues relating to the planning, design, construction, commissioning, management and operation and maintenance of all types of new and refurbished buildings. Assessments under version 4/04 groups the various sustainability issues covered under 'Site Aspects', 'Materials Aspects', 'Energy Use', 'Water Use', and 'Indoor Environmental Quality'. Version 4/04 is a substantial upgrade compared to versions 1/96R and 3/99. A companion method HK-BEAM 5/04 covers 'Existing Buildings'.



Version 4/04

HK-BEAM embraces a range of good practices in planning, design, construction, and management, operation and maintenance of buildings, and is aligned with local regulations, standards and codes of practice. HK-BEAM emphasises indoor environmental quality and amenities as key performance indicators, but not without proper consideration of the local, regional and global environmental impacts. The Client ultimately decides whether obtaining a HK-BEAM label is a worthwhile endeavour, but completion of a HK-BEAM assessment provides assurances as to particular qualities of a building.



#### 4.3.1 BUILDING TYPES

HK-BEAM 4/04 covers all types of buildings, from small single buildings to large buildings on residential and commercial estates. The assessment embraces various types of premises that may be contained within a development, including premises that are only a 'shell' and not fitted-out. Whatever the circumstances, assessment focuses on what the designer, builder and commissioning authority achieves. Assessment of some aspects of performance may be building type dependent, or not feasible for various reasons, so the number of applicable credits and their aggregation will vary. This is taken into account in determining the performance grade.

The numbering sequence of credits in this report follows that used in the HK-BEAM 4/04 checklist as shown in Table 4.2.

Most of the issues listed under site aspects, materials and water use will not vary significantly with the type of building. However, the assessment of energy use in a building housing a variety of uses and building services systems and equipment is a complex process given the number of influencing variables. For the purpose of assessment HK-BEAM classifies buildings/premises into those that are:



- a) (centrally) air-conditioned; or
- b) mechanically ventilated, or
- c) designed to utilise natural ventilation.

Indoor issues included in HK-BEAM are those aspects of building performance that impact on the health, comfort or well-being of the occupants, as well as aspects of performance that improve quality and functionality. Assessment of IEQ differs for typical air-conditioned buildings where the principle is to 'build-tight and ventilate right', from buildings that may use natural ventilation when outdoor conditions permit.

**Table 4.2 Credits and summary of cost impacts for HK-BEAM 4-04 assessments**

Credit Ref:	SITE ASPECTS	Office		Resident'l		Comments
		C	P	C	P	
Credit 2.1.1	<b>Land Use</b> - Uses reclaimed land	1	0,M>H	1	0,M>H	There is no inherent cost premium, either the credit(s) obtained or not, depending on circumstances
	<b>Land Use</b> - Uses Brownfield site	2		2		
Credit 2.1.2	<b>Contaminated Land</b>	1	0,M>H	1	0,M>H	Conditional - Not applicable to Greenfield sites
Credit 2.1.3a	<b>Local Transport</b> - Car parking provisions	1	0	1	0	
Credit 2.1.3b	<b>Local Transport</b> - Pedestrian access to public transport	1	0	1	0	
Credit 2.1.4a	<b>Neighbourhood Amenities</b> - Basic neighbourhood services	1	0+>L	1	0+>L	
Credit 2.1.4b	<b>Neighbourhood Amenities</b> - Recreational facilities	1	0+>L	1	0+>L	
Credit 2.1.4c	<b>Neighbourhood Amenities</b> - Provided recreational facilities	1	L>M	1	L>M	
Credit 2.2.1	<b>Site Design Appraisal</b>	1	L	1	L	
Credit 2.2.2	<b>Ecological Impact</b>	1	L>M	1	L>H	
Credit 2.2.3	<b>Cultural Heritage</b>	1	L	1	L	
Credit 2.2.4a	<b>Landscaping and Planters</b> - Hard landscaping	1	0+	1	0+	
Credit 2.2.4b	<b>Landscaping and Planters</b> - Soft landscaping	1	0+	1	0+	
Credit 2.2.5a	<b>Microclimate around Buildings</b> - Wind amplification	1	U	1	U	
Credit 2.2.5b	<b>Microclimate around Buildings</b> - Elevated temperatures	1	U	1	U	
Credit 2.2.6a	<b>Overshadowing and Views</b> - Minimum daylight	1	0+	1	0+	
Credit 2.2.6b	<b>Overshadowing and Views</b> - Negative impacts	2	0+	2	0+	
Credit 2.2.7	<b>Vehicular Access</b>	1	0	1	0	
Credit 2.2.8	<b>Demolition/ Construction Management Plan</b>	1	0+	1	0+	
Credit 2.3.1	<b>Air Pollution During Construction</b>	1	0+	1	L	
Credit 2.3.2	<b>Noise During Construction</b>	1	0	1	0	
Credit 2.3.3	<b>Water Pollution During Construction</b>	1	0+	1	0+	
Credit 2.3.4	<b>Emissions from Cooling Towers</b>	1	0+	1	0+	
Credit 2.3.5	<b>Noise from Building Equipment</b>	1	0+>L	1	0+	
Credit 2.3.6	<b>Light Pollution</b>	1	0+	1	0+	
Credit Ref:	MATERIALS ASPECTS	C	P	C	P	Comments
Credit 3.1.1	<b>Building Reuse</b> - 15% existing sub-structure or shell	1	0	1	0	Conditional - excludes reclaimed land/Greenfield sites
	<b>Building Reuse</b> - 30% existing sub-structure or shell	2		2		
Credit 3.1.2	<b>Modular and Standardized design</b>	1	0	1	0	
Credit 3.1.3	<b>Off-site Fabrication</b> - 50% of listed elements	1	L>M	1	L>M	
	<b>Off-site Fabrication</b> - 80% of listed elements	2		2		
Credit 3.1.4a	<b>Adaptability and Deconstruction</b> - Structural adaptability	1	M	1	M>H	
Credit 3.1.4b	<b>Adaptability and Deconstruction</b> - Spatial adaptability	1	M	1	M>H	
Credit 3.1.5	<b>Envelope Durability</b>	1	0	1	0	
Credit 3.2.1	<b>Rapidly Renewable Materials</b>	1	L>M	1	L>M	
Credit 3.2.2a	<b>Sustainable Forest Products</b> - Timber for temporary works	1	L>M	1	M	
Credit 3.2.2b	<b>Sustainable Forest Products</b> – Used in the building	1	0+	1	0+	
Credit 3.2.3a	<b>Recycled Materials</b> - Outside surface works	1	0	1	0	
Credit 3.2.3b	<b>Recycled Materials</b> – Building structure	1	0+	1	0+>L	
Credit 3.2.4a	<b>Ozone Depleting Substances</b> – Refrigerants	1	0	1	0	
Credit 3.2.4b	<b>Ozone Depleting Substances</b> – Materials	1	0>L	1	0>L	
Credit 3.3.1a	<b>Demolition Waste - Waste management</b>	1		1		Conditional - either not required or not under client's control, cost implication of these credits will be excluded
Credit 3.3.1b	<b>Demolition Waste - Sorting and recycling</b>	1		1		
Credit 3.3.1c	<b>Demolition Waste - Quantity of recycled waste - &gt;50%</b>	1		1		
	<b>Demolition Waste - Quantity of recycled waste - &gt;75%</b>	2		2		
Credit 3.3.2a	<b>Construction Waste</b> - Waste management	1	0+	1	0+	
Credit 3.3.2b	<b>Construction Waste</b> - Sorting and recycling	1	0+	1	0+>L	
Credit 3.3.2c	<b>Construction Waste</b> - Quantity of recycled waste	1	0+	1	0+	
Credit 3.3.3	<b>Waste Disposal and Recycling Facilities</b>	1	0+	1	0+>L	
Credit Ref:	WATER USE	C	P	C	P	Comments
Credit 5.1.1a	<b>Water Quality</b> - Fresh water plumbing	1	0	1	0	
Credit 5.1.1b	<b>Water Quality</b> – Water quality survey	1	0+	1	0+	
	<b>Annual Water Use</b> - Less 15%	1	0+	1	L	
Credit 5.2.1	<b>Annual Water Use</b> - Less 25%	2	0+>L	2	L>M	
	<b>Annual Water Use</b> - Less 35%	3	0+>L	3	L>M	
Credit 5.2.2	<b>Monitoring and Control</b> - 2 features	1	0+>L	1	0+>M	
	<b>Monitoring and Control</b> - all 3 features	2	0+>L	2	L>M	
Credit 5.2.3	<b>Water Efficient Irrigation</b>	1	U	1	U	Conditional on landscaping area less than 50%
Credit 5.2.4a	<b>Water Recycling</b> - Harvesting rainwater	1	0+	1	L	
Credit 5.2.4b	<b>Water Recycling</b> - Greywater recycling	1B	0+	1B	M	
Credit 5.2.4c	<b>Water Recycling</b> - Recycled water	1B	L	1B	M	
Credit 5.2.5a	<b>Water Efficient Facilities &amp; Appliances</b> - Facilities	1	0+	1	0+	Conditional on whether facilities/appliances installed by client
Credit 5.2.5b	<b>Water Efficient Facilities &amp; Appliances</b> - Appliances	1	0+>L	1	L>M	
Credit 5.3.1	<b>Effluent Discharge to Foul Sewers</b>	1	0+	1	0+	

Credit Ref:	ENERGY USE	C	P	C	P	Comments
Credit 4.1.1a	<b>Annual Energy Use</b> - Annual energy consumption	1>4 5>6 7>10	0+>L M H			1 > 10 credits for 10% > 45% estimated reduction Applies only to curtain wall buildings
Credit 4.1.1b	<b>Annual Energy Use</b> - Maximum electricity demand	1 2>3	0+>M H			1 > 3 credits for 15 > 30% estimated reduction Applies only to curtain wall buildings
Credit 4.1.4a	<b>Annual Energy Use</b> - Annual energy consumption			8	L>H	1 > 8 credits for 3% > 22% estimated reduction
Credit 4.1.4b	<b>Annual Energy Use</b> - Maximum electricity demand			3	0+>M	1 > 3 credits for 8 > 15% estimated reduction
Credit 4.2.1	<b>Embodied Energy in Building Structural Elements</b>	2	0	2	0	1 > 2 credits for 10 > 15% reduction
Credit 4.2.4	<b>Hot Water Supply Systems</b>			1	M	
Credit 4.2.5	<b>Lift and Escalator Systems</b>	1	0	1	0	Conditional on more than one elevator
Credit 4.2.6	<b>Electrical Systems</b>	1	0	1	0	
Credit 4.2.7	<b>Renewable Energy Systems</b>	3B	L>H	3B	L>H	Conditional on location: 2 > 6% urban or 4 > 12% others
Credit 4.3.1a	<b>Air-conditioning Units</b> - Positioning of units			1	U	
	<b>Air-conditioning Units</b> - Heat rejection			1	U	
Credit 4.3.1b	<b>Air-conditioning Units</b> - Additional installation requirements			1	0+>M	
Credit 4.3.2	<b>Clothes Drying Facilities</b>			1	L	
Credit 4.3.3	<b>Energy Efficient Lighting in Public Areas</b>	1	0+	1	0+	
Credit 4.3.6	<b>Energy Efficient Appliances</b>			1	0>L	Conditional on client providing appliances
Credit 4.4.1a	<b>Testing and Commissioning</b> – Commissioning specifications	1	0+			
Credit 4.4.1b	<b>Testing and Commissioning</b> – Commissioning plan	1	L>M			
Credit 4.4.1c	<b>Testing and Commissioning</b> – Commissioning	1	0+	1	0+	
Credit 4.4.1d	<b>Testing and Commissioning</b> – Commissioning report	1	0+	1	0+	
Credit 4.4.2a	<b>Operation &amp; Maintenance</b> - O & M manual	1	0+			
Credit 4.4.2b	<b>Operation &amp; Maintenance</b> - Energy management	1	0+			
Credit 4.4.2c	<b>Operation &amp; Maintenance</b> - Operator training & facilities	1	0+	1	0+	
Credit 4.4.3	<b>Metering &amp; Monitoring</b>	1	L	1	0+	
<b>Credit Ref:</b>	<b>INDOOR ENVIRONMENTAL QUALITY</b>	<b>C</b>	<b>P</b>	<b>C</b>	<b>P</b>	
Credit 6.1.1a	<b>Fire Safety</b> - Design integration	1	0	1	0	
Credit 6.1.1b	<b>Fire Safety</b> - Fire safety manual	1	0	1	0	
Credit 6.1.2	<b>Electromagnetic Compatibility</b>	1	0+	1	0+	
Credit 6.1.3	<b>Security</b>	1	0	1	0	
Credit 6.2.1	<b>Plumbing &amp; Drainage</b>	1	0	1	0	
Credit 6.2.2	<b>Biological Contamination</b>	1	0+			
Credit 6.2.3	<b>Waste Disposal Facilities</b>	1	0+	1	L>M	
Credit 6.3.1a	<b>Construction IAQ Management</b> - Implementation	1	0+			
Credit 6.3.1b	<b>Construction IAQ Management</b> - Filter replacement/flush out	1	0			
Credit 6.3.2a	<b>Outdoor Sources of Air Pollution</b> - Carbon monoxide	1	0+	1	0+	
Credit 6.3.2b	<b>Outdoor Sources of Air Pollution</b> - Nitrogen dioxide	1	0+	1	0+	
Credit 6.3.2c	<b>Outdoor Sources of Air Pollution</b> – Ozone	1	0+	1	0+	
Credit 6.3.2d	<b>Outdoor Sources of Air Pollution</b> – RSP	1	0+	1	0+	
Credit 6.3.3a	<b>Indoor Sources of Air Pollution</b> – VOCs	1	0+	1	0+	
Credit 6.3.3b	<b>Indoor Sources of Air Pollution</b> - Formaldehyde	1	0+	1	0+	
Credit 6.3.3c	<b>Indoor Sources of Air Pollution</b> - Radon	1	0+	1	0+	
Credit 6.3.4	<b>IAQ in Car Parks</b>	1	0+	1	0+	Conditional on whether enclosed car park included
Credit 6.3.5	<b>IAQ in Public Transport Interchanges</b>	1	0+	1	0+	Conditional on whether PTI included
Credit 6.4.1a	<b>Ventilation in air-conditioned premises</b> - Ventilation rate	1	0+			
Credit 6.4.1b	<b>Ventilation in air-conditioned premises</b> - Air change	1	0+			
Credit 6.4.2	<b>Background Ventilation</b> - Windows closed			1	M	
	<b>Background Ventilation</b> - Natural means			1	M	
Credit 6.4.3	<b>Uncontrolled ventilation</b> - Air tightness			2B	0+	
Credit 6.4.4a	<b>Localised Ventilation</b> - Source control	1	0+	1	L	
Credit 6.4.4b	<b>Localised Ventilation</b> - Local exhaust	1				Cost implication of this credit will be excluded
Credit 6.4.5a	<b>Ventilation in Common Areas</b> - Ventilation provided	1	0+	1	L	
Credit 6.4.5b	<b>Ventilation in Common Areas</b> - Use of natural ventilation	1B	0+	1B	L	
Credit 6.5.1a	<b>Thermal Comfort</b> - Temperature (zero occupancy)	1	0+			
	<b>Thermal Comfort</b> - Temperature (simulated full-load)	1				
Credit 6.5.1b	<b>Thermal Comfort</b> - Room air distribution	1	0+			
Credit 6.5.2a	<b>Thermal Comfort</b> - Performance with natural vent. - >80%			1	0+	
	<b>Thermal Comfort</b> - Performance with natural vent. - >90%			2	0+	
Credit 6.5.2b	<b>Thermal Comfort</b> - Performance with air conditioning			1	0+	
Credit 6.6.1	<b>Natural Lighting</b> - VDF or 0.5% DF	1	0+	1	0+	
	<b>Natural Lighting</b> - 1% DF	2	0+	2	0+	
	<b>Natural Lighting</b> - 2% DF	3	0+	3	0+	
Credit 6.6.2a	<b>Interior Lighting in Occupied Areas</b> - Illuminance	1	0+			
Credit 6.6.2b	<b>Interior Lighting in Occupied Areas</b> - Limited glare	1	0+			
	<b>Interior Lighting in Occupied Areas</b> - Modulating output	1	0+			
Credit 6.6.3	<b>Interior Lighting in Areas not Normally Occupied</b>	1	0	1	0	
Credit 6.7.1	<b>Room Acoustics</b>	1	0+	1	0+	
Credit 6.7.2	<b>Noise Isolation</b> - Airborne noise isolation	1	L>M	1	L>M	
	<b>Noise Isolation</b> - Impact noise isolation	1	L>M	1	L>M	
Credit 6.7.3	<b>Background Noise</b>	1	0>H	1	0>H	
Credit 6.7.4	<b>Indoor Vibration</b>	1B	0+>L	1B	0+	
Credit 6.8.1	<b>Access for Persons with Disability</b>	1	0+	1	0+	
Credit 6.8.2a	<b>Amenity Features</b> - For building users	1	U	1	U	
Credit 6.8.2b	<b>Amenity Features</b> - For improved O & M	1	U	1	U	
Credit 6.8.3	<b>IT Provisions</b>	1	U	1	U	
<b>Credit Ref:</b>	<b>INNOVATION AND PERFORMANCE ENHANCEMENTS</b>	<b>C</b>	<b>P</b>	<b>C</b>	<b>P</b>	
Credit 7.1	<b>Innovation Techniques</b>	5B	U	5B	U	
Credit 7.2	<b>Performance Enhancements</b>					

### Performance Grades in HK-BEAM 4/04

The Overall Assessment Grade is based on the percentage (%) of applicable credits gained. It is also necessary to obtain a minimum percentage (%) of credits for IEQ in order to qualify for the overall grade. The award classifications are:

	Overall	IEQ	(Versions 1/96R and 3/99)
Platinum	75%	65%	(Excellent)
Gold	65%	55%	(Very Good)
Silver	55%	50%	(Good)
Bronze	40%	45%	(Above average)

### 4.3.2 CREDITS UNDER HK-BEAM 4/04

Of more than 134 credits listed in Table 4.2, including 'bonus' credits and 'innovative' (bonus) credits, only a proportion apply to a particular building type. Also, the number of 'applicable credits' will vary according to the particular circumstances of a new building project.

As can be seen from Table 4.3, the likely number of credits (excluding 'bonus' credits) that apply to an office-type building is 112-127, around double the number (59) in HK-BEAM 1/96R covered in Stage I of the study. One reason is that a number of assessments in HK-BEAM 4/04 go beyond environmental performance to include broader sustainable issues such as amenity, safety, accessibility, etc. Appendix A2 contrasts the assessment criteria under HK-BEAM 4/04 (as applied to an office building) with those under HK-BEAM 1/96R. Similarly, the number of credits for a high-rise residential building will be 104-120, significantly more than the average of 75 for HK-BEAM 3/99 covered in Stage II of the study. Appendix A3 compares the assessment criteria under HK-BEAM 4/04 (as applied to a high-rise residential building) with those under HK-BEAM 3/99.

**Table 4.3 Types of credits in HK-BEAM 4/04**

All Buildings	Total credits	Core	Specific	Bonus
Site Aspects	25	22	3	0
Materials Aspects	23	17	6	0
Water Use	14	9	3	2
Innovations and Additions	5	0	0	5
<b>Office Building</b>				
Energy Use	29	25	1	3
Indoor Environmental Quality	43	39	2	2
Total	139	112	15	12
<b>Residential Building</b>				
Energy Use	29	24	2	3
Indoor Environmental Quality	38	32	2	4
Total	134	104	16	14

#### Prerequisites

Other than compliance with prevailing legislation and in respect of the assessment of annual energy use, HK-BEAM 4/04 does not include prerequisite requirements within the assessment. Should legislation change affected credits would be modified to take account of the changes.

#### Core credits

These may be regarded as being applicable to all building types. Most of the credits listed under 'Site Aspects', 'Materials Aspects' and 'Water Use' will apply in all assessments. Many of the credits listed under 'Energy Use' and 'IEQ' are also common to different building types, but there is clear demarcation between buildings that are designed to be fully air-conditioned, usually using central plant, and those that are designed to use natural ventilation for some periods of use, so 'core' credits differ between the two categories.

#### Specific credits

Although some core credits are conditional on whether a building is likely to use natural ventilation, this category refers to credits that are affected by other circumstances, such as the nature of the site, building type, or the specific systems or equipment provided. For example, contaminated

land remediation and building reuse do not apply to buildings on Greenfield sites, and water features or appliances may not be installed by developers.

#### *Bonus credits*

In the development of HK-BEAM 4/04 it was considered that certain 'green building' attributes, e.g. use of renewable energy, are highly desirable but expensive provisions with long and unattractive pay-back periods. To include such features as part of the core assessment would make more difficult the attainment of a given grade so, in order to encourage adoption, these credits are awarded as a bonus. This means that they do not count within the total of available credits, yet count towards the credits obtained. In Table 4.2 these credits are identified with the suffix 'B'.

Table 4.3 provides a summary of the credits that apply to a) a typical centrally air-conditioned office building, i.e. the 'generic' office building used in this study, and b) a high-rise residential building using unitary air-conditioners. The particular circumstances of a project, identified during initial phase of the assessment process, may make a number of credits inapplicable. The award of fractions of a credit is also possible under HK-BEAM.

## 5 ENERGY USE ASSESSMENTS

As discussed in Section 3 energy costs are relatively small compared to building construction costs and total occupancy costs but, given the concerns over global warming and climate change, energy efficiency has come under renewed scrutiny. Life cycle energy use in buildings includes the embodied energy of the structure and services (including cyclical replacements) and the operating energy. For large air-conditioned buildings operating energy is by far the dominant component, although for high-rise residential buildings embodied energy is a more significant proportion<sup>[60]</sup>.

### 5.1 ENERGY USE IN BUILDINGS IN HONG KONG

Data on energy end-use<sup>[61]</sup> in Hong Kong's buildings shows that consumption in both the commercial and residential sectors is increasing (Fig. 5.1). In the commercial sector the energy use in offices is significant but comparatively less so than consumption in the retail and catering sectors (Fig. 5.2).

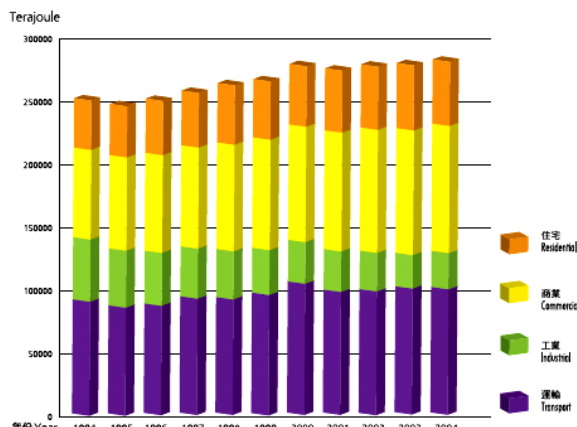


Fig. 5.1 Hong Kong energy end-use in 2004 by sector<sup>[61]</sup>

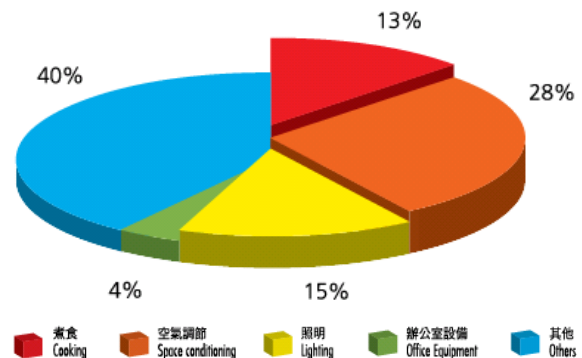


Fig. 5.2 Commercial energy end-uses 2004<sup>[61]</sup>

#### 5.1.1 ENERGY USE IN AIR-CONDITIONED OFFICE BUILDINGS

Whole building energy use is usually separated into two components: *base* building energy use for servicing the building, and *tenant* energy use. The base building (owner/operator) energy consuming servicing includes:

- heating, ventilation and air-conditioning (HVAC) services;
- transportation (lifts and escalators);
- public area lighting and small power; and
- central hot water supply systems.

Tenant loads generally include:

- lighting systems; and

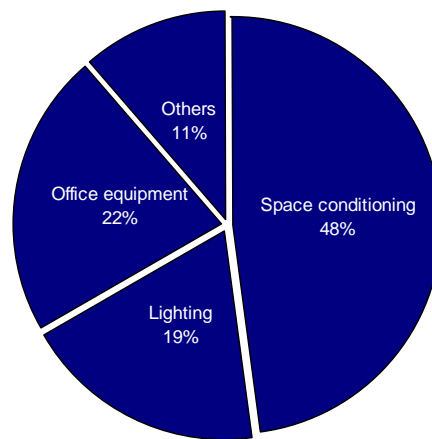
<sup>60</sup> Chen T Y, Burnett J, Chau C K. Analysis of embodied energy use in the residential building of Hong Kong Energy - The International Journal, Vol. 26, No. 4, 323-340, 2001.

<sup>61</sup> Electrical & Mechanical Services Department. Hong Kong Energy End-use Data. September 2006.

- small power loads to workstations and other office equipment.

In Hong Kong's sub-tropical climate air-conditioning energy dominates (Fig. 5.3). The design principle is 'build tight, ventilate right'. Energy is required to overcome the *internal* heat gains from people, equipment, lighting, the external heat gains, and to condition incoming outside air. HVAC systems energy consumption includes chillers, pumps, fans, etc. *External heat gains* include solar gains through fenestration (windows) and conductive heat gains through opaque surfaces (walls, roof).

External heat gains are dependent on weather conditions, inter-shadowing effects of a building and adjacent buildings, facade design, pattern of use, temperature set points, infiltration, etc. Good façade design should seek a balance between reducing solar gains and effectively using daylight whilst avoiding solar glare.



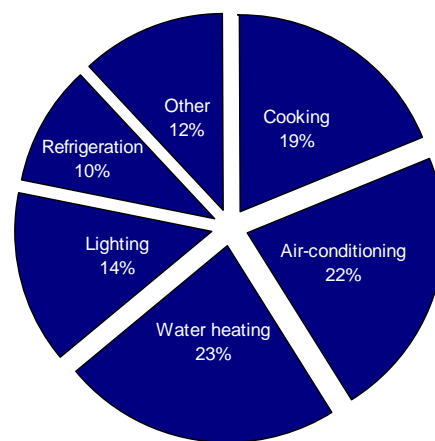
**Fig. 5.3 Energy end-uses in offices segment 2004<sup>[61]</sup>**

Lighting and office equipment in air-conditioned areas make a significant contribution to total building energy use as well as the space cooling load. The patterns of occupancy, lighting use and equipment use vary depending on the nature of the activities, e.g. staff may be absent whilst workstation lighting remains on, and equipment is left on or on standby. In air-conditioned buildings the design, maintenance and operation of the building and HVAC systems has a significant impact on energy use, but so too does the choice of lighting systems and office equipment and the manner of their use.

### 5.1.2 ENERGY USE IN RESIDENTIAL BUILDINGS

As Fig. 5.4 shows the energy consumption in Hong Kong's residential sector is dominated by water heating, air-conditioning and cooking, which are mostly influenced by lifestyle and affordability.

Whilst good building design has the potential to reduce air-conditioning energy use by reducing heat gains through the building envelope during summer and encouraging the use of natural ventilation and daylight, significant reductions in energy use depends on the occupants, i.e. the services they require and the frequency of use. There is the possibility of reducing energy consumption through the use of more efficient appliances (refrigerators, lighting, etc), and through conservation, i.e. switching items off when not required, as this will not detract from the services provided.



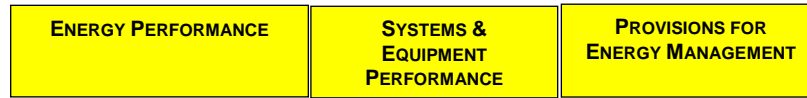
**Fig. 5.4 Energy use in residential segment in 2004<sup>[61]</sup>**

## 5.2 ENERGY USE ASSESSMENTS

Fig. 5.5 illustrates the categories of energy use assessments typically found in BEAMs wherein:

- performance is an assessment of design enhancements for the *assessed* building compared to a *baseline* building, based on detailed calculations and/or computer simulation (modelling);
- features that improve energy efficiency or provide for energy conservation, e.g. heat reclaim, or features that help with maintaining performance in use, e.g. monitoring/metering; and

- provisions for management, operation, maintenance and use, including O&M manuals, tenant fitting-out guide, etc.



**Fig. 5.5 Energy use assessments in building environmental assessment methods**

### 5.2.1 ENERGY PERFORMANCE CRITERIA

In BEAMs energy performance is generally expressed in terms of *annual energy use*, either as *site* energy or *source* energy or emissions, depending on whether it is intended to be an assessment of the design, an estimation of energy consumption during use, or an estimation of the environmental loadings:

- An assessment of the energy efficiency of the building and building services systems designs relative to that of a 'baseline' building which marginally complies with regulations, using default or average occupancy patterns, equipment power densities, and typical weather year, with the criteria based on kWh or MJ measured at the site boundary.
- An estimation of the energy performance in use requires more accurate estimates of occupancy patterns, equipment power densities, control strategies and weather conditions, with the criteria based on kWh or MJ at the site boundary.
- An assessment of the environmental impact includes the consumption of primary energy and CO<sub>2</sub> and other emissions, which are dependent on the efficiency of energy conversion and the treatment of emissions at the 'source'.

For all-electric buildings, expressing performance in terms of kWh/m<sup>2</sup>/annum, MJ/m<sup>2</sup>/annum or kgCO<sub>2</sub>/m<sup>2</sup>/annum is largely a matter of preference when *average* or normalised emission factors are used, rather than the actual emissions which depend on fuel mix and efficiency of conversion at the utility. In Hong Kong the two electricity suppliers China Light & Power and Hongkong Electric differ in respect of generating plant and fuel mix leading to significantly different emissions per unit of electrical energy delivered. Clearly, a building has less environmental impact when supplied from a 'more efficient' and 'cleaner' utility, as CO<sub>2</sub> emissions depend on thermal (conversion) efficiency of generating plant, and RSP, NO<sub>x</sub>, and SO<sub>x</sub> emissions depend on the fuel used and effectiveness of flue gas treatment. Conversely, when supplied from a less efficient energy source reducing site energy results is a proportionally greater reduction in emissions and primary energy consumption.

For buildings where there significant non-electrical energy source, such as a hotel or a hospital using gas or oil, the performance can be expressed in MJ or CO<sub>2</sub><sup>e</sup> (CO<sub>2</sub> equivalent). In addition, any on-site renewable energy is deducted from the estimated energy use for the assessed building, or may be accounted for in a separate assessment, or both (double counting).

### 5.2.2 ENERGY MODELLING

Detailed energy modelling is not general practice in building and system design, but with appropriate assumptions energy use simulations can provide a good indication of the likely improvements in energy performance achievable through design enhancements.

Most assessments focus on the estimated performance improvement for the designed (assessed) building compared to the baseline building (usually expressed as a percentage). As they are outside the control of the designer the simulation will likely use *default* values for occupancy patterns, equipment and lighting use patterns (but not power densities) for *both* the baseline building and the assessed building, as prescribed by the assessment method. The simulation will define default values for temperature set-points, lighting power, equipment load, and occupancy densities, ventilation rate, and certain minimum values for such things as equipment efficiency (e.g. minimum performance of chillers), insulation levels, etc. for the *baseline* building. In practice a simulation usually uses a typical weather year, which may differ from the year(s) when energy consumption is actually measured. Simulation for the designed (assessed) building is based on

design values, or as-built values. Performance enhancement can come from the use of more efficient equipment, reduced lighting and small power densities, and energy conserving features and controls (e.g. daylight saving).

When regulatory codes are different the baseline building will also differ between jurisdictions. For example, in the US the baseline building defined in LEED-NC version 2.1 is ASHRAE 90.1 (1999) compliant, whereas in California the baseline building is Title 24 compliant. This leads to different percentages in estimated performance gains. A building is assessed to be 20% more efficient than ASHRAE 1999, it will be assessed as 12% more efficient against Title 24<sup>[62]</sup>. As codes or standards change, then baseline conditions also change. LEED-NC version 2.2 uses ASHRAE 90.1 (2004) which differs from the 1999 version, so percentage gains in version 2.2 differ from version 2.0 and 2.1.

### Limitations

Simulations can provide a reasonable estimate of percentage performance gain of an assessed (as designed) building compared to a code compliant building, but often underestimates (sometimes by a significant margin) *actual* annual energy consumption. There are a number of reasons for the discrepancies.

- The software used for the simulation (which should be validated against a standard such as ASHRAE 140<sup>[63]</sup>), the experience of the user, the data and assumptions made, etc. can impact significantly on the outcome (number of points or credits achieved).
- The assumed set-points (e.g. temperature settings) and equipment operating schedules used in the simulation may be (are often) changed by building operators or building users.
- Additional equipment 'hot spots' like computer data centres may add significant loads that are not covered by the simulation.
- Energy modelling software generally assumes perfect control of HVAC and lighting systems, which can be a major error, as actual systems are unlikely to operate so perfectly.
- Simulations may not take into account the impact of oversized main plant and equipment or the deterioration in performance over time or because of inadequate maintenance.
- Simulations assume as-designed or as-built performance specifications are met, but this is often not the case when testing and commissioning is inadequate.
- The impact of adjacent buildings (shading, overshadowing, etc) is not usually taken into account.
- Simulations often do not include energy consuming systems such as lifts, exterior and public area lighting and ventilation, water heating, car park lighting and ventilation, etc (which may be accounted for separately in BEAM assessments).

Furthermore, simulations do not usually include estimates of maximum electricity demand, unless linked to software that includes system design and equipment sizing, e.g. HK-BEAM's use of BECON (as described below).

## 5.3 HK-BEAM ENERGY USE ASSESSMENTS FOR OFFICE BUILDINGS

As knowledge, experience and available data have increased it has resulted in changes to the assessment criteria and assessment methods in the three versions of HK-BEAM that apply to office buildings. The philosophy adopted has been consistent, that is, to reward enhancements that reduce the energy consumption (and maximum demand) at the site, i.e. metered energy consumption. Because hotel buildings which can use a variety of energy sources (gas, oil, electricity) assessment of annual energy use (energy efficiency) is based on MJ, but for office buildings where electricity is the dominant energy source it is based on kWh. Table 5.1 compares the energy assessment criteria in versions 1/96R (1999) and 4/04 (2004) as applied to centrally air-conditioned office buildings.

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<sup>62</sup> Ely Associates for California Energy Commission. Comparison of ASHRAE/IESNA Standard 90.1-1999 and the 2001 California Nonresidential Energy Efficiency Standard.

<sup>63</sup> American Society of Heating, Refrigeration and Air-Conditioning Engineers. ASHRAE 140-2001. Standard Method of test for the Evaluation of Building Energy Analysis Computer Programs.



**Table 5.1 Energy assessments in versions 1/96R and 4/04 for office buildings**

HK-BEAM 4/04	NEW BUILDINGS (OFFICE RELATED CREDITS ONLY)	HK-BEAM 1/96R NEW OFFICES	Credits
Section:	Credit Requirement:	Section:	Credit Requirement:
<b>4 ENERGY USE</b>			
4.1.1 ANNUAL ENERGY USE IN COMMERCIAL BUILDINGS	1 to 10 credits for a reduction in the annual energy consumption by 10% to 45%.	10	2.1 D) ELECTRICAL ENERGY CONSUMPTION
	1 to 3 credits for a reduction in the maximum electricity demand by 15% to 30%.	3	3.1 ELECTRICITY MAXIMUM DEMAND
			2.1 B) ELECTRICAL ENERGY CONSUMPTION
4.2.1 EMBODIED ENERGY IN BUILDING STRUCTURAL ELEMENTS	1 credit for demonstrating the embodied energy in the major elements of the building structure of the assessed building is reduced by 10%. 2 credits for demonstrating a reduction by 15%.	2	
4.2.4 HOT WATER SUPPLY SYSTEMS	1 credit for installing energy efficient hot water supply system(s) and equipment that can save 20% or more energy.	1	
4.2.5 LIFT AND ESCALATOR SYSTEMS	1 credit for complying with the Code of Practice for Energy Efficiency of Lift and Escalator Installations.	1	
4.2.6 ELECTRICAL SYSTEMS	1 credit for complying with the Code of Practice for Energy Efficiency of Electrical Installations.	1	
4.2.7 RENEWABLE ENERGY SYSTEMS	1 credit where 2%/4% or more of building energy is obtained from renewable energy sources. 2 credits where 4%/8% of building energy is obtained from renewable energy. 3 credits where 6%/12% of building energy is obtained from renewable energy.	3B	
4.3.3 ENERGY EFFICIENT LIGHTING IN PUBLIC AREAS	1 credit for installation of: energy efficient lighting equipment, and control for the lamps in areas where daylight is available.	1	2.1 A) ELECTRICAL ENERGY CONSUMPTION
4.3.4 HEAT RECLAIM	1 credit for using heat reclaim chillers or heat pumps for: pre-heating domestic hot water supply; or pre-heating hot water supply for winter space heating.	1	2.1 C) ELECTRICAL ENERGY CONSUMPTION
4.4.1 TESTING AND COMMISSIONING	1 credit for provision of appropriate specifications and cost provisions in contract documents detailing the commissioning requirements for all systems and equipment that impact on energy use and indoor environmental quality.	1	
	1 credit for the appointment of a commissioning authority and provision of a detailed commissioning plan that embraces all specified commissioning work.	1	
	1 credit for ensuring full and complete commissioning of all systems, equipment and components that impact on energy use and indoor environmental quality.	1	4.2 HVAC SYSTEM COMMISSIONING
	1 credit for providing fully detailed commissioning reports for all systems, equipment and components that impact on energy use and indoor environmental quality.	1	
4.4.2 OPERATION AND MAINTENANCE	1 credit for providing a fully documented operations and maintenance manual to the minimum specified.	1	
4.4.3 METERING AND MONITORING	1 credit for providing fully documented instructions that enables systems to operate at a high level of energy efficiency.	1	4.3 OPERATIONS AND MAINTENANCE
	1 credit for: providing training for operations and maintenance staff to the minimum specified; and demonstrating that adequate maintenance facilities are provided for operation and maintenance work.	1	
	1 credit for installation of: metering that allows monitoring of electricity use by the main chiller plant and auxiliaries; instruments for monitoring building cooling load and operating parameters central chiller plant; metering that allows separate monitoring of electricity use by the air side of the HVAC system; and metering for landlord's electricity consumption in common space/public areas.	1	4.1 A) METERING AND MONITORING EQUIPMENT
			4.1 B)
			4.1 C)

**Relevance of OTTV to Energy Efficiency**

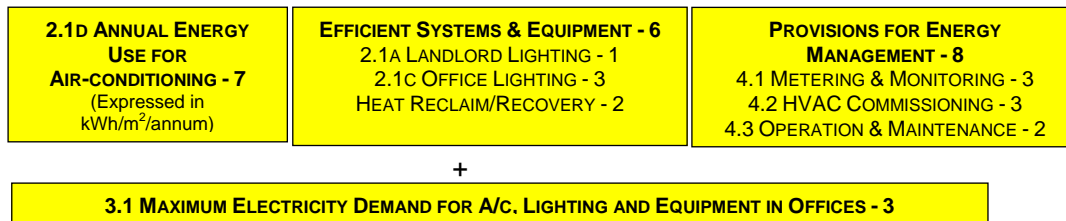
In deep plan office buildings, the façade can be effective in controlling external heat gains and comfort in the perimeter zone but due to the dominant impact of all internal heat gains, may account for only 10-15% of the total cooling load. Consequently, OTTV, which provides a measure of external heat gains, does *not* give a good indication of total energy use in large air-conditioned buildings. This leads to the conclusion that, in such circumstances, OTTV is rather ineffective as an energy efficiency regulation. For this reason the inclusion of OTTV criteria in HK-BEAM 1/96 was removed from the 1/96R version and subsequent versions.

**5.4 ENERGY USE ASSESSMENTS IN VERSION 1/96R (NEW OFFICES)**

In version 1/96R and its predecessor version 1/96 the criteria for electrical energy consumption was listed under *global* issues, maximum demand under *local* issues and provisions for management operation and maintenance under *indoor* issues (Table 5.1). The OTTV criteria in HK-BEAM 1/96 (1996) was discarded in favour of revised energy use criteria in HK-BEAM 1/96R (1999) using kWh/m<sup>2</sup>/year criteria. The lighting power density criteria in 1/96R remained

essentially the same (see Appendix A1).

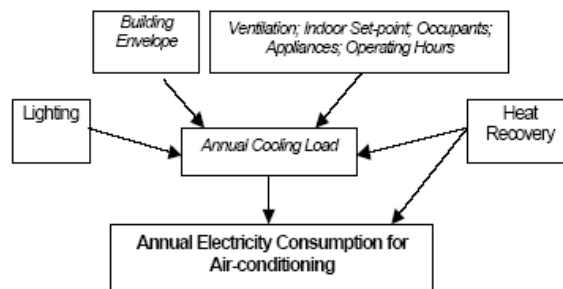
As illustrated in Fig. 5.6 the 24 energy related credits in HK-BEAM 1/96R includes 14 performance-based credits for energy efficient air-conditioning and lighting(including 3 credits for maximum electricity demand), 2 credits for heat reclaim 'features', and 7 credits for the provisions for operation and maintenance (metering, commissioning, etc). It was possible to achieve 10 credits without undertaking detailed energy analysis/modelling and 3 more for a relatively simple lighting design study.



**Fig. 5.6 Energy assessments in HK-BEAM 1/96R (New Offices)**

### *Annual Energy Use for Air-conditioning*

The method of assessment is directed at three major components associated with the air conditioning electricity load (Fig. 5.7). The first is the design office lighting load, which contributes to the space cooling load. The second is associated with provisions for recovering any energy used by the air-conditioning system, and the last concerns the overall efficiency of the building envelope and the air conditioning equipment. The latter involves the consideration of the combined efficiency of the refrigeration units, fans and pumps, and other related systems, e.g. the space/water heating system.



**Fig. 5.7 Assessment of annual energy use for air-conditioning in HK-BEAM 1/96R**

The performance criteria for air-conditioning energy consumption (2.1d) awards 1 to 7 credits for performance of 150 kWh/m<sup>2</sup>/annum reducing to 90 kWh/m<sup>2</sup>/annum. The criterion for lighting energy consumption is based on lighting power density with gaining 1 to 3 credits for performance of 21 W/m<sup>2</sup> down to 15 W/m<sup>2</sup>.

#### **5.4.1 ASSESSMENT OF ANNUAL ENERGY USE AND MAXIMUM DEMAND BY SIMULATION**

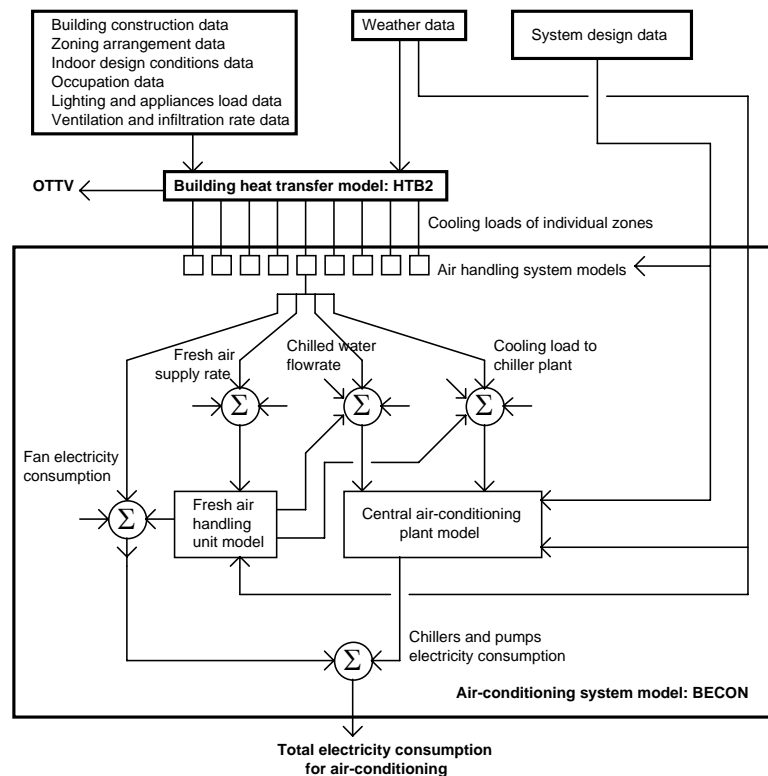
The procedures for air-conditioning load calculation was defined on the basis of cooling load estimations using the building heat transfer model HTB2, and the air-conditioning system model BECON (Fig. 5.8)<sup>[64]</sup>.

##### *HTB2 Software*

HTB2 is a computer program designed for simulation of the thermal performance of buildings. Within HTB2, a building is regarded as comprising a series of spaces linked to each other and to the outside by elements (walls, windows) and ventilation paths. This building is driven by the

<sup>64</sup> Yik F W H, Burnett J, Jones P, Lee W L. Energy performance criteria in the Hong Kong Building Environmental Assessment Method. Energy and Buildings. Vol. 27, 207—219, 1998.

external climate, by heating/cooling system(s) operating under control system(s), and by a network of incidental heat sources. The full range of thermal processes in a building is modelled by the explicit finite difference method.



**Fig. 5.8 Process for energy use modelling in HK-BEAM**

HTB2 allows the user the flexibility to adjust equipment operation schedule, ventilation rate and intensity of the incidental heat sources (occupants, lighting, and appliance loads) to model conditions that will arise in a building in different days. This can be done through appropriate inputs in the relevant input files (the Diary File and the Diary Pages). The time-steps used in the simulation can also be set by the user as far as the stability limit governed by the thermodynamic properties and the sub-division thicknesses of the fabric elements is not violated. HTB2 outputs full details of fabric element states, heat transfer rates and space environmental conditions at regular intervals within the simulation period (the duration between intervals is specified by the user). The hourly space cooling loads of various spaces are extracted and used as the basis for determining the electricity consumption for air-conditioning in a building.

#### *BECON Software*

BECON is a plant simulation program which acts as a postprocessor of HTB2. On the basis of the space cooling load output from HTB2, BECON will calculate the required supply flow rate for individual zones, the total air flow rate to be supplied by individual air-handling equipment, the coil loads on the air-handling equipment, the fan power consumption of individual air-handling equipment, the chilled water flow rate at individual air-handling equipment, the total chilled water flow rate to be supplied by the chilled water pumps, the total cooling load on the chiller plant, the number of chillers and pumps (and cooling towers, where appropriate) to be operated to cope with the load, the power consumption of the main equipment, the total electricity consumption of the entire system, the annual electricity consumption of the system, and the peak electricity consumption of the system and its time of occurrence.

BECON can model the performance of a variety of air-conditioning systems and equipment. This includes, at the air-side, fan-coil systems, all-air constant volume and variable volume systems (with constant and variable speed fans) and, at the water side, single- and two-loop pumping system designs (with constant and variable speed pumps). The component models included are

steady-state models obtained from curve-fitting performance data with operating parameters.

### Defaults

Default data is defined for the benchmark or baseline building, together with occupancy patterns and design criteria. The assessed building would have design improvements but the same occupancy pattern as the baseline building. The assessment would comprise two simulations, where the assessed building is compared with the baseline building (Fig. 5.10). An assessment of maximum electricity demand is also included.

**Table 5.2 Establishing baseline air-conditioning electricity consumption in version 1/96R**

Parameters	For establishing criteria	For assessing a building
Outdoor weather conditions	Weather data of year 1999	
Indoor design conditions:		Design criteria for the building
Cooling    Indoor dry-bulb temperature	25.5 °C	
Indoor relative humidity	54 %	
Heating    Indoor dry-bulb temperature	22.0 °C	
Indoor relative humidity	Not specified	
Normal occupation periods:		
Weekdays	9:00 - 17:00	
Saturdays	9:00 - 13:00	
Sundays and public holidays	Not occupied	
Maximum occupation density	9 m <sup>2</sup> per person	Design criteria for the building
Schedule of occupation densities for various hours in the day (in fractions of the maximum density)	As shown in Table A2	As shown in Table A2
Ventilation rates:		Design criteria for the building As shown in Table A2
When ventilation system is on	10 l/s per person	
When ventilation system is off	0	
Operating hours of ventilation system		
Infiltration rates:		
When ventilation system is on	0.1 air change/hr.	
When ventilation system is off	0.5 air change/hr.	
Maximum lighting load and ratio of heat-of-light to space	25 W/m <sup>2</sup>	Design criteria for the building
Lighting load at various occupied and unoccupied hours in fraction of max. lighting load	As shown in Table A2	As shown in Table A2
Maximum appliances load (assumed constant load)	25 W/m <sup>2</sup>	Design criteria for the building

### Design Variables

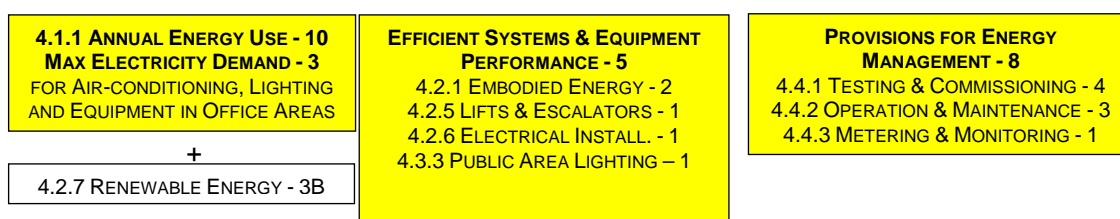
From Table 5.2 it can be seen that the baseline building has as a default indoor dry-bulb temperature of 25.5°C, ventilation rate of 10 l/s per person, maximum occupancy density of 9m<sup>2</sup> and lighting and equipment loads both as 25W/m<sup>2</sup>. These become the design variables for the assessed building. Consequently, a design based on a more preferred temperature of 23°C is 'penalised'. Furthermore, version 1/96R assumes the heat rejection method is by air-cooled plant, consequently buildings using water (seawater) cooled plant gain a significant advantage.

As HK-BEAM 1/96R does not state minimum requirements for energy use buildings can achieve a relatively good grade such as 'Very Good' (65% of the 59 available credits) or 'Excellent' (75%) without scoring well on energy use, even none at all for annual energy consumption.

## 5.5 ENERGY USE ASSESSMENTS IN VERSION 4/04 FOR OFFICE BUILDINGS

As can be seen from Table 5.1 and Fig. 5.9 the Energy Use assessments for air-conditioned buildings have been upgraded in comparison with assessments in version 1/96R. The total credits

is 26 (about 23%) for 4/04 (for office buildings), against 24 (41%) for 1/96R. In HK-BEAM 4/04 the lighting and office equipment energy use is included in the estimation of annual energy use and maximum electricity demand (by simulation). Additional credits deal with embodied energy, efficient equipment, and renewable energy.



**Fig. 5.9 Energy assessments in HK-BEAM 4/04 (Office buildings)**

### *Energy Related Credits in HK-BEAM 4/04*

Of the 25 ‘core’ and 1 ‘specific’ credits (excluding bonus credits), up to 10 are for annual energy use, 3 for electricity maximum demand, 2 for embodied energy, 3 for energy efficient systems in the core building (excluding hot water supply), 8 for provisions for management operation and maintenance. Of these 15 are performance-based. Whilst the energy modelling approach for air-conditioning energy use has remained essentially the same as for version 1/96R the original kWh/m<sup>2</sup>/year criteria has been replaced with percentage gain using the energy budget approach (Fig. 5.10).

### **5.5.1 ENERGY BUDGET APPROACH**

Assessment of annual energy use for air-conditioned buildings in HK-BEAM 4/04 is very similar to that used in the Performance-based Building Energy Code (PBEC)<sup>[55]</sup>. However, an assessment under the PBEC is a pass/fail assessment, whereas a HK-BEAM assessment quantifies the level of performance improvement (and also includes estimation of electricity maximum demand within the simulation). Certification under the PBEC automatically qualifies for one credit under HK-BEAM, irrespective of the simulation software and default values used. For a HK-BEAM assessment the simulation software and default values used must meet the requirements stipulated in HK-BEAM. Where an assessment under HK-BEAM uses software approved under the PBEC then the outcome of the assessment can also be used in a submission for certification under the PBEC.

The Energy Budget assessment includes the following energy uses:

- air-conditioning energy use for the building; and
- lighting and equipment energy use in air-conditioned spaces.

These energy uses are interrelated and together dominate the overall energy use in an air-conditioned building. Computer simulation is taken as the generic method for the prediction of the energy use and maximum electricity demand for air-conditioning. The performance of the building envelope design is indirectly assessed as the air-conditioning energy use is partly dependent on the heat gains from the envelope. The energy use and maximum electricity demand for lighting and equipment is predicted based on the installed power, the operating hours and the pattern of use for each.

The energy budget for the Assessed Building is the predicted annual energy use for the Baseline Building (zero-credit benchmark). The baseline has the same shape and dimensions, mix of premises, as the assessed building except for window-to-wall ratio which is adjusted to meet the OTTV regulatory requirements. The defaults for the Baseline Building are such that it barely meets relevant regulatory requirements or basic design standards. Notwithstanding, the specified minimum criteria for some design aspects (e.g. fan power), the predicted annual energy use of the Assessed Building is based on its specific design or as-built features.

Other energy uses in buildings that do not have an impact on the air-conditioning energy use, such as for lighting installations in non-air-conditioned public areas and services plant rooms, for lift and escalator installations, hot water supply, etc. and energy losses in the electrical

installations are assessed under features and performance of systems and equipment (Table 5.1).

### Heat Rejection

A significant change introduced in version 4/04 is that the baseline building adopts the same heat rejection method as the assessed building. This was introduced to encourage assessment of buildings using air-cooled plant which otherwise would be penalised when compared to those using water cooled plant. Buildings using water cooled plant are inherently more efficient than buildings using air-cooled plant. Conversely, energy efficiency improvements in the latter type of building save a greater amount of energy.

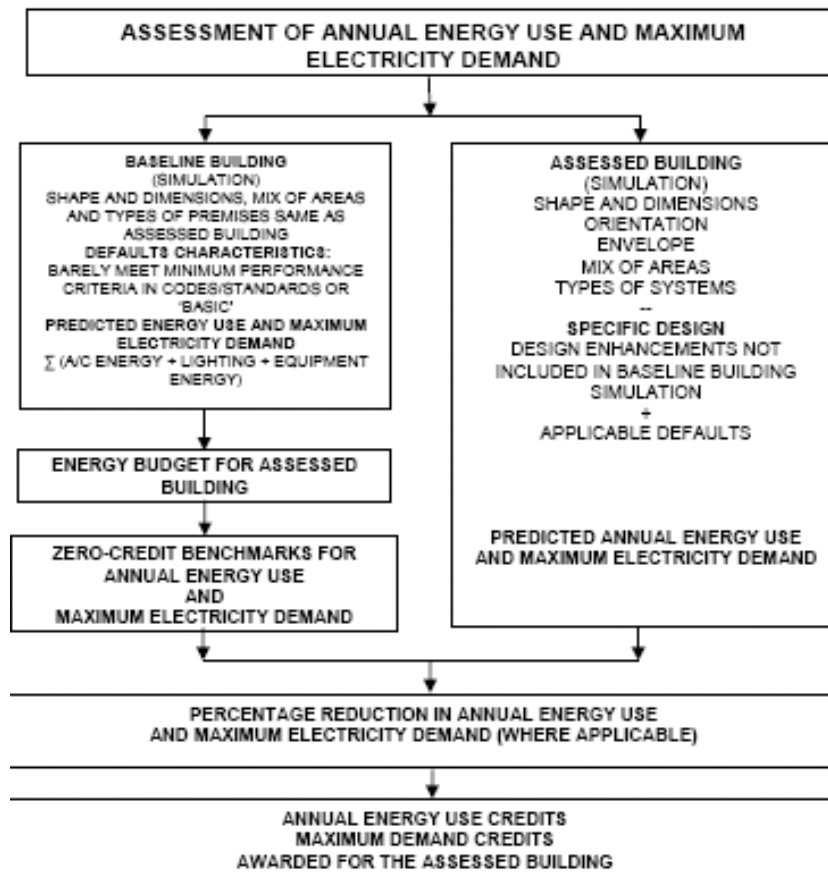


Fig. 5.10 Energy performance assessment in HK-BEAM 4/04

### Design Variables

In HK-BEAM 4/04 the Baseline Building has as a default indoor dry-bulb temperature of 23°C, which is a departure from 25.5°C in version 1/96R. The other design variables are the same as 1/96R, i.e. ventilation rate of 10 l/s per person, maximum occupancy density of 9m<sup>2</sup> and lighting and equipment loads both as 25 W/m<sup>2</sup>, which relate to design values typically found in practice. Table 5.3 gives the assumed patterns of occupancy, fresh air supply, lighting and equipment loads assumed for office premises.

### Assessment of Annual Energy Use and Maximum Demand by Simulation

The procedures for air-conditioning load calculation was defined on the basis of cooling load estimations using the building heat transfer model HTB2, and the air-conditioning system model BECON (Fig. 5.8).

Default data is defined for the Baseline Building, together with occupancy patterns and design criteria. The Assessed Building would have design improvements but the same occupancy pattern as the Baseline Building. The assessment would comprise two simulations, where the Assessed Building is compared with the Baseline Building. Maximum electricity demand reduction for air-conditioning is also estimated.

**Table 5.3 Default patterns of occupancy, fresh air supply and equipment loads for offices**

Hour From	To	Occupancy	Fresh Air Supply	Infiltration rate (ach)	Lighting (Perimeter)	Lighting (Interior)	Equipment
<b>Weekdays</b>							
0	6	0.00	Off	0.50	0.05	0.05	0.10
6	7	0.00	Off	0.50	0.05	0.05	0.10
7	8	0.05	Off	0.50	0.10	0.10	0.15
8	9	0.40	On	0.10	0.50	0.50	0.50
9	10	0.95	On	0.10	0.90	1.00	1.00
10	11	0.95	On	0.10	0.90	1.00	1.00
11	12	0.95	On	0.10	0.90	1.00	1.00
12	13	0.95	On	0.10	0.90	1.00	1.00
13	14	0.45	On	0.10	0.80	0.90	0.80
14	15	0.95	On	0.10	0.90	1.00	1.00
15	16	0.95	On	0.10	0.90	1.00	1.00
16	17	0.95	On	0.10	0.90	1.00	1.00
17	18	0.50	On	0.10	0.80	0.80	0.60
18	19	0.25	On	0.10	0.50	0.50	0.40
19	20	0.10	Off	0.50	0.30	0.30	0.20
20	21	0.05	Off	0.50	0.20	0.20	0.15
22	23	0.00	Off	0.50	0.05	0.05	0.10
23	24	0.00	Off	0.50	0.05	0.05	0.10
<b>Saturdays</b>							
0	7	0.00	Off	0.50	0.05	0.05	0.05
7	8	0.05	Off	0.50	0.10	0.10	0.15
8	9	0.30	On	0.10	0.50	0.50	0.50
9	13	0.60	On	0.10	0.75	0.80	1.00
13	17	0.10	Off	0.50	0.20	0.20	0.20
17	18	0.05	Off	0.50	0.10	0.10	0.10
18	24	0.00	Off	0.50	0.05	0.05	0.05
<b>Sundays and Public Holidays</b>							
0	9	0.00	Off	0.50	0.05	0.05	0.05
9	17	0.05	Off	0.50	0.10	0.10	0.10
17	24	0.00	Off	0.50	0.05	0.05	0.05

(1) Occupancy, lighting load and equipment load patterns are in fractions of their respective peak values.

## 5.6 DIFFERENCES BETWEEN VERSIONS 1/96R AND 4/04

Major differences in regard to the energy assessments under 1/96R and 4/04 are highlighted in Table 5.4. Under 1/96R, separate assessments were conducted for assessing annual electricity use by HVAC loads and lighting loads. Seven credits would be given for a building that could achieve a reduction in annual air-conditioning (HVAC) consumption from 150 kW/m<sup>2</sup>/year to 90 kW/m<sup>2</sup>/year. On the contrary, 4/04 assessments are based on the aggregated annual electricity use by HVAC system, lighting system, and office equipment (small power loads). Up to 10 credits are awarded for a reduction in the annual energy use by HVAC system, lighting system, and equipment, which is equivalent to a 45% reduction when compared to the Baseline Building adopted in version 4/04.

Besides the scope and credit awarding mechanism, the specification standard of the Baseline Building adopted for 4/04 has also been modified in response to the change in the energy efficiency requirements in PNAP 172<sup>[65]</sup> and the Code of Practice for Energy Efficiency of Electrical Installations<sup>[55]</sup>. The modification is deemed necessary as the original baseline building defined for the 1/96R could no longer meet the change in code requirements in the two following aspects:

<sup>65</sup> Buildings Department. Practice Note for Authorized Persons and Registered Structural Engineers, PNAP 172, Energy Efficiency of Buildings Building (Energy Efficiency) Regulation. 2000.

- OTTV value of the baseline building for 1/96R does not meet 30 W/m<sup>2</sup> as laid down by the PNAP 172. In response to this, the specification standard of the Baseline Building for 4/04 has to be modified so as to reduce the OTTV value from 34.7 to 30 W/m<sup>2</sup>.
- Motor efficiencies for pumps and fans have to be upgraded from 75% to a minimum of 84% as required by the Code of Practice for Energy Efficiency of Electrical Installations.

**Table 5.4 Comparison of energy performance assessments in versions 1/96R and 4/04**

	<b>1/96R</b>	<b>4/04</b>
Scope of energy assessments	Assessments were based on annual electricity use by HVAC loads only. Separate assessments would be conducted for assessing the internal lighting power intensity.	Assessments are based on the annual electricity use by the HVAC, lighting systems and equipment
Total number of credits awarded	7 credits would be given for a reduction in the annual HVAC consumption level from 150 kW/m <sup>2</sup> /year to 90 kW/m <sup>2</sup> /year. 3 separate credits were given for reducing the internal lighting power intensity from 21 to 15 W/m <sup>2</sup> .	10 credits will be given for a 45% reduction with respect to the total electricity consumption due to HVAC equipment and lighting loads in the baseline building. No extra credit will be given for any lighting or equipment power intensity reduction.
Energy use benchmark for the baseline building	All the examined office buildings would be compared against the baseline office building that adopted the air-cooled heat rejection method	Different energy benchmarks for different type of commercial buildings. Buildings adopting different heat rejection methods will be assessed under different energy use benchmarks

Other than these two changes, there are also some minor changes, e.g. indoor temperature, being introduced for the Baseline Building in 4/04 (Table 5.5). Version 4/04 allows for separate energy benchmarks for buildings that use air-cooled or water-cooled heat rejection methods, as it was decided that a penalty should not be imposed on buildings that cannot access a water source for heat rejection purposes. After incorporating all these changes, the annual HVAC energy consumption level of the Baseline Building that adopted air-cooled heat rejection method changes from 138 kW/m<sup>2</sup>/year in version 1/96R to 123 kW/m<sup>2</sup>/year in version 4/04.

**Table 5.5 Comparison of specifications for the baseline building in 1/96R and 4/04**

Design System/Criteria	<b>1/96R</b>	<b>4/04</b>
Heat rejection method of HVAC system for baseline building	Air-cooled rejection method was adopted for the HVAC system in the baseline building.	Air cooled systems and water cooled systems are assessed separately under different benchmarks. The annual energy consumption of the assessed building will be compared against the baseline building with the same type of cooling system.
Indoor temperature	25.5°C	23°C
Motor efficiency	75%	84%
Coefficient of fan flow rate control	0.7	0.4
Fan power	15.4 W/m <sup>2</sup>	16.1 W/m <sup>2</sup>
Pump power	4.5 W/m <sup>2</sup>	4.0 W/m <sup>2</sup>

### 5.6.1 COMPARISON WITH AUDIT DATA

Based on the default values for occupancy, temperature set-points, ventilation rate given in Table 5.5 and operating schedules for lighting and equipment given in Table 5.3 (Appendix 8, HK-BEAM 4/04) the estimated annual energy use for air-conditioning is 123 kWh/m<sup>2</sup> for air-cooled heat rejection and 83 kWh/m<sup>2</sup> for water cooled heat rejection. Estimated annual energy consumption



for lighting and equipment are both about 78 kWh/m<sup>2</sup>. Consequently, the estimated total annual electricity use by HVAC system, lighting system and equipment becomes 280 kWh/m<sup>2</sup>/year for air-cooled and 240 kWh/m<sup>2</sup>/year for water cooled.

According to estimates by Ng and Deng<sup>[66]</sup> using another computer simulation the air-conditioning energy use is estimated as 140 kWh/m<sup>2</sup>. Lam et al's survey<sup>[67]</sup> of 20 large, medium and small air-conditioned office buildings revealed annual air-conditioning electricity consumption ranging from 65 kWh/m<sup>2</sup> to 193 kWh/m<sup>2</sup> with a mean of 130 kWh/m<sup>2</sup>. They found lighting energy use varied between 54 kWh/m<sup>2</sup> to 81 kWh/m<sup>2</sup>, and equipment load densities of between 20 to 26 W/m<sup>2</sup>. The average overall energy consumption for air-conditioning, lighting and equipment was reported to be 270 kWh/m<sup>2</sup>.

It is noted that air-conditioning estimates in HK-BEAM 4/04 are on the low side on account that the assessment assumes HVAC equipment meets the minimum performance specified in the air-conditioning code, and because operating schedules, controls and performance of equipment may not be that assumed in the simulation. In the assessment of existing air-conditioned buildings under HK-BEAM 5/04 an additional allowance of 50% is included for estimation of energy use to take into account these variations. On this basis the air-conditioning benchmarks change to 125 kWh/m<sup>2</sup> for water-cooled, and 185 kWh/m<sup>2</sup> for air-cooled, with overall consumption 282 kWh/m<sup>2</sup> to 342 kWh/m<sup>2</sup>. This does not include the 5-10% additional consumption for lifts, escalators, plumbing, etc. These estimates fall within the 200-400 kWh/m<sup>2</sup> range of energy use indices for large air-conditioned buildings in Hong Kong.

### Observations

The analysis demonstrates the problems in estimating total energy consumption for new air-conditioned office buildings, as much depends on the lighting and user equipment power densities and assumed operating schedules. It also demonstrates that besides good design, building owner/occupiers can make a big impact on energy consumption through choice of lighting systems and office equipment, and the way in which they are controlled or used. Good housekeeping practices in respect of equipment use, and implementation of available robust controls such as dimming ballasts for lighting, can achieve energy conservation<sup>[68]</sup>.

## 5.7 RESIDENTIAL BUILDING ENERGY ASSESSMENTS IN HK-BEAM

In high-rise residential buildings, the internal heat gains account for about a third of the total heat gains, with the external heat gains dominant in occupied rooms. Consequently, design of the building envelope is significant in reducing the cooling load and energy use. However, external heat gains also depend on orientation, height of a given unit, overshadowing by adjacent buildings, etc., requiring detailed analysis for any given case.

As Table 5.6 shows the assessment of the building design in version 3/99 focuses on the overall thermal transfer value (OTTV) of the building envelop:

$$\text{OTTV} = \frac{\text{Total heat gain through the building envelope during air-conditioned hours}}{\text{Total air-conditioned hours} \times \text{Envelope area}}$$

The definition highlights the fact that OTTV is based on use of space-conditioning in occupied rooms. Different assumptions on occupancy pattern, temperature set-points lead to different methods of calculating OTTV<sup>[69]</sup>. As walls at different orientations receive different amounts of solar radiation, the general procedure is to calculate the OTTVs of individual walls with the same orientation and construction first. The OTTV of the whole exterior wall is then given by the weighted average of these values.

<sup>66</sup> Ng I W H, Deng S. A Parametric Analysis on Energy and Cost Saving Potentials of Implementing Demand Side Management (DSM) Measures In Hong Long's Office Buildings. HKIE Trans. Vol. 9, No. 3, 34-38, 2002.

<sup>67</sup> Lam J C, Chan R Y C, Tsang C L, Li D H W. Electricity use characteristics of purpose-built office buildings in subtropical climates. Energy Conversion and Management, Vol. 45, 829-844, 2004.

<sup>68</sup> Chung T M, Burnett J, Wu M K T. Office Lighting Retrofit Using Dimmable Electronic Ballasts and Occupancy Controls. HKIE Trans. Vol. 8, No. 3, 8-15, 2001.

<sup>69</sup> Chow W K, Chan K T. Parameterization Study of the Overall Thermal-Transfer Value Equation for Buildings. Applied Energy, Vol. 50, 247-268, 1995.

**Table 5.6 Energy assessments in versions 3/99 and 4/04 for residential buildings**

HK-BEAM 4/04	New Buildings (Residential Related Credits Only)	Credits	HK-BEAM 3/99 High Rise Residential Buildings	Credits	
Section:	Credit Requirement:		Section:	Credit Requirement:	
<b>4</b>	<b>Energy Use</b>				
4.1.4 Annual Energy Use in Residential Buildings	1 to 8 credits for a reduction in the annual energy consumption by 3% to 22%. 1 to 3 credits for a reduction in the maximum electricity demand by 8% to 15%.	8 3	3.2 Overall Thermal Transfer Value	for an OTTV in bedrooms & other living rooms of less than 6 to 12 W/m <sup>2</sup> in bedrooms and 17 to 32 W/m <sup>2</sup> in other rooms	4
4.2.1 Embodied Energy in Building Structural Elements	For demonstrating the embodied energy in the major elements of the building structure of the assessed building is reduced by 10% OR for demonstrating a reduction by 15%.	2			
4.2.5 Lift and Escalator Systems	for complying with the Code of Practice for Energy Efficiency of Lift and Escalator Installations.	1	3.10 Energy Efficient Building Services Equipment	for complying with the requirements of the Code of Practice for Energy Efficiency of Lift & Escalator Installations	1
4.2.6 Electrical Systems	for complying with the Code of Practice for Energy Efficiency of Electrical Installations.	1		for complying with the requirements of the Code of Practice for Energy Efficiency of Electrical Installations	1
4.2.7 Renewable Energy Systems	1 BONUS credit where 2%/4% or more of building energy is obtained from renewable energy sources. 2 BONUS credits where 4%/8% of building energy is obtained from renewable energy. 3 BONUS credits where 6%/12% of building energy is obtained from renewable energy.	3B			
4.2.3 Clothes Drying Facilities	For providing suitable clothes drying facilities which utilise the natural environment for the majority of residential units	1	3.9 Clothes Drying Facilities	for providing suitable clothes drying facilities for the majority of residential units which utilise the natural environment	1
4.3.1 Air-conditioning Units	for complying with the recommended installation positions for air-conditioners with regard to internal spaces.	1	3.8 Air-conditioning Units	for complying with the recommended installation positions for air-conditioners as detailed in Appendix B.	1
	for complying with the minimum width of any external recess with regard to heat rejection. for complying with the items listed in the assessment check-list.	1 1		for complying with not less than four items in the assessment check-list. for complying with all items in the assessment check-list.	1 2
4.3.3 Energy Efficient Lighting in Public Areas	For installation of energy efficient lighting equipment, and control for the lamps in areas where daylight is available.	1	3.11 Public Area Lighting	for specifying and confirming installation of energy efficient lighting, in areas under the control of the building management	1
				for specifying and confirming installation of time switching or photoelectric switching lighting control for the lamps in areas where daylight is available	1
			3.12 Exterior Lighting	for specifying and confirming installation of energy efficient lighting, in areas under the control of the estate management (playgrounds, footpaths, services areas, walkways, etc)	1
				for specifying and confirming installation, in areas under the control of the estate management, of time switching or photoelectric switching lighting control for the lamps in areas where daylight is available	1
4.4.1 Testing and Commissioning	For ensuring full and complete commissioning of all systems, equipment and components that impact on energy use and indoor environmental quality.	1	6.1 Commissioning	for allowing as a cost item in the contract documents, a specific cost for commissioning of all electrical and mechanical systems and equipment to be maintained by the building owner/operator	1
	For providing fully detailed commissioning reports for all systems, equipment and components that impact on energy use and indoor environmental quality.	1			
4.4.2 Operation and Maintenance	For providing training for operations and maintenance staff to the minimum specified, and demonstrating that adequate maintenance facilities are provided for operations and maintenance work.	1		for allowing as a cost item in the contract documents, a specific cost for the preparation of fully documented operations and maintenance manual.	1
4.4.3 Metering and Monitoring	for installation of metering that allows monitoring of electricity use by the main chiller plant and auxiliaries; instruments for monitoring building cooling load and operating parameters central chiller plant, metering that allows separate monitoring of electricity use by the air side of the HVAC system, and metering for landlord's electricity consumption in common space/public areas.	1	6.3a Facilities	for specifying and installing metering which allows separate monitoring of electricity use (input power, energy and maximum demand) by the owner/operator of the building(s)	1
			6.4 Tenant/ Owner's handbook	for a well compiled guide on environmental issues included in a tenant/owner's handbook	1

From Lam et al<sup>[70]</sup>.

$$\begin{aligned}
 OTTV_i &= (Q_w + Q_g + Q_s)/A_i \\
 &= [(A_w \times U_w \times TD_{eq}) + (A_f \times U_f \times DT) + (A_f \times SC \times SF)]/A_i
 \end{aligned}
 \tag{1}$$

where,  $OTTV_i$  is the OTTV of walls with same orientation and construction ( $W/m^2$ );  $Q_w$ , heat conduction through the opaque walls ( $W$ );  $Q_g$ , heat conduction through the windows ( $W$ );  $Q_s$ , solar radiation through the windows ( $W$ );  $A_w$ , area of the opaque walls ( $m^2$ );  $U_w$ , U-value of the opaque walls ( $W/m^2K$ );  $TD_{eq}$ , equivalent temperature difference ( $K$ );  $A_f$ , area of fenestration ( $m^2$ );  $U_f$ , U-value of fenestration (the windows) ( $W/m^2K$ );  $DT$ , temperature difference between exterior and interior design conditions ( $K$ );  $SC$ , shading coefficient of fenestration;  $SF$ , solar factor for that orientation ( $W/m^2$ );  $A_i$ , gross area of the walls ( $m^2$ )= $A_w+A_f$ , and:

<sup>70</sup> Lam J C, Tsang C L, Li H W, Cheung S O. Residential building envelope heat gain and cooling energy requirements. Energy. Vol. 30, 933-951, 2005.

$$OTTV_{wall} = \frac{\sum(OTTV_i \times A_i)}{A_{tw}}$$

where,  $OTTV_{wall}$  is the OTTV of the whole exterior wall ( $W/m^2$ ) and  $A_{tw} = \sum(A_i)$  total gross exterior wall area ( $m^2$ ). Alternatively, (1) can be expressed in terms of window-to-wall ratio, WWR. Thus

$$OTTV_i = (1 - WWR) \times TD_{eq} \times U_w + WWR \times DT \times U_f + WWR \times SC \times SF$$

where, WWR is the ratio of window area to gross wall area =  $A_f/A_i$ . The approach and equations for calculating roof OTTV are similar to those for the walls.

### 5.7.1 ENERGY USE ASSESSMENTS IN VERSION 3/99 (RESIDENTIAL)

As Fig. 5.11 highlights the performance based energy use assessments in version 3/99 are limited to OTTV and an estimation of solar heat gain in apartments (by computer simulation), and comprise only 6 of the 21 credits available.

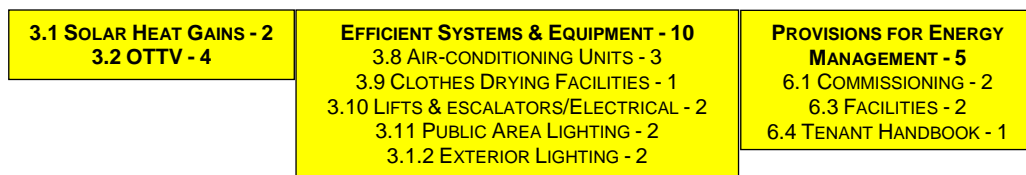


Fig. 5.11 Energy assessments in HK-BEAM 3/99 (Residential)

#### OTTV Criteria

Given that there are no standards for residential buildings in Hong Kong the OTTV assessment criteria in HK-BEAM 3/99 was derived from calculations on 30 selected residential buildings<sup>[71]</sup>, which revealed OTTV figures for bedrooms ranged from 5.9 to 17.1  $W/m^2$ . For air-conditioned living/dining rooms it was 16.9 to 34.9  $W/m^2$ .

### 5.7.2 ENERGY USE ASSESSMENTS IN VERSION 4/04 FOR RESIDENTIAL BUILDINGS

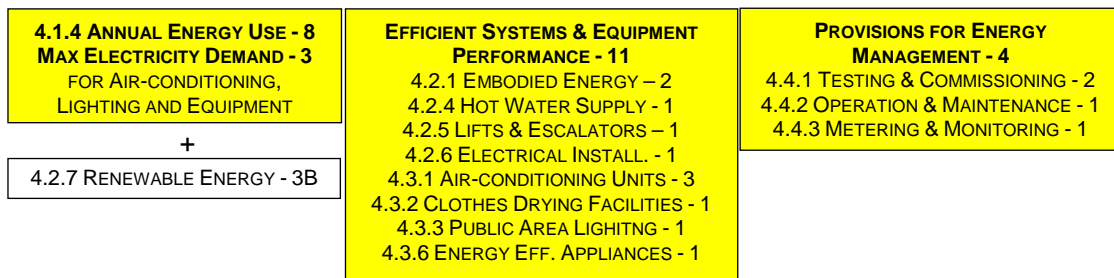


Fig. 5.12 Energy assessments in HK-BEAM 4/04 (Residential buildings)

In version 4/04 there are 24 'core' and 2 'specific' credits that apply to high-rise residential buildings, with an additional credit applicable if energy consuming appliances are installed by the developer. The bonus credits for renewable energy also apply (Fig. 5.12). Assessment of annual energy use and maximum electricity demand for air-conditioning and lighting is based on the energy budget approach similar to that used for air-conditioned buildings. Given that energy use for air-conditioning and lighting is not so dominant and the difficulty in influencing consumption through design in residential buildings the number of credits (8) and the percentage gains (up to 22%) are less than the criteria used for air-conditioned buildings. Because the base (core) building services are generally limited to plumbing and drainage, lifts, and electrical systems the credits assigned to energy management (4) are reduced compared to air-conditioned buildings.

<sup>71</sup> Yik F W H, Wan K S Y, Burnett J. Assessment of Envelope Energy Performance in HK-BEAM for Residential Buildings. HKIE Trans. Vol. 7, No. 2, 49-55, 2000.

### 5.7.3 ENERGY MODELLING FOR RESIDENTIAL BUILDINGS

Energy use for cooling depends on many factors, not least occupants use of equipment (hours of occupancy, set points, etc) so predictions require computer simulations. HK-BEAM uses simulation programmes HTB2 to predict cooling load, and BECREs to simulate performance based on window units or split units, and usage patterns based on survey data<sup>[72]</sup>.

There are specific conditions that apply to residential buildings, such as the method for quantifying the building envelope performance of the Baseline Building model and the use of standardised internal load intensities. For the prediction of annual energy use for air-conditioning in a residential building the months in the year that air-conditioners serving living rooms and bedrooms (the air-conditioned spaces) operate is taken to be April to October inclusive, and that air-conditioning will not be needed outside this period. The predicted annual energy use for lighting and equipment in these rooms shall be their total energy use throughout the year. The patterns of occupancy and operation of air-conditioners, lighting and equipment are given in Tables 5.7 and 5.8.

**Table 5.7 Usage patterns for living/dining rooms in residential flats**

Hour From	To	Occupancy (No./Rm)	AC Operation <sup>(2)</sup>	Fresh Air Supply	Infiltration rate (ach)	Lighting	Equipment (W/Rm)
0	5	0.00	Off			0.00	27
5	6	0.00	Off			0.00	27
6	7	0.00	Off			0.30	52
7	8	0.50	Off			0.50	77
8	9	1.00	Off			0.00	77
9	10	1.00	Off			0.00	77
10	11	1.00	Off			0.00	77
11	12	1.00	Off			0.00	77
12	13	0.90	Off			0.00	77
13	14	1.00	On			0.50	89
14	15	1.00	On	Note (3)	Note (4)	0.00	61
15	16	1.00	On			0.00	61
16	17	1.00	On			0.00	61
17	18	1.00	On			0.00	61
18	19	1.00	On			0.50	61
19	20	1.50	On			1.00	142
20	21	2.00	On			1.00	142
21	22	2.00	On			1.00	142
22	23	2.00	Off			1.00	142
23	24	0	Off			0.5	142

(1) Lighting load pattern is in fractions of the peak values. Occupancy and equipment load patterns are defined directly in number of persons per room and Watt per room.

(2) The air-conditioner operation pattern applies to all days in April to October inclusive. The assumption is made that Air-conditioners will not be used in other months in the year.

(3) Fresh air supply assumed to be absent.

(4) Infiltration rate assumed to be 0.5 air change per hour (ach) during air-conditioned periods and unoccupied periods. Infiltration rate assumed to be 3 ach during non-air-conditioned periods while indoor temperature stays at or below 22 °C and to be 12 ach when this temperature is exceeded.

In predicting the annual air-conditioning energy use in various flats in a high-rise residential building, the inter-shadowing effects among different parts of the same building and among different building blocks in the same development shall be taken into account. For simplicity, only four simulation calculations are carried out for a N-storey building, i.e. the Nth floor (the top floor), the (N-1)th floor, the (N-3)th floor (representing the (N-4)th to the (N-2)th floor), and the (N-10)th floor (representing the 1st floor to the (N-5)th floor). Such inter-shadowing effects will be ignored in predicting the annual air-conditioning energy use in the baseline building model.

The characteristics to be incorporated into the Baseline Building model include:

<sup>72</sup> An evaluation of the appropriateness of using overall thermal transfer value (OTTV) to regulate envelope energy performance of air-conditioned buildings. Yik F W H, Wan K S Y. Energy, Vol. 30, pp 41-71, 2005.

- envelope design features;
- indoor design conditions, ventilation rates, occupation densities and usage patterns;
- internal load intensities and usage patterns, and
- performance of air-conditioning systems and equipment

**Table 5.8 Usage patterns for bedrooms in residential flats**

Hour From	To	Occupancy (No./Rm)	AC Operation <sup>(2)</sup>	Fresh Air Supply	Infiltration rate (ach)	Lighting	Equipment (W/Rm)
0	1	2.00	On			0.30	36
1	5	2.00	On			0.00	0
5	6	2.00	On			0.00	0
6	7	2.00	On			0.50	0
7	8	0.50	Off			0.20	0
8	9	0.00	Off			0.30	0
9	10	0.00	Off			0.00	0
10	11	0.00	Off			0.00	0
11	12	0.00	Off			0.00	0
12	13	0.00	Off			0.00	0
13	14	0.50	On	Note (3)	Note (4)	1.00	0
14	15	0.50	On			1.00	15
15	16	0.50	On			1.00	15
16	17	0.50	On			1.00	15
17	18	0.50	On			0.00	15
18	19	0.50	On			1.00	15
19	20	0.50	On			1.00	36
20	21	1.00	On			1.00	36
21	22	1.00	On			1.00	36
22	23	1.00	On			1.00	45
23	24	2.00	On			0.6	45

(1) Lighting load pattern is in fractions of the peak values. Occupancy and equipment load patterns are defined directly in number of persons per room and Watt per room.

(2) The air-conditioner operation pattern applies to all days in April to October inclusive. The assumption is made that Air-conditioners will not be used in other months in the year.

(3) Fresh air supply assumed to be absent.

(4) Infiltration rate assumed to be 0.5 air change per hour (ach) during air-conditioned periods and unoccupied periods. Infiltration rate assumed to be 3 ach during non-air-conditioned periods while indoor temperature stays at or below 22 °C and to be 12 ach when this temperature is exceeded.

The Baseline Building model shall satisfy the minimum requirement of relevant regulations, code of practice, or those that are regarded in local practice as the basic requirements.

In devising the Baseline Building model for a new residential building, the major façade of each flat in the building is identified, which will be the group of external walls that are exposed to the same direction in which the aggregate window area is the largest amongst all groups of external walls (grouping determined with reference to the orientation of walls). Only external walls that enclose air-conditioned rooms in the flats are considered. In predicting the annual energy use and maximum electricity demand for the Baseline Building model, each flat in the building model is rotated such that its major façade will be facing west, the worst orientation in respect of solar heat gain in the flats. However, the layout design of flats in the building, including their respective orientations, are modelled 'as designed' in the prediction of the annual energy use of the Assessed Building.

The default indoor design conditions to be used for various types of premises in the Baseline Building model shall be as given in Table 5.9. These design indoor conditions correspond to the threshold design conditions as stipulated in the Code of Practice for Energy Efficiency of Air Conditioning Installations or, for those types of premises for which such threshold values are unavailable in the Code, to typical conditions found from surveys in existing buildings.

Prediction of the energy use in the Assessed Building shall be based on the corresponding equipment densities, occupation densities and ventilation rates adopted for the air-conditioning

system design, but the default indoor conditions and occupancy pattern still apply (Although the use of design ventilation rates that are lower than the default values will lead to a better outcome in the energy performance assessment, it is not advisable as it will lead to a worse outcome in the indoor air quality assessment).

**Table 5.9 Default conditions for the baseline building**

Type of Premises	Indoor design condition	Occupancy density	Ventilation rate	Lighting power intensity	Equipment power intensity
	(Temp. °C/RH %)	(m <sup>2</sup> /person)	(l/s-person)	(W/m <sup>2</sup> )	(W/m <sup>2</sup> )
<b>Residential flats</b>					
Bedrooms	22 / 50%	Note (1)	Note (2)	17	Note (1)
Living/dinning rooms	22 / 50%	Note (1)	Note (2)	14	Note (1)
(1) Quantified on per room basis; see Tables 8.5.5 and 8.5.6.					
(2) The assumption is made that there will not be a dedicated ventilation supply for living and dining rooms and bedrooms in residential buildings. Also see footnotes in Tables 8.5.5 and 8.5.6.					

Where unitary, window- or split-type air-conditioners of capacities falling outside the control of the air-conditioning energy code, performance data as summarised in Table 5.10 is assumed for both the Baseline Building model and the Assessed Building. If the developer can provide evidence that air-conditioners of better performance will be adopted in the Assessed Building, the annual energy use prediction for the Assessed Building will be based on such performance.

**Fig. 5.10 Minimum acceptable rated CoP of air-conditioning units**

Rated Input Power	Window type	Split Type and Floor Standing
0.56 - 2.24 (kW)	2.3	2.4
0.75 - 3.0 (hp)		
> 2.24 (kW)	n/a	2.5
> 3.0 (hp)		

<sup>(1)</sup> The rated COP shall be based on 35°C outdoor dry-bulb temperature; 27°C indoor dry-bulb temperature and 19°C indoor wet-bulb temperature; and power supply at 220V, 50Hz.

## 6 STUDY METHODOLOGY

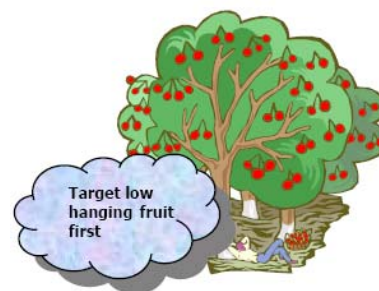
The methodologies employed for estimating the cost and benefits in each stage of the study are basically similar, differing only slightly for Stage I as indicated in Table 6.1.

**Table 6.1 Study Methodology for Various Stages**

	Stage I (1/96R – New Offices)	Stage II (3/99 - New Residential)	Stage III (4/04 – New Buildings)
No. of buildings	18	19	11
Performance Grades	‘Excellent’, ‘Very Good’, etc	‘Excellent’, ‘Very Good’, etc	‘Platinum’, ‘Gold’, etc
Sources of data	Bills of quantities	Bills of quantities and literature data	Bills of quantities and literature data
Energy-related criteria	Estimated by HTB2/BECON simulation	Estimated by HTB2/BECON simulation and literature	Estimated by HTB2/BECON simulation and literature
Investigated timeframe and discount rate used	5 years life cycle year with 5% discount rate	costs and benefits have been annualized	costs and benefits have been annualized

Given that ‘green’ building projects do not collate data on the additional costs over those for ‘non-green’ buildings, costs were estimated for each available credit for both green (certified) and conventional approaches for the same ‘generic’ building or base building.

A bottom-up approach was adopted for estimating the additional cost for different levels of award. In this approach, the approximate cost premiums for individual HK-BEAM credits were estimated before estimating the overall cost premium for a particular performance grade. Generally, these estimates were derived with an underlying premise that an investor/developer had the capability of accessing to all required technical and cost information, and would deploy an investment strategy such that would achieve the performance grade at the least cost. This would entail selecting those credits having the least cost premium, i.e. the ‘low hanging fruits’, until obtaining enough credits for securing the desired overall performance grade.



### 6.1 COST DATA

For this study, additional costs that are required for implementing a specific green measure (credit compliance) has been estimated by using market all-in-rates that were derived from analysis of bills of quantities of project of similar nature, or technical reports issued by government. Where deemed appropriate, construction cost estimates are used in place of unit cost estimates. Where there is a paucity of reliable data for Hong Kong, estimates are based on information obtained from the available literature.

Cost data for Stage I is based as far as possible on actual data or estimated data for the projects assessed under HK-BEAM 1/96R (New Offices), and is presented in terms of dollar values. Use of available cost data for Stage II was more problematic given the widely variable circumstances for high-rise residential building designs in Hong Kong. As the project proceeded it was decided that cost data for Stage II would be incorporated with cost data for residential buildings in Stage III. Since HK-BEAM 4/04 has been expanded in scope and numbers of assessment criteria

compared to previous versions, with more criteria/credits that are dependent on site circumstances and project scale, estimating cost premiums and potential benefits has proven to be more problematic than for the Stage I study. For instance, under 'Site Aspects' the cost premium for neighbourhood services and ecological impact can vary significantly for different locations. In addition, many HK-BEAM projects remain in the assessment stage with cost data for projects and assessment outcomes remaining inconclusive. Furthermore, the cost premiums for achieving the energy use credits can vary significantly given that a number of alternative design approaches can be adopted to achieve the targeted credits.

## 6.2 COST PREMIUM FOR INDIVIDUAL CREDITS

Given the variability of circumstances, cost premiums for Stages II and III are banded into low/insignificant cost, moderate cost, and high cost, respectively. Elsewhere in this report the outcomes of this study are compared to similar studies conducted elsewhere, so for this study the basis for deciding low/moderate/ high cost premiums have been guided by comparisons with what other jurisdictions regard as low, moderate or high cost. In a GSA study<sup>[73]</sup> the cost range was based on lump sum premiums, e.g. US\$ 50,000 – US\$150,000 for moderate cost. Analysis reveals that this represents a premium of around 0.3% for 'moderate' cost premium which seems to be reasonably consistent with the overall cost premium of around 2% for a LEED 'Silver' grade (around 55% of credits satisfied) as conclude in the California study<sup>[2]</sup>.

### 6.2.1 OFFICE BUILDING COST PREMIUMS

The basis for the building cost is HK\$11,300/m<sup>2</sup>, the approximate cost of an 'Average Standard Office' building<sup>[48]</sup>, not including fit-out costs. All credits have been grouped into 4 categories of cost premium (Table 6.2).

**Table 6.2 Cost impact categories defined for stages II and III**

Building Type	Construction Cost (HK\$/m <sup>2</sup> )	Cost Impact	Contribution to Total (%)	Contribution to Total (HK\$/m <sup>2</sup> )
Average standard high-rise office	11,300*	Insignificant cost	< 0.1	< 11 <sup>†</sup>
		Low cost	0.1 – 0.3	11 – 34 <sup>‡</sup>
Prestige high-rise office	14,150*	Moderate cost	> 0.3 – 1.0	> 34 – 113 <sup>‡</sup>
		High cost	> 1.0	> 113 <sup>‡</sup>
Low cost high-rise residential block	4,000*	Insignificant cost	< 0.1	< 4 <sup>†</sup>
Average standard apartment	8,950* (Percentages halved)	Low cost	0.1 – 0.3	4 – 12 <sup>†</sup>
		Moderate cost	> 0.3 – 1.0	> 12 – 40 <sup>†</sup>
		High cost	> 1.0	> 40 <sup>†</sup>

\*Not including fit-out costs.  
<sup>†</sup> The ranges of cost contribution to total are based on the construction cost of low cost high-rise residential block in 2006.  
<sup>‡</sup> The ranges of cost contribution to total are based on the construction cost of an average standard high-rise office in 2006

*Insignificant cost* – a cost premium of less than 0.1% of building cost, i.e. less than HK\$ 11/m<sup>2</sup>;

*Low cost* – a cost premium of 0.1 to 0.3% of building cost, HK\$ 11-34/m<sup>2</sup>;

*Moderate cost* – a cost premium of 0.3 to 1 % of building cost, HK\$ 34-113/m<sup>2</sup>;

*High cost* – a cost premium of over 1% of building cost, over HK\$ 113/m<sup>2</sup>.

### 6.2.2 RESIDENTIAL BUILDING COST PREMIUMS

For this stage the basis for the building cost is HK\$4,000/m<sup>2</sup>, the approximate cost of a 'Low-cost Residential' building (not including air-conditioning units)<sup>[48]</sup>. All credits have been grouped into 4 categories of cost premium (Table 6.2):

<sup>73</sup> US General Services Agency. GSA LEED® Applications Guide. February 2005.



*Insignificant cost* – a cost premium of less than 0.1% of building cost (excluding fit-out cost), i.e. less than HK\$ 4/m<sup>2</sup>;

*Low cost* – a cost premium of 0.1 to 0.3% of building cost, HK\$ 4-12/m<sup>2</sup>;

*Moderate cost* – a cost premium of 0.3 to 1 % of building cost, HK\$ 12-40/m<sup>2</sup>;

*High cost* – a cost premium of over 1% of building cost, over HK\$ 40/m<sup>2</sup>.

Given that the cost for an 'Average Standard Apartment' building is about double (HK\$8,950/m<sup>2</sup>) these percentages would be *halved* when applied to a typical private sector high-rise residential building.

### 6.2.3 CONSTRUCTION COST DATA

Costs estimates associated with neighbourhood and construction practices for external areas on site use data provided by experienced main contractors where appropriate. The costs are based on a rough alignment with the above data:

*Low cost credits* – negligible cost implication as compared to the overall project cost, i.e. HK\$0–\$0.25m;

*Moderate cost credits* – cost premium required falls in a range of HK\$0.25m – \$1.5m; and

*High cost credits* – cost impact over HK\$1.5m, i.e. significant impact on the total cost.

### 6.2.4 EXCLUDED COSTS

The study focuses on so-called 'hard costs', the premium for implementing a given credit. The 'soft cost' for design is not included, although estimates are provided for key design and construction activities such as computer simulations and commissioning. It is noted that many clients/project teams consider some activities as part of the cost of obtaining credits, and the achievement of a particular grade, rather than the cost of undertaking detailed design or full commissioning to confirm the building performs as intended.

Soft costs, such as the cost of computer simulations or surveys by suitably qualified persons, may be regarded in different ways. For example, if computer simulations for energy use are conducted during the course of good design practice then it is part of the design costs (fees). However, if the simulation is done only for the final design and mainly for the purpose of certification, then it would likely be regarded as an additional cost and a part of the cost for certification. Costs for testing and commissioning beyond usual practice would also be regarded as part of the cost for certification.

Also excluded are the 'certification costs' levied by the HK-BEAM Society for the assessment process and certification. This cost is of the order of HK\$75,000 – HK\$ 150,000 depending on the project scale and/or complexity. However, this cost includes advice on the assessment process and guidance with submittals (evidence that a credit has been achieved). Such guidance may be regarded as a benefit derived from the certification process.

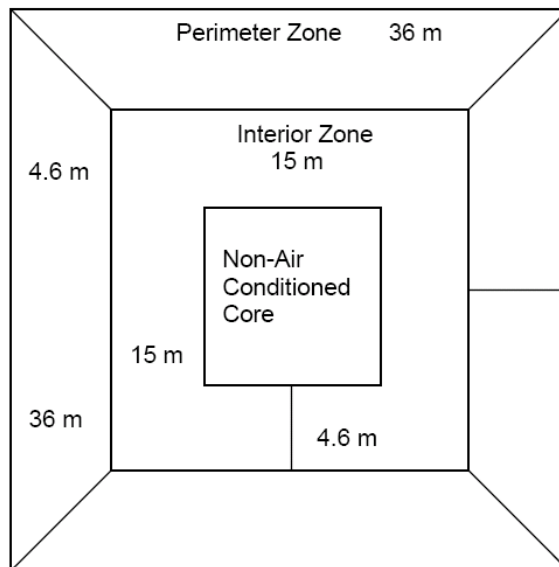
## 6.3 BASELINE OFFICE BUILDING

The baseline configuration and setting for the 'generic' office buildings was determined from a previous territory wide survey<sup>[74]</sup>. Figure 6.1 shows the configuration, and Table 6.3 gives outline specification and design criteria.

The permitted covered areas<sup>[75]</sup> of commercial buildings with height greater than 61m should not exceed 65% of the total site area. 'Total covered area' is the portion of the site covered by building(s) or in simple terms, the footprint of the shadow cast vertically down onto a site.

<sup>74</sup> Yik F W H, Burnett J, Jones, P, Lee W L. Energy performance criteria in the Hong Kong Building Environmental Assessment Method. Energy and Buildings. Vol. 27, 207-219. 1998.

<sup>75</sup> Buildings Department. PN 280 Site Coverage and Space Provision. January 2004.



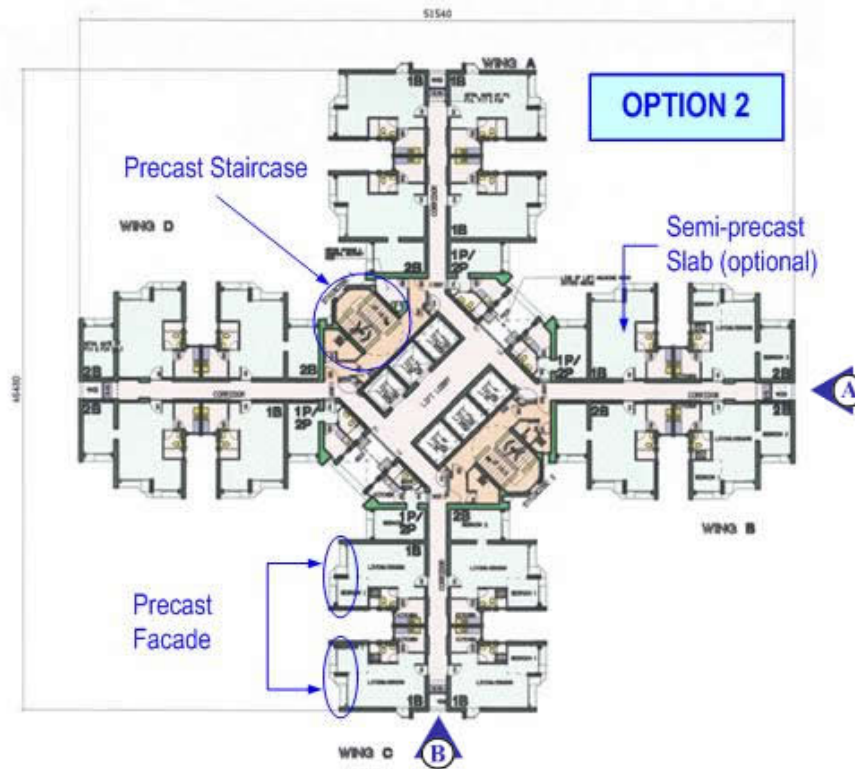
**Figure 6.1 Typical floor plan of the 'generic' office building (baseline building)**

**Table 6.3 Specification for the 'generic' office building (baseline building)**

Parameter	Value
Number of floors	40
Floor to floor height	3.2 m
Perimeter zone area (36 x 36 m)	342 m <sup>2</sup>
Interior zone area (27 x 27 m)	504 m <sup>2</sup>
Core – non A/C (15 x 15 m)	225 m <sup>2</sup>
Floor area	1,071 m <sup>2</sup>
Total floor area	42,840 m <sup>2</sup>
Open space and landscape area	700 m <sup>2*</sup>
Maximum occupation density	9 m <sup>2</sup> /person
Total population	4760
Window/wall area ratio	0.50
Shading coefficient	0.45
OTTV	34.7 W/m <sup>2</sup>
Installed lighting load	25 W/m <sup>2</sup>
Appliances load	25 W/m <sup>2</sup>
Pump efficiency	0.6
Fan efficiency	0.55
Annual electricity consumption	280 kWh/m <sup>2</sup> (air-cooled) 240 kWh/m <sup>2</sup> (water-cooled)
Maximum electricity demand	180 VA/m <sup>2</sup> (air-cooled) 138 VA/m <sup>2</sup> (water-cooled)
Ventilation rates	10 l/s/person
Infiltration rates (with ventilation system on)	0.1 air change/hour
Primary filters	60-65% efficiency (with filter efficiencies of 0.54)
Secondary filters	60-65% efficiency (with filter efficiencies of 0.54)

## 6.4 BASELINE RESIDENTIAL BUILDING

Since it was impossible to cater for all the different residential building designs in one study the cost and benefit estimates provided have been computed with reference to a low-cost residential building design. As more than one third of the total population in Hong Kong live in public rental housing a Housing Authority Harmony Block was selected as the baseline building. Figure 5.2 and Table 5.4 show the configuration and the outline specification and design criteria for the baseline residential building.



**Figure 5.2 Typical floor plan for the 'low-cost' residential building (baseline building)**

**Table 5.4 Specification for the 'low-cost' residential building (baseline building)**

Parameter	Values
Number of floors	41
Floor to floor height	2.7 m
Floor area	896 m <sup>2</sup>
Total floors area	36,736 m <sup>2</sup>
Total no. of units	799
Total pupation	2,431person
Window/wall ratio area	0.65
Open space and landscape area	1590 m <sup>2</sup> – 1260 m <sup>2</sup> *
Window/wall area ratio	0.65
Shading coefficient	0.65
OTTV	42.85 W/m <sup>2</sup>
Installed lighting load	19 W/m <sup>2</sup>
Annual electricity consumption	110 kWh/m <sup>2</sup>
Air conditioning system	Window or split-type units
*open space and landscape area is based on current regulations	

For the residential building, an open recreation and landscape area has been assumed for a housing estate, with areas being defined with reference to the average values laid down in the current regulations of government and common practice of developers. For instance, the permitted covered areas of high-rise residential buildings with height greater than 61m have been assumed not to exceed 40% of the total site area, the maximum laid down in PN 280<sup>[75]</sup>.

## 6.5 KEY ASSUMPTIONS

The analysis has been based on the following key assumptions:

- Potential costs and benefits associated with credits have been projected to a period of 5 years after the completion of building.

- Initial material and equipment costs have been estimated by using the all-in rates.
- The initial costs that have been reported in this study do not include the associated design consultancy fees.
- In the initial estimate, 10% has been applied in the base case scenario for discounting all the future costs and benefits for 5 years.
- Electricity charges of HK\$0.815/kWh and HK\$0.885/kWh have been used for estimating the monetary benefits associated with energy savings for office and residential buildings respectively.
- A water consumption charge of HK\$4.58 per m<sup>3</sup> together with effluent charge of HK\$1.2 per m<sup>3</sup> has been used for estimating the monetary benefits gained by water savings.
- No future price escalation has been considered for fuel prices.
- Landscape and open space area has been based on the current regulation of Buildings Department.
- Technical data and quantities of electrical and mechanical facilities for landscape and open space areas of office and residential buildings have been based on the recent shop drawings and bills of quantities received from Housing Department and developers in the private sector.
- Costs associated with neighbourhoods, surroundings and construction practices have been provided by experienced main contractors and surveyors.

## 6.6 PREMIUM FOR A PARTICULAR PERFORMANCE GRADE

For consistency, this study assumes clients attempt to earn the minimum total number of credits for attaining a particular grade of performance, e.g. 65% for 'Gold', etc. Even so, the total cost premium can vary, as clients are generally free to choose to satisfy any suitable combination of credits. Thus, a range of cost and benefit estimates are expected for attaining a particular performance grade. Of interest in this study are the maximum and minimum total costs (hereinafter called upper and lower bound costs) that would be required for obtaining a particular performance grade. The lower bound cost was computed by identifying the minimum cost required to obtain the minimum number of credits for a particular grade. The minimum cost required was determined by the least cost approach, i.e. by assuming those credits with the least cost would be satisfied first. The upper bound cost was computed by identifying the maximum cost required to obtain the minimum number of credits for a particular grade.

Mainly the 'core' credits listed under HK-BEAM 4/04 (Table 4.2 and Table 4.3) have been used as the basis for evaluating the cost premium for green designs of a standard office building and a low-cost, high-rise residential building.

## 6.7 ESTIMATION OF OVERALL COST PREMIUMS

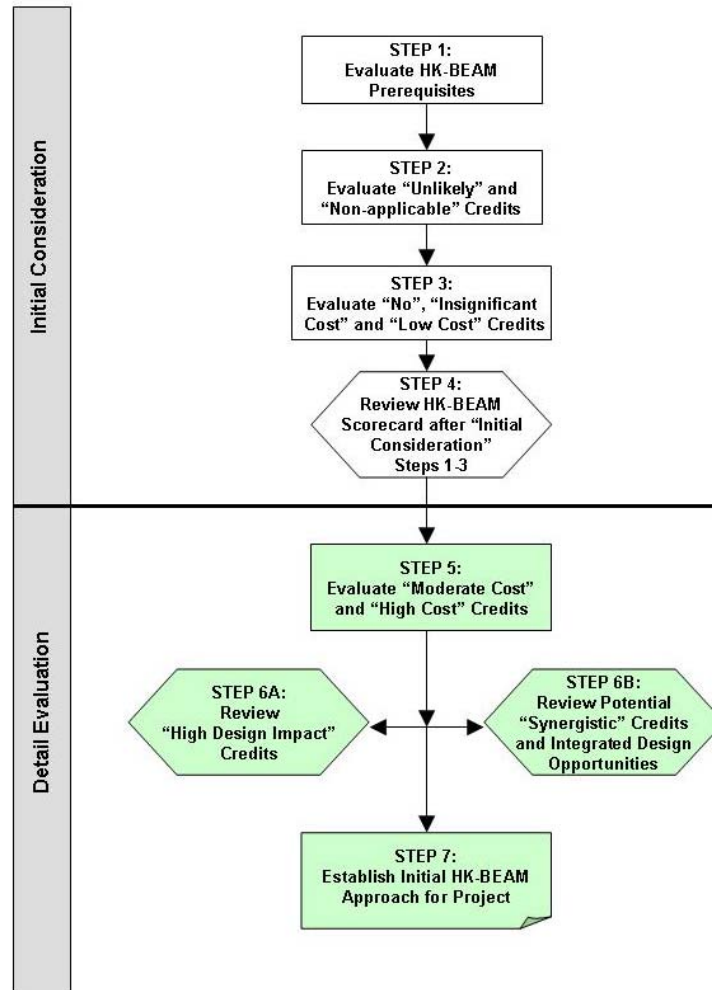
The overall process for assessing individual credits in order to develop preliminary goals for certification follows a similar logic to that outlined in the GSA Guide<sup>[73]</sup>. The process uses the insights into the cost impacts of individual credits in order to estimate the overall cost premium for a target performance grade. The approach first considers those credits that are likely to have no/insignificant-cost or low-cost, before examining credits that are likely to incur moderate to high cost premiums, and warrant a more detailed cost/benefit analysis.

As illustrated in Figure 6.3 the seven steps of the process are divided into two stages, an 'Initial Considerations' stage (Steps 1-4), and a 'Detailed Evaluation' stage (Steps 5-7). Overall, the process mimics activities of project teams in seeking a particular HK-BEAM rating that is within budget for a project, whilst also narrowing the focus on key issues that should command immediate attention during the early design phases.

### *Step 1: Evaluate Prerequisites*

The benchmark for particular performance criteria is established by reference to legal requirements, and which are generally specified as a prerequisite. HK-BEAM uses local performance standards, codes and guides where these are available (e.g. indoor air quality).

Where these are not available (e.g. impact noise) international or national standards, codes and guides are referenced. A HK-BEAM assessment seeks to establish a basic performance criterion for the Client to specify what they consider to be appropriate for their buildings. Meanwhile, it is useful for project teams to ensure prerequisites are met before determining how compliance with individual credits will be achieved.



**Figure 6.3 Green Building Cost Evaluation Process** (following the GSA Guide<sup>[73]</sup>)

**Step 2: Evaluated Unlikely and Non-applicable Credits**

HK-BEAM embraces a wide range of building developments, variable in terms of scale, location and mix of uses (types of premises). The assessment criteria and methods of assessment need to be flexible and allow for alternative means of compliance. Due to this fact it is inevitable that some of the available credits will unlikely or not be applicable. For instance, credits targeted to building reuse do not apply to new construction project on a reclaimed land. To reduce the project team’s workload it is useful to identify these unlikely and non-applicable credits during the Initial Consideration stage. Here the advice from a HK-BEAM Assessor is beneficial.

**Step 3: Evaluate No/Insignificant Cost and Low Cost Credits**

In most projects there will be a number of credits that can be achieved with no or low cost impact. These ‘No/Insignificant cost’ and ‘Low cost’ credits present significant opportunities to project teams and should be identified early in the design process.

**Step 4: Review Credit Scorecard**

The number of credits addressed through steps 1-3 is not insignificant. As such, upon completion of step 3, the project team should review the status of the credits likely to be achieved. It may be

determined at this stage that the targeted HK-BEAM rating is already obtainable, or that a higher rating level is within reach. Alternately, the review will indicate the additional challenges (and potential cost impacts) required to reach the desired rating level.

**Step 5: Assess Moderate Cost and High Cost Credits**

The remaining credits are assessed as to their likely cost impact – moderate to high cost premiums. Some of the credits listed as moderate cost may in fact turn out to have low cost. Where a moderate and/or high cost credit are perceived to have significant benefits for the client or other stakeholders, including the community, and/or where environmental benefits are potentially very significant, the pursuit of credits should be more thoroughly analysed in order to inform the Client.

**Step 6: Evaluate High Impact Credits and Synergistic Credits**

As noted in Step 5, the selection of moderate and high cost credits typically involves detailed evaluations of the costs, benefits, and design implications. Step 6 of the valuation process focuses on the credits with high impact (high performance), and synergies between credits.

**Step 7: Establish Initial HK-BEAM Approach for the Project**

The preceding seven steps in the Evaluation Process are intended to assist project teams in establishing a reasonable assessment grade, based on a cost-benefit approach. After establishing the ‘low-hanging fruit’ from the ‘Initial Considerations’, then evaluating and adding additional moderate or high cost credits through the ‘Detailed Evaluation’ steps, project teams should have a clear understanding of the targeted credits and the intended performance implications, as well as a justification for the certification grade being pursued.

**6.7.1 COST PREMIUM CATEGORIES**

In Table 4.2 the cost premium for each HK-BEAM 4/04 credit are identified according to the cost premium categories given in Table 6.5 for office buildings and Table 6.6 for residential buildings.

**Table 6.5 Cost premium categories for ‘Generic’ office buildings**

<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>
Unable to estimate	No cost (0/m <sup>2</sup> )	Insignificant cost (<\$11/m <sup>2</sup> )	Low cost (11-\$34/m <sup>2</sup> )	Moderate cost (>34-\$113/m <sup>2</sup> )	High cost (>\$113/m <sup>2</sup> )

**Table 6.6 Cost premium categories for low-cost high-rise residential buildings**

<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>
Unable to estimate	No cost (0/m <sup>2</sup> )	Insignificant cost (<\$4/m <sup>2</sup> )	Low cost (4-\$12/m <sup>2</sup> )	Moderate cost (>12-\$40/m <sup>2</sup> )	High cost (>\$40/m <sup>2</sup> )

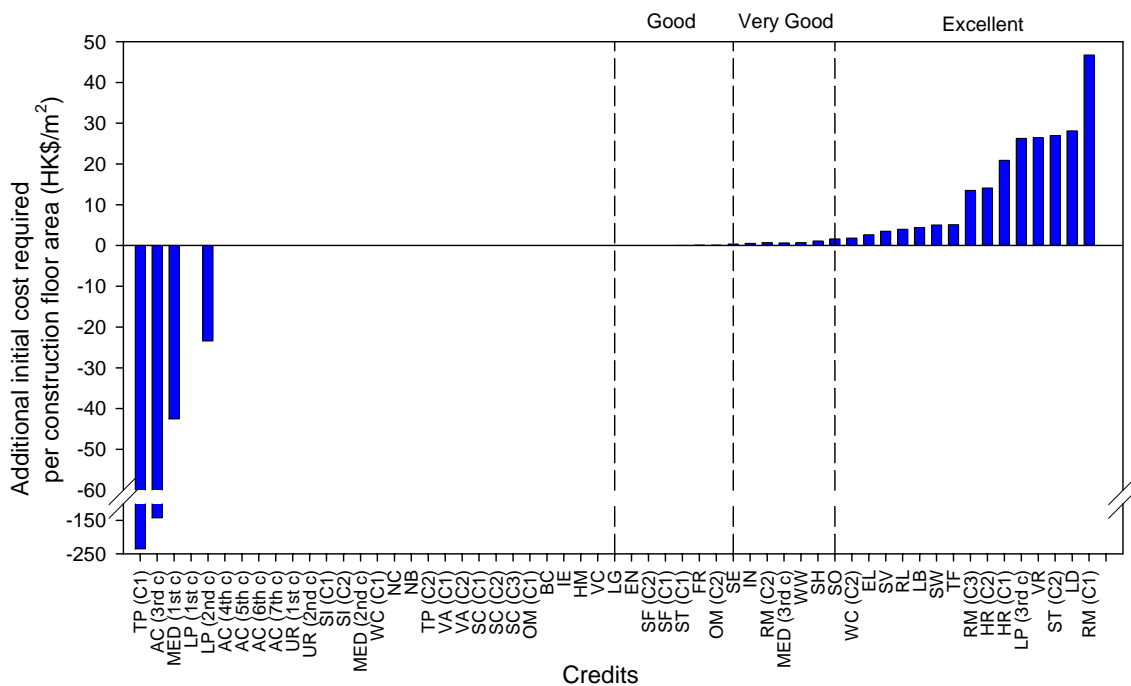
# 7 COST PREMIUMS FOR HK-BEAM ASSESSMENTS

The data used for the Stage I report was mostly circa 2004/5 and with 2005/6 data used in the Stage II and Stage III studies. As the assessments under versions 1/96R (New Office) and 3/99 (Residential) are largely historic the details of cost for individual credits presented in this final report (Section 10) are for version 4/04 only.

## 7.1 COST PREMIUMS FOR CERTIFICATION TO HK-BEAM 1/96R (NEW OFFICES)

Given that a number of projects had been assessed under HK-BEAM 1/96R it was possible to estimate both lower and upper bounds of cost estimates. Figures 7.1 and 7.2 show the profiles of additional initial construction costs required, which were developed using the lower and upper bound estimates for each individual credit, respectively. Table 7.1 lists the applicable credits in HK-BEAM 1/96R.

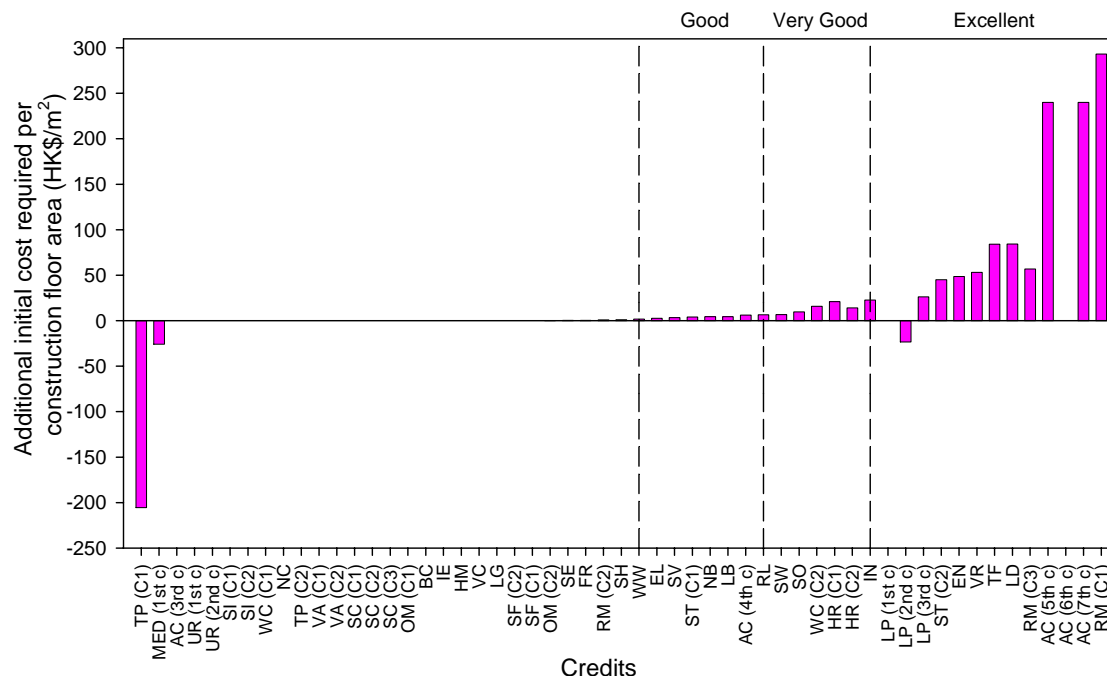
From the perspective of initial cost, the requirements of the first 21 credits (in case of upper bound estimates), or first 29 credits (in case of lower bound estimates) could be easily earned without a significant cost premium. Adopting a conventional office building design could already earn more than one third of the total number of 59 credits in version 1/96R.



**Fig. 7.1 Cost premium for complying with credit requirements in HK-BEAM 1/96R (lower bound estimates)**

Based upon the lower bound estimates, \$1.8/m<sup>2</sup> and \$8.6/m<sup>2</sup> initial premium were required for upgrading from 'Good' to 'Very Good', and from 'Very Good' to 'Excellent' grade, respectively. This amounted to 0.02% and 0.09% of initial construction costs for an average office building. If a developer was ambitious enough to fulfil the requirements of all credits in version 1/96R it would require an additional of HK\$193/m<sup>2</sup> for initial construction costs.

Similarly, based upon upper bound estimates, \$17.7/m<sup>2</sup> and \$64/m<sup>2</sup> initial construction costs were required for upgrading from 'Good' to 'Very Good', and from 'Very Good' to 'Excellent' grade, respectively. They amounted to 0.2% and 0.6% of initial construction costs. Again, the developer would need to pay HK\$1,203/m<sup>2</sup> more in initial construction costs to fulfil the requirements of all credits in version 1/96R, which is equivalent to 12.2% of initial construction cost.



**Figure 7.2 Cost premium for complying with credit requirements in HK-BEAM 1/96R (upper bound estimates)**

**Table 7.1 Listing of credits for Figs. 7.1 and 7.2**

AC	Air-conditioning equipment electricity load	RL	Automatic refrigerant leakage detection
BC	Biological contamination	RM	Specification of recycled materials
CP	Contents of paints	SC	HVAC system commissioning
ED	Electricity maximum demand	SE	Separate monitoring of electricity use (Chillers)
EL	Electrical energy consumption	SF	Specification of filters
EN	External noise levels	SH	Separate monitoring of electricity use (HVAC)
FR	Facility for recycling materials	SI	Specification of insulants
HM	Specification of hazardous materials	SO	Specification of electricity use (Owners)
HR	Heat recovery	ST	Solid timber
IE	Position of outdoor intake and exhausts	SV	Separate ventilation systems
IN	Internal noise levels	SW	Sorting of waste on site
LB	Legionella bacteria from wet cooling tower	TF	Timber formwork
LD	Specification of lighting devices	TP	Transport and pedestrian access
LG	Compliance of lighting guidelines	UR	Use of refrigerants
LP	Office lighting power density	VA	Vehicular access for servicing and for waste disposal
NB	Noise from building	VR	Design of ventilation rate
NC	Noise during construction	WC	Water conservation
OM	Operations and maintenance	WW	Construction wastewater discharge
C1 – C3	Credits 1 to 3	1 <sup>st</sup> -7 <sup>th</sup> c	1st to 7th credit

Furthermore, the initial construction cost constitutes only 9% of total costs required to be committed during the first 5 year lifespan of an office building (as shown in Figure 7.3) with the following underlying assumptions:

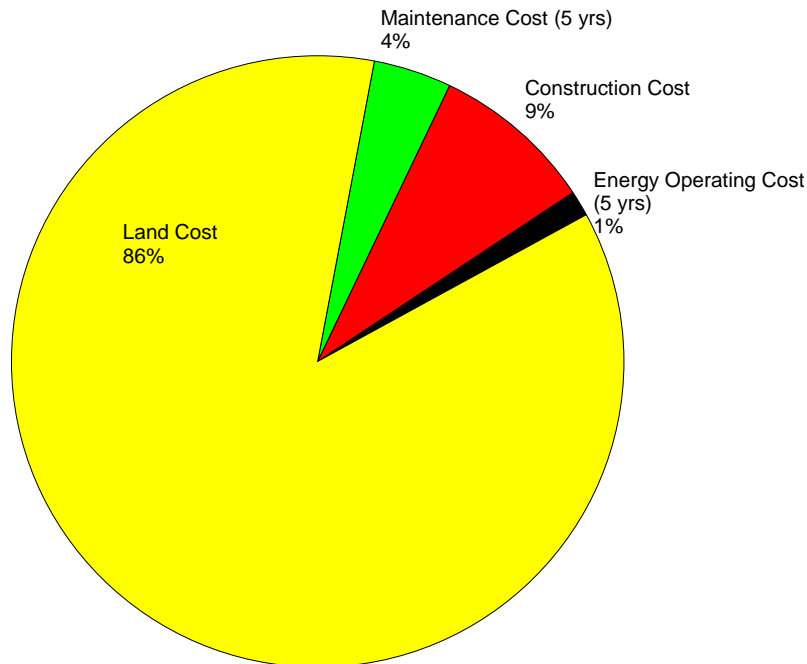
- Land cost in Central (HK\$90,000/m<sup>2</sup>) projected using the auction price for office land development at Kowloon Bay as of March 2005 (HK\$32,360/m<sup>2</sup>);
- Construction cost for Grade A office building is HK\$ 10,000/m<sup>2</sup>(cost in 2005);
- Annual operating fuel cost for public areas in Grade A office building is \$325/m<sup>2</sup>/yr(cost in



2005);

- Annual maintenance and major repair cost is HK\$325/m<sup>2</sup>/yr(cost in 2005),

Alternatively, the price premium of becoming green lie between 0.01% and 0.08% of the total cost (103,000 per m<sup>2</sup> of construction floor area) required to be committed by the investor during the first five years. Thus, the price premium needed for upgrading the environmental performance of an office building to 'Very Good' or even 'Excellent' grade would be very small when compared to other costs required throughout the life-cycle of an office building.



**Figure 7.3 Contribution of different types of cost commitment during a building lifecycle**

### **7.1.1 OVERALL COST PREMIUM FOR ASSESSMENTS UNDER VERSION 1/96R**

As already stated, one of the major objectives of this study is to examine whether the overall cost of constructing a 'Very Good' or 'Excellent' rated building is significantly higher when compared with that required for constructing a conventional building. Cost and benefit estimates were derived by using a bottom up approach with aid of some basic assumptions and certain cost and engineering estimates. However, it is important to cross-check whether the hypothetical estimates derived are reasonable or not.

Given the lack of actual cost data applicable to each individual credit, the total cost required for constructing an excellent rated building was compared with the total cost required for constructing a typical office building in Hong Kong. The initial costs required for constructing a 'green' building were determined from a statistical analysis of 7 office buildings which had been rated excellent under HK-BEAM version 1/96R, but with costs updated to 2005<sup>[76]</sup>. The cost required for constructing a 'conventional' office building was assumed similar to that required for constructing an unrated office building in 2005. Figure 7.4 shows that there is no observable difference in prices between 'green' and 'conventional' office buildings.

### **7.1.2 PREMIUM TO ENHANCE ENERGY PERFORMANCE**

Performance-based credits, such as annual energy use, are awarded when a defined performance level has been achieved, without regard to the strategy adopted. Accordingly, a number of strategy options can be used and combined together in different ways to meet the

<sup>76</sup> Based on the price adjustment indices listed in construction cost handbook 2005 published by DLS

performance requirements. The initial cost will vary according to the strategy, the sequence and combination of measures adopted. Prior to estimating the cost of fulfilling the performance credits, an initial cost-energy saving curve was developed in line with the least-cost integrated planning approach discussed earlier. Specifically, initial costs for different energy efficient design options were prioritized based on their orders of magnitude.

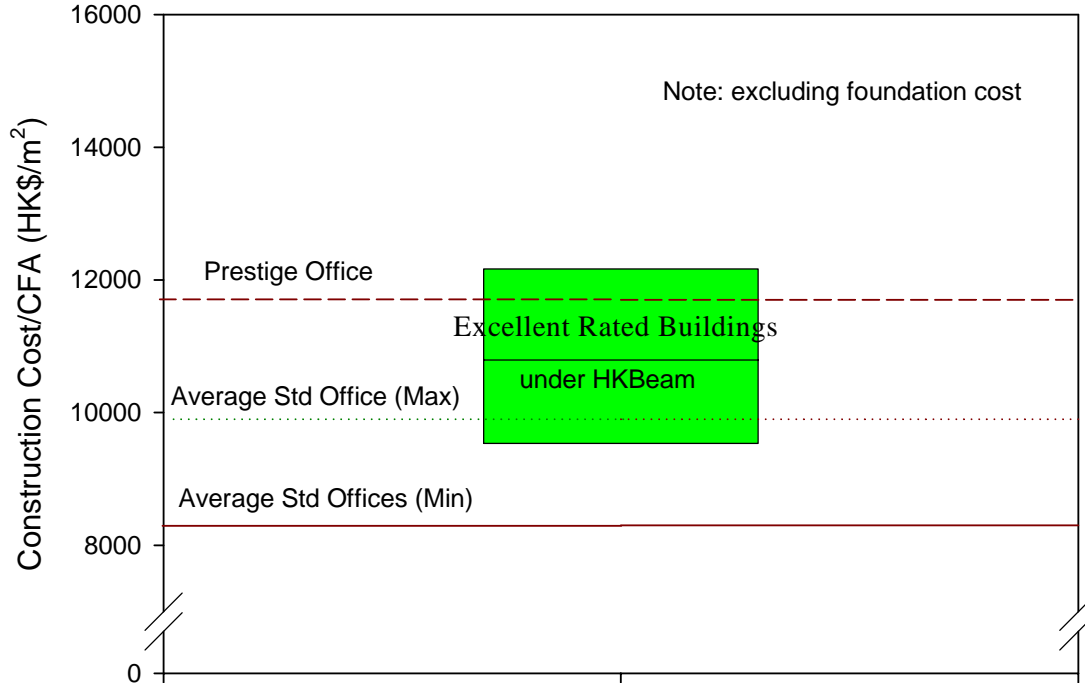
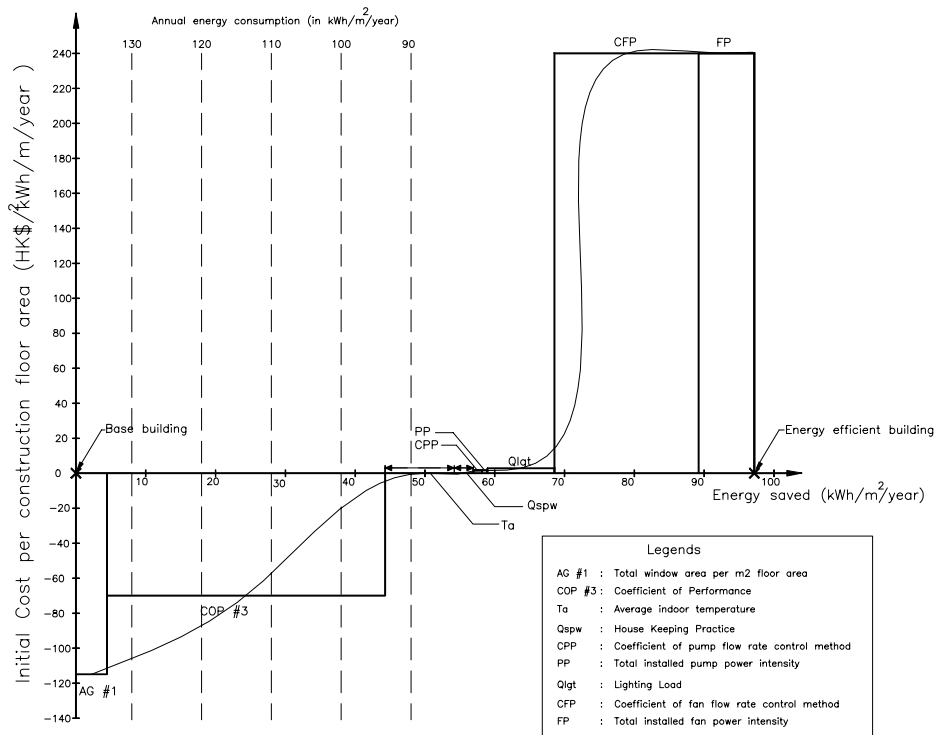


Figure 7.4 Cost premium comparisons for 'green' and 'conventional' office buildings

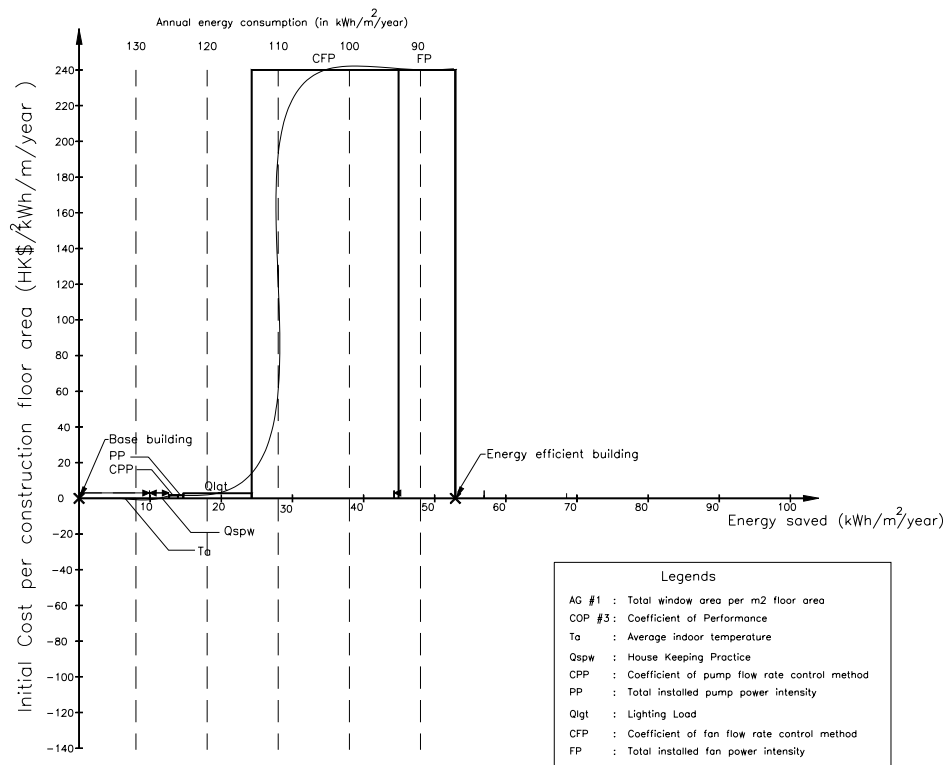


**Figure 7.5 Initial costs for fulfilling energy performance levels (lower bound estimates)**

Energy efficient design options considered fall into one of two general categories: air-conditioning system design options; and other energy efficient options with an objective to reduce the air-conditioning load. The air-conditioning design option includes the use of higher performance equipment and energy efficient systems. Typical examples include the use of chillers with high coefficient of performance (COP) and better control strategies. Other energy efficient options include the use of double-glazing windows, compact fluorescent lighting, as well as a change in the indoor set-point temperature.

The resulting cost-energy saving curves, shown in Figures 7.5 and 7.6, help prioritize the various energy efficient measures in terms of their cost effectiveness, i.e. the initial cost per construction floor area. Figure 7.5 shows the initial costs required for fulfilling credits with an incremental energy saving scale based on the lower bound estimate. No significant initial cost commitment was required for achieving a target performance level of 90 kWh/m<sup>2</sup>/year, by adopting a 0.33 window-to-wall ratio, water cooled heat rejection, and adjusting indoor temperature.

Figure 7.6 show the initial costs required for fulfilling the requirements of different energy performance levels based on assumptions that a window to wall ratio of 0.5 and air cooled heat rejection method is used (upper bound estimates). However, in constructing our upper bound estimate, change of window-to-wall ratio and the use of water cooled heat rejection are excluded. Window-to-wall ratio is not included as a majority of investors in Hong Kong are not readily prepared to sacrifice the view (window areas) for reduced operating energy consumption. Water cooled heat rejection may not always be practicable as only a few office buildings are located in proximity to the sea. With these assumptions, investors would not incur an initial price premium if the energy performance level targeted at 120 kwh/m<sup>2</sup>/year. However, a price premium of \$240/m<sup>2</sup> would be incurred for attaining performance levels of 110 kwh/m<sup>2</sup>/year and 90 kwh/m<sup>2</sup>/year, as a result of improvements in fan power, and total installed power intensity, respectively.



**Figure 7.6 Initial costs for fulfilling energy performance levels (upper bound estimates)**

## 7.2 COST PREMIUMS FOR CERTIFICATION TO HK-BEAM 3/99 (RESIDENTIAL)

Since there are many more variables, such as surroundings or neighbourhood amenities, incorporated into HK-BEAM 3/99, total costs for attainable of a given grade ('Good' etc) was more difficult to estimate. It is assumed that an investor would access all required technical and cost budget, and would deploy an investment strategy such that would achieve the performance grade at the least cost. Based on the concept of 'shooting for the low hanging fruit', 'insignificant' and 'low' cost credits that can be obtained for getting a desired overall performance grade prior to consider the moderate and high cost credits.

### 7.2.1 CREDITS WITH NO/LOW COST IMPACTS

Figure 7.7 shows the contribution of all categories of credits for HK-BEAM version 3/99. Insignificant and low cost credits could contribute up to 54% of total credits and the corresponding HK-BEAM weightings would be in the range of 'Fair' to 'Good'. The premium for such an achievement is not high; lying in the range of HK\$50/m<sup>2</sup> to HK\$84/m<sup>2</sup> based on the average total construction costs for 'low cost' high-rise housing is about HK\$4,000/m<sup>2</sup>. The percentage contributions for obtaining insignificant or low cost credits in HK-BEAM assessment lie in the range of 1.3 to 2.1% for new 'low cost' residential buildings. Given the cost of a 'standard apartment building' is about double that of 'low cost' housing these percentages are halved for a 'standard apartment building'.

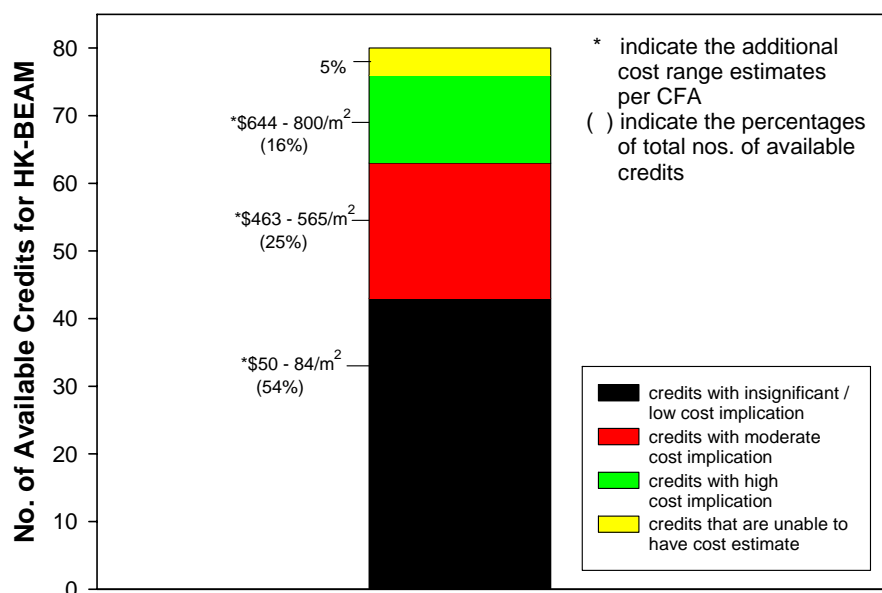


Figure 7.7 Cost premiums for HK-BEAM 3/99 credits

### 7.2.2 CREDITS WITH MODERATE/HIGH COST IMPACTS

The achievement of 'insignificant' and 'low cost' credits secures an overall performance grade of 'Good', which is reasonable given the budget constraints on low cost residential buildings. A grade of 'Very Good' or even 'Excellent' will more likely be the benchmark for private sector projects, and further consideration of moderate and high cost credits would be necessary.

Figure 7.8 reveals the percentages of total number of credits that required for earning a particular performance grade. As discussed before, it was constructed with a basic assumption that the investors would adopted a 'least cost approach', for which they would take the insignificant/low cost credits before taking the moderate cost and before the high cost credits. Noticeably, in

achieving an excellent grade only required earning all the insignificant/low cost credits and the majority of the 'moderate cost' credits, which amounted to a cost premium of HK\$290-393/m<sup>2</sup>, i.e. 7.3-9.8% of the construction cost for a 'low cost' residential building, or 3.3-4.4% for a standard apartment building.

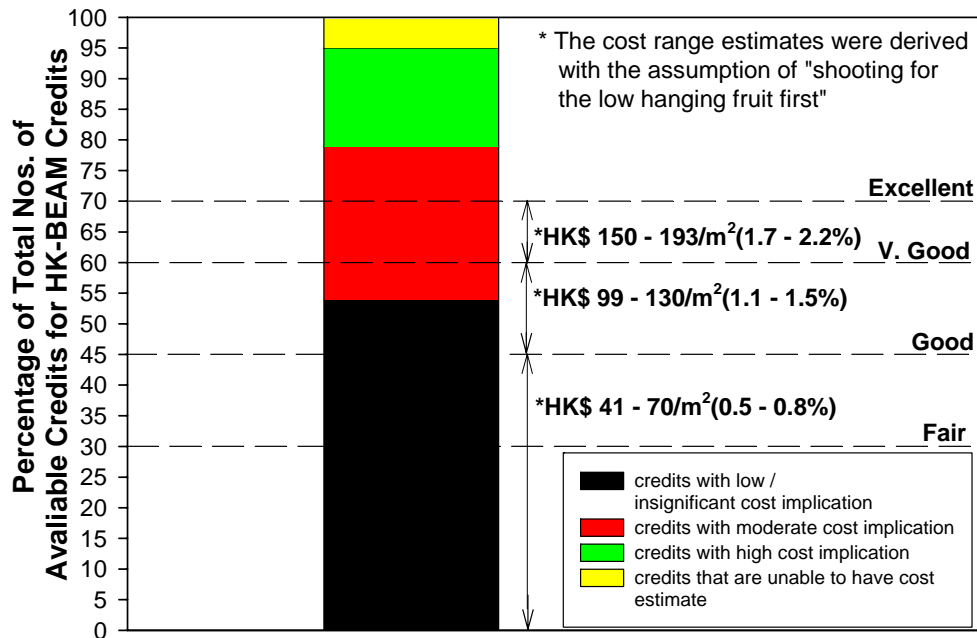


Figure 7.8 Achieving the various grades in HK-BEAM 3/99

### 7.3 COST PREMIUMS FOR CERTIFICATION TO HK-BEAM 4/04 (NEW BUILDINGS)

Figure 7.9 shows the number of available credits with different cost impact categories to the total number of credits assessed under HK-BEAM 4/04 (excluding the bonus credits). Credits that carried no, insignificant and low cost implication altogether accounted for up to 75% and 67% of total credits for office and residential buildings, respectively. Acquiring all these credits would certify a 'Gold', or 'Platinum' grade under HK-BEAM 4/04.

The minimum premium required for such an achievement was not high, i.e. HK\$361/m<sup>2</sup> (i.e. about 3.2% for average standard office of HK\$11,300/m<sup>2</sup>) and \$168/m<sup>2</sup> (i.e. about 4.2% of HK\$4,000/m<sup>2</sup> for 'low cost' apartment in the public sector, and 1.9% of HK\$8,950/m<sup>2</sup> for an average standard apartment building in the private sector).

The data should be used with caution in that the lowest bound estimates shown here were derived by using a base building with an assumption that the original design had already complied with the HK-BEAM requirements on air, water and noise quality during construction and occupancy stages without any special needs in modifying the designs, in any extent, to meet with these requirements. Thus, the estimates should only be regarded as indicative and the actual premium will vary with site circumstances, project scale and building design.

Figure 7.10 shows the percentages of the total number of applicable credits and additional initial cost premiums required to earn a particular performance grade under HK-BEAM 4/04. The premiums were estimated with an underlying assumption that the investors would have adopted a 'least cost approach' such that no/insignificant/low cost credits would be targeted before the moderate cost or the high cost credits.

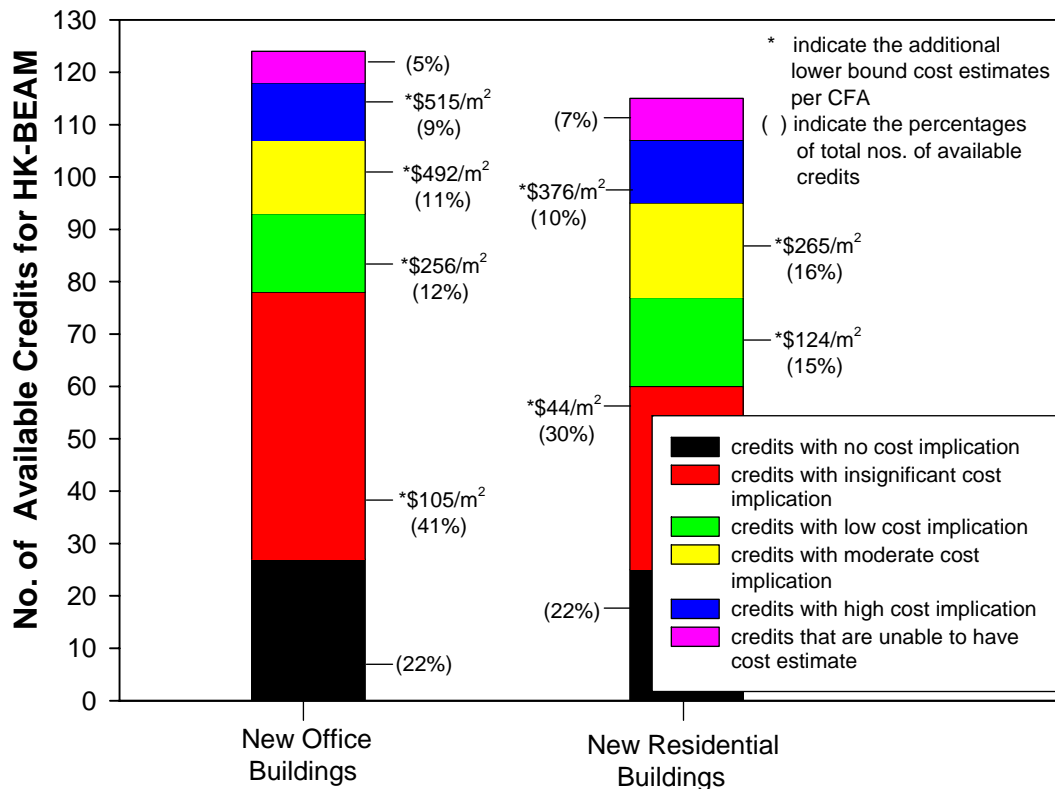


Fig. 7.9 Minimum cost premiums for certification to HK-BEAM 4/04

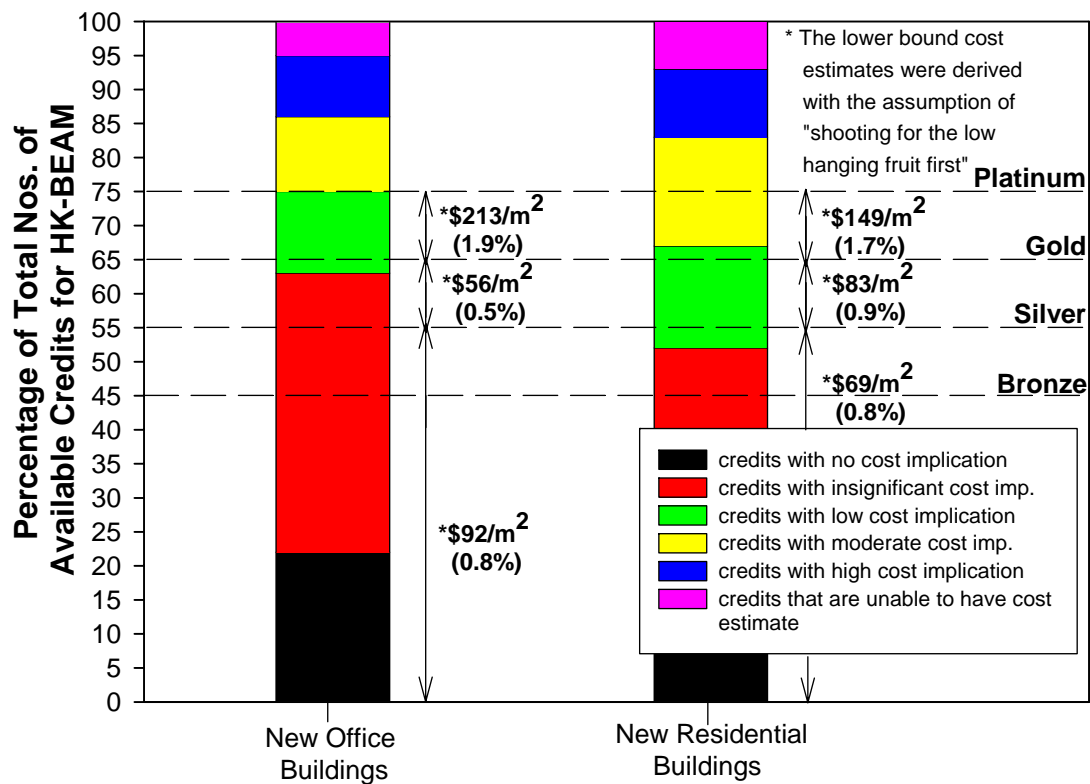


Fig. 7.10 Percentages of credits and minimum premiums for certification to HK-BEAM 4/04

For the average standard office buildings, an initial cost premium of HK\$56/m<sup>2</sup> and HK\$213/m<sup>2</sup> were estimated to be required for upgrading from 'Silver' to 'Gold', and from 'Gold' to 'Platinum'

grade, respectively. They amounted to 0.5% and 1.9% of initial construction cost.

For average standard apartments, an additional initial cost premium of HK\$83/m<sup>2</sup> and HK\$149/m<sup>2</sup> were required for upgrading from 'Silver' to 'Gold', and from 'Gold' to 'Platinum' grade, respectively. It amounted to 0.9 to 1.7% of initial construction cost.

Overall, the *minimum* cost premium to obtain a 'Platinum' performance grade for an office or residential building is about 4% of initial construction cost.

## 7.4 COST PREMIUMS FOR ENERGY EFFICIENT DESIGNS

To obtain the energy credits under 4/04, appropriate energy saving measures are needed to be implemented. Table 7.2 shows a list of energy saving measures that have been implemented for obtaining a maximum number of available credits.

**Table 7.2 Measures to achieve maximum number of energy performance credits**

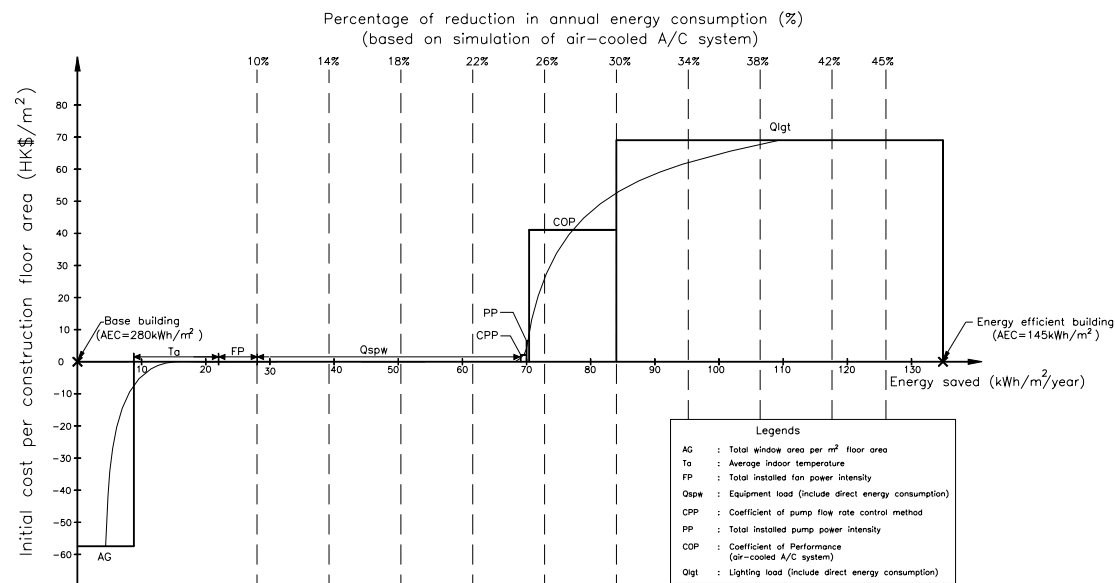
Energy saving measures	Varying range	kWh/m <sup>2</sup> reduction		% reduction		*Accumulative obtainable credits		Additional Cost (HK\$/m <sup>2</sup> )
		Air-cooled	Water-cooled	Air-cooled	Water-cooled	Air-cooled	Water-cooled	
Window to wall ratio	0.2 to 0.1	8.8	5	3	2	0	0	-55
Indoor air temperature	23°C to 25.5°C	13.1	7.2	8	5	0	0	0
Installed fan power intensity	16.1W/m <sup>2</sup> to 13W/m <sup>2</sup>	6.2	6.6	10	8	1	0	0
Intensity of equipment load	25W/m <sup>2</sup> to 14W/m <sup>2</sup>	41	38.6	25	24	4	4	0
Coefficient of pump flow rate control method	1 to 0.7	0.9	1.4	25	24	4	4	2.1
Installed pump power intensity	4W/m <sup>2</sup> to 3.4W/m <sup>2</sup>	0.4	0.9	25	25	4	4	6.5
Coefficient of performance	2.7 to 3.2 (air-cooled)	13.1	1.3	30	25	6	4	41.1 (air-cooled)
	5.3 to 5.4 (water-cooled)							30.6 (water-cooled)
Intensity of lighting load	25W/m <sup>2</sup> to 12W/m <sup>2</sup>	51.4	46.3	48	45	10	10	69

\* based on concept of 'low-hanging fruit first'

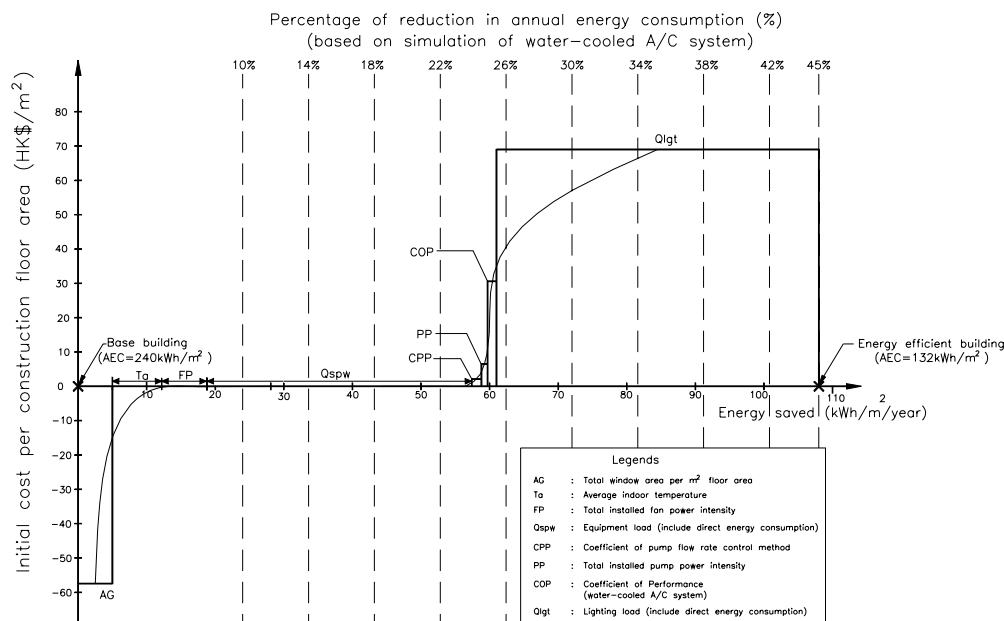
The additional initial cost premium required for obtaining a particular number of credits varies with the type of energy saving measures implemented. To evaluate the additional initial cost premium and benefit gain, we assume that private developers will adopt the 'least cost' approach, where they will reap the cheaper credits or the 'low-hanging fruit first'.

Figures 7.11 and 7.12 shows cost-energy performance curves for different number of annual energy use credit for air-cooled and water-cooled rejection method, respectively. They also show the minimum initial capital costs required for fulfilling the 4/04 requirements on incremental energy performance levels. For air-conditioned building employing air cooled heat rejection method, all ten credits can be obtained with a minimum initial premium of HK\$ 63.7/m<sup>2</sup> being invested in particular energy saving devices. In return, it can bring about an annual operating energy reduction of 135.0kWh/m<sup>2</sup> (i.e. 48% of total HVAC consumption), which corresponded to an annual revenue of HK\$110.0/m<sup>2</sup>. For water-cooled air-conditioned buildings, a total of ten credits can be obtained with a minimum initial premium of HK\$53.2/m<sup>2</sup>. Likewise, in return, this can bring about annual operating energy reduction of 107.2kWh/m<sup>2</sup> (i.e. 45% of total HVAC consumption), which corresponded to an annual revenue of HK\$87.4/m<sup>2</sup>. Given that the use of curtain walling systems is a dominant trend for new Grade A and B office buildings, it is inappropriate to compare

the 'window to wall ratio' of these buildings with that of the baseline office building for which concrete external walling system was adopted. In this case, if we ignore the cost impact due to the change of 'window to wall ratio', the minimum initial premium will increase to HK\$ 118.7/m<sup>2</sup> and 108.2/m<sup>2</sup> for air-cooled and water-cooled heat rejection method, respectively.



**Fig. 7.11 Initial cost premiums for HK-BEAM 4/04 energy performance credits for an idealized air-cooled air-conditioned building**



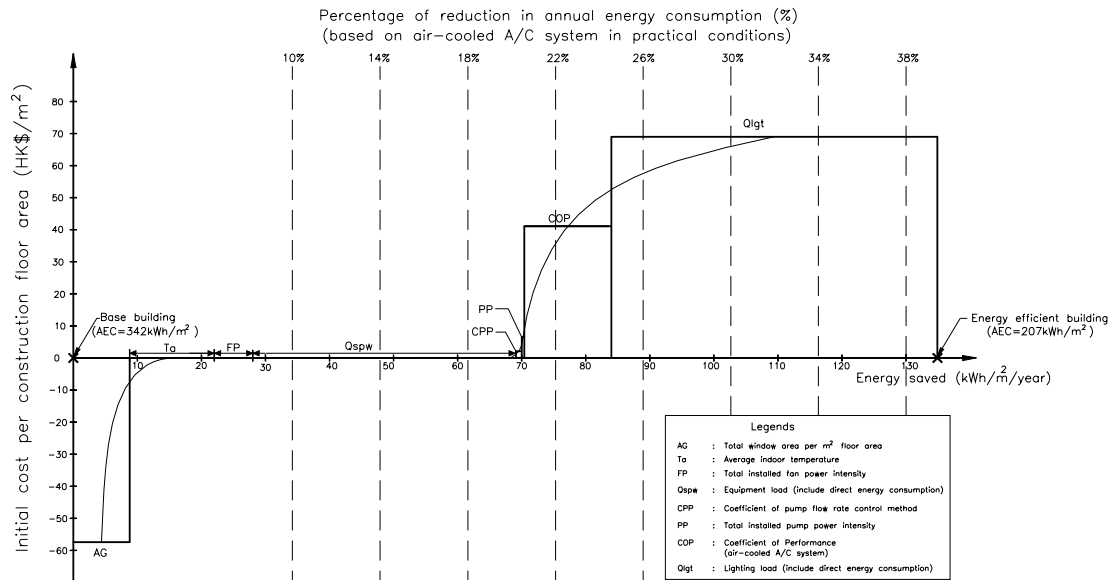
**Fig. 7.12 Initial cost premiums for HK-BEAM 4/04 energy performance credits for an idealized water-cooled air-conditioned building**

All the figures given above were based on an underlying assumption that the HVAC control system is ideal. However, in reality, it rarely happens due to degradation of equipment, poor design and maintenance, differences between actual circumstances and those assumed in the baseline building. Previous experiences and research studies suggest that additional 50% should be added to the HVAC consumption levels estimated by simulation models in to cover such inaccuracies. As such, an adjustment factor of 50% has been added to the annual HVAC

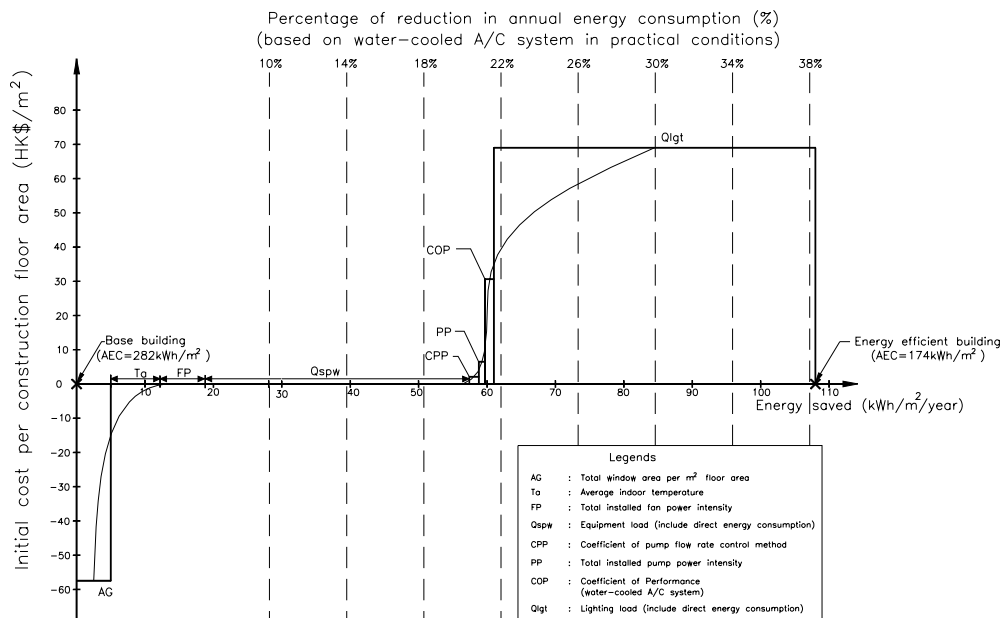


consumption levels that we obtained from our simulation models for the air-cooled and water-cooled baseline buildings.

Figures 7.13 and 7.14 show the resulting cost-energy performance curves with annual energy consumptions of 342kWh/m<sup>2</sup> (for air-cooled) and 282kWh/m<sup>2</sup> (for water-cooled) after the adjustment factor had been incorporated. With such adjustment on the total annual energy use for the baseline building, a maximum of only eight credits could be obtained even for application of all the energy saving devices in either the air-cooled or water-cooled air-conditioned building. In this case, the percentage of annual energy saving gain was reduced to 39% and 38% of the total annual energy use for air-cooled and water-cooled heat rejection method, respectively.



**Fig. 7.13 Initial cost premiums for HK-BEAM 4/04 energy performance credits for a non-idealized air-cooled air-conditioned building**



**Fig. 7.14 Initial cost premiums for HK-BEAM 4/04 energy performance credits for a non-idealized water-cooled air-conditioned building**

## 8 BENEFITS FROM GREEN BUILDING ASSESSMENTS

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As discussed in Section 3 green buildings are perceived to provide tangible benefits such as materials, energy and water savings during use, and the intangible benefits such as improved productivity in workplaces, reduced operation and maintenance costs, reduced demands on infrastructure, enhanced reputation of developers/owners, improved sales, etc.

BEAM assessments provide a range of performance standards, features and provisions that are intended to enhance building performance over and above regulatory or conventional practice. For assessment of new buildings the criteria includes design based assessments, such as estimated annual energy use, construction phase environmental performance, and commissioning and handover of the completed building. However, the added benefits of a certified green building compared to a conventional or non-green building depend on the performance enhancements put in place, i.e. the assessment criteria (credits) confirmed by the certification, and the likelihood of persistence of those measures over a period of building use. The better the grade the higher the proportion of criteria satisfied, but within a given grade the outcomes can vary.

### *HK-BEAM Criteria*

Given that assessments under HK-BEAM versions 1/96R (New Offices) and 3/99 (Residential) are no longer current the emphasis of the study in respect of benefits has been on assessments under version 4/04.

The performance standards, features and provisions promoted by HK-BEAM are guided by knowledge of sub-standard performance found in existing buildings, deficiencies in the practices (processes) used in the production of buildings, and the practicality of achieving performance enhancements that define *greener* buildings.

This section looks at the problems found in existing buildings and the likely causes before considering where compliance with HK-BEAM assessment criteria can improve matters. The emphasis is on indoor environmental quality (IEQ) as it affects productivity in workplaces and the health and comfort of building users and, given the heightened concerns about climate change, on energy efficiency. Potential enhancements under site aspects, water use and materials are also discussed.

In reviewing the outcomes of green building assessments it has become clear that rather than the addition of particular green features, the key issue for improved life-cycle performance of a building is to improve the production process from initial planning through to commissioning and handover, as well as the quality of management, operation and maintenance, and end use. The potential benefits from improving the way buildings are designed and commissioned are outlined.

### 8.1 POST-OCCUPANCY EVALUATION OF EXISTING BUILDINGS

Forty years ago, the Royal Institute of British Architects (RIBA) put a feedback stage into their Plan of Work for Design Team Operation. In spite of this, such feedback is by no means routine in the UK or elsewhere in the world. As discussed by the US Federal Facilities Council<sup>[77]</sup> Post-occupancy Evaluation (POE) has come to mean “any activity that originates out of an interest in learning how a building performs once it is built (if and how well it has met expectations) and how satisfied building users are with the environment that has been created”. POE has been seen as one of a number of practices aimed at understanding design criteria, predicting the effectiveness of emerging designs, reviewing completed designs, supporting facilities management, and linking user response, mainly with regard to the performance of heavily-serviced (e.g. centrally air-conditioned) buildings. However, relatively few organizations have fully incorporated lessons from POE programs into their building delivery processes, job descriptions, or reporting arrangements.

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<sup>77</sup> Federal Facilities Council, Board on Infrastructure and the Constructed Environment, National Research Council. Learning from Our Buildings: A State-of-the-Practice Summary of Post-Occupancy Evaluation. 2004.

One reason for this limited use is the nature of POE itself, which identifies both successes and failures. It is perhaps a reflection on the local culture that few organizations in Hong Kong encourage or reward staff or programs that expose shortcomings.

POE focuses on the needs of building occupants, including health, safety, security, functionality, psychological comfort, aesthetic quality, and satisfaction, as well as technical performance, such as energy efficiency<sup>[78]</sup>. Buildings should provide safe, healthy, convenient and efficient indoor spaces. POE studies conducted world-wide conclude that many buildings, particularly heavily-serviced buildings, fail to provide satisfactory levels of performance, reducing operating efficiency and occupant comfort.

Bordass and his co-authors<sup>[79]</sup> have reported extensively on post occupancy evaluations of buildings in the UK, including 'green' buildings, where failures to provide good indoor conditions, excessive energy use, and poor operability are not uncommon. Objectives for energy efficiency are defeated by control problems, lack of energy management, and a tendency for systems to default to 'on'. Failings are due to inadequacies in design (e.g. oversized equipment), poor quality construction and commissioning, resulting in energy performance below expectations<sup>[80]</sup>.

Given that on average a person in Hong Kong spends around 85% of their time indoors<sup>[81]</sup>, indoor environmental conditions have a significant impact on the quality of life. Indoor environmental quality (IEQ) refers mainly to the 'indoor climate', as defined by indoor air quality (IAQ), thermal comfort, lighting quality (including daylighting), acoustics, noise and vibration. Hygiene is also included within this context, as well as the electromagnetic environment. Sub-standard performance in air-conditioned buildings includes poor IEQ including comfort and IAQ. Reduced productivity affects businesses and the economy, as does increased morbidity and mortality in the general population due to 'sick buildings'.

### **8.1.1 PRODUCTIVITY – INTANGIBLE AND SIGNIFICANT!**

Poor indoor environments in commercial and institutional buildings can impact on productivity and may impose health risks to users. For example, the BCO<sup>[82]</sup> reports that 95% of occupiers say that indoor environments in offices are important, and 70% say very important in attracting and retaining staff. Similar conclusions are reported by BOMA/ULI<sup>[83]</sup> in a N American study. In schools there are concerns about the health impacts of poor indoor air quality (IAQ)<sup>[84]</sup> and an acknowledgement that good indoor environmental quality (IEQ) enhances student performance.

Numerous studies have attempted to put a cost to the loss of productivity in workplaces due to inadequate indoor environmental conditions and, although it is difficult to quantify the benefit of 'superior' conditions, there are risks from unhealthy and/or uncomfortable conditions. According to Fisk<sup>[85]</sup> substantial portion of the U.S. population suffers frequently from communicable respiratory illnesses, allergy and asthma symptoms which could be reduced through improvements in buildings. A decrease of these health effects would lead to reduced sick leave, shorter periods of illness-impaired work performance, and lower health care costs, resulting in annual economic benefits in the tens of billions of dollars. Fisk asserts that awareness of these potential health and economic gains could help bring about a shift in the way buildings are designed, constructed, operated, and utilised, and that the goal should be to provide indoor environments that maximize the health, satisfaction, and performance of building occupants.

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<sup>78</sup> Jaunzens D, Hadi M, Graves H. Environmental Division. Building Research Establishment. Encouraging Post Occupancy Evaluation. CRISP Consultancy Commission 00/12. February 2001.

<sup>79</sup> Bordass B, Cohen R, Standeven M, Leaman A. Assessing building performance in use 3: energy performance of the Probe buildings. Building Research & Information. Vol. 29, No. 2, 114-128, 2001.

<sup>80</sup> Bordass B, Cohen R, Field J. Energy Performance of Non-Domestic Buildings: Closing the Credibility Gap. Advanced Building News, Vol. 08, 3-11, 2005.

<sup>81</sup> Chau C K, Tu E Y, Chan D W T, Burnett J. Estimating the total exposure to air pollutants for population age groups in Hong Kong. Environment International. Vol. 27, 617-630, 2002.

<sup>82</sup> British Council for Offices. Office Occupier's Survey. July 2005.

<sup>83</sup> BOMA International/ Urban Land Institute. What Office Tenants Want. BOMA/ULI Office Tenant Report. 1999.

<sup>84</sup> Tong S Y T, Lam K C. Are nursery schools and kindergartens safe for our kids? The Hong Kong study. The Science of the Total Environment 216, 217-225, 1998.

<sup>85</sup> Fisk W J. Health and Productivity Gains from Better Indoor Environments and Their Implications for the U.S. Department of Energy. E-Vision 2000 Conference, October 11-13, Washington DC. 2000.

## 8.1.2 ADAPTABLE BUILDINGS

Guides describe sustainable or high-performance design of buildings have been around for over a decade<sup>[86,87]</sup> but tend to discuss enhancements in terms of fixed building use. However, for many organisations, private, public, or government, an important measure of a building is its functionality and adaptability, i.e. the ability to accommodate changes in response to changing operational needs. Designs that take account of how buildings will be used, operated and adapted will tend to be more sustainable than otherwise and a greater asset to occupiers<sup>[88]</sup>.

Some buildings are relatively stable and have low technical demands and moderate changes, whereas offices and health care facilities undergo frequent change. The importance of functionality and adaptability, particularly in offices, has increased for a number of reasons: change and churn, flexible use of space, changing requirements for IT, etc. The economic impacts include the costs of making changes and the down-time during reconfiguration. As argued by Arge<sup>[89]</sup>, “adaptability ought to be an important element on all real estate developer’s agenda, regardless of time and market perspective. Adaptability is one way to avoid early obsolescence that is, making buildings sustainable”. Potential change of use has implications on the durability of building elements and systems. Whilst a durable building envelope is always desirable, there is little purpose to install modular systems and durable components if they are discarded early, unless they are going to be reused or recycled.

Flexibility of the building structure includes floor plate design, plan depth, planning grid and columns, circulation routes, etc. Flexibility of building services improves if distribution routes are not too tightly integrated with the structure<sup>[90]</sup>. Flexible services design avoids over-complication, provide good zoning, have good capacity control and be capable of part-floor operation. Flexibility requires making provisions for multiple IT service providers, with spare capacity installed or space allowed. Buildability is also an important feature of design allowing for reducing waste and environmental and social impacts during construction and demolition<sup>[91]</sup>. It is feasible to benchmark the serviceability (adaptability) of a facility, i.e. the capacity to accommodate change such as relocation or rearrangement of workstations. ASTM<sup>[92]</sup> provides a system to match a rating scale (1-9) to a descriptive requirement of the serviceability required in respect of disruption (time frame), relocating services, changes to layout, etc.

## 8.1.3 POST-OCCUPANCY EVALUATION OF BUILDINGS IN HONG KONG

Experience of audit and survey studies for buildings in Hong Kong shows that the common causes of inefficient operation of buildings are not dissimilar to causes found elsewhere, and fall under the following categories<sup>[93]</sup>:

- poor building design, including use of poor quality materials;
- poor construction quality;
- inadequate services system designs, including use of poor quality equipment and controls;
- oversizing of plant and equipment in air-conditioned buildings;
- poor services system installation;
- inadequate testing and commissioning of services systems;
- inefficient operation and maintenance of building services systems; and

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<sup>86</sup> Public Technology Inc, US Green Building Council. Sustainable Building Technical Manual. 1996.

<sup>87</sup> City of New York. High-performance Building Guidelines. April 1999.

<sup>88</sup> Russell R, Moffatt S. Assessing Buildings for Adaptability. Annex 31. Energy-Related Environmental Impact of Buildings. November 2001.

<sup>89</sup> Arge, K. Adaptable office buildings: theory and practice. *Facilities*, Vol. 23, No. 3/4, 119-127. 2005.

<sup>90</sup> CIBSE. Chartered Institution of Building Services Engineers. Flexible Building Services for Office-Based Environments. Principles for Designers, TM27, 2000.

<sup>91</sup> Building and Construction Authority, Singapore. Code of Practice on Buildable Design. January 2004.

<sup>92</sup> ASTM Designation E 1334 – 95. Standard Practice for Rating the Serviceability of a Building or Building-Related Facility. 2005.

<sup>93</sup> Yik F W H, Lee W L. A Preliminary Inquiry into Why Buildings Remain Energy Inefficient and the Potential Remedy. *HKIE Trans.* Vol. 9, No. 1. 32-36, 2002.

- aged plant and equipment.

As discussed later in this section, post-occupancy evaluation of residential buildings have mostly focused on occupant satisfaction with residential estates, including building and estate design, building and estate management, on indoor environmental conditions within apartments, and the condition of existing buildings. Of interest in the context of this study is the importance that residents attach to environmental performance and the extent to which a green building assessment can improve the qualities of high-rise residential buildings.

#### **8.1.4 POTENTIAL BENEFITS OF HK-BEAM ASSESSMENTS**

The benefits of an assessment under HK-BEAM 4/04 'New Buildings' depends on the extent to which the qualities of a building are enhanced as a consequence of the impact of the assessment process on the building production processes. Experiences from the assessments undertaken thus far is that designs are enhanced as a consequence of a Client's wish to obtain the highest rating possible, such as using more efficient systems and equipment, as well as the guidance and information provided by the HK-BEAM assessors that leads to a better solution.

As in the case of estimating cost premiums, estimates for benefits depend on a number of underlying assumptions for the two types of building studied, which credits are obtained and which performance enhancements persist during use. Given the variability of outcomes and the limited data available much of the potential benefits can only be discussed in qualitative terms. Section 10 provides further details on the potential benefit from achieving each credit in HK-BEAM 4/04 for office buildings and residential buildings, respectively.

## **8.2 INDOOR ENVIRONMENTAL QUALITY**

The indoor environment in air-conditioned buildings is dependent on building and services design and operation, tenant fit-out and the activities of users. The extent to which lighting and thermal comfort can be controlled depends on the design of services and interface with the users. Fit-out, such as the position of partitions, can affect thermal comfort and ventilation effectiveness.

Sources of indoor pollutants include outdoor pollutants, building fabric materials, interior finishes, building systems and equipment, appliances, consumer products, and the occupants and their activities. The selection of building materials is important, as pollutants can be emitted for weeks, months or even years after installation. Air intakes should be sited away from pollutant sources and must avoid short-circuiting with exhaust. Ventilation system design should not introduce pollutants, and filtering should be effective in removing outdoor pollutants. IAQ will depend on the ability of the ventilation system to dilute indoor sources of pollution and human body odours. Effective ventilation is essential to avoid stagnant areas or overcooling/drafts.

Indoors environments in residential buildings mainly depend on occupant preference and lifestyle. The building envelope, its integrity and means for moderating heat gains, provisions for daylight and ventilation, and the selection of building materials are the main contributions to IEQ from design.

### **8.2.1 INDOOR AIR QUALITY IN AIR-CONDITIONED BUILDINGS**

Hong Kong designers use a variety of performance standards, international or national, for thermal comfort, ventilation, lighting, acoustics and noise. ASHRAE standards and guides tend to dominate in the case of HVAC system design, with CIBSE guides usually employed for lighting design.

Even though research on indoor air quality has provided a lot of information, it has still not been possible to agree on one international standard. Most existing standards or guidelines for IAQ in conditioned spaces provide criteria in terms of ventilation requirements. According to Olesen<sup>[94]</sup> the most internationally used standard for ventilation and IAQ is ASHRAE Standard 62.1<sup>[95]</sup>. New

<sup>94</sup> Olesen B W. International standards for the indoor environment. Indoor Air, Vol. 14, Suppl. 7, 2004, pp18-26.

<sup>95</sup> American Society of Heating, Refrigeration and Air-Conditioning Engineers, Inc. ASHRAE Standard 62.1. Ventilation for Acceptable Indoor air Quality. 2003.

concepts were introduced in CR1752<sup>[96]</sup>, where criteria for indoor air quality, ventilation, thermal comfort and noise are included.

#### *Indoor Air Quality in Air-conditioned Buildings in Hong Kong*

A consultancy study commissioned by the Environmental Protection Department<sup>[97]</sup> concluded that one third of the Hong Kong air-conditioned buildings were 'sick', mainly due to unacceptable IAQ. A telephone survey found that some 32% of the 2000 respondents from 800 identifiable buildings were dissatisfied with the IAQ at their workplace. On-site measurements on 1183 occupants in 40 selected office premises found that:

- 37.5% of offices had, over an 8-hour period, a mean CO<sub>2</sub> levels exceeding 1000 ppm;
- 90% of office buildings were well below the 7.5 l/s per person recommended by ASHRAE<sup>[98]</sup>;
- 20% had bacteria counts higher than 1000 cfu/m<sup>3</sup> (colony forming units/ m<sup>3</sup>);
- 32.5% with formaldehyde levels above the WHO guideline of 100 µg/m<sup>3</sup>; and
- high levels of organic compounds where redecoration was taking place.

The statistical analysis "showed significant correlation between the occupants' perceptions and measured parameters of IAQ including temperature, humidity, air change per hour, and levels of carbon dioxide, carbon tetrachloride, dichlorobenzene, bacteria and fungal counts". The outcome of the study was the development of the IAQ certification scheme<sup>[99]</sup>, currently operated on a voluntary basis, but with potential for legislative enactment in future.

A more recent study by Lai and Yik<sup>[100]</sup> found from a response from over four hundred building users that air-conditioning performance in buildings to be the least satisfactory, followed by lift and escalator service, and lighting quality.

#### *Assessment of IAQ in Air-conditioned Buildings in Hong Kong*

In the IAQ Certification scheme two levels of assessment criteria are used as benchmarks to label the IAQ of premises these include 3 physical, 8 chemical and one biological parameter. The criteria given in Table 8.1 are not without controversy with Lu et al<sup>[101]</sup> questioning the appropriateness of some of the criteria for pollutant concentrations.

'Excellent' Class represents an "excellent IAQ that a high-class and comfortable building should have". 'Good' Class represents the IAQ that "provides protection to the public at large including the young and the aged". A competent examiner must undertake the full assessment and issue the certificate, which is valid for 12 months, after which carbon dioxide (CO<sub>2</sub>) and respirable suspended particulates (RSP) need to be measured for renewal. After 5 years the full set of parameters must be measured.

Measurements are required to be made on an 8-hour basis, or use the average of four half-hour measurements evenly distributed over the business hours for offices. The number of samples required is based on floor area and all parameters except air movement should also be monitored at fresh air intakes. Also specified is the measurement protocol, including real-time monitoring and the quality assurance procedures for collecting and analysing samples. The 8-hour average IAQ Objectives in Table 8.1 are used as the benchmark for assessing compliance. At least 80% of the sample points for each parameter need to comply, and none of the chemical and biological samples should exceed the criteria by more than 50%. For the physical parameters no sample should deviate by more than 10% of the upper or lower limit.

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<sup>96</sup> European Committee for Standardization. CEN Report CR1752. Ventilation for Buildings - Design Criteria for the Indoor Environment. CEN, Brussels. 1998.

<sup>97</sup> Environmental Protection Department, HKSAR Government.. Indoor Air Pollution in Offices and Public Places in Hong Kong. 1997.

<sup>98</sup> American Society of Heating, Refrigeration and Air-Conditioning Engineers, Inc. ASHRAE 62-1989R. Ventilation for Acceptable Indoor Air Quality. ASHRAE 1989.

<sup>99</sup> Indoor Air Quality Management Group. Guidance Notes for the Management of Indoor Air Quality Certification Scheme in Offices and Public Places. Hong Kong SAR Government. 2005.

<sup>100</sup> Lai J H K, Yik F W H. ASHRAE/CIBSE/HKIE Joint Symposium, Hong Kong. 2005.

<sup>101</sup> Lu B M K, Niu J L, Burnett J. Review of the Objective Pollutant Levels in the IAQ Certification Scheme: HKIE Trans: Vol. 9, No. 3, 26-33, 2002.

### Relevance of Carbon Dioxide (CO<sub>2</sub>)

A widely held view that CO<sub>2</sub> is a good surrogate for IAQ, such that at levels below 1000 ppm it is probable there will be no pollutants present at levels that are harmful to health. This view is reinforced by studies in the US<sup>[102]</sup> and elsewhere that show correlations between Sick Building Syndrome (SBS) symptoms and CO<sub>2</sub> levels. CO<sub>2</sub> is not a pollutant and in itself shows no impact on health at levels, even as high as 5000 ppm. Moreover, ASTM<sup>[103]</sup> warns against overly simplistic interpretations of indoor CO<sub>2</sub> concentration as a comprehensive indicator of IAQ, or in determining adequacy of outdoor ventilation rate.

**Table 8.1 IAQ Objectives for Office Buildings and Public Places<sup>[99]</sup>**

Parameter	Unit	8-hour average <sup>a</sup>	
		Excellent Class	Good Class
Room Temperature	°C	20 to < 25.5 <sup>b</sup>	< 25.5 <sup>b</sup>
Relative Humidity	%	40 to < 70 <sup>c</sup>	< 70
Air movement	m/s	< 0.2	< 0.3
Carbon Dioxide (CO <sub>2</sub> )	ppmv	< 800 <sup>d</sup>	< 1,000 <sup>e</sup>
Carbon Monoxide (CO)	µg/m <sup>3</sup>	< 2,000 <sup>f</sup>	< 10,000 <sup>g</sup>
	ppmv	< 1.7	< 8.7
Respirable Suspended Particulates (PM <sub>10</sub> )	µg/m <sup>3</sup>	< 20 <sup>f</sup>	< 180 <sup>h</sup>
Nitrogen Dioxide (NO <sub>2</sub> )	µg/m <sup>3</sup>	< 40 <sup>g</sup>	< 150 <sup>h</sup>
	ppbv	< 21	< 80
Ozone (O <sub>3</sub> )	µg/m <sup>3</sup>	< 50 <sup>f</sup>	< 120 <sup>g</sup>
	ppbv	< 25	< 61
Formaldehyde (HCHO)	µg/m <sup>3</sup>	< 30 <sup>f</sup>	< 100 <sup>f,g</sup>
	ppbv	< 24	< 81
Total Volatile Organic Compounds (TVOC)	µg/m <sup>3</sup>	< 200 <sup>f</sup>	< 600 <sup>f</sup>
	ppbv	< 87	< 261
Radon (Rn)	Bq/m <sup>3</sup>	< 150 <sup>i</sup>	< 200 <sup>f</sup>
Airborne Bacteria	cfu/m <sup>3</sup>	< 500 <sup>j,k</sup>	< 1,000 <sup>j,k</sup>

ASHRAE's definition of acceptable indoor air quality is "air in which there are no known contaminants at harmful concentrations as determined by cognizant authorities and with which a substantial majority (80% or more) of the people exposed do not express dissatisfaction. The older standard<sup>[98]</sup> suggests that this might be achieved if the metabolic CO<sub>2</sub> level is maintained at a maximum excess of 600-650 ppm over the CO<sub>2</sub> concentration in the outdoor air (say 350 ppm), for which an outside air ventilation rate of around 7.5-8 l/s per person is required. In the absence of significant levels of pollutants and odour sources other than people the 1000 ppm level for 'Good' IAQ will satisfy at least 80% of visitors (unadapted persons) to a space, and 800 ppm will probably satisfy around 85% (illustrating the diminishing return from increasing ventilation). However, ASTM<sup>[103]</sup> notes that these expectations are based on experiments with individuals whose personal hygiene and expectations may differ from the actual visitors to a space. According to ASTM adapted persons can accept CO<sub>2</sub> concentrations above outdoors up to 3 times higher, i.e. 2300 ppm for 350 ppm.

### Ventilation Requirements

There are three basic requirements for ventilation of occupied rooms and rooms used for habitation: background ventilation, local exhaust, and source control. The concepts can be

<sup>102</sup> Apte M G, Fisk W J, Daisey J M. Associations Between Indoor CO<sub>2</sub> Concentrations and Sick Building Syndrome Symptoms in U.S. Office Buildings: An Analysis of the 1994–1996 BASE Study Data. *Indoor Air*, Vol.10, 246–257, 2000.

<sup>103</sup> ASTM International Designation D 6245-98. Standard Guide for Using Indoor carbon Dioxide Concentrations to Evaluate Indoor Air Quality and Ventilation. 2002.

applied to workplaces, classrooms and similar workplaces where people spend long periods of time. Background ventilation is intended to dilute the unavoidable contaminant emissions from people and materials. Background ventilation should be provided for control of radon levels in occupied and habitable rooms, and reduce possibility of mould growth under conditions of high humidity. Local exhaust is intended to remove contaminants from those specific rooms, such as kitchens, in which concentrated sources are expected.

Problems with ventilation systems in many air-conditioned buildings in Hong Kong is the inadequacy of outside (fresh) air supply which often falls below recommended design figures, poor balancing of systems, and poor air diffusion within spaces.

### HK-BEAM Criteria for IAQ and Ventilation in Air-conditioned Buildings

The assessment of indoor air quality (IAQ), ventilation and thermal comfort takes into account:

- the extent to which the building and installed engineering systems can provide for comfortable and healthy premises; and
- the potential 'worst-case' scenario in respect of exposure to harmful substances found in indoor air.

6.3.2	OUTDOOR SOURCES OF AIR POLLUTION	1 credit for demonstrating compliance with appropriate criteria for carbon monoxide.	None.	1
		1 credit for demonstrating compliance with the appropriate criteria for nitrogen dioxide.		1
		1 credit for compliance with the appropriate criteria for ozone.		1
		1 credit for compliance with the appropriate criteria for RSP.		1
6.3.3	INDOOR SOURCES OF AIR POLLUTION	1 credit for compliance with the appropriate criteria for VOCs.	None.	1
		1 credit for compliance with the appropriate criteria for formaldehyde.		1
		1 credit for compliance with the appropriate criteria for radon.		1

The objective of Credit 6.3.2 is to ensure that occupants will not suffer unduly from outside sources of pollution. Credit 6.3.3 is to ensure that occupants will not suffer unduly from pollutants that are mainly attributable to indoor sources. Compliance is demonstrated by measurement, allowing any protocol that is equivalent to that given in the IAQ Certification Scheme. Where the Client does not offer performance criteria, HK-BEAM uses the criteria given in Table 8.1.

In the case of occupied/habitable rooms in air-conditioned/naturally ventilated buildings the concern is indoor air pollutant from indoor sources whilst operating in the background ventilation mode, i.e. all openings other than those provided for background ventilation are 'closed'. The alternative approach to satisfying Credit 6.3.3 is to undergo an evaluation of emissions from pollutant sources, but which is difficult if data is not available. The criterion in HK-BEAM 4/04 is more difficult to satisfy than is most other BEAMs, which tend to rely on performance specifications for materials (finishes, furnishings, etc) used inside a building.

The cost for assessing a building depends on the size, as there would be a minimum number of test locations, but by splitting the assessment between indoor and outdoor sources, and considering the 'worst case' situations (e.g. an office floor above a carpark) there is potential to reduce cost below a full survey required in the IAQ Certification Scheme.

### Ventilation

HK-BEAM seeks to ensure that rooms that contain significant sources of pollutants, such as print rooms, are provided with dedicated exhaust and isolation to avoid entrainment into occupied areas. This concept extends to redecoration and refitting of offices and office floors, whereby the likely heavy sources of pollution such as VOC's from paint can affect adjacent areas.

6.4.1	VENTILATION IN AIR-CONDITIONED PREMISES	1 credit for demonstrating that the corrected design ventilation rate meets the design intent for normally occupied spaces, and the corresponding outdoor air flow rate is achieved.	Residential and similar buildings not centrally air-conditioned.	1
		1 credit for demonstrating that the air change effectiveness in normally occupied areas meets the specified performance.		1
6.4.4	LOCALISED VENTILATION	1 credit for the provision of an adequate ventilation system for rooms/areas where significant indoor pollution sources are generated.	2 <sup>nd</sup> credit not applicable to residential and similar buildings.	1
		1 credit for the provision of a system of local exhaust of premises undergoing fit-out and redecoration.		1
6.4.5	VENTILATION IN COMMON AREAS	1 credit for demonstrating that all enclosed common areas in a building are provided with adequate ventilation.	Spaces covered under the section on Localised Ventilation	1
		1 BONUS credit where the provision for ventilation is by natural means.		1B

### Potential Benefits

Given that a building is tested in an unoccupied and maybe partially completed state IAQ



measurements will not reveal all pollutant sources. However, by carrying out an assessment the Client will be aware of 'hot spots' in respect of IAQ, and provides precursor to undertaking a full certification under the IAQ Certification Scheme. Ensuring the adequacy of ventilation, both in terms of quantity and distribution within occupied areas is an important factor in ensuring the health and comfort of the occupants.

A full assessment of IAQ and ventilation performance provides greater assurance that the building will be healthy and comfortable, reducing the potential for complaints, and increasing tenant/user satisfaction.

## 8.2.2 THERMAL COMFORT IN AIR-CONDITIONED BUILDINGS

Thermal comfort is that condition of mind which expresses satisfaction with the thermal environment. Because there are large variations, physiologically and psychologically, from person to person, the environmental conditions required for comfort are not the same for everyone. The parameters that define the thermal environment are given in standards such as EN ISO 7730<sup>[104]</sup>, CR 1752<sup>[96]</sup> and ASHRAE 55<sup>[105]</sup>:

- temperature - air, radiant, and surface;
- relative humidity;
- air velocity;
- personal attributes - clothing and activity.

The reference standards are based mainly on laboratory studies with test subjects mainly from Europe and North America. But studies with Asian and African subjects under laboratory test conditions have found similar results for general thermal comfort. Criteria for an acceptable thermal environment are specified as requirements for general thermal comfort may be expressed by predicted mean vote - predicted percentage dissatisfied (PMV-PPD)<sup>[104]</sup>. Occupants may be dissatisfied due to general thermal comfort and/or dissatisfied due to local thermal comfort parameters (draught, etc). The level of thermal comfort chosen may be influenced by what are technically possible, economy, energy use, environmental pollution and performance<sup>[94]</sup>. Clearly, a set-point based only on air-temperature, such as the 25.5° setting promoted by the HKSAR Government, is hardly sufficient as thermal comfort criteria in air-conditioned buildings, even if thermostats were able to maintain the temperature within tight limits.

As discussed by Burnett<sup>[106]</sup> the thermal comfort compliance requirement In the IAQ Certification Scheme allows temperature to deviate by up to 10% in 20% of locations, so temperatures highs of 27.5°C and lows of 18°C would be certified. These limits are barely within those suggested by Brager and de Dear<sup>[107]</sup> for naturally ventilated buildings in sub-tropical climates such as Hong Kong's, and is at odds with research indicating occupant preference for 23°C in office premises<sup>[108]</sup>.

### HK-BEAM Criteria for Thermal Comfort in Air-conditioned Buildings

6.5.1 THERMAL COMFORT IN CENTRALLY AIR-CONDITIONED PREMISES	1 credit for sustaining the air temperature at the design value within ±1°C when the air side system is operating at steady state under conditions of zero occupancy.	Premises where air-conditioning is provided by window units or split units.	1
	1 credit for sustaining the air temperature at the design value within ±1°C when the air side system is operating at steady state under simulated full-load conditions.		1
	1 credit where room air diffusers satisfy the Air Diffusion Performance Index.		1

The criterion mainly focuses on the ability of the HVAC system to control the thermal comfort under conditions where occupancy and equipment loads might vary. Given that it is a matter of choice the temperature set-point are defined by the Designer. The specification of ± 1°C is very

<sup>104</sup> International Organization for Standardization. ISO 7730. Moderate thermal environments -Determination of the PMV and PPD indices and specification of the conditions for thermal comfort. 1994.

<sup>105</sup> American Society of Heating, Refrigeration and Air-Conditioning Engineers, Inc. ASHRAE Standard 55-2004. Thermal Environmental Conditions for Human Occupancy. 2004.

<sup>106</sup> Burnett J. Indoor Air Quality Certification Scheme for Hong Kong Buildings. Monitoring Indoor Air Pollution. The 2nd International Conference. Manchester, April, 2004.

<sup>107</sup> Braga GS, de Dear R. A Standard for Natural Ventilation. ASHRAE Journal October 2000; 21-28.

<sup>108</sup> Chan W T D, Burnett J, de Dear R J, Ng C H S. A large-scale survey of thermal comfort in office premises in Hong Kong. ASHRAE Transactions, Vol. 14, No. 1, 76-84, 1998.

tight and may not be achievable in all parts of a large open plan office. Possibly of more relevance to thermal comfort is the ADPI which essentially seeks to show that air diffuser performance meets specification<sup>109</sup>. As for the case of IAQ assessments it is not possible to fully assess thermal comfort in new premises (HK-BEAM stipulates simulated loads for tests), but the focus on temperature control is perhaps more important than maintaining a given temperature set-point.

### 8.2.3 LIGHTING QUALITY IN WORKPLACES

Lighting in buildings has a large impact on both the global environment and the indoor environment. Improving the efficiency of lighting systems reduces energy consumption and improves comfort, work performance and well-being of occupants. Lighting specifications vary by country even for the same application, so specifying simple criteria such as 500 lux in offices hardly addresses the issue of quality, and may not be the required performance in terms of glare, colour rendering, uniformity, etc are of importance. The use of high-frequency electronic ballasts reduces likelihood of eye strain and occupant discomfort<sup>110</sup>.

It is generally agreed that daylighting of interior spaces has a number of benefits. Daylight makes an interior look more attractive as well as providing light for indoor activities. There is evidence that exposure to daylight reduces stress and increases occupant satisfaction. Daylight availability and access to windows (connection with the outside) is an important consideration in offices other workplaces such as schools<sup>111</sup>.

The problem for Hong Kong's high density, high-rise buildings is providing sufficient daylight, and in most offices it is not a design consideration, and in many residential buildings it is patently inadequate. Whilst using criteria such as Daylight Factor is alright for unobstructed buildings and windows, the criteria for obstructed buildings/overshadowed windows is more appropriately addressed by Vertical Daylight Factor, criteria for which is provided as a performance-based alternative to Hong Kong's building regulations<sup>112</sup>. Problems with assessing the lighting criteria in HK-BEAM version 1/96R as well as changes to the building regulations resulted in changes to the criteria in version 4/04.

#### HK-BEAM Criteria for Lighting in Workplaces

The criterion covers daylight provisions on a scale from 1 to 3 credits, where the minimum is defined in terms of Vertical Daylight Factor or Daylight Factor, with added credits for DF in the perimeter zone (of deep plan office buildings). Criterion for interior lighting addresses the issue of both quantity (as defined by the Assessed Building design) and quality (as defined by the standards referenced by the design).

6.6.1	NATURAL LIGHTING	1 credit where the provision of daylight meets the levels specified in PNAP 278 for vertical daylight factor OR the average daylight factor (DF) is at least 0.5% for all normally occupied spaces. 2 credits where the average daylight factor in all normally occupied spaces is at least 1%. 3 credits where the average daylight factor in all normally occupied spaces is at least 2%.	None.	3
6.6.2	INTERIOR LIGHTING IN NORMALLY OCCUPIED AREAS	1 credit where the prescribed lighting performance in each type of premises in respect of maintained illuminance and illuminance variation is achieved. 1 credit for lighting installations in which: the limiting unified glare rating is achieved; and light sources have an appropriate colour rendering index.	Residential buildings.	1 1
6.6.3	INTERIOR LIGHTING IN AREAS NOT NORMALLY OCCUPIED	1 credit where fluorescent and other lamps with modulating (fluctuating) output are fitted with dimmable high-frequency ballasts in all work areas. 1 credit where the prescribed lighting performance in each type of common or service space in respect of light output and lighting quality is achieved.	None.	1 1

#### Potential Benefits

For rooms which have a window or vision to the outside there is a comfort and health benefit to occupants in that workplaces feel less isolated or enclosed (vision to outside allows the eyes to relax, connection to the outside helps maintain the biological clock). Provided solar glare is not excessive lighting quality maybe enhanced by letting in daylight, with the potential to save energy

<sup>109</sup> American Society of Heating, Refrigeration and Air-Conditioning Engineers, Inc. ASHRAE Standard 113. Method of Testing for Room Air Diffusion. 1990.

<sup>110</sup> Chung T M, Burnett J. Lighting criteria in the Hong Kong Building Environmental Assessment Method. Lighting Research and Technology. Vol. 31, No. 3, 89-95, 1999.

<sup>111</sup> Boyce P, Hunter C, Howlett O. The Benefits of Daylight through Windows. Report for Capturing the daylight Dividend Program. US, September 2003

<sup>112</sup> Buildings Department. Practice Note for Authorized Persons and registered Structural Engineers, PNAP 278. Lighting and Ventilation Requirements – Performance-based Approach. 2003.

by dimming interior lights. The quality of artificial lighting can improve work performance but, given the adaptability of humans to light levels, quantity of light may not be as significant as quality.

## 8.2.4 ACOUSTICS, NOISE AND VIBRATION IN BUILDINGS

Many Hong Kong buildings housing noise sensitive premises are built close to roads and railway lines such that ground transportation noise impacts on occupants. Noise from fixed sources and aircraft may also pose a problem for some developments. Noise mitigation measures such as appropriate road surface design, screening by non-noise sensitive building structures, podium structures or purpose built barriers, orientation, or disposition and internal layout of buildings should be explored in an effort to minimise rail and road traffic noise.

The design of a building façade, including windows, balconies, openings for air-conditioners and ventilators, etc is important in further reducing the propagation of noise into noise sensitive premises, particularly where external noise levels exceed the limits given in the Hong Kong Planning Standards and Guidelines. Even where external sources of noise and/or noise mitigation measures are such as to satisfy the guidelines, further attention to indoor noise is warranted on the grounds of comfort and privacy.

The selection and erection of building services systems and equipment also influences the background noise levels inside offices, and may also induce unwanted vibration. The sound insulation properties of floors and internal walls are crucial in controlling noise propagation inside a building. It is also necessary to consider how the design of premises affects speech intelligibility.

### HK-BEAM Criteria for Acoustics, Noise and Vibration

A large scale survey<sup>[113]</sup> on the acoustic environment in 26 open-plan offices found that office workers in general regarded the air-conditioning system as a major source of noise, particularly low frequency noise. It appears that the office workers were satisfied with their acoustic environment at  $L_{eq}$  of 53.3 dBA. Both this neutral value and the corresponding NC value of NC48 exceed the recommendations in international noise standards. The noise criteria in HK-BEAM was amended to take into account conditions found locally, but seeks to improve on the situation<sup>[114]</sup>.

6.7.1	ROOM ACOUSTICS	1 credit for demonstrating that the reverberation time in applicable rooms meets the prescribed criteria for given types of premises.	Buildings/premises where speech intelligibility is not important, and rooms of a special acoustical nature.	1
6.7.2	NOISE ISOLATION	1 credit for demonstrating airborne noise isolation between rooms, spaces and premises meets the prescribed criteria. 1 credit for demonstrating impact noise isolation between floors meets the prescribed criteria.	Buildings/premises which are inherently noisy and unaffected by noise.	1 1
6.7.3	BACKGROUND NOISE	1 credit for demonstrating background noise levels are within the prescribed criteria.	Buildings/premises in which speech intelligibility is not important.	1
6.7.4	INDOOR VIBRATION	1 credit for demonstrating vibration levels shall not exceed the prescribed criteria.	None.	1B

Although HK-BEAM limits the criteria to a relatively simple measure of reverberation time, and does not cover special premises such as auditoria, it does remind designers of the importance of room acoustics in rooms where speech intelligibility is important.

Noise isolation is a design issue not covered in Hong Kong's building regulations yet appears to be given attention elsewhere. HK-BEAM provides performance criteria in respect of airborne noise between rooms, and impact noise between floors.

In office buildings attenuation of any potentially distracting outside noise sources is very much a matter of façade design, and given that it is rarely possible to open windows for safety and security reasons, is not a particularly difficult issue to address, so the background noise criteria addresses mainly air-conditioning system noise.

<sup>113</sup> Tang S K, Burnett J. A Field Survey of Acoustical Environment in Office Premises in Hong Kong. Research Report, Department of Building Services Engineering, Hong Kong Polytechnic University. January 1996.

<sup>114</sup> Chan D W T, Tang S K, Burnett J. Noise Criteria for Hong Kong Building Environmental Assessment Method for New Offices and Existing Offices. HKIE Trans. Vol. 5, No. 2, 1-5, 1998.

### *Potential Benefits*

There is a productivity issue in office buildings if noise from building services equipment (air-conditioning, pumps, lifts, etc) is a distraction or even impacts on well-being of occupants. It is a privacy issue and can be annoyance in some buildings, such as air-conditioned apartments and hotels.

## **8.2.5 INDOOR ENVIRONMENTAL CONDITIONS IN RESIDENTIAL BUILDINGS**

It is apparent that IEQ with windows open will depend on the external conditions, particularly air quality, humidity and noise, as well as odours and noise from neighbours. Unsatisfactory conditions will result in windows being closed and possibly increase in the use of air-conditioning. With windows closed IEQ very much depends on the lifestyle and activities of the occupants, such as provisions for ventilation, choice of furniture and furnishings, materials used for cleaning, and activities such as smoking and incense burning.

### *Indoor Air Quality in Residential Buildings in Hong Kong*

The sources of air pollution are either mainly from outdoors (including neighbouring premises), or mainly from indoors. Proximity to outdoor 'point' sources such as industrial or commercial buildings, or 'line' sources such as vehicular traffic on adjacent roads, need to be assessed for potential impact. Of particular concern is particulate from vehicle exhausts and combustion processes. The indoor sources are from building materials over which designers have some control, from furnishings which are controlled by occupants, or from the activities of occupants, such as cooking, smoking, incense burning, etc.

A territory-wide survey<sup>[115]</sup> conducted in 1996-7 investigated the indoor airborne particulate levels in 50 residential apartments in 18 districts of Hong Kong covering both public housing and private housing. The TSP level varied from 37.5 to 227.1  $\mu\text{g}/\text{m}^3$  and the PM10 level varied from 35.1 to 161.6  $\mu\text{g}/\text{m}^3$ , much higher than the levels measured in western countries. A high proportion of respirable (PM10) content in the indoor environment indicated a significant contribution from indoor activities such as smoking, incense burning and cooking.

Radon from building materials is a somewhat unique problem for high-rise buildings in Hong Kong due to the type of concrete and other building materials in use. Mitigation of radon release is achievable through the use of wall coverings, but the indoor level can be kept low by background ventilation. An air-change rate of around 0.5 air changes per hour can reduce the radon level below the criteria given in Table 8.1<sup>[116]</sup>.

### *Ventilation*

Ventilation strategy for residential buildings is threefold:

- local exhaust (operable windows, mechanical extract, etc) to remove pollutants (and water vapour) from specific rooms (kitchens, bathrooms, etc) before they enter habitable rooms;
- ventilation of habitable rooms for respiration and to dilute unavoidable contaminant emissions from people, materials, etc; and
- rapid ventilation (operable windows) to cater for episodic occupant controlled events such as smoking, painting, etc.

### *HK-BEAM Criteria for IAQ and Ventilation Residential Buildings*

The criteria for both outdoor and indoor sources of air pollution are the same as for air-conditioned buildings. Residential building design can achieve reductions in indoor pollutants such as radon, and reduce potential problems from high levels of humidity, by providing adequate background ventilation. The use of extract fans with suitable gaps or vents in doors can provide adequate background ventilation, providing users are aware of the issue. Arguably, where buildings are close to roads, windows should not be operable other than for maintenance, and other means of ventilation should be provided.

<sup>115</sup> Tung T C W, Chao C Y H, Burnett J, Pang S W, Lee R Y M. A territory wide survey on indoor particulate level in Hong Kong. *Building and Environment*, Vol. 34, 213-220, 1999.

<sup>116</sup> Chao C Y H, Tung T C W, Burnett J Influence of Ventilation on Indoor Radon Level. *Building and Environment*, Vol. 32, No. 6, 527-534, 1997.

6.3.2	OUTDOOR SOURCES OF AIR POLLUTION	1 credit for demonstrating compliance with appropriate criteria for carbon monoxide.	None.	1
		1 credit for demonstrating compliance with the appropriate criteria for nitrogen dioxide.		1
		1 credit for compliance with the appropriate criteria for ozone.		1
		1 credit for compliance with the appropriate criteria for RSP.		1
6.3.3	INDOOR SOURCES OF AIR POLLUTION	1 credit for compliance with the appropriate criteria for VOCs.	None.	1
		1 credit for compliance with the appropriate criteria for formaldehyde.		1
		1 credit for compliance with the appropriate criteria for radon.		1
6.4.2	BACKGROUND VENTILATION	1 credit for demonstrating the adequacy of ventilation in all normally occupied or habitable rooms with windows closed. 1 additional credit where it can be demonstrated that adequate ventilation can be achieved by natural means.	Buildings with central air-conditioning.	2
6.4.3	UNCONTROLLED VENTILATION	1 credit for undertaking tests in multi-zone buildings using a non-balanced test method on a representative sample of units, to demonstrate that the air tightness is within recognized limits, OR 2 credits for undertaking tests using either a whole building test method or, in the case of multi-zone buildings (e.g. apartment blocks) a 'guarded cell' (or balanced) test method, on a representative sample of units, to demonstrate that the air tightness is within recognized limits.	Air-conditioned buildings.	2B
6.4.4	LOCALISED VENTILATION	1 credit for the provision of an adequate ventilation system for rooms/areas where significant indoor pollution sources are generated.	2 <sup>nd</sup> credit not applicable to residential and similar buildings.	1
		1 credit for the provision of a system of local exhaust of premises undergoing fit-out and redecoration.		1
6.4.5	VENTILATION IN COMMON AREAS	1 credit for demonstrating that all enclosed common areas in a building are provided with adequate ventilation.	Spaces covered under the section on Localised Ventilation	1
		1 BONUS credit where the provision for ventilation is by natural means.		1B

### Potential Benefits

The benefits relate to reduced health risks from exposure to pollutants, a benefit to individual occupants, but also to society through reduced cost for health care and reduced absenteeism from workplaces.

### Thermal Comfort in Residential Buildings

Thermal comfort in high-rise residential buildings is a design issue, where the focus should be to mitigate solar heat gains, particularly on upper floors and solar-facing facades that are not shaded by adjacent structures. In residential buildings people adapt to (or tolerate) the thermal conditions that they can afford. Residents have greater control of the indoor environment, and behavioural adjustments provide an opportunity to maintain thermal comfort.

As reported by Brager and de Dear<sup>[117]</sup> people in naturally ventilated buildings seem to demonstrate a preference for a wider range of thermal conditions, perhaps due to their ability to exert control over the environment, by opening windows, operating fans and adjusting clothing, or because of changed expectations. They also tend to prefer conditions that more closely reflect outdoor conditions. The comfort standard for naturally ventilated conditions (Fig. 8.1) is given in terms of outdoor temperature applies to buildings in which occupants control operable windows and where activity levels are 'sedentary' (less than 1.2 met). Providing outdoor conditions are satisfactory and good air movement is provided, people will be inclined to use natural means for cooling and ventilation.

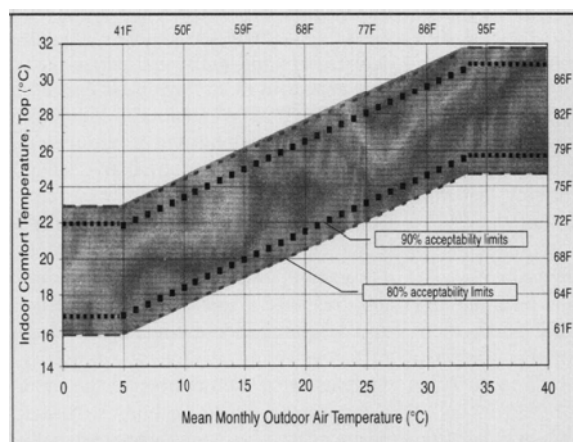


Fig. 8.1 Adaptive standard for naturally ventilated buildings

<sup>117</sup> Brager G S, de Dear R. A Standard for Natural Ventilation. ASHRAE Journal, 21-28, October 2000.

### HK-BEAM Criteria for Thermal Comfort in Residential Buildings

HK-BEAM seeks to reduce indoor temperatures through better design of building facades and improved ventilation under natural ventilation conditions. Where air-conditioning units (window-type or split-type) are installed the criteria seeks to improve on design (location, rating and control) of installed units, but which may not be a practical assessment where residents are free to install units of their choice.

6.5.2	THERMAL COMFORT IN AIR-CONDITIONED/ NATURALLY VENTILATED PREMISES	1 credit for demonstrating indoor operative temperatures in occupied/habitable rooms meet the 80% acceptability limits.	Buildings that are not designed to utilise natural ventilation.	2
		2 credits for demonstrating indoor operative temperatures in occupied/habitable rooms meet the 90% acceptability limits.		1
		1 credit for sustaining the air temperature at the design value within $\pm 1.5^{\circ}\text{C}$ when the air-conditioning unit is operating at steady state under conditions of zero occupancy.		

### Lighting in Residential Buildings

Artificial lighting in residences is matter of user preference and perhaps the major design issue is flexibility to allow adaptation to user preferences. Daylighting provisions are an important design issue given the benefits to comfort and health (as well as energy savings). Sunlight, provided it is not excessive, gives a sense of brightness and cheerfulness and has a therapeutic effect. For unobstructed buildings the target is to provide as much daylight as possible without excessive glare and solar gains.

For densely packed high-rise residential buildings the challenge is to get daylight into rooms on lower floors that are heavily overshadowed by adjacent structures. Whilst there is some concern that the criteria of VDF of 8% in habitable rooms will translate into a significant value of DF (interior daylighting), the approach offers an alternative design criteria to the Building Regulations.

### HK-BEAM Criteria for Lighting Quality in Residential Buildings

The criteria for residential buildings is no different from air-conditioned buildings, with the same objectives and likely benefits.

6.6.1	NATURAL LIGHTING	1 credit where the provision of daylight meets the levels specified in PNAP 278 for vertical daylight factor OR the average daylight factor (DF) is at least 0.5% for all normally occupied spaces. 2 credits where the average daylight factor in all normally occupied spaces is at least 1%. 3 credits where the average daylight factor in all normally occupied spaces is at least 2%.	None.	3
6.6.3	INTERIOR LIGHTING IN AREAS NOT NORMALLY OCCUPIED	1 credit where the prescribed lighting performance in each type of common or service space in respect of light output and lighting quality is achieved.	None.	1

## 8.2.6 ADDITIONAL HK-BEAM IEQ CRITERIA

Listed under IEQ are other performance issues that add to building performance in terms of safety, reducing potential impacts on health and comfort, or add to amenity or functionality. These aspects of building quality/performance apply to all types of buildings.

Attention to Fire Safety addresses concerns that compliance with the detailed requirements of fire services regulations may not be sufficient if there is a lack of integration between systems, with communication and security systems.

Credit 6.1.2 addresses a concern that has arisen in Hong Kong on a number of occasions, whether it is a matter of interference with the performance of sensitive equipment, or the concerns about potential impacts on human health. Likewise, Credits 6.2.1 and 6.2.3 are concerned with health issues following the SARs outbreak. Credit 6.8.1 seeks to improve the access for persons with disability above current regulatory requirements.

6.1.1	FIRE SAFETY	1 credit for demonstrating design integration between fire services systems, communication systems, and non-fire services systems.	None.	1
		1 credit for provision of a fire safety manual based on a fire risk assessment for the building		1
6.1.2	ELECTROMAGNETIC COMPATIBILITY	1 credit for designs that meet the electromagnetic compatibility requirements in respect of power quality and low frequency magnetic fields.	None.	1
6.1.3	SECURITY	1 credit for scoring at least 75% of the applicable security measures and facilities for the building.	None.	1
6.2.1	PLUMBING AND DRAINAGE	1 credit for designs that reduce the potential for transmission of harmful bacteria viruses, and odours.	None.	1
6.2.2	BIOLOGICAL CONTAMINATION	1 credit for complying with the recommendations given in the Code of Practice - Prevention of Legionnaires Disease, in respect of air-conditioning and ventilation and water systems.	Residential buildings.	1
6.2.3	WASTE DISPOSAL FACILITIES	1 credit for the provision of a hygienic refuse collection system.	None.	1

6.3.4	IAQ IN CAR PARKS	1 credit for compliance with the design requirements specified in ProPECC PN 2/96.	Buildings with no car park.	1
6.3.5	IAQ IN PUBLIC TRANSPORT INTERCHANGES	1 credit for compliance with the design requirements specified in ProPECC PN 1/98.	Buildings with no PTI.	1
6.8.1	ACCESS FOR PERSONS WITH DISABILITY	1 credit for providing enhanced provisions for access for disabled persons.	None.	1
6.8.2	AMENITY FEATURES	1 credit for providing amenity features that enhance the quality and functionality of a building to the benefit of building users.	None.	1
		1 credit for providing amenity features that allow for greater flexibility in building use and improved operation and maintenance of the building and its engineering services.		1

### Potential Benefits

The CII Health Building study<sup>[118]</sup> has highlighted where residents held concerns about their living environment and the ‘willingness to pay’ for better conditions. A study by Chau et al<sup>[119]</sup> found that the residential environment that potentially threatened the health was of importance in terms of ‘willingness to pay’. However, it is clear that there is a very low understanding of green building labelling and the benefits it would bring to home owners and occupiers.

## 8.3 SITE ASPECTS

Credits under this category apply to most developments, but cost and benefit is also a matter of project scale and type. Credits 2.1.1 to 2.1.4 targets the potential environmental benefits associated with land use, and the building location in respect of accessibility to amenities and mass transit systems, providing social, economic and environmental benefits.

2.1.1	LAND USE	1 credit where the building development uses reclaimed land. 2 credits where the building development uses a previously developed site.	None.	2
2.1.2	CONTAMINATED LAND	1 credit for conducting a site contamination assessment on developed or reclaimed land and implementing measures for rehabilitation as necessary, and/or proper preparation of sites and structures adjacent to landfill sites.	Building developments on Greenfield sites.	1
2.1.3	LOCAL TRANSPORT	1 credit if no car parking is provided other than provisions intended for use by company vehicles and/or any shuttle service vehicles.	None.	1
		1 credit where there exists convenient pedestrian access to mainstream public transport.		1
2.1.4	NEIGHBOURHOOD AMENITIES	1 credit where neighbourhood services are sufficient to provide for basic needs of the users of the building.	None.	1
		1 credit where existing recreational facilities and open space is adequate and available for building users.		1
		1 credit if recreational facilities and open space provided within the development that is open to the public.		1

Credits 2.2.1 to 2.2.4 are intended to enhance site planning, reduce impacts on neighbouring properties, and reduce ecological impacts, providing a mix of environmental and social benefits.

2.2.1	SITE DESIGN APPRAISAL	1 credit for a site design appraisal report which demonstrates a proactive approach to achieve greater integration of site planning issues.	None.	1
2.2.2	ECOLOGICAL IMPACT	1 credit for designs that demonstrate how landscaping and other site design strategies minimises ecological impact for Greenfield sites, or contributes positively to the ecological value of Brownfield sites.	None.	1
2.2.3	CULTURAL HERITAGE	1 credit where development does not have a negative impact on sites of cultural heritage.	None.	1
2.2.4	LANDSCAPING AND PLANTERS	1 credit for using pervious materials for a minimum of 50% of hard landscaped areas.	None.	1
		1 credit for providing appropriate planting on site equivalent to at least 30% of the site area.		1
2.2.5	MICROCLIMATE AROUND BUILDINGS	1 credit for demonstrating that no pedestrian areas will be subject to excessive wind velocities caused by amplification due to the site layout and/or building design.	None.	1
		1 credit for demonstrating that steps have been taken to reduce elevated temperatures in exposed public areas due to site layout and choice of materials.		1
2.2.6	OVERSHADOWING AND VIEWS	1 credit for designs for which the access to daylight of neighbouring sensitive buildings is maintained to the prescribed level, OR 2 credits where the building development has no negative impact on neighbouring buildings in respect of access to daylight, views and natural breezes.	Buildings where daylight and views are of no value to neighbouring properties.	2
2.2.7	VEHICULAR ACCESS	1 credit for providing safe and efficient access for vehicles entering and leaving the site and buildings.	None.	1

Credits 2.2.8 to 2.3.3 seek to reduce the environmental impacts of construction.

<sup>118</sup> Construction Institute Hong Kong. Solutions Implementation for Healthy Buildings in Hong Kong. December 2004.

<sup>119</sup> Chau C K, Yung H K, Leung TM, Law MY. Evaluation of relative importance of environmental issues associated with a residential estate in Hong Kong. Landscape and Urban Planning, Vol. 77, 67–79, 2006.

2.2.8	DEMOLITION/ CONSTRUCTION MANAGEMENT PLAN	1 credit for a Demolition/Construction Management Plan including provisions for Environmental Monitoring and Auditing.	None.	1
2.3.1	AIR POLLUTION DURING CONSTRUCTION	1 credit for applying adequate mitigation measures for dust and air emissions during the construction as the recommended by the Environmental Protection Department, and demonstrating compliance with the air quality management guidelines as detailed in the Environmental Monitoring and Audit Manual.	None.	1
2.3.2	NOISE DURING CONSTRUCTION	1 credit for demonstrating and confirming that the criteria and requirements laid down in ProPECC PN 2/93 has been achieved, for all Noise Sensitive Receivers.	None.	1
2.3.3	WATER POLLUTION DURING CONSTRUCTION	1 credit for undertaking measures to reduce water pollution during construction as outlined in ProPECC FN 1/94.	None.	1

Credits 2.3.4 to 2.3.6 seek to reduce potential health risks and nuisance to neighbouring properties during building use.

2.3.4	EMISSIONS FROM WET COOLING TOWERS	1 credit for a building development in which wet cooling towers are not used, or use seawater, or water from an acceptable source and are designed and maintained as specified in the Code of Practice for the Prevention of Legionnaires Disease.	None.	1
2.3.5	NOISE FROM BUILDING EQUIPMENT	1 credit for demonstrating that the level of the intruding noise at the facade of the nearest sensitive receiver is in compliance with the criteria recommended in the Hong Kong Planning Standards and Guidelines.	None.	1
2.3.6	LIGHT POLLUTION	1 credit for demonstrating that obtrusive light from exterior lighting meets the specified performance for the environmental zone in which the building development is located.	None.	1

### Potential Benefits

A number of studies have focused on occupant satisfaction with housing in Hong Kong. Liu<sup>[120]</sup> studied physical and social factors which influenced residential satisfaction of a sample of occupants in private and public housing in selected areas in Hong Kong. Apart from spatial movement, which concerns the internal living environment, most concerns were about the external environment. Occupants in private housing were dissatisfied with 'special requirements for the disabled', 'elderly centres' and 'nurseries and child care centres'. In public housing 'cleanliness of public areas', 'security measures of the building', ease of access to public transport', adequacy of public transport', 'water tightness from rain' figured in the unsatisfactory ratings. According to Liu attending to deficiencies and sub-standard provisions (as voted by residents) may enhance the private developer's competitive standing and improve the company's public image and reputation. A study by university students some years ago, in which residents were invited to offer opinions on features that they valued about their estate found that facilities on the estate were highly valued.

## 8.4 MATERIALS ASPECTS

Credits 3.1.1, 3.1.5, and 3.2.1 to 3.2.3 encourage resource efficiency through reuse and the choice of materials used in construction. Building reuse and the use of recycled materials can reduce cost and will reduce embodied energy.

3.1.1	BUILDING REUSE	1 credit for the reuse of 15% of the existing building sub-structure or shell. 2 credits for the reuse of 25% of the existing building sub-structure or shell.	Buildings on reclaimed land or Greenfield sites.	2
3.1.5	ENVELOPE DURABILITY	1 credit for demonstrating the integration of building envelope systems which optimises the integrity of the envelope over the building life.	None.	1
3.2.1	RAPIDLY RENEWABLE MATERIALS	1 credit for demonstrating that in applications where rapidly renewable materials can be employed at least 50% are used in the building.	None.	1
3.2.2	SUSTAINABLE FOREST PRODUCTS	1 credit where virgin forest products are not used for temporary works during construction. 1 credit for sourcing timber and composite timber products which are from well managed sources, including reuse of salvaged timber.	None.	1
3.2.3	RECYCLED MATERIALS	1 credit for use 50% of recycled materials in site exterior surfacing work, structures and features. 1 credit for: using 5% of recycled materials, other than PFA, in the construction of the building; and maximising use of PFA or similar in concrete.	None.	1

Modular design allows for off-site fabrication and can improve buildability, and possibly salvaging of materials during deconstruction. The ability to adapt to new uses can reduce the cost and time for remodelling and down-time for alterations to interiors.

<sup>120</sup> Liu A M M. Residential satisfaction in housing estates: a Hong Kong perspective. Automation in Construction. Vol. 8, 511-524, 1999.



3.1.2	MODULAR AND STANDARDISED DESIGN	1 credit for demonstrating the application of modular and standardized design in buildings.	None.	1
3.1.3	OFF-SITE FABRICATION	1 credit when the manufacture of 50% of listed building elements has been off-site. 1 additional credit where the manufacture of 80% of listed building elements has been off-site.	None.	2
3.1.4	ADAPTABILITY AND DECONSTRUCTION	1 credit for designs providing flexibility through the choice of building structural system that allows for change in future use, and which is coordinated with interior planning modules. 1 credit for designs providing spatial flexibility that can adapt spaces for different uses, and allows for expansion to permit additional spatial requirements to be accommodated.	None.	1

Credits 3.2.4, and 3.3.1 to 3.2.3 seek to reduce environmental impacts, which are likely to result in cost premiums for construction phases.

3.2.4	OZONE DEPLETING SUBSTANCES	1 credit for using refrigerants with a ozone depleting potential 0.03 or less and a global warming potential of 1600 or less. 1 credit for the use of products in the building fabric and services that avoids the use of ozone depleting substances in their manufacture, composition or use.	None	1
3.3.1	DEMOLITION WASTE	1 credit for implementation of a waste management system that provides for the sorting and proper disposal of inert and non-inert demolition materials. 1 credit sorting and recycling specified demolition waste.	Projects where demolition is not required or is not under the Client's control.	1
		1 credit for demonstrating that at least 50% of demolition waste is recycled. 2 credits for demonstrating that at least 75% of demolition waste is recycled.		1
3.3.2	CONSTRUCTION WASTE	1 credit for implementation of a waste management system that provides for the sorting and proper disposal of inert and non-inert construction materials. 1 credit sorting and recycling specified construction waste.	None	1
		1 credit for demonstrating that at least 50% of construction waste is recycled.		1
3.3.3	WASTE DISPOSAL AND RECYCLING FACILITIES	1 credit for providing facilities for the collection, sorting, storage and disposal of waste and recovered materials.	None	1

## 8.5 ENERGY USE IN OFFICE BUILDINGS

4.1.1	ANNUAL ENERGY USE IN COMMERCIAL BUILDINGS	1 to 10 credits for a reduction in the annual energy consumption by 10% to 45%. 1 to 3 credits for a reduction in the maximum electricity demand by 15% to 30%.	Other types of buildings.	10 3
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Energy use in air-conditioned buildings is dominated by electricity use for air-conditioning, followed by lighting and small power (equipment) loads. Energy efficient operation is difficult to achieve if equipment is oversized, and controls are too complex for building operators to maintain<sup>[80]</sup>. Based on an outdated rule of thumb, excessive use of 'allowance for contingency' and over estimates of cooling loads, central plant for large buildings can be oversized by 50-100%, with knock-on effects through to system, equipment and component sizing. Oversized or over-provision of plant and equipment, use of inefficient system designs or equipment, use of sub-standard measuring instruments and control equipment, undersized ducts and pipes, poor locations or layout of systems and equipment, lack of adequate provisions for testing and recommissioning are the outcome of poor services designs and are costly or difficult to rectify subsequently.

According to Yik et al<sup>[121]</sup> grossly oversized air-conditioning equipment is one major reason for poor efficiency of HVAC systems, particularly when only one or two chillers are installed. In such cases the plant can be operating for much of the time at part load and lower efficiency. Comparing the capacity of installed plant in 6 commercial buildings with the widely adopted CLTD/SCL/CLF method and detailed simulation by HTB2/BECON the authors concluded that the CLTD overestimated the space cooling load by 15% or more, and given the propensity of designers to allow for safety margins in sizing plant it can be understood why many air-conditioning systems in Hong Kong can cope with the peak cooling demand with around two thirds or less of the installed capacity.

Lao and Deng<sup>[122]</sup> draw attention to the use of outdated 'rules of thumb' in cooling load estimations which generally leads to an overestimation for air-conditioning. The actual peak cooling load for a building was compared with estimates from computer simulation, CLTD method and the range of rules of thumb found from a survey of five design consultant offices in Hong Kong. They recommend 153 W/m<sup>2</sup> for exterior zones, 97 W/m<sup>2</sup> for interior zones and 129 W/m<sup>2</sup> overall for an office floor. The benefits of detailed energy modelling for large air-conditioned buildings, using appropriate weather, design, occupancy and equipment loads is made clear by Lee et al<sup>[123]</sup>.

<sup>121</sup> Yik F W H, Lee W L, Burnett J, Jones P. Chiller Plant Sizing by Cooling Load Simulation as Means to Avoid Oversized Plant. HKIE Trans. Vol. 6, No. 2, 19-25, 1999.

<sup>122</sup> Lao S T H, Deng S. An Evaluation of the Rules of Thumb for Estimating Cooling Load for Office Buildings. HKIE Transactions, Vol. 8, No. 3, pp 58-59. 2001.

<sup>123</sup> Lee W L, Yik W H, Jones P, Burnett J. Energy saving by realistic design data for commercial buildings in Hong Kong. Applied Energy, Vol. 70, No. 1, 2001, pp. 59-75.

Although the design criteria recommended by ASHRAE and CIBSE are commonly adopted by designers in Hong Kong, the assumptions made in deriving the recommended design values are often ignored resulting in plant oversizing. With the use of more realistic design criteria established from published energy end use surveys it was estimated that saving in electricity consumption of 6-22% due to more efficient operation of correctly sized equipment.

The concept of matching plant capacity to load profile extends to choice of plant ratings. For smaller buildings with only two chillers it is likely that sizing can differentiate between peak cooling demand in summer and lower demand in winter, i.e. unequal size chillers may be employed depending on the load profile. However, where 3 or more chillers are employed it is probable that equal sized chillers can meet the load profile<sup>[124]</sup>, which also means O&M is less demanding.

### Energy Efficient Systems and Equipment

4.2.1	EMBODIED ENERGY IN BUILDING STRUCTURAL ELEMENTS	1 credit for demonstrating the embodied energy in the major elements of the building structure of the assessed building is reduced by 10%. 2 credits for demonstrating a reduction by 15%.	None.	2
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As already mentioned embodied energy can be significant in the case of high-rise residential buildings. The credit seeks to encourage recycling to reduce energy use, such as recycled steel and aluminium. Arguably, reuse of structural elements could also count towards the calculation of embodied energy saved.

The credits under 4.2.5 and 4.3.6 address energy efficiency of systems and equipment that do not fall under the calculation of air-conditioning, lighting and equipment use in occupied areas.

Efficient lift and escalators systems are important from the aspect of service quality, with energy efficiency dependent on efficient drives and lift controls that can improve match with user demands. Efficient electrical installations also include reduction of electrical harmonics and power factor which improves on electricity demand.

4.2.5	LIFT AND ESCALATOR SYSTEMS	1 credit for complying with the Code of Practice for Energy Efficiency of Lift and Escalator Installations.	Building with one or no elevators.	1
4.2.6	ELECTRICAL SYSTEMS	1 credit for complying with the Code of Practice for Energy Efficiency of Electrical Installations.	None.	1
4.2.7	RENEWABLE ENERGY SYSTEMS	1 credit where 2%/4% of building energy is obtained from renewable energy sources. 2 credits where 4%/8% of building energy is obtained from renewable energy. 3 credits where 6%/12% of building energy is obtained from renewable energy.	None.	3B
4.3.3	ENERGY EFFICIENT LIGHTING IN PUBLIC AREAS	1 credit for installation of: energy efficient lighting equipment; and control for the lamps in areas where daylight is available.	None	1
4.3.6	ENERGY EFFICIENT APPLIANCES	1 credit for specifying the use of certified energy efficient appliances.	Buildings where appliances are not provided by the Client.	1

### Provisions for Operation & Maintenance

4.4.1	TESTING AND COMMISSIONING	1 credit for provision of appropriate specifications and cost provisions in contract documents detailing the commissioning requirements for all systems and equipment that impact on energy use and indoor environmental quality.	All 4 credits applicable to buildings with central HVAC/services.	1
		1 credit for the appointment of a commissioning authority and provision of a detailed commissioning plan that embraces all specified commissioning work.		1
		1 credit for ensuring full and complete commissioning of all systems, equipment and components that impact on energy use and indoor environmental quality.		1
		1 credit for providing fully detailed commissioning reports for all systems, equipment and components that impact on energy use and indoor environmental quality.		1
4.4.2	OPERATION AND MAINTENANCE	1 credit for providing a fully documented operations and maintenance manual to the minimum specified. 1 credit for providing fully documented instructions that enables systems to operate at a high level of energy efficiency.	All 3 credits applicable to buildings with central/HVAC services.	3
		1 credit for: providing training for operations and maintenance staff to the minimum specified; and demonstrating that adequate maintenance facilities are provided for operations and maintenance work in the form of workshop(s), office accommodation and control room.		
4.4.3	METERING AND MONITORING	1 credit for installation of: metering that allows monitoring of electricity use by the main chiller plant and auxiliaries; instruments for monitoring building cooling load and operating parameters central chiller plant; metering that allows separate monitoring of electricity use by the air side of the HVAC system; and metering for landlord's electricity consumption in common space/public areas.	None.	1

Besides good design systems need provisions for test, inspection and maintenance, and auditing. The inclusion of building management, operation and maintenance issues in a BEAM for new buildings is based on the evidence that (testing &) commissioning is generally poor or inadequate in Hong Kong, even for essential fire safety systems suffer<sup>[125]</sup>, let alone for more complicated

<sup>124</sup> Kee W L, Lee S H. Developing a simplified model for evaluating chiller-system configurations. Applied Energy. Vol. 84, 290-306, 2007.

<sup>125</sup> Fong N K, Wong L Y, Wong L T. Fire services installation related contributors of construction delays. Building and Environment, 2006: 41: 211-222.

HVAC systems<sup>[126]</sup>. For O&M staff to achieve good performance requires adequate records of the outcomes of commissioning, presented in a clear and concise O&M manuals and supported by adequate training. Evidence is available to show that investment in the knowledge and skills of facilities staff improves performance<sup>[127]</sup>.

#### Potential Benefits

The discussion on commissioning that follows provides details of the potential benefits.

## 8.6 ENERGY USE IN RESIDENTIAL BUILDINGS

4.1.4	ANNUAL ENERGY USE IN RESIDENTIAL BUILDINGS	1 to 8 credits for a reduction in the annual energy consumption by 3% to 22%. 1 to 3 credits for a reduction in the maximum electricity demand by 8% to 15%.	Other types of buildings.	8 3
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From Fig. 5.4 it is clear that design has much less influence on residential energy use than do user activities, both in terms of selection of household appliances and their use and maintenance. It has already been made that for most Hong Kong households the cost of energy is a small part of household expenditure, and in an affluent society it is unlikely that households will reduce energy use at the expense of comfort and convenience. The possible areas for improvement lie in more efficient appliances and encouraging users to practice energy conservation.

#### Air-conditioning Energy Use

Hong Kong's climate is classified as sub-tropical. In the winter months of November to February the mean temperature is approximately 15–18°C, but it is not uncommon for temperatures to drop below 10°C in urban areas, with the lowest temperature recorded at 0°C. The spring season is short, humid and sometimes foggy with the temperature tending to fluctuate widely from day to day. In the summer months of May to September, the weather is mainly hot and humid with occasional showers or thunderstorms, creating a big demand for air-conditioning for comfort cooling. Afternoon temperatures frequently exceed 32°C in June to September, with the mean temperature around 27–29°C. The autumn season lasts from September to early November. The mean annual rainfall is about 2225 mm of which 80% falls between May and September.

Providing that the outdoor humidity, air quality and noise environment is not to the dissatisfaction of the occupant, there is potential for encouraging less use of air-conditioning through provision of adequate ventilation. Whether or not opening windows can provide the required comfort depends on the availability of breeze (which may be influenced by adjacent buildings) and the ability to capture the breeze in an occupied room. Rooms with single-sided ventilation are unlikely to be very successful in this regard hence the promotion of cross-ventilation, whereby rooms have openings on two exterior surfaces.

There is the potential to improve the heat transfer properties of the building envelope through the use of glazing that can reduce solar glare, and the use of thermal insulation to reduce external heat gain. Cheung et al.<sup>[128]</sup> used simulation to estimate the impact of an integrated passive design approach to reduce the cooling requirements for high-rise apartments through an improved envelope design. The HVAC system for the baseline model, a HKHA Concord block design, was assumed to be window-mounted direct expansion air-conditioners with a typical coefficient of performance (CoP) of 2.5. The living room, bedrooms and the study room were conditioned with a set point of 24°C. The power densities of lighting were 10 W/ m<sup>2</sup> for the bathroom, 20 W/m<sup>2</sup> for living room, 17 W/ m<sup>2</sup> for the kitchen, bedrooms and study room. The living room plug load was assumed to be 28 W/m<sup>2</sup> during occupied hours and 1.4 W/m<sup>2</sup> during unoccupied hours, with bedrooms having a plug load of 24 W/m<sup>2</sup> during occupied hours. The kitchen plug load was 25.9 W/m<sup>2</sup>, but an extra load of 493 W/m<sup>2</sup> was assumed for the gas stove during cooking hours. The bathrooms have no plug loads. After reviewing the effect of individual strategies, the following combination of strategies was selected:

- Introducing 100mm thick EPS insulation to the inner surface of external walls.

<sup>126</sup> McMahan G. The Testing and Commissioning of Building Services in Hong Kong. Joint ASHRAE/CIBSE/HKIE Symposium, November 2005.

<sup>127</sup> Lai J H K, Yik F W H. Knowledge and perception of operation and maintenance practitioners in Hong Kong about sustainable buildings. *Facilities*, Vol. 24, No. 3/4, 90-105, 2006.

<sup>128</sup> Cheung C K, Fuller R J, Luther M B. Energy-efficient envelope design for high-rise apartments. *Energy and Buildings*. Vol. 37, 37-48, 2005.

- Changing the external wall colour to white with a solar absorptance of 0.2.
- Replacing the glazing with 6mm thick Evergreen™ glass with reflective coating.
- Introducing 1500mm long overhang and wing wall to all windows.

It was found that by modifying the building envelope with the above strategies, the annual required cooling energy (sensible) for the whole flat reduced from 4454 kWh to 3056 kWh, i.e. a saving of 31.4%. The peak cooling load also reduced significantly from 6.2kW down to 3.9kW, i.e. 36.8% reduction. When considering a typical floor of an entire block, consisting of all eight flats, the reduction in annual required cooling energy ranged from 26.9% to 27.9%.

Lam et al<sup>[129]</sup> surveyed 144 buildings in the month of June during 1992-2001 to investigate the energy performance of the building envelopes in terms of OTTV. To develop the appropriated parameters used in OTTV calculation, long-term measured weather data such as ambient temperature, horizontal global solar radiation and global solar radiation on vertical surfaces were examined. The OTTV found varied from 27 to 44 W/m<sup>2</sup> with a mean value of 37.7 W/m<sup>2</sup>. Building energy simulation technique using DOE-2.1E was employed to determine the cooling requirements and hence electricity use for building envelope designs with different OTTVs. With many variations<sup>[128]</sup>, it is very difficult to generalise outcomes in terms of cost and benefits.

### Energy Efficient Systems and Equipment

The criteria are essentially the same as for air-conditioned buildings.

4.2.1	EMBODIED ENERGY IN BUILDING STRUCTURAL ELEMENTS	1 credit for demonstrating the embodied energy in the major elements of the building structure of the assessed building is reduced by 10%. 2 credits for demonstrating a reduction by 15%.	None.	2
4.2.4	HOT WATER SUPPLY SYSTEMS	1 credit for installing energy efficient hot water supply system(s) and equipment that can save 20% or more energy.	Buildings where the energy used for supplying hot water is less than 10% of total.	1
4.2.5	LIFT AND ESCALATOR SYSTEMS	1 credit for complying with the Code of Practice for Energy Efficiency of Lift and Escalator Installations.	Building with one or no elevators.	1
4.2.6	ELECTRICAL SYSTEMS	1 credit for complying with the Code of Practice for Energy Efficiency of Electrical Installations.	None.	1
4.2.7	RENEWABLE ENERGY SYSTEMS	1 credit where 2%/4% of building energy is obtained from renewable energy sources. 2 credits where 4%/8% of building energy is obtained from renewable energy. 3 credits where 6%/12% of building energy is obtained from renewable energy.	None.	3B
4.3.1	AIR-CONDITIONING UNITS	1 credit for complying with the recommended installation positions for air-conditioners with regard to internal spaces.	Buildings not using window and/or split-type air-conditioners.	1
		1 credit for complying with the minimum width of any external recess with regard to heat rejection. 1 credit for complying with the items listed in the assessment check-list.		1
4.3.2	CLOTHES DRYING FACILITIES	1 credit for providing suitable clothes drying facilities which utilise the natural environment for the majority of residential units.	Buildings other than residential buildings.	1
4.3.3	ENERGY EFFICIENT LIGHTING IN PUBLIC AREAS	1 credit for installation of energy efficient lighting equipment, and control for the lamps in areas where daylight is available.	None	1
4.3.6	ENERGY EFFICIENT APPLIANCES	1 credit for specifying the use of certified energy efficient appliances.	Buildings where appliances are not provided by the Client.	1

The location of air-conditioning units in flats can improve operating efficiency through improved air movement and diffusion of cooling within rooms, and heat rejection to the outside. Thereafter, efficiency depends on maintenance and user preferences for operation.

### Energy Use for Water Heating

With significant consumption of energy for water heating, be it by gas or electricity, there is the potential to reduce energy consumption through water efficiency.

### Lighting Energy Use

A variety of luminaire types and lamps are used in residential buildings, largely dictated by occupant choice and affordability. Perhaps it is the relatively low cost of electricity, sometimes unreliable products, and poor lighting quality that deters greater use of energy efficient compact fluorescent lighting, plus the fact that for many people lighting is a part of interior design as much as for functional purposes.

### Potential Socio-Environmental Benefits

Various stages of electricity generation inflict 'costs' on society and the environment, which are not reflected in the traditional costing of electricity; these impacts constitute 'externalities' in the

<sup>129</sup> Lam J C, Tsang C L, Li D H W, Cheung S O. Residential building envelope heat gain and cooling energy requirements. Energy. Vol. 30, 933-951, 2005.

electricity sector. It is perceived that 'full costs' of electricity – costs accounting for externalities – could better guide decisions on fuel mix, location and scale as well as power generation and mining technologies.

Besides reducing plant size, annual energy use and maximum electricity demand there are external costs, i.e. for socio-environmental damages due to electricity generation. Wind power is favourable for both pollutants emissions (SO<sub>2</sub>, NO<sub>x</sub>, TSP, etc) and greenhouse gas emissions (CO<sub>2</sub>, etc). Nuclear power in general generates low external costs, not counting accidents, and low emissions. Photovoltaics is a very clean technology provided embodied energy is not significant (the difference are in the energy source used for cell production). Gas-fired technologies are relatively clean, with respect to pollutants, but impact on climate change depends on the efficiency of conversion. Combined-cycle plant reduces greenhouse gases. Coal and oil technologies have high impacts in all categories resulting in higher external costs (Table 8.2)<sup>[130]</sup>.

**Table 8.2 External cost figures for electricity production in the EU for existing technologies - €cent/kWh<sup>\*[130]</sup>**

Country	Coal & lignite	Peat	Oil	Gas	Nuclear	Biomass	Hydro	PV	Wind
AT				1-3		2-3	0.1		
BE	4-15			1-2	0.5				
DE	3-6		5-8	1-2	0.2	3		0.6	0.05
DK	4-7			2-3		1			0.1
ES	5-8			1-2		3-5**			0.2
FI	2-4	2-5				1			
FR	7-10		8-11	2-4	0.3	1	1		
GR	5-8		3-5	1		0-0.8	1		0.25
IE	6-8	3-4							
IT			3-6	2-3			0.3		
NL	3-4			1-2	0.7	0.5			
NO				1-2		0.2	0.2		0-0.25
PT	4-7			1-2		1-2	0.03		
SE	2-4					0.3	0-0.7		
UK	4-7		3-5	1-2	0.25	1			0.15

\* sub-total of quantifiable externalities (such as global warming, public health, occupational health, material damage)

\*\* biomass co-fired with lignites

## 8.7 WATER USE

Water is becoming a more precious and high-demand resource in regions adjoining Hong Kong. Fresh water supplies to Hong Kong are increasingly affected by a number of factors including catchment areas, contamination of sources, and rising demand. Between 70 and 80 per cent of Hong Kong's fresh water supply is piped into the SAR from Dongjiang, in Guangdong province. In 2005, this accounted for 771 million cubic metres of water, or 79.7 per cent of Hong Kong's consumption for the entire year (Fig. 8.2). In budget terms, this water came at a cost of HK\$2,530 million<sup>[131]</sup>.

### Water Quality

5.1.1	WATER QUALITY	1 credit where fresh water plumbing installations comply with the referenced good practice guides.	None.	1
		1 credit for demonstrating that the quality of potable water meets the referenced drinking water quality standards at all points of use.		1

In Hong Kong the WSD controls water quality, such as taste, odour, hardness, sediment, pH, the quantity of dissolve iron, etc. in order to provide water that meets the Guidelines for Drinking-water Quality recommended by the World Health Organization (WHO). Samples are taken at treatment works, service reservoirs, consumer taps and analysed at site and at WSD's laboratories. Nevertheless, the quality of potable water delivered at taps is often perceived to be

<sup>130</sup> European Commission. Community Research. External Costs. Research results on socio-environmental damages due to electricity and transport. 2003'

<sup>131</sup> Water Supplies Department. Annual Report 2005-2006.

unsatisfactory by consumers, resulting in an average consumption of bottled water of around 50 l/person/annum in 2003 and rising<sup>[132]</sup>. The problems may be due to the corrosion of water pipes or the cleanliness of water tanks. As a consequence the use of bottled water is widespread, but is not considered to be an environmentally preferred solution on account of the production and transport requirements. To ensure the health of consumers' buildings need to ensure optimal potable water quality at the tap - potable water that is both safe and acceptable in terms of taste, colour and odour.

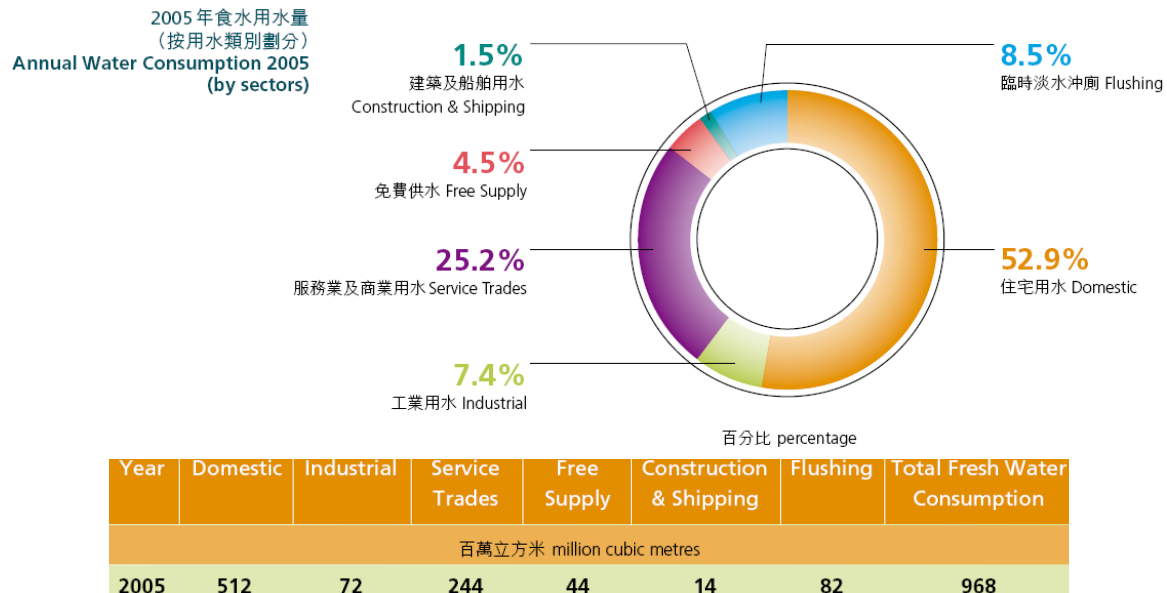


Fig. 8.2 Annual water consumption in Hong Kong in 2005<sup>[131]</sup>

5.2.1	ANNUAL WATER USE	1 to 3 credits for demonstrating that the use of water saving devices leads to an estimated aggregate annual saving of 15% to 35%.	None.	3
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Figure 8.2 shows that the domestic sector dominates fresh water consumption in Hong Kong followed by service trades. Average freshwater consumption in the domestic sector is around 200 l/person/day, similar to that in most developed nations<sup>[133]</sup>, but perhaps rather high given the availability of seawater for flushing purposes. In the absence of gardens and lawns in residential buildings the use of potable water for irrigation will also be low.

There is potential for the installation of water saving features such as low-flow shower heads and faucets<sup>[134]</sup>. However, a potential problem with such devices is that they require maintenance, else become inefficient. Whilst managers of commercial buildings can monitor and maintain the low-flow fixtures, the problem with the domestic market is that user ignorance can result in neglect and subsequent dissatisfaction leading to disuse. Some models of gas water heater also 'waste' water when significant flow is required before the desired operating temperature is reached. As already mentioned more efficient use of hot water has the added benefit of reducing energy use.

### Conservation and Recycling

Credit 5.2.2 seeks to establish if means are in place that can effectively limit the wastage of water by shutting off fixtures automatically when left open, and the ability to detect water leaks in buried pipework. Various approaches are available and HK-BEAM is not intended to be prescriptive as to which should be used.

Credit 5.2.3 is mainly targeting developments with significant landscaping, as defined by the coverage of soft landscaping, greenery and planters there is likely to be a significant consumption of potable water. Irrigation by lower quality (harvested or recycled) water can be equally effective.

<sup>132</sup> The World's Water 2006-2007. Table 13.

<sup>133</sup> Cheng C L. Evaluating water conservation measures for Green Building in Taiwan. Building and Environment, Vol. 38, 369-379, 2003.

<sup>134</sup> Department of Building Services Engineering. Hong Kong polytechnic University. Good Practice Guide to Water Conservation for Hotels in Hong Kong.

Native plants can survive without additional watering, and require less fertilizer and pesticides, thereby reducing impacts on local waters.

5.2.2	MONITORING AND CONTROL	1 credit for installations of any two features: 2 credits for installation of all three features: automatic shut-off of devices for the purposes of water conservation; monitoring water leakage within the fresh water distribution system; monitoring of water flow at main supply branches for audit purposes.	None.	2
5.2.3	WATER EFFICIENT IRRIGATION	1 credit for the use of an irrigation system which does not require the use of municipal potable water supply after a period of establishment is complete.	Where soft landscaping coverage is less than 50% of the area of the building footprint.	1
5.2.4	WATER RECYCLING	1 credit for harvesting of rainwater will lead to a reduction of 10% or more in the consumption of fresh water. 1 credit for the provision of plumbing and drainage systems that provide for separation of grey water from black water. 1 additional credit where harvested or recycled water will lead to a reduction of 10% or more in the consumption of fresh water.	None.	1 + 2B

The water recycling Credit 5.2.4 that leads to the reduced use of fresh water is also counted in the estimated percentage of reduction in the consumption of fresh water that leads to credits under Annual Water Use. The problem for Hong Kong's high-rise dense built environments is that the potential for collecting rainwater is limited. Yang et al.<sup>[135]</sup> provide the main parameters and their relationship to estimate the amount of rainwater that may be collected on different roof areas and different sizes of tanks, based on the amount of rainfall as recorded by the Hong Kong Observatory. However, given the difficulty and cost of achieving harvesting and recycling only one credit for rainwater harvesting counts towards the total of applicable credits, with the recycling credits awarded as bonus.

### Water Efficient Equipment

5.2.5	WATER EFFICIENT FACILITIES AND APPLIANCES	1 credit for demonstrating that installed water facilities are more efficient than otherwise. 1 credit for installing water efficient appliances that are at least 20% more efficient than otherwise.	Buildings in which facilities and/or devices are not installed by the developer.	1 1
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Where facilities such as pools, spas and water features, and equipment such as washing machines are installed by the client credits are awarded to encourage the use of water efficient equipment.

### Effluent Discharge

5.3.1	EFFLUENT DISCHARGE TO FOUL SEWERS	1 credit for demonstrating an estimated reduction in annual sewage volumes by 25%.	None.	1
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In Hong Kong the provision of seawater for toilet flushing significantly reduces the consumption of potable water. In 2005 an average of 0.72 million m<sup>3</sup> per day, 263 million m<sup>3</sup> total, was supplied for flushing purposes (compared to 82 million m<sup>3</sup> of fresh water for flushing). This seawater is treated to WSD quality objectives and its quality is regularly monitored to ensure compliance. To prevent bacterial and biological growth in the supply system, the sea water supplied is disinfected by electro-chlorination. Where seawater flushing is provided the benefits are limited to a small reduction in water charges, but where this is not the case then reducing the use of potable water is an added benefit.

### Potential Benefits

Reducing the need for effluent treatment saves on capital cost for plant and energy cost for treatment. Cheng<sup>[136]</sup> gives a figure of 0.39 kWh/m<sup>3</sup> for urban water supply and 0.41 kWh/m<sup>3</sup> for urban water supply sewage treatment in Taipei.

## 8.8 PRODUCTION OF BUILDINGS

Improved performance of large, centrally air-conditioned buildings depends very much on the quality of design, construction and commissioning of the building and the engineering services. The reasons why many new buildings fail to deliver quality at reasonable cost are cited in a number of studies. In the UK, initiatives to improve performance are driven by European laws on energy efficiency, as well as recognition that buildings can be cheaper to build and run<sup>[137]</sup>.

<sup>135</sup> Yang H X, Chow W H, Burnett J. Water and Energy Conservation of Rainwater Collection Systems on Building Roofs. Advances in Building Technology, Vol. 2. Elsevier. 2002. pp 1281-1288.

<sup>136</sup> Cheng C L. Study of the inter-relationship between water use and energy conservation for a building. Energy and Buildings. Vol. 34, 261-266, 2002.

<sup>137</sup> UK Office of Government Commerce. Achieving Excellence in Construction. Procurement Guide. 2003.

Likewise, the US government recognises the merit in improving the procurement process for new buildings<sup>[138]</sup>, which find resonance in the CIRC report<sup>[139]</sup>. Failures are related to:

- lack of a complete and comprehensive client brief, leading to excessive variation orders;
- lack of integration amongst the design team with limited or no input from contractors, specialist supplies, facility managers, etc;
- inappropriate fee scales and absence of consideration of life cycle costs and impacts;
- incomplete design detailing and specifications;
- fragmented construction processes with too many sub-contractors;
- inadequate project management and site supervision;
- inadequate building commissioning and provisions for operation and maintenance, etc.

According to the CIRC report in order to achieve the envisaged results, radical improvements are called for in the way construction projects are delivered, the way risks are shared, the way industry participants interact with one another and the ethical standards within the industry. Whilst Meikle and Dickson<sup>[140]</sup> assert that there is little evidence that good processes necessarily produce good outcomes, POE provide evidence demonstrating that bad processes tend to produce poor outcomes. Kaatz et al<sup>[141]</sup> argue that the principles of sustainable development are best implemented within the process rather than by features embedded in a building. According to the DOE Roadmap initiative<sup>[142]</sup> process is primary and the technology and product development only secondary in relative importance. The Roadmap highlights the importance of IT, design tools and management techniques in the delivery process, without which the impacts of new techniques and technologies are minimised. Unfortunately, a universal problem is the many different entities who must work together to deliver a building means control of the overall process is highly problematic.

### 8.8.1 PLANNING AND DESIGN

Planning pays an important role in delivering elements of green buildings that cannot be delivered through control of individual buildings alone<sup>[143]</sup>. Integration of building regulations with planning is important in promoting green buildings. Within the framework of urban planning building design can embrace issues such as provision of breezeways, view corridors, biotope, enhance neighbourhoods, help deter crime, etc. Planning can also encourage district schemes for more efficient heating, cooling and/or heat rejection, waste management, etc.

#### *Integrated Design*

Adopting a process view in building procurement whereby stakeholder views are taken into account early in the process is highlighted by the Design Quality Indicator (DQI), a toolkit for improving the design of buildings by providing feedback and capturing perceptions of design quality<sup>[144]</sup>. The three main elements of the toolkit (conceptual framework, data gathering tool, weighting mechanism) maps the value of buildings in relation to their design for different uses and their ability to meet a variety of physical, aspirational and emotional needs of occupants and users<sup>[145]</sup>.

The integrated design approach is now well-recognised as a key process in achieving better

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<sup>138</sup> US Department of Energy. High-performance Commercial Buildings. A Technological Roadmap. October 2000.

<sup>139</sup> Construct for Excellence. Report of the Construction Industry Review Committee. January 2001.

<sup>140</sup> Meikle J, Dickson M. Understanding the social and economic value of construction. Editorial. Building Research & Information. Vol. 34, No. 3, 191-196, 2006.

<sup>141</sup> Kaatz E, Root D, Bowen P. Broadening project participation through a modified building sustainability assessment. Building Research & Information. Vol. 33, No. 5, 441-454, 2005.

<sup>142</sup> US Department of Energy. High-performance Commercial Buildings. A Technological Roadmap. October 2000.

<sup>143</sup> Sustainable Buildings Task Group, UK. Better buildings – better lives. Report 2004.

<sup>144</sup> Gann D M, Salter A J, Whyte J K. Design Quality Indicator as a tool for thinking. Building Research & Information, Vol. 31, No. 5, 318-333, 2003.

<sup>145</sup> Thomson D S, Austin S A, Devine-Wright H, Mills G R. Managing value and quality in design. Building Research & Information. Vol. 31, No. 5, 334-345, 2003.



quality designs<sup>[146, 147]</sup>. However, such initiatives are difficult to implement in the case of speculative commercial developments. Furthermore, Rees and Gordon<sup>[148]</sup> bemoan the fact that many designers are addressing elements of sustainability in their designs, yet their capacity to influence key performance issues is constrained because many early decisions on site and building form will have been made by others. They argue involving more professionals at the beginning of a project is likely to cost more initially and extend design time but can cost less over the entire process.

Often missing from the design of new buildings are the provisions for testing and commissioning, adequate metering for the purpose of energy and water auditing, and access for ease of operation and maintenance.

## 8.8.2 POTENTIAL SAVING IN ANNUAL ENERGY USE BY DETAILED MODELLING

Detailed design simulations, especially in respect of energy modelling, is not common practice in many countries, but appears to be seriously lacking in Hong Kong. Experiences from HK-BEAM assessments to date suggest that energy modelling is usually undertaken only for the purpose of the assessment, after all major design decisions have been made. Usually the simulation is contracted to a third party meaning that in-house experience is limited and the potential benefits of using simulation at the early design stage are not realised.

The potential reduction in energy use and added costs based on improvements in an Assessed Building compared to the Baseline Building model described in HK-BEAM 4/04 is given in Figures 8.4 and 8.5. The construction cost and M&E services cost given in Table 8.3 are based on local cost data<sup>[48,149]</sup>, percentage reduction<sup>[150]</sup> for the reference case described by Chau et al<sup>[151]</sup>.

**Table 8.3 Source data for Estimating Energy Use Reduction and Additional Cost**

Item	Codes /Standards	Energy Use		Estimated Cost				Change in design parameters		
		% Reduction	kWh/m <sup>2</sup>	Construction		E&M Services		Typical	Code/HKBEAM	Add Cost HK\$/m <sup>2</sup>
				HK\$/m <sup>2</sup>	%	HK\$/m <sup>2</sup>	%			
1	Reference Case	100	138	10500	100	2550	100			
2	LGT Code	99	136	10520	100	2570	101	Conventional lighting 22W/m <sup>2</sup>	Energy efficient lighting 15 W/m <sup>2</sup>	+20
3	AC Code	94	130	10513	100	2563	101	Motor efficiency 65%	Motor efficiency 80%	+15.3
4	OTTV Code	99	137	10652	101	2702	106	6 mm reflective glass	Double glazing	+152
5	Building Codes	92	127	10685	102	2735	107	(2) + (3) +(4)		
6	Design by Simulation	94	130	10500	100	2550	100	Rule of thumb /1-step method	Good design practice	+0
7	Design by Realistic Data	91	126	10500	100	2550	100	CIBSE /ASHRAE Standards	Surveyed data	+0
8	HKBEAM - LGT	88	121	10546	100	2596	102	Same as (2)	Energy efficient lighting + electronic ballast 14 W/m <sup>2</sup>	(2) +26
9	HKBEAM - AC	77	106	10755	102	2805	110	CAV + air-cooled	(3) + VAV + water-cooled	(3) + 200 + 0
10	HK-BEAM - ALL	50	68	10761	102	2811	110	(6)+(7)+(8)+(9) = + 261.3		

<sup>146</sup> Office of the Chief Architect. US General Services Administration. Facilities Standards for the Public Buildings Service. March 2003.

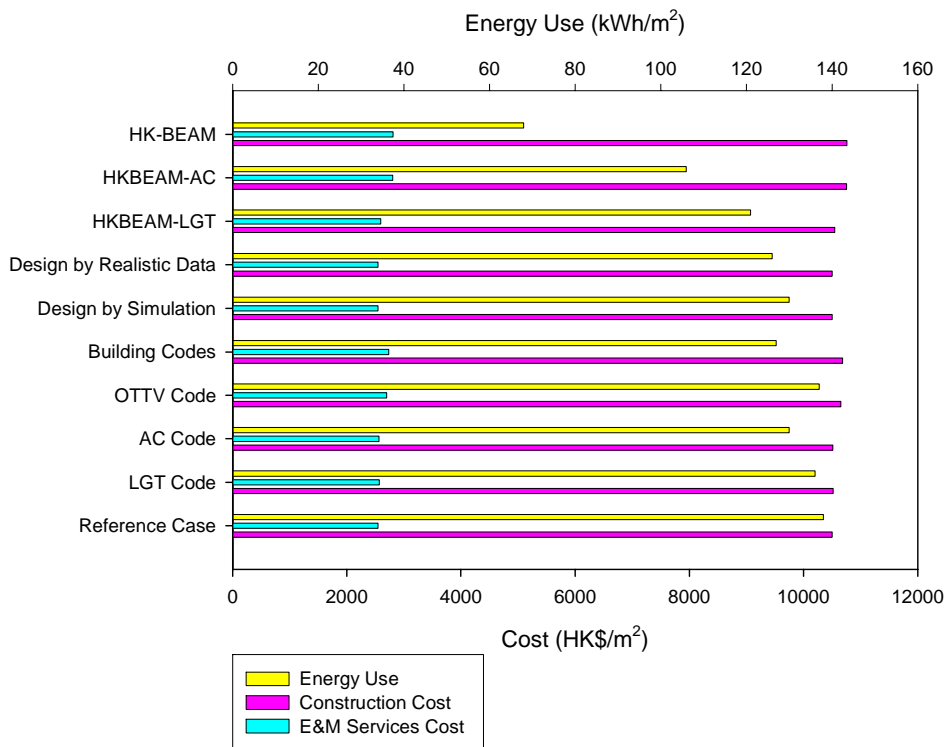
<sup>147</sup> UK Office of Government Commerce. Achieving Excellence in Construction. Procurement Guide. 2003.

<sup>148</sup> Reed W G, Gordon E B. Integrated design and building process: what research and methodologies are needed? Building Research & Information. Vol. 28, No. 5/6, 325-337, 2000.

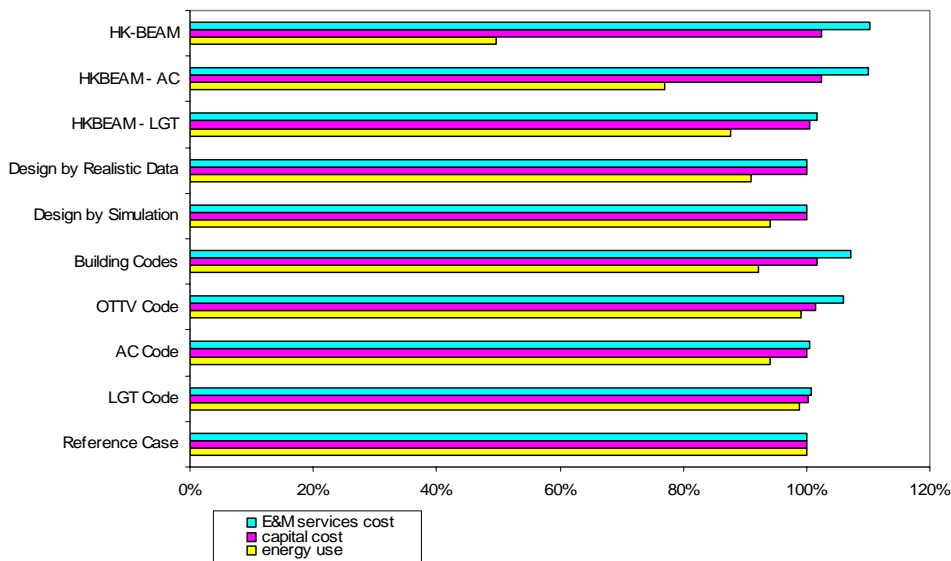
<sup>149</sup> Energy Efficiency Office. Electrical & Mechanical Services Department. Report on Pilot Energy Management Opportunities Implementation Programme in Government Buildings.

<sup>150</sup> Energy Efficiency Office..Electrical & Mechanical Services Department. Report of the Pilot High Output 'T5' Fluorescent Lighting Project at East Kai Tak Indoor Games Hall.

<sup>151</sup> Chau C K, Burnett J, Lee W L. Assessing the Cost Effectiveness of an Environmental Assessment Scheme. Building and Environment, Vol. 35, 307-320, 2000.



**Fig. 8.3 Reduction/increase in energy and costs by various standards and codes**



**Fig. 8.4 Percentage reduction/increase in energy and costs by various standards/codes**

### Potential Capital Cost Saving

Whilst additional plant room space for potential future use can be designed in, the deferred capital cost of plant may be significant. Suitable sizing of plant to match the load profile of a building is also a benefit as plant operates more efficiently near to design load capacity<sup>[152]</sup>.

### 8.8.3 COMMISSIONING AND HANDOVER

Construction quality is matter of adequate specifications, explicit contractual arrangements,

<sup>152</sup> Sat P S K, Yik F W H. Comparison of Predictions of the Building Energy Simulation Programs HTB2 and BECON with Metered Building Energy Data. HKIE Trans, 10(3), 34-47, 2003.

abilities and skills of the main contractor and appointed subcontractors, and the quality of oversight. Building commissioning is recognised as a quality assurance process that can address some, most or nearly all design and construction problems, depending on its scope and quality. As Fig, 8.5 illustrates, the scope of commissioning can be divided in three broad levels of coverage, as follows:

*Testing and commissioning:* a description common to Hong Kong which tends to focus on equipment and systems as separate entities, and generally towards the end of construction.

*Commissioning management:* implying overall management of commissioning starting at an early stage of construction to achieve better integration of building services systems and is now a requirement of the UK building regulations<sup>[153]</sup>.

*Commissioning process:* as promoted in the US<sup>[154]</sup> which, ideally, starts at the earliest stages of planning and design and continues through to post-occupancy.

For almost a decade professional guides and government publications, particularly in the US, extol the virtue and value of the commissioning process, so it is surprising to read that in the US it is a relatively new quality assurance process<sup>[155]</sup>, and the scope of activity and the quality of outcomes is variable. Similarly, in the UK commissioning required by regulations is now the norm, but full building commissioning tends to be the exception.

### *Testing and Commissioning*

Wong and Chow<sup>[156]</sup> pointed out that Hong Kong practice in T&C of HVAC systems is treated as an exercise before handing over of the building to clients rather than as a continuous and integrated process of ensuring the quality and performance of the building systems. Lau and Chan<sup>[157]</sup> stated that the inclusion of provisions for commissioning in tender documents will ensure that there are resources allowed for commissioning, but that the Hong Kong HVAC sector has room for improvement, requiring a new mind-set and approach to the design and construction processes, requiring the client, design team and contractor to work as a team to deliver the desired quality. In the Hong Kong Building Commissioning Centre guide<sup>[158]</sup> it is noted that the Hong Kong SAR Government as one of the major developers it has an influential role in setting quality standards in the building industry, and the dozen sets T&C procedures published by Architectural Services Department<sup>[159]</sup> are widely accepted as standard references for private sector projects. It also notes that some clients have introduced an independent commissioning contract under a service sub-contract or a main contract.

The specifications published by ArchD which lay down the minimum requirements to be carried out by the contractor on new government buildings. The procedures seek to facilitate the engineers and inspectors to vet, approve and witness T&C procedures, and receive certificates and supporting data. Whether or not systems are properly commissioned depends on the skill and diligence of the sub-contractors, and the quality of oversight, but even if each is complete, conflicts between systems may remain unresolved. The private sector, whilst adopting similar specifications T&C seems to be under less due diligence.

Even mandatory and straightforward T&C of fire services systems has caused delays in obtaining an occupancy permit<sup>[125]</sup>. Principal factors contributing to delays included improper site co-ordination and management, and lack of timely decision making by the client. For HVACR systems there are no mandatory checks on acceptance and consequently, the systems that potentially have the greatest impact on both IEQ and energy efficiency, tend to be poorly

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<sup>153</sup> HM Government. Building Regulations. Approved Document L2. Conservation of fuel and power in buildings other than dwellings. 2006.

<sup>154</sup> American Society of Heating, Refrigeration and Air-Conditioning Engineers, Inc. ASHRAE Guideline 0-2005. The Commissioning Process. 2005.

<sup>155</sup> Mills E, Friedman H, Powell T, Bourassa N, Claridge D, Haasl T, Piette M A. The Cost-Effectiveness of Commercial Buildings Commissioning. Lawrence Berkeley National Laboratory. 2004

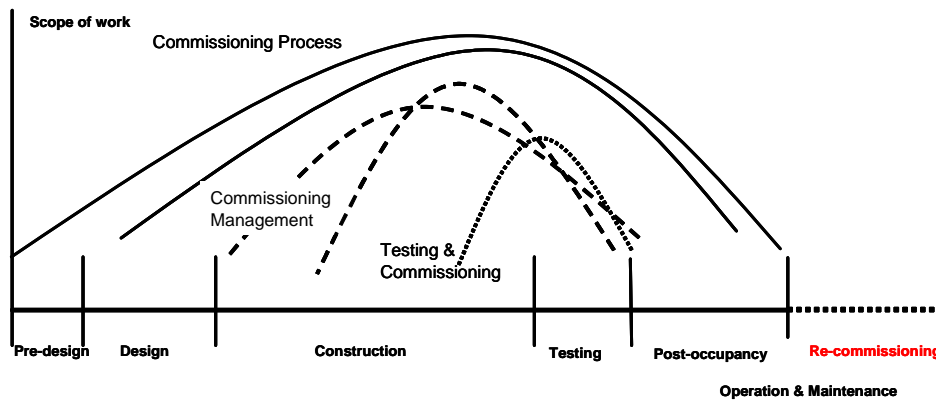
<sup>156</sup> Wong C F, Chow K H. Building Commissioning - A Perspective and Development in Hong Kong. Proc. Int. Symposium on HVAC Commissioning. Kyoto, April 2003.

<sup>157</sup> Lau K F, Chan Y C. An Overview of Testing and Commissioning of HVAC Systems in Hong Kong. Proc. ASHRAE/CIBSE/HKIE Joint Symposium, November 2002.

<sup>158</sup> Hong Kong Building Commissioning Centre. A Practice Guide to Building Commissioning Management (Practice Guide M1) for Hong Kong. February 2006.

<sup>159</sup> ArchD, Architectural Services Department. <http://www.archsd.gov.hk>.

commissioned<sup>[126]</sup>. Chu<sup>[160]</sup> reported from a survey of over fifty HVAC contractors that the least satisfactory factors that affected commissioning were the time allowed for T&C, the cost allowance and the site conditions for commissioning. Chu noted that there is no formal programme for training and certification of T&C technicians or engineers in Hong Kong. Given the lack of resources for O&M, corrective action by operators tends to focus on minimising occupant complaints about IEQ, rather than optimising energy performance.



**Fig. 8.5 Scope of commissioning practices** <sup>[from 161]</sup>

### Commissioning Management

According to CIBSE<sup>[162]</sup> commissioning programmes produced by building services installers and their sub-contractors in the UK are frequently over-optimistic and uncoordinated, leading to a risk of project overrun unless the interdependencies of all building services systems are identified, together with their integration with construction activities. Potts and Wall<sup>[163]</sup> found that commissioning of building services has been very much the 'Cinderella' activity in the construction cycle, and that the process requires planning and managing from the earliest possible stage, and provide for better end-user documentation and training. Much of this is now addressed by the UK Building Regulations<sup>[153]</sup>, which requires:

- testing thermal insulation continuity and airtightness to limit heat loss;
- commissioning of heating, hot water, lighting and ACMV systems; and
- provision of concise and understandable information, including results of performance tests, showing how the building and its services can be operated and maintained with energy efficiency.

Compliance with requirements of Part L is a statutory duty of the building owner or his/her agent. Evidence is required, e.g. compliance with CIBSE commissioning codes for automatic control, air-distribution systems, boilers, water systems, etc, that systems have been commissioned and are operating correctly. Provision of a suitable log book<sup>[164]</sup> is also recognised as being important part of the deliverables to owners and operators of buildings.

### Commissioning Process

The latest ASHRAE guide<sup>[154]</sup> defines the Commissioning Process as a quality-oriented process for achieving, verifying, and documenting that the performance of facilities, systems, and assemblies meets defined objectives and criteria. Fig. 8.2 illustrates the extent of the full building

<sup>160</sup> Chu K C. Cost and Benefits of Commissioning for Hong Kong Buildings. Research Project, Department of Building Services Engineering, Hong Kong Polytechnic University. 2006.

<sup>161</sup> Burnett J. Building Commissioning - Neglected QA! Paper in preparation.

<sup>162</sup> CIBSE. Chartered Institution of Building Services Engineers. Commissioning management. Commissioning Code M. 2003.

<sup>163</sup> Potts K, Wall M. Managing the commissioning of building services. Engineering, Construction & Architectural Management, Vol. 9, No. 4, 336–344, 2002.

<sup>164</sup> CIBSE. Chartered Institution of Building Services Engineers. Building log book toolkit, TM31, Revised 2006.

commissioning process<sup>[165]</sup>, but which references other technical guidelines for specific details. The process is not seen as an additional layer of construction management, rather its purpose increase value to owners, occupants, and users. It assumes that owners, designers, contractors, and O&M entities are fully accountable for the quality of their work, but seeks to provide for better co-ordination. Emphasis is on documentation of the Client's requirements at an early stage of a project, and the proper transfer of information between all parties involved in the design, construction and commissioning.

Full building commissioning applies a process of review, verification, and documentation to ensure that the 'final product' conforms to the project design requirements in every way, and whilst flawed components may not necessarily prevent equipment and systems from operating, nor prevent occupancy, they can reduce the value of the building or cause unexpected capital and O&M expenditures<sup>[166]</sup>. As Berning and Grunenwald<sup>[167]</sup> observe, typical problems when commissioning 'green' building include unmanageable complexity in building system design and control problems, such as ambiguous or non-existent sequences of operation. A full Commissioning Process includes training for building operators and a period of post-occupancy fine tuning<sup>[168]</sup>.

PLANNING	DESIGN	CONSTRUCTION	POST-OCCUPANCY
Identify Commissioning Team	Incorporate Commissioning in Scope of Services	Review Submittals for Performance Parameters	Perform Deferred and Seasonal Testing
Define Client's Project Requirements	Retain Commissioning Agent Services	Develop & Utilise Construction Checklists	Review Performance before end of Warranty Period
Develop Preliminary Commissioning Plan	Review Client's Project Requirements and Basis of Design	Oversee & Document Functional Performance Testing	Complete Final Commissioning Report
Establish Initial Budget for Commissioning	Concept, DD and CD Design Reviews	Commissioning Team Meetings and Reports	Final Satisfaction Review with Customer
	Update/Refine Commissioning Plan	Conduct Owner Staff Training	
	Develop Commissioning Specifications	Turnover Commissioning Records	<i>Re-commission Facility Every 3-5 years</i>
Integration into Feasibility and Program Development	Contract Documents Aligned with Client's Requirements	System Performance Documented & Accepted	<i>System Performance Sustained</i>

**Fig. 8.6 Commission Process (modified from GSA<sup>[165]</sup>)**

Full building commissioning is essential to the success of green designs<sup>[169]</sup> and, together with adequate training of facilities staff, lease conditions and tenant guidance, can help ensure the design becomes an operational success. Consequently, commissioning and handover should be an important part of BEAM assessments.

#### 8.8.4 COMMISSIONING COSTS AND BENEFITS

Full commissioning implies all active and passive systems are put into effective operation at the early stage of occupancy. The direct cost depends on the allowance provided in the contract sum, but full cost and the benefits depend also on investments in the design and construction management. R S Means<sup>[170]</sup> estimates commissioning costs at between 0.5% and 0.75%. A study on LEED projects found costs ranged between 0.75% and 1.5% of total construction cost<sup>[171]</sup>. In Hong Kong the allowance for commissioning HVAC systems is of similar order. The

<sup>165</sup> US General Services Administration. Public Buildings Service, Office of the Chief Architect. The building commissioning guide. 2005.

<sup>166</sup> Della Barba M. P. The Dollar Value of Commissioning. Proc. National Conference on Building Commissioning, US, May 4-6, 2005.

<sup>167</sup> Berning M, Grunenwald B. How to Achieve LEED Certification for Commissioning Projects. Proc. National Conference on Building Commissioning, US, May 4-6.

<sup>168</sup> Bordass, B., Cohen, R., Standeven, M., Leaman, A. Assessing building performance in use 3: energy performance of the Probe buildings. Building Research & Information. Vol. 29, No. 2, 114-128, 2001.

<sup>169</sup> Stum K. The Importance of Commissioning 'GREEN' Buildings. HPAC Engineering, February, 27-32, 2000.

<sup>170</sup> R S Means Company. Green Building: Project Planning & Cost Estimating. 2002.

<sup>171</sup> Eijadi D, Vaidya P, Reinertsen J, Kumar S. Introducing Comparative Analysis to the LEED System. ACEEE Energy Efficiency in Buildings, 2002.

HVAC commissioning costs included at the tender stage as reported by Chu<sup>[172]</sup> were 0.5% (office tower), 0.76% (office + carpark), 1.02% (office + laboratory) for three government projects, and 0.76% (office + hotel), 0.88% (office + carpark) and 1.07% (office + retail) for three private developments

The benefits of commissioning systems are difficult to determine, as it requires a comparison between outcomes achieved with full commissioning with the outcomes where there is none, and the persistence of 'fixes', except those accessible to operators, e.g. scheduling and control strategies<sup>[173]</sup>. Persistence also depends on operator training and support, and facilities that permit performance tracking. The additional cost of a commissioning authority can be some two-thirds of the cost of commissioning, but an experienced authority can improve outcomes through:

- verification of design intent and correcting deficiencies;
- oversight of key installations such as actuators and controllers;
- co-ordination and oversight of acceptance tests and commissioning on site;
- training operators and providing O&M manuals and operating data;
- optimising start-up performance, etc.

Correcting design faults (oversized plant, controls, etc) and improving construction specifications through early attention to commissioning can lead to reduced construction time and variation orders. From a meta-analysis, Mills et al<sup>[174]</sup> found median commissioning costs were 0.6% of total construction costs, yielding a median payback time of 4.8 years excluding non-energy impacts. With non-energy impacts included cost-effectiveness increases considerably, and the net cost for was often zero or even negative. Paying more for commissioning seems a good investment, but only if the contracted parties are able to deliver the quality.

### 8.8.5 PROVISIONS FOR MANAGEMENT, OPERATION & MAINTENANCE

The on-going performance of buildings, even those that have been well-designed and fully commissioned depends on the available resources for management, operation and maintenance. This includes the staffing levels, appropriate training and instructions, and the adequacy of facilities to carry out O&M. Guidance literature on sustainable building practices for facility managers are limited, and as Ring and Ingwalson<sup>[175]</sup> point out, "many green buildings include systems that are innovative but not well understood by installers, building operators, and users", and "if the engineering solutions of a building far exceed the sophistication of the installers or operators, significant deficiencies are inevitable". Furthermore, as Friedman et al<sup>[176]</sup> report, "the long-term persistence of commissioning fixes and energy savings hinged on the abilities of the operators to troubleshoot and understand how systems were supposed to operate".

Owners taking possession of a building rarely find the information contained in operating and maintenance manuals to be accessible, with design details, operating instructions and commissioning records often incomplete. In recognition, the UK building regulations now requires all new and refurbished buildings to be provided with a building log book "containing sufficient information about the building, the fixed building services and their maintenance requirements so that the building can be operated in such a manner as to use no more fuel and power than is reasonable in the circumstances"<sup>[177]</sup>. The development of the log book starts at the briefing stage, to overcome the gaps between design and operation, to enhance commissioning and handover and improve long-term management and recording of alterations and performance.

Difficulties in measuring and therefore improving the energy performance of existing air-

<sup>172</sup> Chu, K. C., Cost and Benefits of Commissioning for Hong Kong Buildings. Department of Building Services Engineering, Hong Kong Polytechnic University. 2006

<sup>173</sup> Friedman H, Potter A, Haasl T, Claridge D, Cho S. Persistence of Benefits from New Building Commissioning, National Conference on Building Commissioning: May 20-22, 2003

<sup>174</sup> Mills E, Friedman H, Powell T, Bourassa N, Claridge D, Haasl T, Piette M A. The Cost-Effectiveness of Commercial Buildings Commissioning. National Conference on Building Commissioning: May 4-6, 2005.

<sup>175</sup> Ring E, Ingwalson J. (2005). Not that Again! Recurring findings from the commissioning of green buildings. Proc. National Conf. on Building Commissioning, US, May 4-6, 2005.

<sup>176</sup> Friedman H, Potter A, Haasl T, Claridge D. Strategies for Improving Persistence of Commissioning Benefits. June, 2003.

<sup>177</sup> Chartered Institution of Building Services Engineers. Building log book toolkit, CIBSE TM31, Revised 2006.

conditioned buildings due to poor provisions for metering and monitoring are highlighted in a number of studies. Based on detailed site surveys Deng and Burnett<sup>[178]</sup> highlight that problems relating to plant design and operation which influence the overall operating efficiency can be revealed by a good quality monitoring system or instrumentation to help operators diagnose problems and optimise plant performance. Yik and Chiu<sup>[179]</sup> examined chiller plant instrumentation and concluded that without good quality instruments and proper calibration uncertainties in performance measurements could result in errors in CoP estimates of over 10% at full load, and more than 20% at half load. Yik et al<sup>[180]</sup> show that detailed energy audits of buildings are only made easy by extensive provision of sub-meters, which also allow the effects of improvement measures to be evaluated.

In Hong Kong, knowledge about 'green and sustainable' buildings is sorely lacking amongst most building O&M personnel<sup>[181]</sup>. Whilst most acknowledged the importance of good building performance in this regard, they possessed little knowledge about best practices for enhancing energy efficiency and IAQ. Although provision of sub-meters for recording separately the energy use by different systems should be regarded as essential, few buildings in Hong Kong are adequately equipped with metering and monitoring and very few have measured data properly recorded<sup>[182]</sup>. The lack of facilities for basic management functions such as waste disposal and recycling are also a limitation. For the majority of existing buildings then, improving performance is to say the least, problematic, but suggests that periodic recommissioning is a worthwhile exercise to improve performance and building value<sup>[155]</sup>.

## 8.9 MINIMISING COSTS AND MAXIMISING BENEFITS

The perceptions of the key decision makers determine the demand for green buildings. If the perceived extra cost of going green outweighs the perceived benefits then clients are unlikely to specify green building performance, i.e. seek an eco-label. The developer incurs the initial costs for the site, and for design, construction and commissioning, so interest in a green building label is likely to focus on marketing benefits that help with the sale. For the owner-occupier operating costs are also incurred so life-cycle cost should be considered. Tenants will be concerned about IEQ, services and amenities, given the impact on their business activities, but less so about energy efficiency. The tangible benefits from green (energy efficient) buildings lie in the reduced capital cost for developers when major plant is downsized, and construction work is reduced. Owners and tenants benefit from reduced energy and operation & maintenance costs. Payback from energy, water and materials savings is in a matter of years. The main benefit, but one which is difficult to quantify for any particular building, accrues to tenants/users through increased productivity and reduced absenteeism from better IEQ.

From the literature it is clear that over the life cycle of a building there is potential to minimise costs and maximise benefits through judicious investments in key processes, including:

- involvement of end-users in initial planning and design is critical in reducing cost premiums and maximising benefits;
- integrated design solutions, particular in respect of whole building energy use, can reduce initial cost by avoiding oversizing and unnecessary complexity;
- design detailing needs to be completed as far as possible prior to construction;
- strong oversight of construction to ensure quality of workmanship and installations;
- full building commissioning to realise the design intent.

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<sup>178</sup> Deng S M, Burnett J, Performance Monitoring and Measurement for Central Air Conditioning Chiller Plants in Buildings in Hong Kong. HKIE Trans. Vol. 4, No. 1, 7-12, 1996.

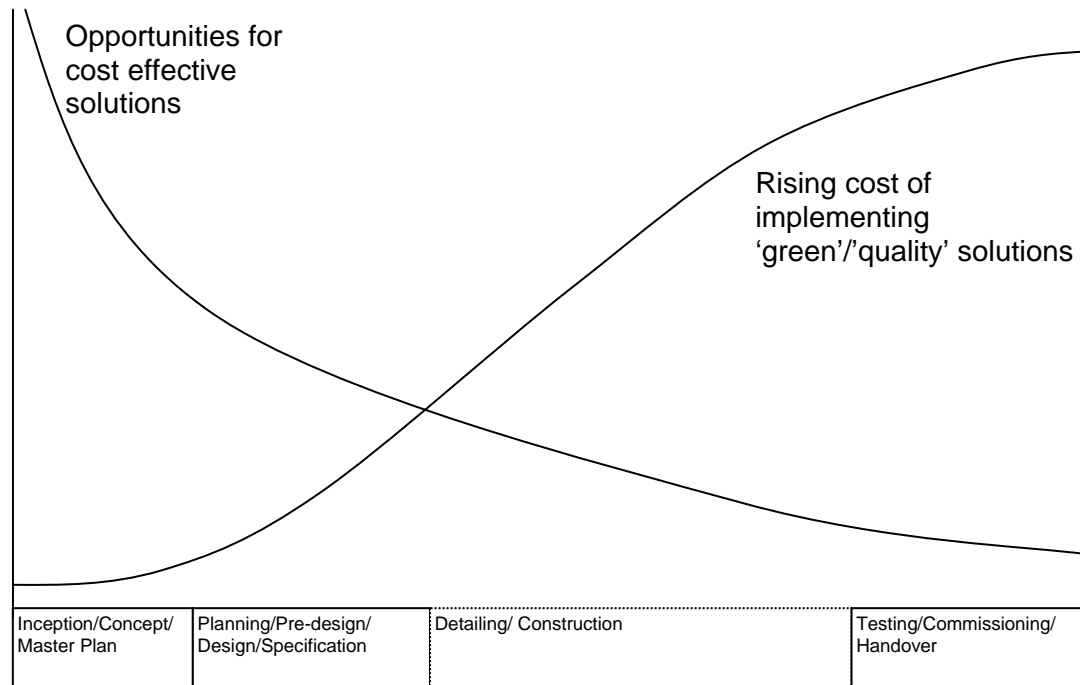
<sup>179</sup> Yik F W H, Chiu T W. Measuring Instruments in Chiller Plants and Uncertainties in Performance Evaluation. HKIE Trans. Vol. 5, No. 3, 95-99, 1997.

<sup>180</sup> Yik F W H, Yee K F, Sat P S K, Chan C W H. A Detailed Energy Audit for a Commercial Office Building in Hong Kong. HKIE Trans. Vol. 5, No. 3, 84-88, 1997.

<sup>181</sup> Lai J H K, Yik F W H. Knowledge and perception of operation and maintenance practitioners in Hong Kong about sustainable buildings. Facilities, 24(3/4), 90-105, 2006.

<sup>182</sup> Sat P S K, Yik F W H. Comparison of Predictions of the Building Energy Simulation Programs HTB2 and BECON with Metered Building Energy Data. HKIE Trans, 10(3), 34-47, 2003.

- quality management, operation and maintenance is a requirement to realise the benefits of good design and commissioning.
- building user awareness that their activities impact on indoor conditions and energy use.



**Fig. 8.7 Opportunities for lowering the cost for building green.**

The main opportunities for lowering 'green cost premiums' and enhancing benefits for new buildings are at the early stages of the production process (Fig. 8.7). Late introduction of 'green measures' or 'green features' are likely to result in escalating cost and greater difficulty in implementation.



## 9 OBSERVATIONS AND RECOMMENDATIONS

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This report addresses the cost premiums for green building assessments, and based on available data suggests that cost premiums over conventional buildings depends on the particular circumstances of a new building development and the performance enhancements that have been implemented. The potential benefits that accrue also depend on the performance enhancements for the new building and the maintenance of the performance during use. Arising from the study is a number of observations and suggestions for the further development of green buildings in Hong Kong.

### 9.1 INCREASED VALUE OF GREEN BUILDINGS

The report stresses that green building assessments has the potential to improve living and working conditions in Hong Kong's services dominated economy. Better buildings, in terms of the indoor environments and services, add value to the stock of buildings, are more sustainable for businesses, and enhance the quality of life. Sub-standard buildings detract from sustainability in all aspects; economic, social and environmental.

A significant problem is putting value on the benefits of green assessments of commercial buildings. Investors/Developers are, relatively speaking, good at measuring costs associated with building design and construction but much weaker at assessing value, and therefore justifying any additional investment. Whilst life cycle costing has not featured in this report, Owner/Occupiers of commercial buildings should not let first cost dominate decisions, and seek to evaluate life cycle costs and impacts, especially when decisions impact on IEQ and long term energy performance. The delivery of valuable buildings is not through cutting costs; rather it is an investment in quality processes.

#### 9.1.1 AIR-CONDITIONED BUILDINGS

This report adds to the observations made by the CIRC in stating that better design integration and energy modelling is a prerequisite for resource efficient buildings, providing design and construction quality is demonstrated through full building commissioning. This is especially true for HVAC and lighting systems that have the main impact on both indoor environmental quality and energy use. However, Fig. 5.4 in Section 5 highlights the fact that energy efficiency in workplaces such as office buildings is a shared responsibility. For the owner/occupier it should be clear that whilst building and building services systems design, particular HVAC systems and equipment, has a significant impact on energy performance, overall performance is enhanced by installing energy efficient lighting and controls, and using energy efficient office equipment in air-conditioned areas. Building energy efficiency improves by selecting efficient equipment, conserving energy by switching off equipment when not in use, and reducing demand through control, such as dimming control for lighting and 'idling' controls on equipment.

##### *Detailed Design and Full Building Commissioning*

The report demonstrates that detailed energy modelling at the early stages of design within an integrated design approach is the basis for energy efficiency, and can avoid unnecessary expenditure. It is observed that such practice does not appear to be widespread, perhaps as a consequence of overly competitive fees and restricted timeframes for design.

The apparent lack of sufficient expertise to fully utilise the benefits of the sophisticated design tools now available suggests an opportunity for those who can provide the appropriate training. Likewise, there is evidence to show that serious attention is needed in the short term to train and certify contractors who undertake testing and commissioning. Based on experience in the US and UK it would appear that there is a business opportunity for those who can demonstrate expertise to manage whole building commissioning. Enhancing the quality of buildings through better quality processes is a matter that Clients (paymasters) are in the best position to address.

### Targeting the Retail and Catering Sectors

From energy end-use data presented in Section 5 it is clear that the retail and catering sectors are dominant users of energy, yet have received relatively little attention in energy end-use studies. These areas of use fall somewhere between residential buildings and office buildings in that end-use is dominated by food preparation, water heating, display lighting, and like, and where those responsible have similar levels of awareness as residents. Energy efficient design, full commissioning and good operation & maintenance can improve energy performance, but the use of efficient appliances, lighting equipment, etc needs to penetrate the market. Similar considerations apply to water use in the catering sector.

### Existing Buildings

According to a study by Yik and Lee<sup>[93]</sup> the reason why existing commercial buildings in Hong Kong remain inefficient with little or no action being taken to rectify the situation are knowledge, financial and motivation barriers. The lack of motivation for owners arises due to the relative small financial benefits that can be derived from improved energy efficiency compared to rental income. Lack of motivation amongst O&M staff, lack of resources (manpower and capital) and limits to knowledge and experience need to be addressed. A study by Yik et al<sup>[183]</sup> revealed that buildings in Hong Kong operating with higher energy performance were associated with O&M personnel who were better paid. The income of the personnel was associated with academic qualification and experience but a steady rate of rise could only be sustained through continued improvement.

## 9.1.2 RESIDENTIAL BUILDINGS

Currently it is doubtful if designers can fully respond to the challenges of designing high-rise residential buildings to the extent that optimises performance in terms of mitigating external impacts whilst gaining benefits from natural ventilation and daylight. As demonstrated in a study for the Housing Authority<sup>[184]</sup>, probably the most comprehensive design analysis for high-rise residential buildings, modelling of a group of high-rise, naturally ventilated buildings requires the use of sophisticated simulation tools. The modelling included the development of a database for annual wind conditions for the site, Computational Fluid Dynamics to estimate wind pressure coefficients on building facades in order to model ventilation rates inside rooms. Modelling also included the use of HTB2 and BECON software using occupancy patterns found from surveys. The whole process may be too time consuming and may not provide the required answers in a form that can be used by designers.

In any event, as discussed in Section 5, whether or not residents will utilise design improvements such as provision of cross ventilation depends on outside environmental conditions and user preference. Garnering the potential benefits available from improved building design depends on end user awareness of how some practices can impact on both their health, on the environment, if not their pocket. Unfortunately, Hong Kong residents do demonstrate ignorance when it comes to the use of facilities in their homes. As Lin and Deng found from a survey<sup>[185]</sup> whilst most respondents might not be satisfied with the indoor air quality, 68% did not use any ventilation control intentionally during sleep with their room air-conditioners turned on, suggesting the lack of knowledge of the ventilation control devices provided on window type room air conditioners required an urgent need for user education.

## 9.2 INCENTIVES TO ENHANCE ENERGY PERFORMANCE

With energy costs for businesses and households only of the order of 2-3% of outlay there seems little incentive to save energy in order to save money. Individuals, through awareness and social conscious may strive to reduce waste, especially if it does not detract from comfort, convenience or facility. The implementation of an energy tax to cover the hidden costs of energy supply is worth investigating as it requires relatively little effort to collect taxes with energy bills.

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<sup>183</sup> Yik F W H, Lee W L, Ng C K. Building energy efficiency and the remuneration of operation and maintenance personnel. *Facilities*. Vol. 20, No. 13/14, 406-413, 2002.

<sup>184</sup> Housing Authority. Development of Environmental Responsive Façade Engineering to enhance Livability, Sustainability and Energy Conservation in Optimised Design of Public Housing. May 2006.

<sup>185</sup> Lin Z, Deng S. A questionnaire survey on sleeping thermal environment and bedroom air conditioning in high-rise residences in Hong Kong. *Energy and Buildings*. Vol. 38, 1302-1307, 2006.

For residential buildings Lam<sup>[186]</sup> performed regression and correlation analysis to correlate annual electricity consumption over 23 years from 1971 to 1993 with annual household income, household size, electricity price and cooling degree days. The annual income elasticity showed a 10% increase in income could result in a 5% increase in electricity use. A 10% increase in electricity price would reduce consumption by 1.8%, and a 10% increase in cooling degree days as a result of higher average annual ambient temperatures would result in a 2.2% rise in electricity consumption. Whilst the potential gain may be less than that attainable from heightening social awareness, it would reinforce the message that saving energy is 'good'.

### **9.2.1 GOVERNMENT'S ROLE**

There is potential for the HKSAR Government to provide incentives for green buildings, through the same kind of incentives provided in the Joint Practice Notes for new buildings, and through tax penalties or rebates for existing buildings. In any case the Government should follow the lead of OECD countries by implementing energy efficiency regulations for new buildings (with higher targets than the existing energy codes) as well as implementing regulations requiring all buildings to provide public notification of energy performance.

### **9.2.2 HONG KONG GREEN BUILDING ASSESSMENT METHODS**

HK-BEAM provides an over-arching set of criteria for enhancing the environmental performance of new buildings, with standards set above those required by building regulations or regarded as acceptable conventional practice. As in the case of construction standards<sup>[187]</sup>, the expectations of designers and builders and the constraints set by technical difficulties, a mix of performance-based and prescriptive approaches is inevitable.

The current version for new buildings, version 4/04, should be revised to take account of the observations made in this report, including:

- reviewing the method to enhance key building production processes, particularly design and commissioning;
- provide preliminary certification at the planning and design stages similar to that proposed in CEPAS, in order to encourage best practice and commit clients, designers and builders to meet design targets;
- change the weightings (credits) to reflect current concerns over climate change, including prerequisites in certain key areas of building performance, i.e. IEQ and annual energy use;
- revise and separate the assessment method for high-rise residential buildings as they present significantly different challenges from air-conditioned buildings.

### **9.2.3 CII-HONG KONG**

Given that this study has not been able to embrace all aspects of the costs and financial benefits of green building assessments it is recommended that CII-Hong Kong, maybe in collaboration with other parties, seek to develop the study in the following areas:

- development of whole building commissioning practices in Hong Kong;
- the costs and benefits of green building assessments for existing buildings in Hong Kong.

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<sup>186</sup> Lam J C. Climatic and Economic Influences on Residential Electricity Consumption. Energy Conversion Management. Vol. 39, No. 7, 623-629, 1998.

<sup>187</sup> Construction Industry Institute, Hong Kong. Construction Standards for Hong Kong. CII-HK Report No. 5. 2006.

## 10 COST PREMIUMS FOR HK-BEAM 4/04 CREDITS

Typically around 112 ‘core’ credits, plus a number of additional credits are applicable to an office building. Similarly, around 104 credits, plus a number of additional credits, may be applicable to high-rise residential buildings (excluding ‘bonus’ innovative credits). The credits that have been evaluated in Stage III of this study have been grouped under 5 different cost premium categories. The evaluation process has been used to:

- estimate the potential cost premium to achieve a credit, using the appropriate base building as reference;
- reveal origin and basis of cost assumption, these assumptions give the history of the investment of credit achievement;
- indicate degree of practical applications, and state the applicability of HK-BEAM credit achievement in the local construction industry;
- indicate availability of benefits that can be obtained by complying with the credit requirement.

### *Cost Premium Categories for Standard Office Buildings:*

<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>
Unable to estimate	No cost (0/m <sup>2</sup> )	Insignificant cost (<\$11/m <sup>2</sup> )	Low cost (11-\$34/m <sup>2</sup> )	Moderate cost (>34-\$113/m <sup>2</sup> )	High cost (>\$113/m <sup>2</sup> )

### *Cost Premium Categories for High-rise Residential Buildings:*

<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>
Unable to estimate	No cost (0/m <sup>2</sup> )	Insignificant cost (<\$4/m <sup>2</sup> )	Low cost (4-\$12/m <sup>2</sup> )	Moderate cost (>12-\$40/m <sup>2</sup> )	High cost (>\$40/m <sup>2</sup> )

Credits are listed as they appear in Table I. Credits under ‘Site Aspects’, ‘Materials Aspects’ and ‘Water use’ are listed first as these tend to be common to all building types. The ‘Energy Use’ and ‘IEQ’ credits follow, first for office buildings, then for residential buildings.

### 10.1 CREDITS UNDER SITE ASPECTS

This focuses on the land use and its location with respect to local transport and amenities, planning and design for the site to take account of both beneficial and negative impacts on neighbours and the development itself, mitigation of ecological impacts and emissions from the site over the building’s lifetime, and aspects of site management. There will be significant differences between large scale developments, such as estates, as compared to single buildings, which needs to be reflected in the assessment criteria and weighting of credits.

#### **Site Location:**

##### *Land Use, Contaminated Land, Local Transport, Neighbourhood Amenities*

Due to the shortage of land on which to build the choices for building location are limited. However, from an environmental perspective credit is given where new developments make use of sites that have already been developed or are on reclaimed land, thereby preserving natural environments. Additional credit is awarded when contaminated land and land adjacent to landfill sites are put to use. Site location also is important in respect of adequacy of local amenities and public transport provisions, in order to reduce travel needs and reliance on private vehicles.

#### **Site Planning and Design:**

*Site Design Appraisal, Ecological Impact, Cultural Heritage, Landscaping and Planters, Microclimate Around Buildings, Overshadowing and Views, Vehicular Access, Demolition/Construction Management Plan*

The planning and design issues which affect the environmental performance of a site and master layout planning should be comprehensive in covering disposition, orientation and spatial relationship buildings, built form, balance of built-up and landscaped/open area, environmental enhancements, etc. Greenfield site development should seek to minimise disturbance, including the ecology of the site and impacts on cultural heritage. The aim is to ensure that appropriate landscape treatment is provided on site to ameliorate visual impact, and conserve natural features. For Brownfield sites the emphasis should be on restoration of the local ecology and local environment. Planning and design needs to take into account and allow for the adverse impacts that inevitably arise during construction, with high quality construction management the key to minimising the impacts.

**Emissions from the Site:**

*Air, Noise, Water Pollution During Construction, Emission from Cooling Towers, Noise from Building Equipment, Light Pollution*

The various discharges and emissions from the site are considered over a building’s lifetime. Construction site require appropriate steps to be taken to reduce the emissions to air, land and waters, and to reduce construction related noise. Emissions from buildings on the site, as they may affect neighbouring properties, especially noise sensitive receivers such as hospitals, schools, residential buildings, etc., should be minimised. Of concern is any air pollution, noise pollution and light pollution arising from the building engineering systems and equipment, all of which can be alleviated by good design and proper installation and maintenance.

**Specific Credits:**

2.1.2 Contaminated Land does not apply to developments on Greenfield sites. Although costs are considered they are not included in the estimate for overall cost premium.

2.2.6 Overshadowing and Views - depends on circumstances, i.e. where the building development is adjacent to neighbouring properties such as schools and residential buildings.

2.3.4 Emission from Wet Cooling Towers – applies only to the office building.

3.3.1 Demolition Waste - included only in projects where demolition is not required or is not under the Client’s control. The cost premium is excluded form the analysis.

**2.1.1 Land Use (2 credits)**

- Exclusions: None.
- Objective: Encourage building development on land that was previously developed or has been reclaimed in order to preserve habitat and natural resources.
- Credit requirement: 1 credit where the building development uses reclaimed land.  
2 credits where the building development uses a previously developed site (Brownfield site).
- Assessment: Credit is not obtained if the building development is on a Greenfield site (virgin land). The Client shall provide evidence in the form of a report by a suitably qualified person as to the previous uses of the land prior to the construction of the building development. Where the development uses previously developed land (Brownfield site), or where use is made of reclaimed land the credit shall be awarded.

**Cost Premium:**

<b>Office</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>
<b>Residential</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>

**Basis for Estimate:**

The achievement of this credit is depended upon the government policy in respect of release of land for development purposes and an Investor/Developer’s investment decision. A development

on reclaimed land earns one credit without condition, as does the use of a Brownfield site.

There is no cost premium for building 'green' compared to a conventional building as the site preparation and foundation works will likely be the same.

**Benefits:**

The benefit is environmental in that virgin land or cultivated land is not used.

**2.1.2 Contaminated Land (1 credit)**

- Exclusions: **Building developments on Greenfield sites.**
- Objective: Ensure proper investigation and remediation of potential contamination of redevelopment sites, or proper precautions for sites adjacent to landfill sites.
- Credit requirement: 1 credit for conducting a site contamination assessment on developed or reclaimed land and implementing measures for rehabilitation as necessary, and/or proper preparation of sites and structures adjacent to landfill sites.
- Assessment:
  - a) Contaminated sites  
The Client shall submit evidence in the form of a report prepared by a suitably qualified person that demonstrates through a site contamination assessment that the issues and requirements outlined in ProPECC PN 3/94 have been addressed and that the immediate environs are free from any hazardous contamination. The report shall confirm that the required remedial measures, other than excavation and transfer to land fill (which is not regarded as an environmentally sound solution), have been completed to restore the land to an acceptable condition for use for the building redevelopment.
  - b) Sites adjacent to landfill  
The Client shall provide evidence in the form of a report prepared by a suitably qualified person confirming that the site has been properly assessed and all issues and requirements outlined in ProPECC PN 3/96 have been adequately addressed. Due consideration to gas hazards that may arise during the construction phase shall be included.

**Cost Premium:**

<b>Office</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>
<b>Residential</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>

**Basis for Estimate:**

Requirements set out in PN 3/94<sup>1</sup> and PN 3/96<sup>2</sup> are incorporated through the land use planning process, either as conditions to planning permissions, or as special conditions in relevant land-title documents.

Where land has had previous use prescribed in ProPECC PN 3/96 it is necessary to undertake site remediation work to ensure contamination does not have any negative impact on the building. If there is no contamination the only cost is for the survey but this is not a cost premium for building 'green'.

Where there is contamination the extent and size of the site will dictate costs for *on-site* remediation in order to achieve the credit, which may be moderate or relatively high.

In line with the Hong Kong Planning Standards and Guidelines (HKPSG)<sup>3</sup>, the Environmental Protection Department (EPD) has been requiring, by administrative means, project proponents of relevant developments to carry out a landfill gas hazard assessment and to submit a report on the findings to the EPD for vetting. The report requires identification and implementation of precautionary measures and provisions for periodic monitoring, the cost of which depends on the extent of the hazard.

According to the HK-BEAM Assessor for Greenfield sites the credit is marked 'non-applicable' and

<sup>1</sup> Practice Notes for Professional Persons. ProPECC PN 3/94. Contaminated Land Assessment and Remediation. [http://www.epd.gov.hk/epd/textonly/english/resources\\_pub/publications/files/pn94\\_3.pdf](http://www.epd.gov.hk/epd/textonly/english/resources_pub/publications/files/pn94_3.pdf)  
<sup>2</sup> Practice Notes for Professional Persons. ProPECC PN 3/96. Landfill Gas Hazard Assessment for Developments Adjacent to Landfills. [http://www.epd.gov.hk/epd/textonly/english/resources\\_pub/publications/files/pn96\\_3.pdf](http://www.epd.gov.hk/epd/textonly/english/resources_pub/publications/files/pn96_3.pdf)  
<sup>3</sup> Planning Department. Hong Kong Planning and Standards Guidelines. [http://www.info.gov.hk/planning/index\\_e.htm](http://www.info.gov.hk/planning/index_e.htm)

therefore does not count towards the total of available credits.

**Benefits:**

Besides the environmental benefit of reducing the dumping to landfill of contaminated waste onsite treatment would exclude transportation and landfill charges.

**2.1.3 Local Transport (2 credits)**

- Exclusions: None.
- Objective Discourage the use of private vehicles and taxis by building users, with the aim to reduce air pollution, energy use, and noise from traffic.
- Credit requirement a) Car parking provisions: 1 credit if no car parking is provided other than provisions intended for use by disabled persons, company vehicles and/or any shuttle service vehicles.  
b) Public transport: 1 credit where there exists convenient pedestrian access to mainstream public transport.

**a) Car parking provisions (1 credit)**

Assessment: The Client shall provide details of any car parking facilities and the restrictions on use. To obtain credit any car park shall be provided with access that ensures simultaneous free flow of vehicles in and out of the car park; and provisions to avoid ground contamination from oil run-off.

**Cost Premium:**

<b>Office</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>
<b>Residential</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>

**Basis for Estimate:**

The credit will be obtained if no car parking spaces are provided other than for the purposes indicated. This will be a financial decision by the Investor/Developer depending on the grade of office or residential building.

**Office Building:**

The following figures demonstrate the potential cost savings depending car parking provisions.

Based on Construction Price Book published by Davis Langdon & Seah in 2006, the additional cost for provision of a car parking space = \$54,000 – 73,000/m<sup>2</sup>

Based on statistical survey for office buildings, number of car parking spaces required by government per construction floor area (CFA) = 0.0033 to 0.0059/m<sup>2</sup>

Number of car parking space range actually provided per CFA = 0.0019 to 0.0044/m<sup>2</sup>

Reduction in number of car parking space ranges from 0.0014 to 0.0015/m<sup>2</sup>

Total cost premium (saving) in construction cost for car parking space per CFA:

Upper bound estimate = -0.0015 x 73,000 = \$-109.5/m<sup>2</sup> (negative figure indicates saving)

Lower bound estimate = -0.0014 x 54,000 = \$-75.6/m<sup>2</sup>

**Residential Building:**

CFA of the base building = 36,750m<sup>2</sup>

Based on Construction Price Book published by Davis Langdon & Seah in 2006, the additional cost for provision of a car parking space in podium = \$50,000 – 60,000

Number of residential units = 799

Number of car parking space range required per CFA = (799/4) / 36,750 = 0.0054 (based on 4 residential units require one car parking space)

Total cost premium (saving) in construction cost for car parking space per CFA:

Upper bound estimate = -0.0054 x 50,000 = \$ -270.0/m<sup>2</sup> (negative figure indicates saving)

Lower bound estimate = -0.0054 x 60,000 = \$ -324.0/m<sup>2</sup>

**Benefit:**

The difference between construction cost and income from sale or rental of car parking space will provide a net economic benefit or loss. Environmental benefits include reduced air pollution, fuel use and noise from private cars and public taxis.

**b) Public transport (1 credit)**

Assessment: The design plans or completed site will be checked to ensure that building users have easy pedestrian access to and from a major transport interchange such as a station, or main stream mass transport such as multiple cross-harbour bus stops. As a guideline a walking distance that takes less than 5 minutes is regarded as reasonable. In dense urban centres the provision of elevated walkways and linked buildings to reduce pedestrian exposure to traffic are deemed to satisfy this requirement. For sites not directly served by mainstream public transport, the provision of a shuttle bus service which links to a main stream mass transport interchange may be deemed to satisfy the criteria. The onus is on the Client to demonstrate that the service is of adequate capacity and frequency to meet the needs of building users.

**Cost Premium:**

<b>Office</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>
<b>Residential</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>

**Basis for Estimate:**

For new development areas, and upgrades during redevelopment the requirements for pedestrian facilities should be given priority in the formulation of transport facilities so as to reduce the requirement for private transport so, depending on policy, the government could impose requirements for pedestrian facilities in respect of a new development. Provision of such facility does not incur a cost premium when building ‘green’.

**Benefits:**

The Developer may be required to provide the facility as part of the conditions of land use and development, and would be factored in with the investment decisions. If such a facility is provided without conditions, then there would be a premium. The benefit could come from improved saleability if highlighted to potential tenants or owner/occupiers the benefits of easy access to public transport work, school and other commutes.

Environmental benefits include reduced air pollution, fuel use and noise from private cars and public taxis. Social benefits include accessibility to and from workplaces and homes for less affluent citizens.

**2.1.4 Neighbourhood Amenities (3 credits)**

Exclusions: None.

Objective: Encourage building development that is integrated within, and an asset to, the immediate neighbourhood.

Credit requirement: a) Provision of basic services: 1 credit where neighbourhood services are sufficient to provide for basic needs of the users of the building.  
b) Neighbourhood recreational facilities: 1 credit where neighbourhood recreational facilities and open space is adequate and available for building users.  
c) Provided recreational facilities: 1 credit if recreational facilities and open space provided within the development that is open to the public.

Assessment: Assessment is based on the overall provisions for local residents and building users within the immediate vicinity of the building development, whether these are provided within the immediate neighbourhood, or are an additional provision within the development for the benefit of the neighbourhood.

**a) Provision of basic services**

Assessment: The Client shall provide a report based on a survey of the immediate neighbourhood and details of the development itself to demonstrate adequate provision of basic services for building users, such as restaurants and shops. The onus is on the Client



to demonstrate that basic services, appropriate to the needs of the intended building users, exist within the site or within reasonable walking distances.

**Cost Premium:**

<b>Office</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>
<b>Residential</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>

**Basis for Estimate:**

The location of the building with respect to neighbouring premises that provide for basic services will determine whether or not either or both of these credits are awarded at no cost premium. Downtown office developments and residential estates are likely to meet these requirements at no cost, whereas more remote single buildings may not. If such facilities are inadequate then to obtain either credit there will be a need to provide certain facilities to make up any shortfall.

Where there are adequate provisions of services such as restaurants and shops that cover basic needs of workers or residents, i.e. within reasonable walking distance, the credit is achieved without cost. For developments where this is not achieved it would be reasonable for the Developer to provide such facility onsite, such as restaurants, shops, etc. This would incur a low cost premium, but is likely to improve saleability.

**Benefits:**

Similar to 2.1.3 b).

**b) Neighbourhood recreational facilities**

Assessment: The Client shall provide a report based on a survey of the immediate neighbourhood and details of the development itself to demonstrate adequate provision of recreational facilities and open space for building users. The onus is on the Client to demonstrate that the facilities, appropriate to the needs of the intended building users, exist within the site or within reasonable walking distances.

**Cost Premium:**

<b>Office</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>
<b>Residential</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>

**Basis for Estimate:**

Recreational open space is outdoor open-air space used for active and/or passive recreation use. Active recreation facilities include core activities such as ball games, swimming pool and sports facilities, etc, while passive recreational facilities refer to parks, gardens, sitting-out areas, waterfront promenades, paved areas for informal games, children's playgrounds, etc.

The considerations are similar to a) above, but given the limited recreational space in Hong Kong, particularly in older urban areas

**Benefits:**

Environmental and social benefits are similar to those given in 2.1.3.

**c) Provided recreational facilities**

Assessment: The Client shall provide evidence that on-site facilities will be made available for public use, including details of any restrictions or conditions of access that will be in place. Credit shall be awarded where the provision of recreational facilities or open space adds to those available within the immediate neighbourhood, and provide for reasonable access by the public. Judgement as to the nature of basic services and the provision of recreational facilities and open space with respect to a particular building development shall be made with reference to the Hong Kong Planning and Standards Guidelines<sup>3</sup>.

**Cost Premium:**

<b>Office</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>
<b>Residential</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>

**Basis for Estimate:**

To enhance the quality of a neighbourhood a development can bring additional recreational

facilities and open space that is accessible by the public within reasonable restrictions on time of use, etc.

Developers should cooperate with the government regarding the integration of buildings within the immediate surroundings. Based on estimates from experienced developers the cost premium for these this credit will lie in the range of low to moderate ranges.

**Benefits:**

Any benefit to a developer is likely to be in terms of corporate image when providing recreational facilities accessible to the public. The potential social benefits depend on the facilities provided, but have the potential to add to the quality of life of local residents and/or workers.

Provision of recreational facilities and open space are essential to the mental and physical well-being of the individual and the community as a whole. It contributes to the quality of life of building users, and is more sustainability.

**2.2.1 Site Design Appraisal (1 credit)**

- Exclusions: None.
- Objective: Encourage a proactive approach in order to achieve greater integration of site planning issues.
- Credit requirement: 1 credit for a site design appraisal report which demonstrates a proactive approach to achieve greater integration of site planning issues.
- Assessment: The onus is on the Client to demonstrate that site planning and design have taken into full account the physical and environmental aspects of the immediate site surroundings and neighbourhood. A report shall be submitted that explains and details the design team’s efforts in achieving integration of the development with the immediate surroundings, covering as a minimum the negative, neutral or positive impacts associated with:
  - o building scale (height, skyline and massing) in relation to adjoining streets and roads, existing view corridors (to harbour, mountains, etc) and surrounding topography;
  - o access to daylight and views for neighbouring properties;
  - o impact on breezeways and corridors providing natural ventilation and flushing of pollutants;
  - o wind amplification adjacent to the site;
  - o building and surface materials and finishes as they affect reflected solar energy and sunlight onto adjacent buildings, public areas, roads, etc;
  - o green and open space provisions and connecting corridors;
  - o disturbances with respect to traffic and pedestrian flows during and after construction;
  - o integration with neighbouring low-rise and recreational areas;
  - o harmonisation with the local setting (rural, new town, or urban);
  - o integration of pre-existing site features;
  - o mixed-use development for regeneration of urban fabric;
  - o shading for buildings on site to mitigate noise, optimise daylighting and natural ventilation, minimise solar heat gains, etc.

**Cost Premium:**

<b>Office</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>
<b>Residential</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>

**Basis for Estimate:**

Although feasibility studies regarding site design appraisal are normally undertaken, HK-BEAM seeks to ensure that such studies are comprehensive and inform on better design integration. This will require the use of sophisticated modelling tools, such as computational fluid dynamic studies to assess wind amplification, natural ventilation, etc. Cost premium will depend on the scale of the project, the larger the project the higher the cost, but lower the premium in percentage terms! However, the credit does not require full implementation of the design aspects. This credit calls for extra design effort over conventional design on site design appraisal. Assuming a 5% additional design fee will be spent by the architect/specialist on the site design

appraisal, and the design fees charged by architect/specialist is 4% of construction cost for office buildings or 3% for residential buildings,

Based on construction cost of \$11,300, the additional premium for office buildings = 4% of 5% of 11,300/m<sup>2</sup> = \$22.6/m<sup>2</sup> for office.

Based on construction cost of \$4,000, the additional premium for residential building = 3% of 5% of \$4000/m<sup>2</sup> = 6.0/m<sup>2</sup>.

As there are synergies with credits 2.2.5 Microclimate Around Buildings and 2.2.6 Overshadowing and Views where some of these design costs are included, the premium overall is 'low'.

**Benefits:**

If all or at least most of the issues listed are included in the appraisal there could be numerous benefits from any resulting design integration.

**2.2.2 Ecological Impact (1 credit)**

- Exclusions: None.
- Objective: Encourage planning and design of Greenfield sites that minimises damage to the local ecology or areas of natural beauty, and where feasible, improve the ecological value of Brownfield sites.
- Pre-requisites: For designated projects (DP) as specified under the Environmental Impact Assessment Ordinance (EIA), Environmental Permit shall be obtained by following the statutory Environmental Impact Assessment Process, unless exempted.
- Credit requirement: 1 credit for designs that demonstrate how landscaping and other site design strategies minimises ecological impact for Greenfield sites, or contributes positively to the ecological value of Brownfield sites.
- Assessment: The Client shall provide a master landscape plan prepared by an appropriately qualified person which illustrates the various design strategies in relation to the ecological value of the site. Details of the impact on the flora, fauna and other components of the ecological habitats within and immediately adjacent to the development area shall be provided. The report shall also detail the means adopted to protect, maintain or rehabilitate the natural environment. In particular, it shall be demonstrated that development had no negative impacts on recognised sites of conservation importance, and on other ecological sensitive areas.  
Where it can be demonstrated that all practical measures have been taken to conserve the ecology of a Greenfield site or to increase the ecological value of a Brownfield site, the credit shall be awarded.  
The criterion for evaluating ecological impacts is given in the EIA Technical Memorandum<sup>4</sup>. EIAO Guidance Note 6/2002 provides the basis of a check list of items to be addressed<sup>5</sup>.

**Cost Premium:**

<b>Office</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>
<b>Residential</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>

**Basis for Estimate:**

The EIA ordinance requires large developments that have potential to significantly affect habitats and species, to submit a detailed Environmental Impact Assessment and to obtain EPD's approval prior to commencement of the works. The objective of an ecological assessment is to provide sufficient data to allow a complete identification, prediction and evaluation of the potential ecological impacts, and/or opportunities to restore or improve matters. Given the ecology characteristics of a Greenfield site can be very variable, and beyond the control of the developer, expenditure to minimise impacts may vary greatly, and can incur relatively high cost for large sites.

For Brownfield sites the ecological conditions are likely to be such that improvements can be

<sup>4</sup> Technical Memorandum. Annex 8 : Criteria for Evaluating Ecological Impact  
<http://www.epd.gov.hk/eia/english/legis/memorandum/annex8.html>

<sup>5</sup> Guidance Note No. 6/2002. Some Observations on Ecological Assessment from the Environmental Impact Assessment Ordinance Perspective. <http://www.epd.gov.hk/epd/eia/hb/materials/GN6.doc>

made and relatively low cost.

**Benefits:**

Ecological impact refers to a habitat or species being affected directly or indirectly due to changes in the environment brought about by a development. Besides magnitude and scale, the significance of an ecological impact is also related to the importance of the habitat or species affected. The principle is first to minimise damage to the existing local ecology, and then to enhance it as far as practicable. Preserving or reinstating wildlife corridors, sustaining or creating wildlife habitats, and creation of low maintenance soft landscaping are significant steps to restore the ecology of Hong Kong's built-up areas.

**2.2.3 Cultural Heritage (1 credit)**

- Exclusions: None.
- Objective: Conserve and protect archaeological remains, historic buildings and monuments so as to maintain the local and regional cultural heritage.
- Pre-requisites: Compliance with the Antiquities and Monuments Ordinance, and where applicable to the development, the Environmental Impact Assessment Ordinance
- Credit requirement: 1 credit where development does not have a negative impact on sites of cultural heritage.
- Assessment: The Client shall conduct a site survey and desktop study to identify if there are any sites of cultural heritage on or in the near vicinity of the development site. The information of the identified sites of cultural heritage shall be assembled from the Antiquities and Monuments Office<sup>6</sup>, public libraries and archives and tertiary institutions. The guidelines and criteria for the assessment of sites of cultural interest shall follow Annex 10 and Annex 19 of Technical Memorandum to the Environmental Impact Assessment Process<sup>7</sup>. The guidelines on conservation of historical buildings contained in the Chapter 10 of Hong Kong Planning and Standards Guidelines shall be followed.  
Credit shall be awarded where evidence in the form of report by a suitably qualified person is provided detailing the findings and confirming that site preparation (including the process of reclamation), construction and building commissioning has had no adverse impacts on these sites.

**Cost Premium:**

<b>Office</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>
<b>Residential</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>

**Basis for Estimate:**

Cultural Heritage Impact Assessment is a part of Environmental Impact Assessment and similar to credit no. 2.2.2. However, the scale of which compared with EIA is much smaller and it may involve some historic buildings or cultural heritage features only. The expenditure for protection of culture heritage in site developments is low cost impacts according to the current estimates by local developers.

**Benefits:**

The benefit to Developers is limited to corporate image, given that there has been a great deal of concern in Hong Kong in recent times over the lack of protection to sites regarded to have cultural and historic value.

**2.2.4 Landscaping and Planters**

- Exclusions: None.
- Objective: Encourage building development to preserve or expand urban greenery to enhance the quality of living environment, reduce surface runoff to drainage system and

<sup>6</sup> Antiquities and Monuments Office. <http://www.lcsd.gov.hk/CE/Museum/Monument/en/index.php>

<sup>7</sup> Environmental Protection Department. Technical Memorandum on Environmental Impact Assessment Process. <http://www.epd.gov.hk/eia/legis/index3.htm>

- minimise impacts on fresh water and ground water systems during building use.
- Pre-requisites: Management of any trees on or immediately adjacent to the site follow Government stipulated requirements.
- Credit requirement: a) Hard landscaping: 1 credit for using pervious materials for a minimum of 50% of hard landscaped areas.  
b) Soft landscaping: 1 credit for providing appropriate planting on site equivalent to at least 30% of the site area.
- Assessment: The Client shall provide a report prepared by a suitably qualified person that outlines the Master Landscape Plan for the site and provides a dialogue that demonstrates how soft landscaping has addressed the guidelines and recommendations provided in the Hong Kong Planning Standards and Guidelines Chapter 4 Section 2 Greenery<sup>8</sup>, appropriate to the type and scale of the building development and the immediate surroundings. The report shall detail the landscape treatment of the development including the planting and hard finishes of all landscaped areas, slopes and retaining structures, including but not limited to details of:
- o compliance with existing legislation and administrative measures relevant to preservation of vegetation, including the felling of trees;
  - o trees retained, replanted or removed, and work undertaken to protect existing trees both during construction and permanently;
  - o site formation with specific details of slope treatment;
  - o the choice of finishes in qualitative terms for all hardwork elements, indicating any perceived or quantifiable environmental benefits;
  - o planting plans with the character and planting densities for all softwork elements, details of the species used, and assessment of environmental benefits;
  - o the adequacy of soil depth and drainage for all planted areas;
  - o the method of irrigation used and source of water supply; and future maintenance provisions.

#### a) Hard landscaping

Where it can be demonstrated that a minimum 50% of hard landscaped area (roadways, surface parking, plazas, pathways, etc), are pervious and measures are taken to restrict the contamination of ground waters by oil and similar contaminants, the credit shall be awarded.

#### Cost Premium:

<b>Office</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>
<b>Residential</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>

#### Basis for Estimate:

##### Office Building:

CFA of the base building = 42,840m<sup>2</sup>

Open space and landscape area for the base office building = 700m<sup>2</sup>

Based on common design practice in the private sector, hard landscaping area comprises 10% i.e. 700 x 0.1 = 70m<sup>2</sup>

Range of additional cost if pervious materials are used<sup>9</sup> i.e. cost of open paving blocks is, \$ 9 - 68/m<sup>2</sup>

Upper bound estimate (50% of hard landscaping area) = 70 x 68 x 50% / 42,840 = \$0.1/m<sup>2</sup>

Lower bound estimate (50% of hard landscaping area) = 69.8 x 9 x 50% / 42,840 = \$0.01/m<sup>2</sup>.

##### Residential Building:

CFA of the base building = 36,750m<sup>2</sup>

Open space and landscape area for the base residential building 1260 - 1590m<sup>2</sup>

Based on common design practice in the private sector, hard landscaping area comprises 10% =

<sup>8</sup> Hong Kong Planning Standards and Guidelines, Chapter 4 – Recreation, Open Space and Greening. [http://www.info.gov.hk/planning/tech\\_doc/hkpsg/english/ch4/ch4\\_text.htm](http://www.info.gov.hk/planning/tech_doc/hkpsg/english/ch4/ch4_text.htm)

<sup>9</sup> H&A Asia Construction Price Book, Vol. 1. 2006.

$$1260 \times 0.1 = 126\text{m}^2 \text{ to } 1590 \times 0.1 = 159\text{m}^2$$

Range of additional cost if pervious materials used, i.e. cost of open paving blocks is, \$ 9 – 68/m<sup>2</sup>

$$\text{Upper bound estimate (50\% of hard landscaping area)} = 159 \times 68 \times 50\% / 36,750 = \$0.1/\text{m}^2$$

$$\text{Lower bound estimate (50\% of hard landscaping area)} = 126 \times 9 \times 50\% / 36,750 = \$0.02/\text{m}^2$$

#### Benefits:

The use of pervious materials such as in pavers, pervious asphalt, etc., together with landscaped areas helps reduce stormwater runoff, mitigates heat island effects and elevated temperatures in external areas.

#### b) Soft landscaping

Assessment: Providing appropriate planting on site equivalent to at least 30% of the site area. It is expected that due account shall be taken of the plant type and planter designs to minimise watering and maintenance requirements. The species, density, topsoil, fertiliser, pesticide, planting maintenance, etc. should comply with the General Specification for Building Section 25: Landscape, or at least equal equivalent. The Client shall demonstrate compliance through quantification of the areas of greenery on the site and any building, including sky gardens, podium areas, roofs and other parts of the building.

#### Cost Premium:

<b>Office</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>
<b>Residential</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>

#### Office Building:

$$\text{CFA of the base building} = 42,840\text{m}^2$$

$$\text{Open space and landscape area for the base office building} = 698\text{m}^2$$

Range of cost for indigenous planting<sup>9</sup>, i.e. hybrid grass spring planting is, \$61 – 71/m<sup>2</sup>

$$\text{Upper bound estimate (30\% of landscaping area)} = 71 \times 698 \times 30\% / 42,840 = \$0.3/\text{m}^2$$

$$\text{Lower bound estimate (30\% of landscaping area)} = 61 \times 698 \times 30\% / 42,840 = \$0.3/\text{m}^2$$

#### Residential Building:

$$\text{CFA of the base building} = 36,750\text{m}^2$$

Range of cost for indigenous planting, i.e. hybrid grass spring planting is, \$61 – 71/m<sup>2</sup>

$$\text{Upper bound estimate (30\% of landscaping area)} = 71 \times 1590 \times 30\% / 36,750 = \$0.9/\text{m}^2$$

$$\text{Lower bound estimate (30\% of landscaping area)} = 61 \times 1,261 \times 30\% / 36,750 = \$0.6/\text{m}^2$$

#### Benefits:

Landscaped areas helps reduce stormwater runoff, mitigates heat island effects and elevated temperatures in external areas, and contributes to making the city greener. For example, a building rooftop covered with greenery can significantly reduce surface temperature in summer, compared with bare asphalt or concrete rooftops. Roof greenery also can reduce peak roof runoff and alleviate storm drainage pressure. To protect and improve the built and natural environment the Government in promoting the construction of green and innovative buildings has identified communal sky gardens and communal podium gardens<sup>10,11</sup>.

### 2.2.5 Microclimate Around Buildings (2 credits)

Exclusions: None.

<sup>10</sup> Buildings Department et al. Joint Practice Note No. 1. Green and Innovative Buildings. February 2001. <http://www.info.gov.hk/bd/english/documents/joint/JPN01.pdf>

<sup>11</sup> Buildings Department et al. Joint Practice Note No. 2. Second Package of Incentives to Promote Green and Innovative Buildings. February 2002. <http://www.info.gov.hk/bd/english/documents/joint/JPN02.pdf>

- Objective: Ensure the microclimate around and adjacent to buildings has been adequately considered, and where appropriate, suitable mitigation measures are provided.
- Credit requirement: a) Wind amplification: 1 credit for demonstrating that no pedestrian areas will be subject to excessive wind velocities caused by amplification due to the site layout and/or building design.  
b) Elevated temperatures: 1 credit for demonstrating that steps have been taken to reduce elevated temperatures in exposed public areas due to site layout and choice of materials.
- Assessment: The microclimate includes sky and podium gardens, walkways, sitting-out areas, etc.

### **a) Wind amplification**

- Assessment: The Client shall submit a report prepared by a suitably qualified person demonstrating compliance.
- Relative wind speeds around buildings shall be assessed by placing a suitable scale model of the building and surrounding large structures within 500m radius from the development site in a boundary layer wind tunnel. Profiles of relative wind flow can be predicted at pedestrian levels. Measurement may be through multiple point measurement or through erosion techniques. The wind amplification factor, the developed site ground wind speed relative to the open ground site wind speed, can be estimated at pedestrian areas. These include entrances and exits to buildings, car parks, pedestrian routes, play areas, etc.
- Alternatively, wind flow around the estate can be simulated using computer airflow modelling (CFD), and areas of relative wind speed predicted. Tests should be carried out for average wind speed for the site and the main prevailing wind directions. It should be demonstrated that under prevailing wind conditions
- o no pedestrian areas on or immediately adjacent to the site shall have local wind speeds accelerated by factors greater than 2; and
  - o there are no stagnant areas which has a wind speed of less than  $1.5 \text{ ms}^{-1}$  and not 'flushed' by breezes.

### **Cost Premium:**

<b>Office</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>
<b>Residential</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>

### **Basis for Estimate:**

The cost of a wind tunnel or CFD study depends on the scale of the development and the topology of the surroundings. For a large residential or commercial site this would involve taking account of surrounding natural features such as mountains and buildings of relatively similar height to ensure adequacy of the boundary conditions. For a smaller urban site the surrounding buildings would need to be modelled. However, in a dense urban setting a single building may not impact so much on wind amplification on site as much as the adjacent buildings.

A cost of HK\$100,000 to \$300,000 for a detailed study may not be unreasonable. Where a number of similar buildings exist on a residential estate the study would cover the whole estate, and costs would be shared.

The cost of mitigating excessive wind amplification or reducing the likelihood of stagnant areas would depend on many factors involving building design at 'podium' level, with voids at podium level (serving also as play areas), wind catchers or shelters, and is difficult to estimate.

### **Office Building:**

CFA of the base building =  $42,840 \text{ m}^2$

Upper bound estimate =  $300,000 / 42,840 = \$7/\text{m}^2$

Upper bound estimate =  $100,000 / 42,840 = \$2.3/\text{m}^2$

### **Residential Building:**

CFA of the base building =  $36,750 \text{ m}^2$

Upper bound estimate =  $300,000 / 36,750 = \$8.2/\text{m}^2$

Upper bound estimate =  $100,000 / 36,750 = \$2.7/\text{m}^2$

### **b) Elevated temperatures**

- Assessment: The Client shall submit a report detailing strategies and design solutions to mitigate elevated temperatures in exposed public areas. This should consider adverse impacts on the microclimate within and immediately adjacent to the site, demonstrating the benefits through:
- o appropriate choices of materials on the building;
  - o site surface finishes and landscaping features;
  - o shading devices;
  - o use of water features, etc.
- Credit can be achieved by the adoption of one or more of the following measures or any alternatives demonstrating the effectiveness of reducing temperatures:
- o provide shade on at least 50% of non-roof impervious surfaces on the site (parking, walkways, plazas) using light coloured high-albedo materials (reflectance of at least 0.3);
  - o provide high emissivity roofing (emissivity of at least 0.9) covering at least 50% of the total roof area;
  - o provide vegetation covering at least 50% of the total roof area.

**Cost Premium:**

<b>Office</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>
<b>Residential</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>

**Basis for Estimate:**

As there are synergies with credits 2.2.2 and 2.2.4 regarding design of external areas on site, and the fact that the credit could be earned by a combination of measures applied to the building or external areas on site, it is difficult to estimate the cost premium.

The provision of shading will depend on the design of sidewalks, plazas, pathways, and landscape features. For urban sites providing shading not only reduces ground level or podium level temperatures but also shelters for pedestrians and building users against sun and rain. In is possible that standard concrete paving can meet the specified reflectance of 0.3.

The most direct and least expensive strategy for roofs is to use a light-coloured roof system with an emissivity of 0.9 when tested according to ASTM 408<sup>12</sup>.

The vegetated roofing system is likely to be at higher cost, subject to design constraints to match of extreme weather conditions, but can provide additional benefit in stormwater management, and/or use as part of a recreation facility. It is noted that communal sky gardens and communal podium gardens are encouraged by government in the promotion of green and innovative buildings<sup>10</sup>.

**Benefit:**

Good microclimate designs around buildings could avoid discomfort and fatigue for pedestrians, damage to plant life, accumulation of debris, danger from impeded walking and flying objects. Recently, green roofs have been promoted for commercial buildings in Hong Kong as well as the other part of the world. Although they incur additional initial premium of about HK\$1,500/m<sup>2</sup>, green roofs can help reduce the cooling load as well as the energy consumption of air conditioning system. A study conducted by Onmura<sup>13</sup> in India revealed that in enclosed spaces underneath the planted roofs, the air temperature beneath had a temperature of 4-5°C lower than that of the air above. Current experiments conducted by the Hong Kong University on green roofs of the commercial buildings conducted also reinforced the observation that they were effective in reducing the air temperatures for the uppermost floors.

**2.2.6 Overshadowing and Views (2 credits)**

- Exclusions: **Buildings where daylight and views are of no value to neighbouring properties.**  
 Objective: Encourage building development which is sensitive to the needs of neighbours in

<sup>12</sup> ASTM Designation E 408-71. Testing the solar emittance of materials. 1990.  
<sup>13</sup> Onmura S, Matsumoto M, Hokoi S. 2001. Study on evaporative cooling effect of roof lawn gardens. Energy and Buildings; 33: 653-66.



respect of preserving daylight and views.

Pre-requisites: Compliance with Building (Planning) Regulation (CAP 123F) Regulation 37.

Credit requirement: a) Minimum daylight: 1 credit for designs for which the access to daylight of neighbouring sensitive buildings is maintained to the prescribed level.  
b) Negative impacts: 2 credits where the building development has no negative impact on neighbouring buildings in respect of access to daylight, views and natural breezes.

Assessment: Neighbouring buildings and public spaces (i.e. active and passive recreational spaces), both existing and planned, shall be assessed to determine the value of daylight (and to some extent sunlight), view corridors, and breezeways to sensitive buildings and spaces. Assessment shall be by appropriate computer and/or physical modelling.

The Client shall submit a report prepared by a suitably qualified person containing a comprehensive analysis (calculations and drawings) that qualifies and quantifies the extent to which the building development will impact on the sensitive neighbouring buildings and public spaces in respect of access to daylight, view corridors and breezeways.

Change in the access to daylight may be objectively assessed in terms of the change in Vertical Daylight Factor (VDF) on the façades of sensitive receivers, or change in viewing angle, whichever is deemed most appropriate. Change of views and natural breezes, being more subjective, can be assessed in qualitative terms.

Where the VDF on the façade of the lowest floor of the sensitive receiver most affected is either unchanged or is no less than 12%, or the viewing angle is reduced by less than 5%, the first credit shall be awarded.

Where it is demonstrated that there is no impact on neighbouring sensitive receivers two credits shall be awarded.

**Cost Premium:**

<b>Office</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>
<b>Residential</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>

**Basis for Estimate:**

Where neighbouring properties such as schools, hospitals, residential buildings, etc. are likely to be affected by a new development it is necessary to undertake an assessment of the potential negative impacts on such properties by the new building. Although views and breezeways are included the focus is mainly on access to daylight. Any impact of breezeways could be assessed under with studies conducted under Credits 2.2.1 and 2.2.5. The assessment of daylight and views can be undertaken through relatively uncomplicated daylight design software, and would not incur significant cost. As it is unlikely that a new building design would be changed to meet the credit requirements, unless there is no impact on investment consideration, it will largely be a case of the credit(s) being achieved or not achieved, but will have no significant cost implication.

Estimated cost for analysing site and surroundings (excluding costs associated with Credits 2.2.1 and 2.2.5) is HK\$50,000.

The cost premium is of the order of HK\$1.5/m<sup>2</sup>.

**Benefit:**

The proper profile of a building and its layout could allow access of daylight and natural breezeways around the development. The availability of sea view has been shown to able to increase the sale price of an apartment by 4.6%<sup>14</sup>.

**2.2.7 Vehicular Access (1 credit)**

Exclusions: None

Objective: Encourage proper management of vehicles requiring access to the site and buildings.

Pre-requisites: Compliance with the Building (Refuse Storage And Material Recovery Chambers And Refuse Chutes) Regulations Chapter 123H Regulation. Compliance with the

<sup>14</sup> Hui E.C.M. et al. 2007, Measuring the neighbouring and environmental effects on residential property value using spatial weighting matrix, Building and Environment.

requirements of PNAP 98<sup>15</sup> deemed to satisfy the relevant provisions of the Regulations.

Credit requirement: 1 credit for providing safe and efficient access for vehicles entering and leaving the site and buildings.

Assessment: The Client shall submit a report prepared by a suitably qualified person detailing the provisions for the movement of all vehicles entering and leaving the site, within the site, and within premises, for the purpose of setting down and picking up passengers, delivery and collection of goods, collection of waste, etc.

The report shall state and confirm compliance with all requirements stipulated by the Transport Department in respect of run-ins and run-outs and the adjacent layout design, compliance with the Building (Refuse Storage And Material Recovery Chambers And Refuse Chutes) Regulations, and details of how the recommendations given in PNAP 236<sup>16</sup> have been met.

Where there are deviations from the requirements due to site constraints, etc., the report shall highlight these and demonstrate that due care has been exercised to ensure the safety of building users, passers-by and operators.

Where it can be demonstrated that vehicular access to the building(s) is such that on-street queuing and parking of vehicles will be avoided the credit shall be awarded.

**Cost Premium:**

<b>Office</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>
<b>Residential</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>

**Basis for Estimate:**

This credit focuses on nuisance caused by vehicles queuing and obstruction the roads adjacent to building entrances and exists. Much of the requirements appear to be covered by guidance notes that are likely to be taken into account in the approval of site and building designs. In such circumstances there would appear to be no cost premium to meet the requirements. An additional feature, however, is emphasis on the safety of building users, passers-by and operators, including potential influence of noxious fumes from any vehicles operating in confined spaces.

**Benefits:**

Easy access to a building for the purpose of delivering goods, removals and hygienic waste disposal would appear to be a positive feature for a building's marketability. Although not highlighted, there is also relevance to indoor air quality due to pollutants from vehicles entering into a building directly, or through air intakes.

**2.2.8 Demolition/ Construction Management Plan (1 credit)**

Exclusions: None.

Objective: Encourage a higher standard of environmental management during construction.

Pre-requisites: Compliance with all relevant environmental protection and pollution control ordinances. Any evidence of non-compliance shall nullify the award of any credits. The relevant enacted ordinances and their regulations are summarised in the Recommended pollution control clauses for construction contracts by the Environmental Protection Department.

Credit requirement: 1 credit for a Demolition/Construction Management Plan including provisions for Environmental Monitoring and Auditing.

Assessment: The Client shall provide copies of relevant contract documents highlighting the clauses appropriate to the construction activities for the building development in accordance with recommendations set out by the Environmental Protection Department. The Demolition/Construction Management Plan should be submitted which takes into account the Checklist and practical advice given in PNRC 17 Appendix A<sup>17</sup>. The Client

<sup>15</sup> Practice Note for Authorized Persons and Registered Structural Engineers PNAP 98, Refuse Storage and Collection - Building (Refuse Storage and Material Recovery Chambers and Refuse Chutes) Regulations, Sep 2000. <http://www.info.gov.hk/bd/english/documents/pnap/Pnap098.pdf>

<sup>16</sup> Practice Note for Authorized Persons and Registered Structural Engineers PNAP 236, Design of Car Parks and Loading/Unloading Facilities, Mar 2000. <http://www.info.gov.hk/bd/english/documents/pnap/Pnap236.pdf>

<sup>17</sup> Buildings Department. Practice Note for Registered Contractors PNRC 17. Control of Environmental Nuisance from Construction Sites. August 1997. <http://www.info.gov.hk/bd/english/documents/pnrc/Pnrc17.pdf>

shall confirm through a report derived from appropriate site management and monitoring that environmental management practices on site are such as to comply with legislative requirements and to minimise nuisance. Appendix A of PNRC 17 should be used as a point of reference in reporting on implementation of the environmental management on site.

Where it can be demonstrated that contract documents, specifications and cost provisions provide for a Management Plan conforming to the guidelines, and the plan has been properly executed, the credit shall be awarded.

*Cost Premium:*

<b>Office</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>
<b>Residential</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>

*Basis for Estimate:*

According to PNRC 17, “Construction sites if not properly managed may become the source of serious environmental nuisance and related pollution affecting not only the workers on site but also adjoining occupants and the general public. Registered contractors are therefore strongly urged to take appropriate steps to minimize the impact of construction activities on the surrounding environment”. Appropriate pollution control clauses should be included in demolition and construction contracts in accordance with recommendations by the Environmental Protection Department<sup>18</sup>, with a reasonable cost provision to undertake management, monitoring and reporting. The additional premium will be estimated and reported in the later credit provisions. Such a cost provision is not significant in relation to site management, but execution of the Plan depends on the integrity and experience of site management staff. The award of the credit depends on the proper execution of the Plan as demonstrated to the HK-BEAM Assessor. Any evidence of non-compliance with regulations regarding noise, air, water or other aspects shall nullify the award of any credits.

*Benefit:*

Reduce the environmental impacts arising during demolition and construction, i.e. affecting site ecology, air, noise and water quality as well as nuisance from waste within and outside the site.

**2.3.1 Air Pollution During Construction (1 credit)**

- Exclusions: None
- Objective: Minimise air pollution during the construction of buildings and the infrastructure serving buildings.
- Pre-requisites: Observance and compliance with the Air Pollution Control Ordinance and its subsidiary regulations, particularly the Air Pollution Control (Open Burning) Regulation and Air Pollution Control (Construction Dust) Regulation and Air Pollution Control (Smoke) Regulation.
- Credit requirement: 1 credit for applying adequate mitigation measures for dust and air emissions during the construction as the recommended by the Environmental Protection Department, and demonstrating compliance with the air quality management guidelines as detailed in the Environmental Monitoring and Audit Manual.
- Assessment: Where demolition is included as part of the works it shall be included in the assessment.  
 The Client shall submit confirmation in the form of a report from suitably qualified person that the works have been carried out without violation of the Air Pollution Control Ordinance and no conviction or complaint about air pollution from the site has been upheld by the Environmental Protection Department.  
 The Client shall present evidence in the form of specifications and contract documents detailing the requirements to control dust and air emissions generated by construction activities. The Client’s representative on site shall be responsible for monitoring and reporting on the execution of the instructions. The representative shall confirm in writing to the Assessor that the control of dust on site followed the requirements as laid down in the specifications and contract documents.

<sup>18</sup> Environmental Protection Department. Recommended Pollution Control Clauses for Construction Contracts. [http://www.epd.gov.hk/epd/english/environmentinhk/eia\\_planning/guide\\_ref/rpc.html](http://www.epd.gov.hk/epd/english/environmentinhk/eia_planning/guide_ref/rpc.html)

The Client shall also present evidence in the form of a report prepared by a suitably qualified person that the monitoring and audit of Respirable Suspended Particulates (RSP) and Total Suspended Particulates (TSP) has been satisfactory for the scale of the works involved.

For major projects compliance with EPD's Environmental Monitoring and Audit Manual<sup>19</sup> is required. For those projects for which this it is not a requirement the frequency of the monitoring can be reduced, and/or monitoring undertaken during key phases of construction. For instance, 1-hour TSP monitoring should be undertaken with a sampling frequency of at least three times in every six days, and when the highest dust impact occurs.

**Cost Premium:**

<b>Office</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>
<b>Residential</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>

**Basis for Estimate:**

According to cost estimate by an experienced environmental consultant, cost of implementing measures for mitigating dust and air emissions = \$250,000 – 350,000

**Office Building:**

CFA of the base building = 42,840m<sup>2</sup>

Upper bound estimate = 350,000 / 42,840 = \$8.2/m<sup>2</sup>

Lower bound estimate = 250,000 / 42,840 = \$5.8/m<sup>2</sup>

**Residential Building:**

CFA of the base building = 36,750m<sup>2</sup>

Upper bound estimate = 350,000 / 36,750 = \$9.5/m<sup>2</sup>

Lower bound estimate = 250,000 / 36,750 = \$6.8/m<sup>2</sup>

**2.3.2 Noise During Construction (1 credit)**

- Exclusions: None
- Objective: Minimise nuisance to the immediate neighbourhood caused by noise during the construction of buildings and the infrastructure serving buildings.
- Pre-requisites: Observance and compliance with the Noise Control Ordinance.
- Credit requirement: 1 credit for demonstrating and confirming that the criteria and requirements laid down in ProPECC PN 2/93 has been achieved, for all Noise Sensitive Receivers.
- Assessment: Where demolition is included as part of the works it shall be included in the assessment.  
 The Client shall submit confirmation in the form of a report from suitably qualified person that the works have been carried out without violation of the Noise Control Ordinance, and that no complaint about noise from the site has been upheld by the Authority (Environmental Protection Department) or the Police leading to the issue of a fine or prosecution.  
 The Client's representative on site, who shall be a suitably qualified person, shall be responsible for monitoring and shall submit monthly reports confirming that the control of noise on site has met the requirements laid down in ProPECC PN 2/93<sup>20</sup> in respect of all Noise Sensitive Receivers as defined in Annex 13 of the Technical Memorandum under the Environmental Impact Assessment Ordinance<sup>21</sup>.

**Cost Premium:**

<b>Office</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>
<b>Residential</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>

<sup>19</sup> Environmental Protection Department, Generic Environmental Monitoring and Audit Manual, Chapter 2, Air Quality.

<sup>20</sup> Practice Note for professional Persons. ProPECC PN 2/93. Noise from Construction Activities – Non-statutory Controls. [http://www.epd.gov.hk/epd/english/resources\\_publications/files/pn93\\_2.pdf](http://www.epd.gov.hk/epd/english/resources_publications/files/pn93_2.pdf)

<sup>21</sup> Environmental Protection Department. EIA Technical Memorandum. Annex 13 Guidelines for Noise Assessment. <http://www.epd.gov.hk/eia/english/legis/memorandum/annex13.html>

#### *Basis for Estimate:*

The credit seeks to reward good practice during construction in order to reduce noise impacts on neighbouring properties, particular schools, dwellings, etc. ProPECC PN 2/93 provides the criteria for performance in respect of noise levels at the façades of such noise sensitive receivers. Noise from construction equipment can be moderated at little additional cost by adopting the practices set out in the guide published by the Hong Kong Construction Association (HKCA)<sup>22</sup>, which is intended to enhance the environmental awareness of the construction industry by providing practical solutions.

#### *Benefit:*

Controlling noise pollution can ensure that a satisfactory noise environment is maintained to safeguard the quality of life of the neighbourhood.

### **2.3.3 Water Pollution During Construction**

Exclusions:	None
Objective:	Ensure the proper management of construction site discharges.
Pre-requisites:	Observance and compliance with the Water Pollution Control Ordinance and its subsidiary regulation.
Credit requirement:	1 credit for undertaking measures to reduce water pollution during construction as outlined in ProPECC PN 1/94.
Assessment:	Where demolition is included as part of the works it shall be included in the assessment. The Client shall submit confirmation in the form of a report from suitably qualified person that the works have been carried out without violation of the Water Pollution Control Ordinance and no conviction or complaint about air pollution from the site has been upheld by the Environmental Protection Department. The Client shall present evidence in the form of specifications and contract documents detailing the requirements to undertake measures to reduce water pollution during construction, as laid down in ProPECC PN 1/94 <sup>23</sup> . The Client's representative on site shall be responsible for monitoring and reporting the execution of the instructions. The Client shall confirm in writing that the works were conducted in accordance with the recommendations given in ProPECC PN 1/94 as appropriate to the particular circumstances of the site.

#### *Cost Premium:*

<b>Office</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>
<b>Residential</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>

#### *Basis for Estimate:*

The following cost estimates were based on \$30,000 – \$80,000 being required for provision of a sedimentation tank, neutralization tank, and sand trap for filtration.

#### *Office Building:*

CFA of the base building = 42,840m<sup>2</sup>  
Upper bound estimate = \$80,000 / 42,840 = \$1.9/m<sup>2</sup>  
Lower bound estimate = \$30,000 / 42,840 = \$0.7/m<sup>2</sup>

#### *Residential Building:*

CFA of the base building = 36,750m<sup>2</sup>  
Upper bound estimate = \$80,000 / 36,750 = \$2.2/m<sup>2</sup>  
Lower bound estimate = \$30,000 / 36,750 = \$0.8/m<sup>2</sup>

<sup>22</sup> Hong Kong Construction Association (HKCA). Best Practice Guide for Environmental Protection on Construction Sites. November 2002.

<sup>23</sup> Environmental Protection Department. Practice Note for Professional Persons. ProPECC PN 1/94. Construction site drainage. [http://www.epd.gov.hk/epd/english/resources\\_pub/publications/files/pn94\\_1.pdf](http://www.epd.gov.hk/epd/english/resources_pub/publications/files/pn94_1.pdf)

### Benefits:

Waste water discharge control can lower the environmental impact of surroundings.

### 2.3.4 Emission from Wet Cooling Towers (1 credit)

Exclusions:	None. <i>Should be listed as excluding residential buildings!</i>
Objective:	Minimise the threat of Legionnaires' disease arising from cooling towers.
Credit requirement:	1 credit for a building development in which wet cooling towers are not used, or use seawater, or water from an acceptable source and are designed and maintained as specified in the Code of Practice for the Prevention of Legionnaires Disease.
Assessment:	When wet cooling towers are to be specified and do not use seawater they shall be designed to the specifications outlined in the Code of Practice Prevention of Legionnaires Disease <sup>24</sup> . The Client shall submit details of the installation and confirm compliance with the Code of Practice. Any deviations from the specifications given in the CoP shall be identified together with confirmation that there is no increased risk of dispersal of airborne droplets or mists.

### Cost Premium:

<b>Office</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>
<b>Residential</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>

### Basis for Estimate:

The credit is earned by default when wet cooling towers are not used, such as in buildings provided by seawater cooling, or buildings using window units or split units. Where cooling towers are installed the design should comply with the recommendations contained in the Code of Practice. This is good design practice and should not add significant cost to cooling towers.

### Benefit:

Legionnaires' disease (LD) is an acute respiratory infection caused by Legionella pneumophila, commonly commences with non-specific flu-like symptoms and progresses to pneumonia indistinguishable from other causes of atypical pneumonia, and was first recognized during an outbreak of pneumonia involving delegates to the 1976 American Legion Convention at a Philadelphia hotel. The infection is by the inhalation of aerosols contaminated with the Legionella bacteria, and man-made sources which generate aerosols and provide a favourable environment for growth, e.g. a temperature of 25-45°C and stagnation, are major important sources of the bacteria. Although incidence of Legionnaires' disease are relatively low in Hong Kong<sup>25</sup>, due diligence is required in the control of bacteria in building services systems. If systems follow the design and operating guidance provided in the Code of Practice building users can be assured that health risks will remain low.

### 2.3.5 Noise from Building Equipment

Exclusions:	None.
Objective:	Encourage proactive design techniques intended to reduce the nuisance caused to neighbours by noise from building services equipment.
Pre-requisites:	Compliance with the Noise Control Ordinance and Subsidiary Regulations.
Credit requirement:	1 credit for demonstrating that the level of the intruding noise at the facade of the nearest sensitive receiver is in compliance with the criteria recommended in the Hong Kong Planning Standards and Guidelines.
Assessment:	On the basis of promoting good environmental design assessment shall assume that a noise sensitive development already exists or has the potential to exist and be affected by the building development. Ideally, therefore, assessment should be made at the façade of the nearest or most affected adjacent building, or site boundary.

<sup>24</sup> Prevention of Legionnaires' Disease Committee, Electrical and Mechanical Services Department, Hong Kong Government. Code of Practice for the Prevention of Legionnaires' Disease in Hong Kong. 2000.

<sup>25</sup> Ng S, Chung T. Epidemiology of Legionnaires' Disease in Hong Kong, Department of Health, Health & Epidemiology, Bulletin, Vol. 12, No. 3, June 2003

The noise assessments shall be conducted in accordance with the Technical Memorandum<sup>26</sup>. This lays down statutory Acceptable Noise Levels (ANL). However, in order to plan for a better environment, all fixed noise sources should be so located and designed that when assessed in accordance with the Technical Memorandum, the level of the intruding noise at the facade of the nearest sensitive receiver should be at least 5 dB(A) below the appropriate ANL shown in Table 3 of the Technical Memorandum or, in the case of the background being 5 dB(A) lower than the ANL, should not be higher than the background, in accordance with paragraph 4.2.13, Chapter 9 of the Hong Kong Planning and Standards Guidelines<sup>27</sup>.

The Client shall provide evidence in the form of detailed analysis, appropriate calculations and/or measurements that the building complies with the assessment criteria.

**Cost Premium:**

<b>Office</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>
<b>Residential</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>

**Basis for Estimate:**

The assessment requires that the predicted noise level at the façade of the nearest noise sensitive receiver, e.g. school, is within the recommended limits. Appropriate assessment methods do not incur significant cost. Furthermore, the cost of mitigation measures such as acoustic barriers and enclosures are likely to be ‘low’. A particular problem is M&E plants that are situated outside the building envelope, which will generate noise that propagate to neighbouring buildings. To avoid this, building enclosures can be built to enclose the noisy M&E plants. According to our cost database, the cost of provision of enclosure and/or acoustic insulation for E & M plant rooms lies in the range of HK\$179,500 to 598,790.

**Office Building:**

CFA of the base building = 42,840m<sup>2</sup>.

Upper bound estimate = 598,790 / 42,840 = \$14.0/m<sup>2</sup>

Lower bound estimate = 179,500 / 42,840 = \$4.2/m<sup>2</sup>

Cost of acoustic assessment is in the order of less than \$1/m<sup>2</sup>

**Residential Building:**

Given that there tends to be little by way of potentially noisy plant on residential buildings the cost premium is likely to be insignificant if basic practice in terms of plant isolation and enclosures is applied.

**Benefits:**

This will inhibit the unwanted sound from equipment on and around buildings that contributed to noise pollution with potential impacts on neighboring properties.

**2.3.6 Light Pollution (1 credit)**

Exclusions:	None
Objective:	Ensure that exterior lighting does not create unwanted and unnecessary light pollution.
Credit requirement:	1 credit for demonstrating that obtrusive light from exterior lighting meets the specified performance for the environmental zone in which the building development is located.
Assessment:	The Client shall provide evidence that the site and building lighting installations comply with the criteria given in the reference publications through submission of detailed measurements, calculations and/or modelling studies carried out by a suitably qualified person.

<sup>26</sup> Environmental Protection Department. Technical Memorandum for the Assessment of Noise from Places Other than Domestic Premises, Public Places or Construction Sites.  
[http://www.epd.gov.hk/epd/english/environmentinhk/noise/guide\\_ref/files/tm\\_nondomestic.pdf](http://www.epd.gov.hk/epd/english/environmentinhk/noise/guide_ref/files/tm_nondomestic.pdf)

<sup>27</sup> Hong Kong Planning and Standards Guidelines, Chapter 9 Environment  
[http://www.info.gov.hk/planning/tech\\_doc/hkpsg/english/ch9/ch9\\_text.htm](http://www.info.gov.hk/planning/tech_doc/hkpsg/english/ch9/ch9_text.htm)

Compliance is achieved when the designs are within the maximum figure for each parameter (sky glow, light into windows, source intensity, and building luminance), taken from Tables 2.1 to 2.6 in CIE 150<sup>28</sup>, Table 1 in CIBSE Factfile7<sup>29</sup>, or Table 1 in ILE Guidance Notes<sup>30</sup>.

**Cost Premium:**

<b>Office</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>
<b>Residential</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>

**Basis for Estimate:**

The credit deals with sky glow, whereby upward directed light, intentionally (as in the case of floodlighting) or unintentionally (poor luminaire design) obstructs the night sky, light trespass into adjoining properties due to overspill from exterior lighting, annoyance caused by neon signs, etc.

Depending on site conditions the design, selection and installation of exterior lighting fixtures for sidewalks, parking areas, on-site roads, etc should be able to avoid problems of light trespass whilst balancing functional and aesthetic requirements, without a cost premium. It may be that security concerns will override the credit requirements, but this is largely dependent on particular concerns and needs.

Floodlighting that project vertically into the night sky should be avoided, as is the use of neon signs that create reflection on the facades of neighbouring properties.

**Benefits:**

Avoiding sky glow is regarded as a social issue given that residents are denied clear visible access to the night sky. Where light pollution affects neighbouring properties it may create annoyance and potential health and productivity due to sleep disturbance.

## 10.2 CREDITS UNDER MATERIALS ASPECTS

The amount and range of materials used in the construction, operation and maintenance and fitting-out of buildings represents a significant use of natural resources, in terms of extracted raw materials, emissions, and embodied energy. There are opportunities to reduce environmental impacts through improved design, choice of materials, and installation methods.

**Efficient Use of Materials**

*Building Reuse, Modular and Standardised Design, Off-site Fabrication, Adaptability and Deconstruction, Envelope Durability*

Efficiency in the use of materials can be significantly improved through reuse of building elements, such as foundations, main structures, facades, etc. Flexibility in design allows for change in use and layout of the premises within a building development. High standards of design detailing permits off-site fabrication of major building components, allows for deconstruction, and improves durability and longevity of buildings.

**Selection of Materials**

*Rapidly Renewable Materials, Sustainable Forest Products, Recycled Materials, Ozone Depleting Substances*

The selection of materials that can be planted and harvested within a relatively short time, that are otherwise sustainable, have significant recycled content, or otherwise have relatively low environmental impacts should be considered at the earliest stages of planning and design of building developments, and carried over to fit-out and subsequent redecoration.

<sup>28</sup> International Commission on Illumination. Guide on the limitation of the effects of obtrusive light from outdoor lighting installations. Technical Report CIE 150:2003.

<sup>29</sup> Chartered Institution of Building Services Engineers. Environmental Considerations for Exterior Lighting. Factfile No.7, 2003. <http://www.cibse.org/pdfs/fact72003.pdf>

<sup>30</sup> The Institution of Lighting Engineers. Guidance notes for the reduction of light pollution. <http://www.ile.org.uk/documents/guidance-notes-light-pollution.pdf>



## Waste Management

### Demolition Waste, Construction Waste, Waste Recycling Facilities

Hong Kong is running out of land for waste disposal, and without concerted effort the existing landfill sites could be exhausted by 2015. To tackle the problem, much effort has been put on reducing waste generation and identifying outlets for reusing the inert material.

#### Specific Credits:

2.1.1 Building Reuse - only applicable to Brownfield developments, and is unlikely to occur in practice unless the building is a major renovation, or where the building has historic or cultural value.

3.1.1 Demolition Waste - applies only where demolition is under the control of the developer. It is not included in the cost-benefit analysis.

#### 3.1.1 Building Reuse (2 credits)

Exclusions:	<b>Buildings on reclaimed land or Greenfield sites.</b>
Objective:	Encourage the reuse of major elements of existing buildings, to reduce demolition waste, conserve resources and reduce environmental impacts during construction.
Pre-requisites:	The reuse of major elements from existing building structure or shell shall comply with Building (Construction) Regulations Chapter 123B Regulation 90 Fire resisting construction and other relevant Building regulations.
Credit requirement:	1 credit for the reuse of 15% or more of existing sub-structure or shell. 2 credits for the reuse of 30% or more of existing sub-structure or shell.
Assessment:	The Client shall provide a report prepared by a suitably qualified person outlining the extent to which major building elements from an existing building were used in the building. The report shall include pre-construction and post-construction details highlighting and quantifying the reused elements, be it foundations, structural elements or facades, but windows, doors and similar assemblies may be excluded. The percentage of building materials shall be calculated as the amount (volume or weight) of building material elements reused as a percentage of the total amount (volume or weight) of that building material in the new development. When it can be demonstrated that the target percentage of original building elements are reused the credit(s) shall be awarded.

#### Cost Premium:

<b>Office</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>
<b>Residential</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>

#### Basis for Estimate:

It is not common practice for the reuse of existing building structures in new building developments, as it is difficult to incorporate the new building designs into existing building frameworks. It may be a feature where the existing building has historic value and retention of above ground structures such as the façade would be seen as advantageous. The credits would also be applicable where an old building undergoes renovation. It is probably that the extent of reuse is limited to the sub-structure. However, given the variability of circumstances, the cost estimate provided here can only be illustrative.

#### Office Building:

Unit price of reinforced concrete = \$750/m<sup>3</sup>

CFA of the base building = 42,840m<sup>2</sup>

Volume of reinforced concrete used in building substructure and shell<sup>31</sup> = 17,162 – 35,887m<sup>3</sup>

Lower bound estimate (assume 15% of structure to be reused) = -750 x 17,162 x 15% / 42,840 =

<sup>31</sup> Based on the findings of the statistical survey reported in the EMSD consultancy report in CAO L013

\$-45.1/m<sup>2</sup>

Upper bound estimate (assume 30% of structure to be reused) =  $-750 \times 35,887 \times 30\% / 42,840 =$   
\$ -188.5/m<sup>2</sup> (negative figures indicate saving)

#### *Residential Building:*

CFA of the base building = 36,750m<sup>2</sup>

Volume of reinforced concrete used in building substructure and shell<sup>32</sup> = 31,987 – 37,603m<sup>3</sup>

Lower bound estimate (assume 15% of structure to be reused)

=  $-750 \times 31,987 \times 15\% / 36,750 =$  \$-97.9/m<sup>2</sup>

Upper bound estimate (assume 50% of structure to be reused)

=  $-750 \times 37,603 \times 50\% / 36,750 =$  \$-383.7/m<sup>2</sup> (negative figures indicate saving)

#### *Benefits:*

Cost savings will be obtained due to reduced quantities of materials used in sub-structures. Additional cost savings can be obtained in terms of reduced construction time frame for sub-structure. From the environmental perspectives, there will also be reduced environmental impacts, due to reduced embodied energy (in concrete manufacture, transport, etc), and reduced amount of construction waste, etc.

### **3.1.2 Modular and Standard design (1 credit)**

Exclusions:	None.
Objective:	Encourage increased use of modular and standardised components in building design in order to enhance buildability and reduce waste.
Pre-requisites:	Full compliance with the Building (Construction) Regulations.
Credit requirement:	1 credit for demonstrating the application of modular and standardized design.
Assessment:	The Client shall submit a report that includes detailed drawings and specifications that demonstrates and highlights the extent of application of modular design of building systems and components. Where it can be demonstrated that the building development incorporates modular and standardised layouts and components for over 50% of the major elements and modules the credit shall be awarded. For the purposes of assessment the extent of modular and standardised design shall make reference to the check-list provided. Additional or alternative examples may be submitted at the discretion of the Client.

Structural elements:	Structural beams system, Concrete slab, Concrete flooring
Façade elements:	External wall, Bay-window unit, Cladding unit, Utility platform
Architectural/Internal building elements:	Internal partition/wall panels, Door sets, Staircases
Building services elements Fire services:	Sanitary fittings, Luminaires, Air-Conditioning components

#### *Cost Premium:*

<b>Office</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>
<b>Residential</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>

#### *Basis for Estimate:*

The principal purpose of modular coordination is to simplify and make more economical the design and construction of buildings, by standardization of sizes, in such a way that components fit with each other when assembled on site as parts of a building. According to BSI<sup>33</sup> modular coordination is based on a standard reference system which uses the international basic module of 100 mm for the coordinated control of spaces in buildings, as well as for the sizing and locating of building components and elements.

<sup>32</sup> Based on the bills of quantities of public (Harmony) and private housing in 2006

<sup>33</sup> British Standards Institution. BS 6750. Specification for Modular coordination in building. 1986.

It is anticipated that this credit does not incur a cost premium where design practice for structures, architecture and building services is aware of the opportunities and benefits of incorporating modular and standardized design. Environment, Transport, and Works Bureau publishes a one-stop service to help you access and locate those standardised components and modular components that have been successfully used in construction, and find out the standardised practices, including standard designs, construction methods, and techniques adopted in the construction industry<sup>34</sup>.

**Benefit:**

Modular coordination is of particular significance with increased use of computers in design, costing and construction, where three dimensional coordinates are invariably needed to describe the location and size of spaces, elements and components and as a basis for the assessment, calculation and specification<sup>33</sup>.

According to ISO<sup>35</sup> “the principal objective of modular coordination is to assist the building industry and associated industries, by standardization in such a way that components fit with each other, with other components and with the building assembly on site, thereby improving the economics of building”.

**3.1.3 Off-site Fabrication (2 credits)**

- Exclusions: None.
- Objective: Encourage off-site fabrication of building elements in order to reduce wastage of materials and quantities of on-site waste.
- Credit requirement: 1 credit when the manufacture of 50% of listed building elements has been off-site.  
1 additional credit where the manufacture of 80% of listed building elements has been off-site.
- Assessment: The listed building elements includes:
  - o facades; staircases; slabs; external elements; balcony/utility platform;
  - o bridge-decks; footbridges; pavement paving;
  - o partition walls; and internal fittings.
 Additional or alternative elements may be included, which the Client believes to demonstrate a significant contribution to the assessment criteria. Off-site in this context means a factory or similar purpose built facility but not a temporary site set up for the purpose of producing said elements.  
 The Client shall demonstrate through the submission of contract specifications, drawings and other supporting documents the quantities (by weight or volume) of those building elements fabricated off-site in accordance with the Code of Practice for Pre-cast Construction 2003. The assessment shall take into account the number and quantities of building elements in the building development that can be fabricated off-site and award credits where the assessment criteria have been met.

**Cost Premium:**

<b>Office</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>
<b>Residential</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>

**Basis for Estimate:**

The Hong Kong Construction Industry Review Committee<sup>36</sup> wrote in its report that prefabrication, coupled with the use of standardised and modular components, will contribute to improved buildability and should be widely promoted. Prefabrication is promoted as a manufacturing approach to construction not necessarily to decrease construction cost, but to increase quality

<sup>34</sup> Environment, Transport, and Works Bureau. Standardised Components and Practices. [http://www.etwb.gov.hk/press\\_releases\\_and\\_publications/publications/standardised/index.aspx?langno=1&nodeid=1232#benefits](http://www.etwb.gov.hk/press_releases_and_publications/publications/standardised/index.aspx?langno=1&nodeid=1232#benefits)

<sup>35</sup> ISO 2848 Building Construction – Modular coordination – Principles and rules. 1984.

<sup>36</sup> CIRC. Construct for excellence: Report of the construction industry review committee, January 2001.

and efficiency, and to reduce wet trades and construction waste. Yeung et al<sup>37</sup> reviewed the use of prefabrication techniques for improving project performance of public housing in Hong Kong in terms of time, cost and quality considerations. Such techniques include precast concrete facade elements, semi-precast concrete floor slabs, and other standardized prefabricated building components. The adoption of prefabricated structural elements and building components should be more widely promoted in local construction, with the public sector taking the lead.

Here, the construction costs are considered to be *lower* due to the standard size factory made building assemblies and the cut-off of labour force on wet-trade building process. The cost estimates are based on the cost differences by using pre-fabricated building materials compared with in-situ concrete work for the base building.

*Office Building: 50% or 80% of listed building elements:*

According to an experienced contractor, the net additional cost for using prefabricated/precast concrete elements instead of in-situ concrete, i.e. Hardiwall Systems, is about 5%. This cost incurred has already taken into account 3% lesser in quantities in the amount of waste generated by the precast concrete. (Poon et al<sup>38</sup>).

*Residential Building: 50% or 80% of listed building elements*

Similar figures apply to residential buildings.

*Benefit:*

Off-site fabrication is the manufacture of sections of a building at the factory so they can be easily and rapidly assembled at the building site, improving the buildability of the building. Since the factory fabrication of building elements are produced under controlled conditions, it allows for more efficient disposal of debris and waste. Noise, dust, site traffic and other environmental nuisances can also be reduced. Interior millwork and custom metalwork should be detailed to be shop-finished and installed to the highest degree to limit the need for on-site painting and finishing work. Based on the statistical survey report<sup>31</sup> a maximum of 288,780m<sup>2</sup> of timber formwork can be saved by using precast concrete in lieu of in-situ concrete.

### **3.1.4 Adaptability and Deconstruction (2 credits)**

Exclusions:	None.
Objective:	Encourage the design of building interior elements and building services components that allow modifications to space layout, and to reduce waste during churning, refurbishment and deconstruction.
Credit requirement:	a) Structural adaptability: 1 credit for designs providing flexibility through the choice of building structural system that allows for change in future use, and which is coordinated with interior planning modules. b) Spatial adaptability: 1 credit for designs providing spatial flexibility that can adapt spaces for different uses, and allows for expansion to permit additional spatial requirements to be accommodated.
Assessment:	The Client shall provide a report prepared by a suitably qualified person presenting evidence as to how and the extent to which building adaptability and deconstruction is provided. The report shall include drawings and documents including building plans and detail specifications together with elaboration and justification of specific design strategies that provide for the intended outcome. Assessment shall be guided by the check-lists included. Additions to list may be proposed at the discretion of the Client. Where it can be demonstrated that applicable good practices in respect of structural and/or spatial flexibility, and/or flexibility in servicing have been adopted whenever feasible, the credit(s) shall be awarded.

Adaptability refers to the capacity of buildings to accommodate substantial changes. The concept

<sup>37</sup> Yeung, N.S.Y., Chan, A.P.C. Chan, D.W.M. Application of Prefabrication in Construction - A New Research Agenda for Reform by CII-HK". Proceedings of the Conference on Precast Concrete Building Systems, 26-27 November 2002, Hong Kong

<sup>38</sup> Poon C.S, Yu A.T.W, Jaillon L. Reducing building waste at construction sites in Hong Kong, Construction Management and Economics, Vol. 22, 461-470, 2004.

of adaptability can be broken down into a number of simple strategies that are familiar to most designers including flexibility, or enabling minor shifts in space planning, and convertibility, or allowing for changes in use within a building.

### a) Structural adaptability

#### Cost Premium:

<b>Office</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>
<b>Residential</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>

#### Basis for Estimate:

Key measures such as design of foundations to allow for potential vertical expansion of the building, reliance on a central core for lateral load resistance to allow local modifications to the structure while maintaining complete structural integrity, use of a wide structural grid, design of lower floors for heavier live loads, etc are likely to incur moderate to high cost. The estimates are based on the two structural designs compared with base buildings.

- Additional costs will be incurred for structural slabs and columns if loading span is increased to 6m.
- Additional costs will be incurred for structural slabs if live loads of lower floor slabs have a capacity up to 4.8kPa.
- It is noted that this is not likely to be an option for typical residential buildings which are sold to end users and so are unlikely to be redeveloped.

### b) Spatial adaptability

#### Cost Premium:

<b>Office</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>
<b>Residential</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>

#### Basis for Estimate:

Flexibility is improved where, for example, there is use of a structural floor system that accommodates a number of mechanical and electrical service distribution schemes, a building envelope independent of the structure, means for access to the exterior wall system from inside the building, installation of hybrid HVAC systems, with a balance between centralised components and distributed components, spaces designed for a loose fit rather than tight fit, use of interior partitions that are demountable, reusable and recyclable.

Given the high rates of change and churn in modern office buildings spatial adaptability is a benefit for businesses in reduced down time or vacancies as changes are carried out.

In residential buildings there is a benefit in allowing changes to rooms as the demography of families change.

#### Benefits:

Whether the extra investment in adaptability is a profitable investment or not seen from the developer's side, depends on the willingness of property owners and investors or tenants to pay a premium. The real benefit depends on how early and how often the need to change the functions, the internal work place solutions or internal space plans occur, which depends how often tenants change, and the kind of organizations occupying the building. The initial cost of adaptability can be high and the benefits are uncertain and only show over time.

The environmental benefits include reduced waste during changes (churn), refurbishment and deconstruction. Designs that allow users flexibility in the layout of premises and designs that allow for dismantling during deconstruction can significantly reduce consumption of resources and generation of waste.

### 3.1.5 Envelope Durability (1 credit)

Exclusions: None.

Objective:	Encourage good design detailing and use of materials to promote longevity of the building envelope.
Pre-requisites:	Full compliance with the specific requirements set out in Building (Construction) regulation.
Credit requirement:	1 credit for demonstrating the integration of building envelope systems which optimises the integrity of the envelope over the building life.
Assessment:	<p>The Client shall submit a report prepared by a suitably qualified person detailing the design of the building envelope and providing supporting drawings and specification documents that demonstrates how the design and materials used in the building envelope can achieve the projected life with low maintenance, thereby minimising the consumption of resources over the life of the building. The adequacy of construction methods that provide effective protection against building failure should also be considered in the report.</p> <p>For the purposes of assessment reference shall be made to the check-list included. A similar checklist detailing how the prerequisites and listed good practices should be submitted by the Client. Where it can be demonstrated that applicable good practices have been adopted whenever feasible, the credit shall be awarded.</p>

**Cost Premium:**

<b>Office</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>
<b>Residential</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>

**Basis for Estimate:**

Durability is regarded as the capability of a building part to perform its required function over a specified period of time under conditions anticipated in service, and is seen as the capability of a material to withstand degradation in the expected conditions. The service life is the period of time after installation during which a building part meets or exceeds the required performance.

The HK-BEAM check-list includes pre-requisites that items such as cladding, curtain wall systems, cantilevered projecting structures (canopies, balconies, bay windows, air-conditioner platforms, etc), windows and window walls, and roofs, comply with applicable regulations. Otherwise, reference is made to ASTM<sup>39</sup> in respect of doors, windows, roof and joints. The ISO 15686 series<sup>40</sup> prescribes design information for determining the expected service life of a component with a prescribed probability of earlier failure based on knowledge about materials and building technology. The methodology considers a standard reference service life for components with assumptions made for its quality and its incorporation within the structure.

It is expected that experienced design teams will be able to meet the credit requirements with no cost premium.

**Benefits:**

The advantages are well-known: durable materials and building systems are long lasting, can reduce maintenance and repair costs, and are often cost-effective from a life-cycle perspective. Additional benefits include minimized disruption of building operations due to repairs and maintenance, and environmental benefits resulting from the reduced disposal and replacement of materials.

Additional benefit comes from the design process, i.e. service life planning can reduce the costs of building ownership, as an assessment of how long each part of a building will last helps to decide the appropriate specification and detailing. With service life building parts established, maintenance planning and value engineering techniques can be applied.

**3.2.1 Rapidly Renewable Materials (1 credit)**

Exclusions:	None.
Objective:	Encourage the wider use of rapidly renewable materials in appropriate applications.
Pre-requisites:	Compliance with the Building (Construction) Regulations.

<sup>39</sup> ASTM International. ASTM E2136-01, Standard Guide for Specifying and Evaluating Performance of Single Family Attached and Detached Dwellings – Durability

<sup>40</sup> ISO 15686-1 Buildings and Constructed Assets - Service Life Planning.

Credit requirement: 1 credit for demonstrating that in applications where rapidly renewable materials can be employed at least 50% are used in the building.

Assessment: The Client shall submit a report prepared by a suitably qualified person listing applications where rapidly renewable materials have been employed, and quantifying (in terms of area, weight or volume) the amount of materials employed, as a percentage of the total of the potential amount of materials that could be employed. The report shall include supporting documentation from suppliers listing the rapidly renewable materials and quantities contained in the products used.

The report should highlight where rapidly renewable materials could be used, and where they have been used to replace other more commonly used materials. Provide calculations demonstrating that rapidly renewable building materials have been in at least 50% of possible applications.

For the purposes of assessment reference shall be made to the check-list provided.

Rapidly renewable materials and products are those made from plant matters that are typically harvested over a period of ten years or less. Examples given in HK-BEAM 4/04 include:

- Flooring: Bamboo, Natural Linoleum, Cork
- Panels/Partitions: Sunflower Seed, Bamboo, Wheatboard
- Cabinetry/Fittings: Wheatboard, Strawboard. Soy bean composite, Bamboo
- Insulation: Cotton, Strawbale, Soy-based foam

*Cost Premium:*

<b>Office</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>
<b>Residential</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>

*Basis for Estimate:*

As many of this type of products are still relatively new to the market, it is unlikely that they will be incorporated in projects given that specifications and quality aspects of material remain at an early stage. A confounding factor is the extent to which the fit-out of occupied areas of office buildings will be under the control of the client, so the credit may be marked as ‘not applicable’ in an assessment. In the residential sector, developers will be reluctant to introduce products that are unfamiliar to purchasers who may subsequently substitute more traditional alternatives.

The credit criteria calls for 50% of potential applications use rapidly renewable materials, but due to the variety of circumstances it is difficult to place a dollar value on cost premiums, so estimates are restricted to the four interior finishes:

- Flooring – natural linoleum vs carpet tiles
- Panels/ Partitions – wheatboard vs chipboards
- Cabinetry/ Fittings – wheatboard vs chipboards
- Insulation – cotton vs fiber-glass

*Benefits:*

The intent is to reduce the use and depletion of raw materials and long-cycle renewable materials through replacement. Realising the benefit depends on greater acceptability of such products in the market.

**3.2.2 Sustainable Forests Products (2 credits)**

Exclusions: None.

Objective: Encourage the use of timber from well-managed forests.

Pre-requisites: None.

Credit requirement: a) Timber used for temporary works: 1 credit where virgin forest products are not used for temporary works during construction.  
 b) Forest products used in the building: 1 credit for sourcing timber and composite timber products which are from well managed sources, including reuse of salvaged timber.

**a) Timber used for temporary works**

Assessment: The Client shall provide a report prepared by a suitably qualified person demonstrating that no virgin forest products were used for temporary works, unless exceptional circumstances required such use. The report should highlight how contract documents and specifications precluded such use in form work, hoardings, walkways, etc., together with evidence such as site photos and records to demonstrate that no new timber or timber products were used. Where circumstances required the use of new timber products the reasons, details and quantities used shall be reported. The reuse of timber and timber products is allowed, but shall also be identified in the report.

The Client’s representative on site shall be responsible for monitoring and reporting on construction activities, and shall confirm in writing that the works were conducted in accordance with the specifications and contract documents, and that all details regarding the use of timber contained in the report are correct.

The Assessor may carry out site inspections during construction.

Where it can be demonstrated that all practical steps have been taken to avoid the use of virgin forest products the credit shall be awarded.

**Cost Premium:**

<b>Office</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>
<b>Residential</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>

**Basis for Estimate:**

The quantities and cost differences of timber for temporary works are given by bills of quantities of 11 examined buildings and the base buildings.

**Office Building:**

CFA of the base building = 42,840m<sup>2</sup>.  
 Additional cost incurred by using sustainable timber formwork = \$110 – 130/m<sup>2</sup>  
 Number of times that timber formwork can be used = 13  
 Area of timber formwork used = 68,081 – 360,978m<sup>2</sup>.  
 Upper bound estimate = 130 x (360,978 / 13) / 42,840 = \$84.3/m<sup>2</sup>.  
 Lower bound estimate = 110 x (68,081 / 13) / 42,840 = \$13.4/m<sup>2</sup>.

**Residential Building:**

CFA of the base building = 36,750m<sup>2</sup>.  
 Based on statistical survey for public and private housing projects, the area of timber formwork used = 120,663 – 123,155m<sup>2</sup>.  
 Upper bound estimate = 130 x (123,155 / 13) / 36,750 = \$33.5/m<sup>2</sup>.  
 Lower bound estimate = 110 x (120,663 / 13) / 36,750 = \$27.8/m<sup>2</sup>.

**Benefit:**

Reduce the consumption of non-sustainable tropical timbers and encourage the use of timber from managed forests. Deforestation contributes to global warming since trees help regulate the amount of carbon dioxide in the atmosphere.

**b) Forest products used in the building**

Assessment: The Client shall provide a report prepared by a suitably qualified person demonstrating that reasonable effort has been made to secure forest products from well-managed sources. Evidence should include as far as practicable:

- o the supplier’s environmental policy with regard to the wood products;
- o the species and country of origin;
- o the country of origin supplying the timber;
- o a copy of the forestry policy being pursued for the plantation or concession; and
- o shipping documents confirming that the timber supplied was obtained from a well-managed source.

The assessment shall take into account the Client’s efforts to secure forest products (building components including, but not limited to, structural framing, flooring, finishes,



fitted furnishings, etc. from well-managed sources by adopting the stepwise approach recommended by EcoWood@sia<sup>[41]</sup>, by seeking:

- o sources that comply with sound forest management policies;
- o legal sources;
- o sources progressing towards certification; and
- o creditable certified sources.

**Cost Premium:**

<b>Office</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>
<b>Residential</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>

**Basis for Estimate:**

The quantities and cost differences of timber products are given by bills of quantities of 11 examined buildings and the base buildings.

**Office Building:**

CFA of the base building = 42,840m<sup>2</sup>

Additional cost for using timber products from well-managed sources = \$750 – 1250/m<sup>3</sup>

Volume of timber product used in building = 4.3 – 141.4m<sup>3</sup>.

Upper bound estimate = 1250 x 141.4 / 42,840 = \$4.1/m<sup>2</sup>

Lower bound estimate = 750 x 4.3 / 42,840 = \$0.1/m<sup>2</sup>

**Residential Building:**

CFA of the base building = 36,750m<sup>2</sup>.

Additional cost for using timber products from well-managed sources = \$750 – 1250/ m<sup>3</sup>.

Volume of timber product use in building Error! Bookmark not defined. = 7.4 – 40.4m<sup>3</sup>.

Upper bound estimate = 1250 x 40.4 / 36,750 = \$1.4/m<sup>2</sup>

Lower bound estimate = 750 x 7.4 / 36,750 = \$0.2/m<sup>2</sup>

**Benefit:**

Reduce the consumption of non-sustainable tropical timbers and encourage the use of timber from managed forests.

**3.2.3 Recycled Materials (2 credits)**

- Exclusions: None.
- Objective: Promote use of recycled materials in order to reduce the consumption of virgin resources.
- Pre-requisites: Compliance with the Building (Construction) Regulations, Chapter 123B Regulation 3.
- Credit requirement:
  - a) Outside surface works and structures: 1 credit for use 50% of recycled materials in site exterior surfacing work, structures and features.
  - b) Building structure: 1 credit for: using 5% of recycled materials, other than PFA, in the construction of the building; and maximising use of PFA or similar in concrete.

**a) Outside surface works and structures**

Assessment: The Client shall submit a report prepared by a suitably qualified person detailing the recycled materials used (minerals, plastics, etc), their quantities by weight, percentage and/or volume as compared to the total amount of materials used in exterior surfacing works and structures (structures and features, which include paths, surfaces for recreational areas, structures such as seating, playground features, etc), and technical and/or economic reasons for not using elements made from recycled materials. Credit will be awarded where there is sufficient evidence that the use of recycled materials is no less than 50% by weight or volume.

<sup>41</sup> EcoWood@sia. <http://www.ecowoodasia.org/>

### Cost Premium:

<b>Office</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>
<b>Residential</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>

### Basis for Estimate:

As shown by reference to government information<sup>42</sup> present Hong Kong has made limited progress in the use of recycled materials. Waste materials and industrial by-products can be used in building construction in an unprocessed form, e.g. as fill material, or processed to a limited degree for use as aggregates in concrete, or used as raw material for manufacturing building products. The basic properties required for technical acceptance are that they can perform their intended functions throughout the design life without being deleterious on the environment or associated constructional features.

PNAP 275<sup>43</sup> sets out the technical guidelines for using recycled aggregates in prescribed mix concrete of specified grade strength of 20P and designed mix concrete of specified grade strengths of 25D to 35D. Prescribed mix concrete of specified grade strength of 20P with 100% recycled aggregate should only be used for minor structural or non-structural works in accordance with Building (Construction) Regulation 60(1). They may include, for examples, on-grade slabs, blinding layer, U-channels/stepped channels, bedding and hunching for pipe works, concrete footings for posts and fences, and mass concrete fill which does not sustain appreciable loading. Designed mix concrete of specified grade strengths of 25D to 35D with a maximum of 20% recycled aggregates may be used for the following applications that do not have major structural concern: (a) concrete or reinforced concrete landscape features such as planters and planter walls, fence walls, mass concrete walls and footings for supporting landscape features; (b) manholes and sand traps except manholes for foul water, grease traps and petrol interceptors where leakage of contaminated liquid to surrounding soil is undesirable; and (c) carriageway pavement or overlay, reinforced concrete infill walls and mass concrete under footings or rafts.

### Office Building:

CFA of the base building = 42,840m<sup>2</sup>.

Based on estimate by an experienced quantity surveyor, the cost of exterior site surfacing work = \$200,000 – 500,000, and assuming 'no cost' will be incurred for the recycled content.

Based on 50% of recycled materials used in exterior works, then:

Upper bound estimate =  $-500,000 \times 50\% / 42,840 = \$-5.8/m^2$

Lower bound estimate =  $-200,000 \times 50\% / 42,840 = \$-2.3/m^2$  (negative figures indicate cost saving)

The additional cost for recycled materials such as crushed aggregates would reduce this net benefit, as would the cost of any additional quality assurance effort to ensure the materials or products were fit for purpose.

### Residential Building:

Similar figures apply to residential buildings.

### Benefit:

Local construction activities produce some 20 million tonnes of construction and demolition (C&D) materials a year, of which about 10% are inert hard materials suitable for recycling into aggregates. Recycling provides an alternative outlet for such hard materials, which otherwise would have displaced the soft fill materials in reclamation projects or taken up precious landfill space. Recycling also helps conserve natural resources by reducing the demand on virgin aggregates.

### b) Building structure

<sup>42</sup> Recycled Products for Construction Industry.  
[http://sc.info.gov.hk/gb/www.epd.gov.hk/epd/misc/cdm/products\\_main.htm](http://sc.info.gov.hk/gb/www.epd.gov.hk/epd/misc/cdm/products_main.htm)

<sup>43</sup> Building Department, Practice Note for Authorized Persons and Registered Structural Engineers, PNAP 275, Use of Recycled Aggregates in Concrete. <http://www.info.gov.hk/bd/english/documents/pnap/Pnap275.pdf>

Assessment: The Client shall submit a report prepared by a suitably qualified person detailing the use of recycled materials in the building, such as foundations, structural elements, etc., but excluding PFA. Also, the use of existing structural elements in situ shall not be counted.

The report shall also detail the use of PFA or similar as cementitious content, and as an admixture or as fine aggregate.

Where recycled material other than PFA accounts for no less than 5% by weight or volume, and the use of PFA is maximised to extent permitted by design codes, the credit shall be awarded.

*Cost Premium:*

<b>Office</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>
<b>Residential</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>

*Basis for Estimate:*

According to PNAP 275 prescribed mix concrete of specified grade strength of 20P with 100% recycled aggregate should only be used for minor structural or non-structural works in accordance with Building (Construction) Regulation 60(1).

PNAP 90<sup>44</sup> specifies conditions for the use of PFA as a partial replacement for Ordinary Portland Cement (OPC) in concrete. Blended cement containing PFA that complies with BS 6588:1985 has a nominal PFA content not exceeding 25%, and PFA should not be used as a partial cement replacement in concrete in addition to blended cement. Whilst there is potential to increase the percentage of PFA in concrete, the limit of 25% is used in this analysis.

*Office Building:*

*i) Maximum use of PFA (25%):*

An earlier estimate derived from a price quote indicated that the cost of using concrete with PFA is \$350/m<sup>3</sup> more than using conventional concrete. In order to verify this, we have approached a number of other professionals and contractors for the price quotes. Based on the latest cost estimate from an experienced contractor, no significant difference would be found in cost between conventional concrete and concrete with PFA. Accordingly, based upon the most recent estimates, it is determined to have no significant cost implication of using concrete with PFA instead of conventional concrete.

*ii) Use of recycled materials (5%):*

CFA of the base building = 42,840m<sup>2</sup>

Based on statistical survey from the government consultancy projects, range of additional cost of recycled aggregates for concrete = \$76 – 100/m<sup>3</sup>

Volume of reinforced concrete used in minor structural or non-structural building element = 12,872 – 26,915m<sup>3</sup> (based on the statistical survey in CAO L013 2004<sup>31</sup>)

Upper bound estimate = 100 x 26,915 x 0.05 / 42,840 = \$3.1/m<sup>2</sup>

Lower bound estimate = 76 x 12,872 x 0.05 / 42,840 = \$1.1/m<sup>2</sup>

*Residential Building:*

CFA of the base building = 36,750m<sup>2</sup>

Based on statistical survey from the government consultancy project, range of additional cost of recycled aggregates for concrete = \$76 – 100/m<sup>3</sup>

Volume of reinforced concrete used in minor structural or non-structural building element = 29,220 – 35,017m<sup>3</sup> (based on the bills of quantities<sup>32</sup>)

Upper bound estimate = 100 x 35,017 x 0.05 / 36,750 = \$4.8/m<sup>2</sup>

Lower bound estimate = 76 x 29,220 x 0.05 / 36,750 = \$3.0/m<sup>2</sup>

<sup>44</sup> Practice Note for Authorized Persons and Registered Structural Engineers, PNAP 90. Pulverised Fuel Ash in Concrete. <http://www.info.gov.hk/bd/english/documents/pnap/Pnap090.pdf>

### *Benefits:*

To reduce the burden of dumping waste materials, the use of recycled construction materials is strongly encouraged. Based on figures given in California report, a net monetary benefit of \$451 per ton could be earned by the society if recycled materials were used. This estimate also includes monetary benefits resulting from reducing the release of hazardous substances and other pollutants. According to bill of quantities of base building and data from California report 2003, full use of PFA for concreting would bring HK\$32/m<sup>2</sup> and HK\$39/m<sup>2</sup> of environmental benefits for office buildings and residential buildings respectively.

### *Office Building:*

In the absence of local benefit estimate for recycled materials, figures given in California report<sup>45</sup> were used and adjusted for GDP difference between Hong Kong and US. The adjustment factor was derived from the GDP per capita (0.917) and exchange rate figure (US\$1 = HK\$7.8) published by the World Bank in 2005 to account for difference in income level between them.

Net monetary benefit if recycled construction materials were used = \$451/ton or \$1082/m<sup>3</sup>

Referring to the statistical survey in CAO L013 2004, range of total volumes of concrete used per CFA = 0.40 to 0.84 m<sup>3</sup>/m<sup>2</sup>

Percentage of PFA in concrete = 5 - 25% (PN90 by Buildings Department)

Percentage by volume of cement in concrete = 14%

### *Upper bound estimate:*

Net monetary benefit per CFA if a maximum allowable amount of PFA was used in concrete  
= 1082 x 0.8377 x 0.25 x 0.14 = \$31.7/m<sup>2</sup>

### *Lower bound estimate:*

Net monetary benefit per CFA if 5% recycled aggregate concrete was used  
= 1082 x 0.4006 x 0.05 x 0.14 = \$3.0/m<sup>2</sup>

### *Residential Building:*

In the absence of local benefit estimate for recycled materials, figures given in California report<sup>45</sup> were used and adjusted for GDP difference between Hong Kong and US. The adjustment factor was derived from the GDP per capita (0.917) and exchange rate figures (US\$1 = HK\$7.8) published by the World Bank in 2005 to account for difference in income level between them.  
Net monetary benefit by using recycled construction materials = \$451/ton or \$1082/m<sup>3</sup>

Refer to statistical survey in CAO L013 2004, volume range of total concrete per CFA = 0.87 to 1.02 m<sup>3</sup>/m<sup>2</sup>

Percentage of PFA in concrete = 5 - 25% (PN90 by Buildings Department)

Percentage by volume of cement in concrete = 14%

Upper bound estimate:

Net monetary benefit per CFA if a maximum allowable amount of PFA was used in concrete  
= 1082 x 1.02 x 0.25 x 0.14 = \$38.6/m<sup>2</sup>

Lower bound estimate:

Net monetary benefit per CFA if 5% recycled aggregated concrete was used  
= 1082 x 0.87 x 0.05 x 0.14 = \$6.6/m<sup>2</sup>

## **3.2.4 Ozone Depleting Substances (2 credits)**

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<sup>45</sup> Greg Kats and Captial E., 2003, The Costs and Financial Benefits of Green Buildings, A Report to California's Sustainable Building Task Force.

- Exclusions: None.
- Objective: Reduce the release of chlorofluorocarbons and hydrochlorofluorocarbons into the atmosphere.
- Pre-requisites: Compliance with the Ozone Layer Protection Ordinance Chapter 403.
- Credit requirement: a) Refrigerants: 1 credit for using refrigerants with a ozone depleting potential 0.03 or less and a global warming potential of 1600 or less.  
b) Ozone depleting materials: 1 credit for the use of products in the building fabric and services that avoids the use of ozone depleting substances in their manufacture, composition or use.

### a) Refrigerants

Assessment: The Client shall submit a report by a suitably qualified person giving details of the air-conditioning and refrigeration equipment installed and confirm that the global warming potential (GWP) of the refrigerants used in equipment meets the specified requirement. Reference shall be made to refrigerant supplies and/or equipment manufacturer's data together with guidance provided by recognised authorities such as ASHRAE, CIBSE, etc.

#### Cost Premium:

<b>Office</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>
<b>Residential</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>

#### Basis for Estimate:

The most appropriate criteria for the selection of refrigerants seems to remain a matter for debate, given that whilst some modern blends minimise impacts on the ozone layer, there may be a reduction in the energy efficiency of major plant, thereby increasing energy use and emissions.

While refrigerants contribute to the environmental concerns, their role is comparatively small<sup>46</sup>. One distinction from other uses of the same chemicals is that refrigerants do not have to be released to perform their function. In fact, avoiding such releases improves system performance and lowers costs; the problem is not refrigerants in systems, but their release during use and maintenance. Calm recommends that "Engineers, building owners, and others involved in chiller decisions should revert to traditional chiller specifications based on cost, performance, local manufacturer support, service options, and reliability. Anticipating more stringent environmental regulations, they also should take all practical steps to reduce refrigerant releases and increase efficiency." On this basis there would be no cost premium if good design practice is followed.

#### Benefit:

Reduce the release of CFCs (chlorofluorocarbons) and HCFCs(hydrochlorofluorocarbons) into atmosphere and thus to reduce the rate of ozone layer depletion. The stratospheric ozone layer reduces the amount of short-wavelength ultraviolet radiation from the Sun that reaches the Earth's surface. Exposure to this radiation can have harmful effects on plants, agricultural crops and marine organisms, and cause skin cancer and eye cataracts.

### b) Ozone depleting materials

Assessment: The Client shall provide a full description and specifications of all major thermal insulation and fire retardant materials specified in roof constructions, walls, chilled water pipes, refrigerant pipes, ductwork, etc., advising the presence or otherwise of ozone depleting agents. Where there is any doubt as to the ozone depletion potential of a material or product, the Client shall ascertain details from the supplier. Credit shall be awarded where it can be demonstrated that reasonable effort has been made to avoid the use of products that have significant ozone depletion potential.

#### Cost Premium:

<b>Office</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>
<b>Residential</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>

<sup>46</sup> Calm S M. Option and outlook for chiller refrigerants. International Journal of Refrigeration. Vol. 25, 2002, 705-715.

### *Basis for Estimate:*

The criterion in HK-BEAM 4/04 is rather vague in terms of application, quantification and also has difficulty in verification, with many potential applications, making a cost estimate very problematic. The effort for designers is in sourcing materials that do not involve the use of CFC's in manufacture, and to ensure performance meets the specification for the intended use. There is increasing restrictions on the use of CFC's in manufacturing in many countries and it is expected that many products imported to Hong Kong should meet the credit criteria.

### *Benefit:*

Reduce the release of CFCs (chlorofluorocarbons) and HCFCs(hydrochlorofluorocarbons) into atmosphere and thus to reduce the rate of ozone layer depletion.

### **3.3.1 Demolition Waste**

This credit is excluded from the analysis.

### **3.3.2 Construction Waste (3 credits)**

Exclusions:	None.
Objective:	Encourage best practices in the management of waste, including sorting, recycling and disposal of construction waste.
Pre-requisites:	Compliance with the Waste Disposal (Chemical Waste) (General) Regulation.
Credit requirement:	a) Waste Management: 1 credit for implementation of a waste management system that provides for the sorting and proper disposal of inert and non-inert construction materials. b) Sorting and recycling of waste: 1 credit for sorting and recycling specified construction waste. c) Quantity of recycled waste: 1 credit for demonstrating that at least 50% of construction waste is recycled.
Assessment:	The Client shall present evidence in the form a report by a suitably qualified person that the carrying out of the construction works complied with all the requirements specified.

#### **a) Waste management**

Assessment:	The Client shall demonstrate through the submission of tender documents, contract conditions and specifications to demonstrate that the contractor was able and required to prepare and implement a waste management plan essentially in accordance with the guidelines provided in Environment, Transport and Works Bureau (ETWB) Technical Circular 15/2003 <sup>47</sup> . Where it can be demonstrated that the waste management system covered the items listed in the Buildings Department's PNAP 243 <sup>48</sup> and that all materials arising from or in connection with the works were separated into inert and non-inert materials, and disposed of in accordance with the WBTC No. 21/2002 <sup>49</sup> , as they apply to the nature of the development work, the credit shall be awarded.
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### *Cost Premium:*

<b>Office</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>
<b>Residential</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>

### *Basis for Estimate:*

The HKSAR Government has sought to improve waste management with Technical Circular<sup>47</sup> setting out the policy and procedures requiring contractors to prepare and implement an

<sup>47</sup> Environment, Transport and Works Bureau Technical Circular (Works) 15/2003, Waste Management on Construction Sites. <http://www.etwb.gov.hk/utilmanager/tc/2003/c-2003-15-0-1.pdf>

<sup>48</sup> Buildings Department. Practice Note for Authorized Persons and Registered Structural Engineers 243. Construction and Demolition Waste. June 2000. <http://www.info.gov.hk/bd/english/documents/pnap/Pnap243.pdf>

<sup>49</sup> Works Bureau Technical Circular 21/2002. Trip-ticket System for Disposal of Construction and Demolition Material. June 2002. <http://www.etwb.gov.hk/UtilManager/tc/2002/wb2102.doc>

enhanced Waste Management Plan (WMP) to encourage on-site sorting of Construction and Demolition (C&D) materials and to minimize their generation during the course of construction. The requirements of this Circular apply to capital works contracts, including electrical and mechanical (E&M) contracts and Design and Build (D&B) contracts but excluding term contracts.

To enhance waste management on construction sites, this Circular introduces additional measures to: (i) strengthen the requirements for WMP; (ii) enforce its implementation; (iii) enhance site monitoring and control; (iv) establish measurement on contractor's performance through the framework of the "Pay for Safety Scheme (PFSS)", which has been re-titled to the "Pay for Safety and Environment Scheme" (PFSES) under ETWB TCW No. 14/2003 to cover the environmental aspects. However, recent studies<sup>38</sup> suggest that, in general, waste management is not given priority on many private sector projects.

PNAP 243 lays down requirements in respect of waste management plan:

- i) the types of waste and their estimated quantities;
- ii) the timing of waste arising;
- iii) measures for reducing waste generation;
- iv) on-site waste separation;
- v) on-site and off-site material reuse;
- vi) areas for waste storage;
- vii) quantities of waste requiring off-site disposal;
- viii) disposal outlets;
- ix) monitoring and auditing programme;
- x) organisation structure for waste management;
- xi) a list of materials to be reused or recycled with estimated quantities;
- xii) implementation of the trip ticket system;
- xiii) method of processing, storing and disposal of hazardous waste; and
- xiv) method of dealing with packaging material.

Charging for disposal of construction waste has started on 20 January 2006 and from this day, any person before using waste disposal facilities for disposal of construction waste needs to open an account. Typical disposal charge is \$125 per tonne.

**Benefits:**

This will inhibit chemical, semi-solid and solid wastes that are hazardous in nature or constitute a risk of pollution to the environment.

**b) Sorting & recycling**

Assessment: The following shall guide the assessment:

- o how excavated materials are sorted to recover the inert portions for reuse on site or disposal (not as landfill);
- o how metals are recovered for collection by recycling contractors; and
- o the extent to which cardboard and paper packaging recovered, properly stockpiled and recycled.

Where it can be demonstrated through appropriate record keeping that sorting for the items of construction waste items specified in WTBC TWC 15.2003 has been carried out, the credit shall be awarded.

**Cost Premium:**

<b>Office</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>
<b>Residential</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>

**Basis for Estimate:**

Site constraints can inhibit recycling due to lack of space for storage. Cost of recycling includes direct labour, and a management element for monitoring and reporting, but the cost associated with extra management effort will be considered and estimate in the part (c) of this credit..

*Office Building:*

CFA of the base building = 42,840m<sup>2</sup>

Range of average labour cost based on the average labour salary for Hong Kong published by the Labour Department in Hong Kong

= \$288,000 – 144,000 (Assume 1 to 2 labours were employed for waste sorting and recycling works for one year)

Upper bound estimate = 288,000 / 42,840 = \$6.7/m<sup>2</sup>

Lower bound estimate = 144,000 / 42,840 = \$3.4/m<sup>2</sup>

*Residential Building:*

The figures will be similar for a high-rise residential building.

**c) Quantity of recycled waste**

Assessment: Where at least 50% (by weight or by volume) of all waste generated on site can be shown to have been recycled the credit shall be awarded.

The Client's representative on site shall be responsible for monitoring and reporting on the execution of the instructions and shall confirm through monthly reports the extent to which recycling and sorting has been achieved. WTBC TWC 15/2003 should be used as a guide to the nature of reporting and recording keeping.

*Cost Premium:*

<b>Office</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>
<b>Residential</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>

*Basis for Estimate:*

*Office Building:*

Assuming 15% overhead was added to cover the management cost for deploying additional labour for sorting and recycling works.

Upper bound estimate = 6.7 x 15% = \$1.0/m<sup>2</sup>

Lower bound estimate = 3.4 x 15% = \$0.5/m<sup>2</sup>

*Residential Building:*

The figures are similar for a high-rise residential building

*Benefits:*

*Office Building:*

In the absence of local benefit estimate for recycled materials, figures given in California report were used and are adjusted for GDP difference between Hong Kong and US. The adjustment factor was derived from the GDP per capita (0.917) and exchange rate figure (US\$1= HK\$7.8) published by the World Bank in 2005 to account for difference in income level between them.

Net monetary benefit by using recycled construction materials = \$451/ton or \$1082/m<sup>3</sup>

Refer to statistical survey in CAO L013 2004<sup>31</sup>, range of total volumes of concrete used per CFA = 0.40 to 0.84 m<sup>3</sup>/m<sup>2</sup>

Percentage of demolition waste = 3% (Pool et al. 2004<sup>38</sup>)

Upper bound estimate:

Net monetary benefit per CFA if 50% off-site pre-cast concrete was used

= 1082 x 0.84 x 50% x 0.03 = \$13.6/m<sup>2</sup>

Lower bound estimate:

Net monetary benefit per CFA if 50% off-site pre-cast concrete was used

= 1082 x 0.40 x 50% x 0.03 = \$6.5/m<sup>2</sup>



*Residential Building:*

Refer to bills of quantities<sup>32</sup>, range of total volumes total concrete used per CFA = 0.87 to 1.0 m<sup>3</sup>/m<sup>2</sup>

Percentage of construction waste = 3% (Pool et al. 2004<sup>38</sup>)

Upper bound estimate:

Net monetary benefit per CFA if 50% off-site pre-cast concrete was used

$$= 1082 \times 1.0 \times 0.5 \times 0.03 = \$16.2/m^2$$

Lower bound estimate:

$$\text{Net monetary benefit per CFA if 50\% off-site pre-cast concrete was used} = 1082 \times 0.87 \times 0.5 \times 0.03 = \$14.1/m^2$$

According to a case study<sup>50</sup> funded by the Construction Industry Development Board (CIDB) of Malaysia the net benefit of reusing and recycling of waste materials is estimated at 2.5% of the total project budget.

**3.3.3 Waste Disposal and Recycling Facilities (1 credit)**

- Exclusions: None.
- Objective: Reduce pressure on landfill sites and help to preserve non-renewable resources by promoting recycling of waste materials.
- Pre-requisites: Compliance with the Building (Refuse Storage and Material Recovery Chambers and Refuse Chutes) Regulations.
- Credit requirement: 1 credit for providing facilities for the collection, sorting, storage and disposal of waste and recovered materials.
- Assessment: The assessment seeks to establish the extent to which facilities are provided to allow for the recycling of waste. The means to facilitate waste recycling is not prescribed as much depends on the design and type of building, and the activities carried out within. The Client shall submit details of expected waste streams and estimated quantities for the building (organic, recyclable and non-recyclable), and demonstrate the adequacy of the waste storage, sorting and recycling facilities, appropriate to the type and size of the development, that will encourage and facilitate waste recycling. The assessment shall take into account how a system of waste collection, storage sorting, recycling and disposal can be managed for the buildings, with consideration given to the adequacy of space provisions on individual floors, within the building as a whole, and at local/estate level. Opportunity should exist to manage different waste types, such as organic, non-recyclable and recyclable waste. There should be easy access to facilities for cleaning staff/contractors and/or building users, and for waste recycling and collection companies. The storage area shall be adequately sized to allow for recycling of, as a minimum, paper, glass, plastics, metals and organic materials. The HK-BEAM Assessor may scrutinise designs and specifications for the waste management facilities and may carry out inspections to check compliance.

*Cost Premium:*

<b>Office</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>
<b>Residential</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>

*Basis for Estimate:*

Cost estimates are based on bills of quantities of base buildings.

*Office Building:*

$$\text{CFA of the base building} = 42,840m^2$$

Floor area requirement:

<sup>50</sup> Begum R A, Siwar C, Pereira J J, Jaafar A H. A benefit–cost analysis on the economic feasibility of construction waste minimisation: The case of Malaysia. Resources, Conservation and Recycling, Vol. 48, pp 86–98, 2006.

Cost for providing recycling facilities, storage area and mechanical ventilation for such waste disposal (i.e. ventilation fan) = \$200,000

Upper bound estimate =  $200,000 / 42,840 = \$4.7/m^2$

Lower bound estimate =  $150,000 / 42,840 = \$3.5/m^2$

*Residential Building:*

Similar figures apply to residential buildings

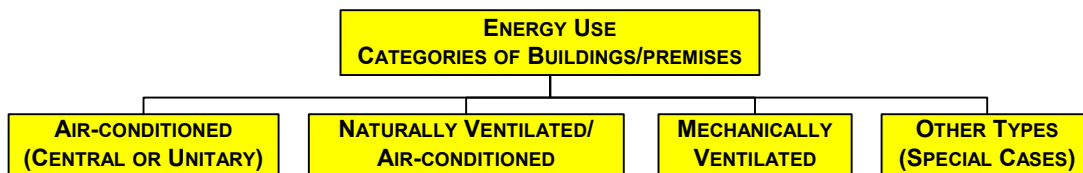
*Benefit:*

Reduce pressure on landfill sites and help to preserve non-renewable resources by promoting recycling waste materials.

**10.3 CREDITS UNDER ENERGY USE**

HK-BEAM encourages detailed design of buildings and systems, and provisions that enhance energy efficiency and energy conservation. Credits are awarded on the basis of enhanced energy performance, the provision of energy efficient systems and equipment, and the provisions for energy management. The number of Annual Energy Use credits available for a particular building development will vary depending on particular circumstances.

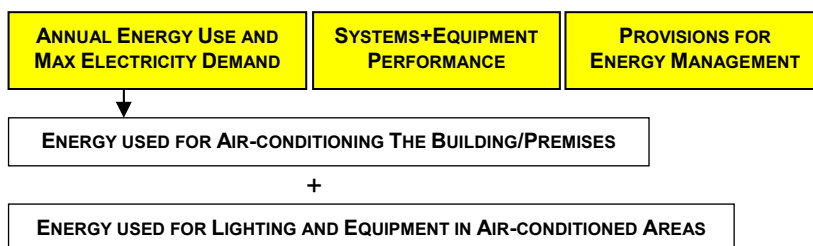
To deal with the wide range of building that may be encountered, buildings/premises are categorised according to the provisions for air-conditioning and ventilation. This is necessary as the operational needs of buildings together with the different air-conditioning and ventilation systems that serve their needs results in large variations in energy use between buildings.



**Categories of buildings for energy use assessments in HK-BEAM 4/04**

HK-BEAM 4/04 assessments take account of the specific characteristics of the building development, such as the type and usage of premises it houses and the range and operational characteristics of the systems and equipment required to meet the needs of users, i.e:

- estimated Annual Energy Use (and where appropriate, Maximum Electricity Demand) for air-conditioning the building, and for lighting and equipment in air-conditioned areas;
- features and performance of specific systems and equipment; and
- testing and commissioning of systems and provisions that facilitate energy efficient management, operation and maintenance.



**Assessment issues in HK-BEAM 4/04**

### **Annual Energy Use:**

*Annual Energy Use in Commercial, Hotel, Educational, and Residential Buildings are assessed separately.*

The assessment of energy performance is based on estimations obtained from computer simulations. The criteria for the award of credits have been established using a detailed building heat transfer simulation program HTB2<sup>51</sup> and an air-conditioning system simulation program BECON<sup>52</sup>. BECON has been developed to ensure that system design and equipment sizing can better match cooling load demand profiles, thereby improving efficiency and enabling better control of indoor environmental conditions. Notwithstanding, for the purpose of assessment, building energy use predictions may be performed with the use of any suitable building energy simulation program.

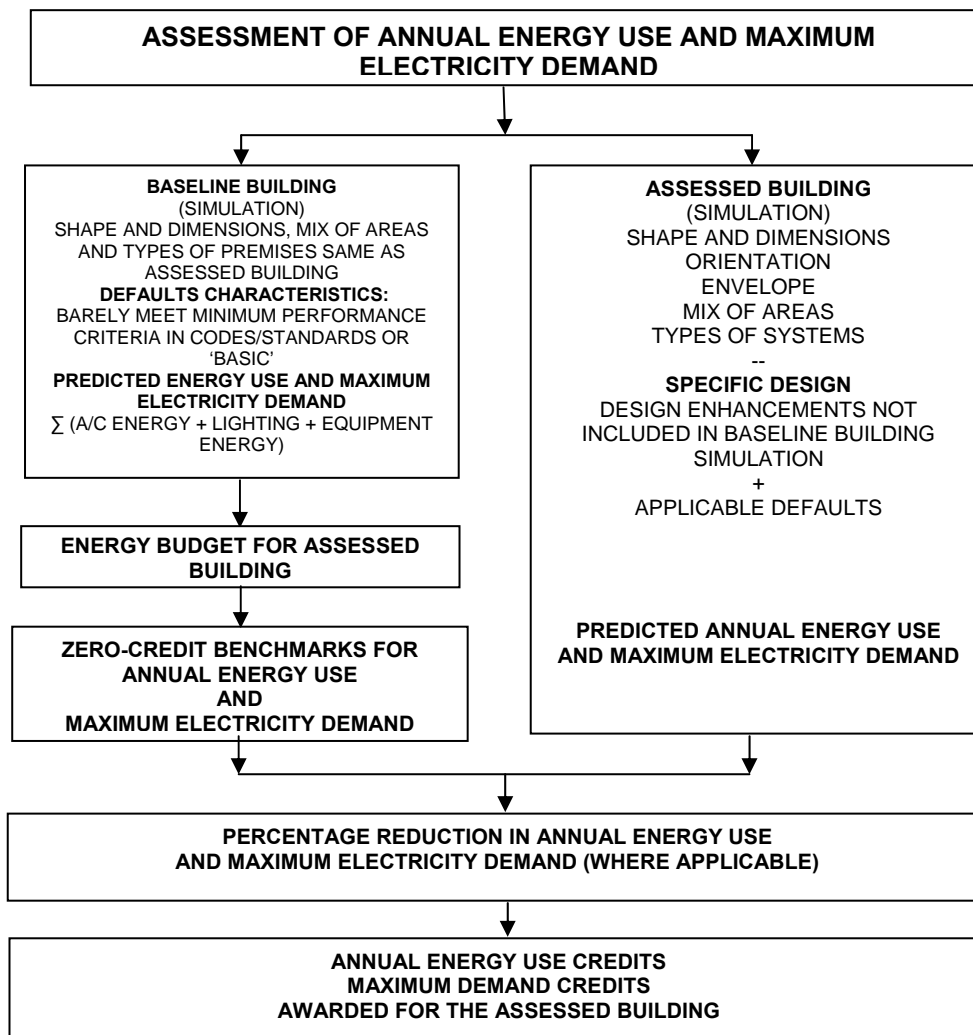
Assessment of annual energy use in HK-BEAM is very similar to that used in the Performance-based Building Energy Code (PBEC)<sup>53</sup>. However, an assessment under the PBEC is a pass/fail assessment, whereas a HK-BEAM assessment quantifies the level of performance improvement (and also includes estimation of electricity maximum demand within the simulation). Certification under the PBEC automatically qualifies for one credit under HK-BEAM, irrespective of the simulation software and default values. For a HK-BEAM assessment the simulation software and default values used must meet the requirements stipulated in HK-BEAM. Where an assessment under HK-BEAM uses software approved under the PBEC then the outcome of the assessment can also be used in a submission for certification under the PBEC.

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<sup>51</sup> Alexander D K. HTB2 User Manual Version 2.0. Welsh School of Architecture, Cardiff University.

<sup>52</sup> Yik F W H. User Manual for BECON for Windows. A Building Energy Consumption Simulation Program. Department of Building Services Engineering, The Hong Kong Polytechnic University.

<sup>53</sup> Electrical and Mechanical Services Department. Performance-based Building Energy Code. [http://www.emsd.gov.hk/emsd/e\\_download/pee/pb-bec.pdf](http://www.emsd.gov.hk/emsd/e_download/pee/pb-bec.pdf)



### Building energy performance assessment in HK-BEAM 4/04

The Energy Budget is assessment includes the following energy uses:

- air-conditioning energy use for the entire building development; and
- lighting and equipment energy use in air-conditioned spaces.

Other energy uses in buildings that do not have an impact on the air-conditioning energy use, such as for lighting installations in non-air-conditioned public areas and services plant rooms, for lift and escalator installations, hot water supply, etc., and energy losses in the electrical installations are assessed under features and performance of systems and equipment.

#### **Energy Efficient Systems:**

- 4.2.1 Embodied Energy in Building Structural Elements
- 4.2.2 Ventilation Systems in Mechanically Ventilated Buildings – *not included in this study.*
- 4.2.3 Lighting Systems in Mechanically Ventilated Buildings – *not included in this study.*
- 4.2.4 Hot Water Supply Systems – *applies only to the residential building.*
- 4.2.5 Lift and Escalator Systems
- 4.2.6 Electrical Systems
- 4.2.7 Renewable Energy Systems – *bonus credits not included in overall cost premium*

#### **Energy Efficient Equipment:**

- 4.3.1 Air-conditioning Units – *applies only to the residential building.*
- 4.3.2 Clothes Drying Facilities – *applies only to the residential building.*
- 4.3.3 Energy Efficient Lighting in Public Areas
- 4.3.4 Heat Reclaim – *not included in this study.*
- 4.3.5 Mechanical Ventilation in Hotel Buildings - *not included in this study.*
- 4.3.6 Energy Efficient Appliances – *only applies when installed by the developer.*

**Provisions for Energy Management:**

- 4.4.1 Testing and Commissioning – *not all credits apply to residential building.*
- 4.4.2 Operation and Maintenance
- 4.4.3 Metering and Monitoring

**Summary:**

The following credits apply *only* to the office building:

- 4.1.1 Annual Energy Use in Commercial Buildings.

The following credits apply *only* to the residential building:

- 4.1.4 Annual Energy Use in Residential Buildings.

- 4.3.1 Air-conditioning Units.
- 4.3.2 Clothes Drying Facilities.

Bonus credits that are not included in the overall cost premium:

- 4.2.7 Renewable Energy Systems.

**4.1.1 Annual Energy Use in Commercial Buildings (13 credits)**

Objectives:	Reduce the consumption of non-renewable energy resources and the consequent harmful emissions to the atmosphere. Encourage energy conservation and methods to reduce maximum electricity demand.
Pre-requisites:	Defined in Appendices to HK-BEAM 4/04 Section 8.1.2.
Credit requirement:	<ul style="list-style-type: none"> <li>a) Estimated annual energy consumption <ul style="list-style-type: none"> <li>1 credit for a reduction in the annual energy consumption by 10%.</li> <li>2 credits for a reduction in the annual energy consumption by 14%.</li> <li>3 credits for a reduction in the annual energy consumption by 18%.</li> <li>4 credits for a reduction in the annual energy consumption by 22%.</li> <li>5 credits for a reduction in the annual energy consumption by 26%.</li> <li>6 credits for a reduction in the annual energy consumption by 30%.</li> <li>7 credits for a reduction in the annual energy consumption by 34%.</li> <li>8 credits for a reduction in the annual energy consumption by 38%.</li> <li>9 credits for a reduction in the annual energy consumption by 42%.</li> <li>10 credits for a reduction in the annual energy consumption by 45%.</li> </ul> </li> <li>b) Estimated maximum electricity demand <ul style="list-style-type: none"> <li>1 credit for a reduction in the maximum electricity demand by 15%.</li> <li>2 credits for a reduction in the maximum electricity demand by 23%.</li> <li>3 credits for a reduction in the maximum electricity demand by 30%.</li> </ul> </li> </ul>
Assessment:	<p>The number of credits to be awarded will be determined with reference to the percentage reduction in the annual energy use and maximum electricity demand, respectively, of the assessed building relative to the respective benchmark (zero-credit) criteria evaluated from the Baseline Building model.</p> <ul style="list-style-type: none"> <li>a) Estimated annual energy use <p>A new commercial building or commercial complex, which may be an office-only building, an office/commercial building, a commercial building (such as a standalone shopping centre, or the commercial portion of a residential development) will be assessed based on the method for air-conditioned buildings, as in Section 8.1.</p> </li> </ul>

The prediction of the annual energy use and maximum electricity demand will be based on the design lighting power densities for various premises in the building, as ascertained from the lighting installation designs.

Where the lighting installations will be provided by tenants or sub-owners, the default lighting power densities will also apply to the assessed building, unless the developer can confirm that the prospective tenants or owners of premises will not install lighting that exceeds the design lighting power intensities. In this case, the design values used and the evidence that such values will not be exceeded, such as given in a 'Tenants Fitting-out Specification', shall be included in the submission.

Likewise, the default equipment power densities will be used to assess the energy performance of the building, but design values provided by the building owner will be used instead if sufficient details are provided.

b) Estimated maximum electricity demand

The assessment is included within the assessment of annual energy use for commercial buildings.

Alternative:

a) Estimated annual energy use

For conventional building designs, regression models may be used as an alternative to the generic simulation method, for the prediction of the zero-credit energy use and maximum electricity demand criteria (based on the baseline building model), and for the prediction of the annual energy use and the maximum electricity demand of the assessed building. The available regression models and their applicable limits are described in Section 8.5.

Certification under the Performance-based Building Energy Code<sup>54</sup> automatically qualifies for one credit, irrespective of the simulation software and default values used. Likewise, certification covering the energy efficiency of air-conditioning and lighting installations under the Energy Efficiency Registration Scheme for Buildings<sup>55</sup> automatically qualifies for one credit.

**a) Annual energy consumption (10 credits)**

*Cost Premium:*

<b>Office</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>
<b>Residential</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>

**b) Maximum electricity demand (3 credits)**

*Cost Premium:*

<b>Office</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>
<b>Residential</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>

*Basis for Estimate:*

The additional costs required for lowering the AEC and MED will depend on the energy efficient design options, which fall into one of two general categories: i) air-conditioning system design options; and ii) other energy efficient options that reduce the air-conditioning load. The air-conditioning design option includes the use of chillers with high coefficient of performance (COP) and better control strategies. Other energy efficient options include the use of double-glazed windows, low energy fluorescent lighting, as well as a change in the indoor set-point temperature. Energy consumption by adopting these design options are estimated by using the energy simulation software HTB2<sup>51</sup>.

*Office Building:*

The model developed by Lee and Yik<sup>56</sup> was used for estimating annual electrical energy consumption:

$$AEC = 4.763 - 13.84 (AG \times UG \times T_a / COP) + 364.709 (AG \times UG / COP) + 75.683 (VR / COP)$$

<sup>54</sup> Electrical and Mechanical Services Department. Performance-based Building Energy Code. [http://www.emsd.gov.hk/emsd/e\\_download/pee/pb-bec.pdf](http://www.emsd.gov.hk/emsd/e_download/pee/pb-bec.pdf)

<sup>55</sup> Electrical and Mechanical Services Department. Energy Efficiency Registration Scheme for Buildings. [http://www.emsd.gov.hk/emsd/e\\_download/pee/sch\\_c\\_v19.pdf](http://www.emsd.gov.hk/emsd/e_download/pee/sch_c_v19.pdf)

<sup>56</sup> Lee & Yik 2002

$$+ 2.359 (Q_{LGT}/COP) + 1.484 (Q_{SPW}/COP) + 0.688 (CPP \times PP) + 4.966 (CFP \times FP)$$

$$MED = 9.404 + 125.489 (AG \times SC/COP) + 160.496 (VR/COP) - 8.114 (VR \times W_a/COP) + 0.813 (Q_{LGT}/COP) + 0.865 (Q_{SPW}/COP) + 1.856 (FP) + Q_{LGP} + Q_{SPW}$$

Where:

*AEC* = annual electricity consumption of a chiller plant per m<sup>2</sup> of air-conditioned area (kWh/m<sup>2</sup>);

*AG* = total window area per m<sup>2</sup> floor area;

*CFP* = coefficient of fan flow-rate control method;

*COP* = coefficient of performance of chillers;

*CPP* = coefficient of pump flow rate control method;

*FP* = total installed fan power intensity (W/m<sup>2</sup>);

*PP* = total installed pump power intensity (W/m<sup>2</sup>);

*Q<sub>LGT</sub>* = intensity of lighting load (W/m<sup>2</sup>);

*Q<sub>SPW</sub>* = intensity of equipment load (W/m<sup>2</sup>);

*SC* = area-weight shading-coefficient of window glasses;

*T<sub>a</sub>* = indoor design temperature (°C);

*UG* = area weighted average heat-transfer coefficient of window glasses (W/m<sup>2</sup>K);

*VR* = fresh-air supply rate per m<sup>2</sup> floor area (l/s);

*MED* = total maximum electricity demand (VA/m<sup>2</sup>); and

*W<sub>a</sub>* = indoor design moisture content (g/kg dry air)

For idealized air-conditioned building:

*AEC* of base building = 280 kWh/m<sup>2</sup> (for air-cooled heat rejection system)

= 240 kWh/m<sup>2</sup> (for water-cooled heat rejection system)

*MED* of base building = 180 VA/m<sup>2</sup> (for air-cooled heat rejection system and Power Factor = 0.9)

= 138 VA/m<sup>2</sup> (for water-cooled heat rejection system and Power Factor = 0.9)

Based on the above figures, the cost premiums for provision of energy saving measures for reducing the annual energy consumption levels are shown Table 1.

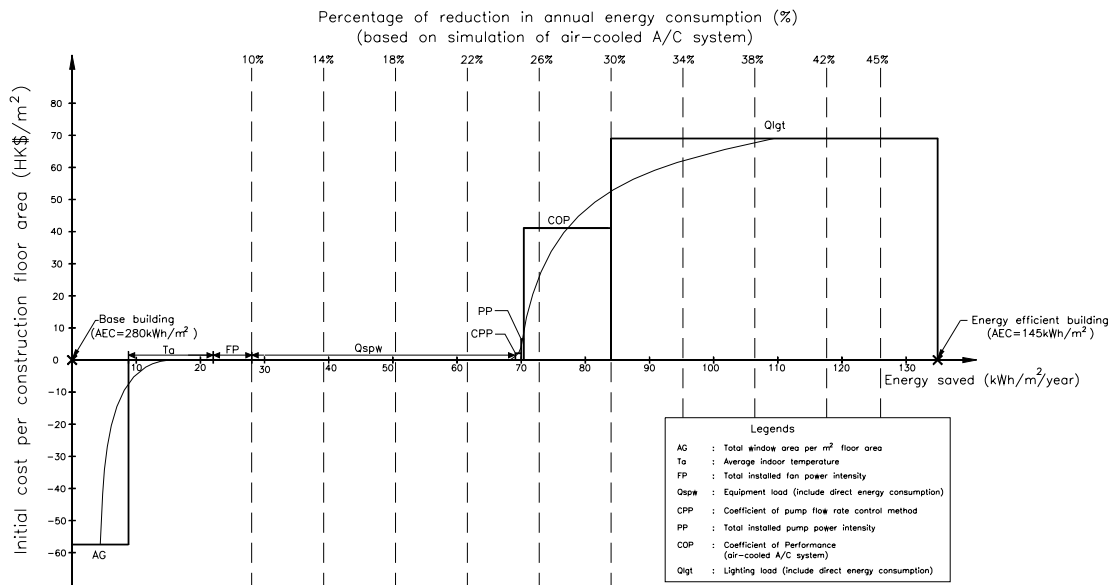
Figures 1 and 2 show the minimum initial cost premiums required for fulfilling 4/04 credit requirements based on incremental energy performance levels for idealized air-cooled and water-cooled air-conditioned office building, respectively.

**Table 1 Minimum additional cost premiums for provision of various energy saving measures for reducing the annual energy consumption levels**

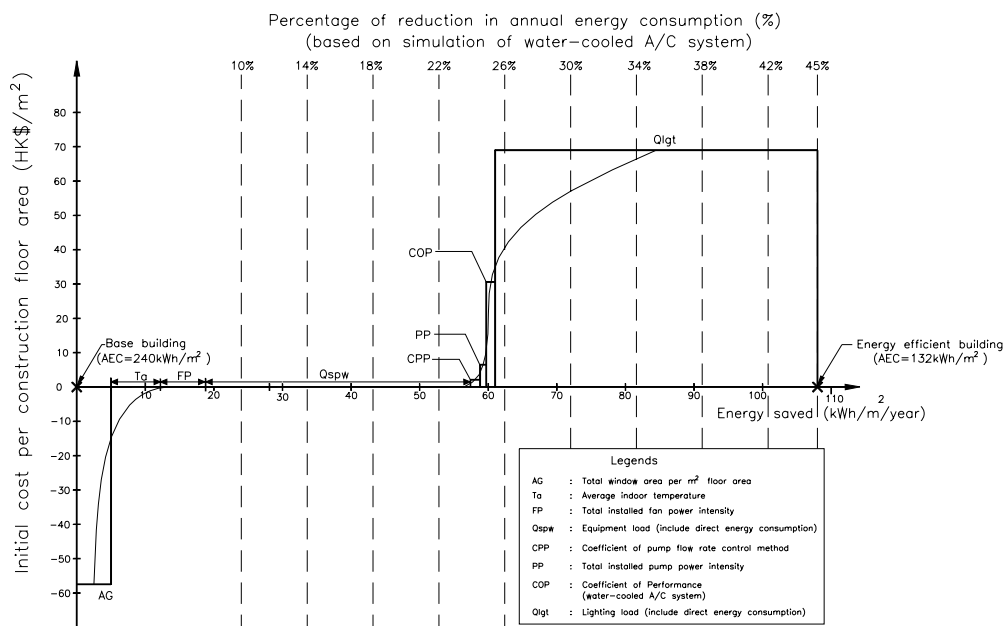
Energy saving measures	Varying range	kWh/m <sup>2</sup> reduction		*Accumulative % reduction		*Accumulative credits		Additional Cost (HK\$/m <sup>2</sup> )
		Air-cooled	Water-Cooled	Air-cooled	Water-cooled	Air-cooled	Water-cooled	
Window to wall ratio	0.2 to 0.1	8.8	5	3	2	0	0	-55
Indoor air temperature	23°C to 25.5°C	13.1	7.2	8	5	0	0	0
Installed fan power intensity	16.1W/m <sup>2</sup> to 13W/m <sup>2</sup>	6.2	6.6	10	8	1	0	0
Intensity of equipment load	25W/m <sup>2</sup> to 14W/m <sup>2</sup>	41	38.6	25	24	4	4	0
Coefficient of pump flow rate control method	1 to 0.7	0.9	1.4	25	24	4	4	2.1

Installed pump power intensity	4W/m <sup>2</sup> to 3.4W/m <sup>2</sup>	0.4	0.9	25	25	4	4	6.5
Coefficient of performance	2.7 to 3.2 (air-cooled) 5.3 to 5.4 (water-cooled)	13.1	1.3	30	25	6	4	41.1 (air-cooled) 30.6 (water-cooled)
Intensity of lighting load	25W/m <sup>2</sup> to 12W/m <sup>2</sup>	51.4	46.3	48	45	10	10	69

\* based on concept of 'low-hanging fruit first'



**Fig. 1 Minimum additional initial cost premiums for fulfilling HK-BEAM 4/04 credit requirement for an idealized air-cooled air-conditioned building**





**Fig. 2 Minimum additional initial cost premiums required for fulfilling HK-BEAM 4/04 credit requirement for an idealized water-cooled air-conditioned building**

Meanwhile, the minimum additional cost premiums required for provision of various energy saving measures for reducing the maximum energy demand.

**Table 2 Minimum additional cost premiums for provision of various energy saving measures for reducing the maximum energy demand**

Energy saving measures	Varying range	kWh/m <sup>2</sup> reduction		* Accumulative % reduction		*Accumulative obtainable credits		Additional Cost (HK\$/m <sup>2</sup> )
		Air-cooled	Water-Cooled	Air-cooled	Water-cooled	Air-cooled	Water-cooled	
Window to wall ratio	0.2 to 0.1	1.8	1	1	1	0	0	-55
Installed fan power intensity	16.1W/m <sup>2</sup> to 13W/m <sup>2</sup>	5.2	5.3	4	5	0	0	0
Intensity of equipment load	25W/m <sup>2</sup> to 14W/m <sup>2</sup>	13	12.1	12	15	0	1	0
Coefficient of performance	2.7 to 3.2 (air-cooled) 5.3 to 5.4 (water-cooled)	11.9	0.1	20	15	1	1	41.1 (air-cooled) 30.6 (water-cooled)
Intensity of lighting load	25W/m <sup>2</sup> to 12W/m <sup>2</sup>	16	14.6	30	27	3	2	69

\* based on concept of 'low-hanging fruit first'

The complication here is that the cost premiums for energy efficient measures will depend on the building and systems designs, i.e. the number of credits achieved, and percentage improvement, depends on which measure(s) are adopted. What is clear is that a detailed design simulation using appropriate assumptions on occupancy patterns, lighting and equipment loads leads to a reduction in air-conditioning plant capacity, and reductions in initial cost. However, in reality, it rarely happens due to degradation of equipment, poor design and maintenance, differences between actual circumstances and those assumed in the baseline building. Previous experiences and research studies<sup>57</sup> suggest that additional 50% should be added to the HVAC consumption levels estimated by simulation models in to cover such inaccuracies.

For non-idealized air-conditioned building:

AEC of base building = 342 kWh/m<sup>2</sup> (for air-cooled heat rejection system)

= 282 kWh/m<sup>2</sup> (for water-cooled heat rejection system)

Assuming the increase of percentage in MED is the same of AEC, then,

MED of base building = 242 VA/m<sup>2</sup> (for air-cooled heat rejection system and Power Factor = 0.9)

= 179 VA/m<sup>2</sup> (for water-cooled heat rejection system and Power Factor = 0.9)

#### Benefits:

The monetary benefit would accrue to the owner of a wholly owned and occupied building, but would split between owner (air-conditioning) and tenants (lighting and equipments) assuming

<sup>57</sup> Yik F.W.H and Lee W.L. 2002, Framework for formulating a performance-based incentive-rebate scale for the demand-side-energy management scheme for commercial buildings in Hong Kong, Applied Energy 73, 139-166.

separate billing arrangements. Energy use for areas not occupied and systems such as lifts, is not included as a cost or benefit in this analysis..

The energy savings from reduced air-conditioning and lighting energy use are based on the lower limits of percentage savings assuming the computed energy use of the baseline office building is 'accurate', and the upper limit takes into account that actual A/C energy use is 50% greater, but percentage savings remain the same.

*Office Building:*

Energy charge per kWh = \$0.815 (based on current electricity tariff).

Demand charge per kVA = \$41.6 (based on current electricity tariff)

*For air-cooled A/C buildings:*

Benefits of 1st credit in AEC (10% reduction):

Upper limit =  $342 \times 10\% \times 0.815 = \$27.9/m^2$

Lower limit =  $280 \times 10\% \times 0.815 = \$22.8/m^2$

Benefits of 1<sup>st</sup> credit in MED per year (15% reduction)

Upper limit =  $(242 / 1000) \times 15\% \times 41.6 \times 12 \text{ months} = \$18.1/m^2$

Lower limit =  $(180 / 1000) \times 15\% \times 41.6 \times 12 \text{ months} = \$13.5/m^2$

Benefits of 10th credit in AEC (10% reduction):

Upper limit =  $342 \times 45\% \times 0.815 = \$125.4/m^2$

Lower limit =  $280 \times 45\% \times 0.815 = \$102.7/m^2$

Benefits of 10<sup>th</sup> credit in MED per year (30% reduction)

Upper limit =  $(242 / 1000) \times 30\% \times 41.6 \times 12 \text{ months} = \$36.2/m^2$

Lower limit =  $(180 / 1000) \times 30\% \times 41.6 \times 12 \text{ months} = \$30.0/m^2$

*For water-cooled A/C buildings:*

Benefits of 1st credit in AEC (10% reduction):

Upper limit =  $282 \times 10\% \times 0.815 = \$23.0/m^2$

Lower limit =  $240 \times 10\% \times 0.815 = \$19.6/m^2$

Benefits of 1<sup>st</sup> credit in MED per year (15% reduction)

Upper limit =  $(179 / 1000) \times 15\% \times 41.6 \times 12 \text{ months} = \$13.4/m^2$

Lower limit =  $(138 / 1000) \times 15\% \times 41.6 \times 12 \text{ months} = \$10.3/m^2$

Benefits of 10th credit in AEC (10% reduction):

Upper limit =  $282 \times 45\% \times 0.815 = \$103.4/m^2$

Lower limit =  $240 \times 45\% \times 0.815 = \$88.0/m^2$

Benefits of 10<sup>th</sup> credit in MED per year (30% reduction)

Upper limit =  $(179 / 1000) \times 30\% \times 41.6 \times 12 \text{ months} = \$26.8/m^2$

Lower limit =  $(138 / 1000) \times 30\% \times 41.6 \times 12 \text{ months} = \$20.7/m^2$

The generation of electricity has a significant impact on the global environment:

- burning any fossil fuel leads to the production of carbon dioxide and so contributes to the potential for global warming through the greenhouse effect;
- oxides of nitrogen and sulphur are emitted when certain fossil fuels (particularly coal and oil) are burnt, thus contributing to acid rain and the potential of damage to the environment;
- extraction of fossil fuels represents the depletion of valuable natural resources and has its own environmental impact.

The energy used for running the building over its lifetime is many times greater than the sum of the energy used during construction. Energy efficiency in operation is therefore the most effective means of reducing the above impact.

On the other hand, reduction of maximum electricity demand can reduce the rate of expansion of power station generating capacity and reduce overall flue gas emissions.

#### 4.2.1 Embodied energy in building structural elements (2 credits)

Exclusions: None.

Objectives: Encourage the design of structural elements and choice of materials that results in lower embodied energy.

Pre-requisites: None.

Credit requirement: 1 credit for demonstrating the embodied energy in the major elements of the building structure of the assessed building is reduced by 10%. 2 credits for demonstrating a reduction by 15%.

Assessment: The assessment covers only the elements and materials used in the building foundations, building core, walls, etc, i.e., the main elements that comprise the building structure, façade, and the roof. Interior services and fit-out components are not included.

The Client shall provide a report detailing where changes in the design of the main structural elements, for example the use of less materials or alternative constructions, etc., that provide for a reduction in embodied energy beyond that which would result if the enhancements were not included.

The method to estimate reduction in embodied energy should follow a well-established Life Cycle Assessment (LCA) approach. Given the variability of approaches and the potential use of different software tools for estimating embodied energy HK-BEAM does not prescribe which approach shall be adopted, nor the data to be used in the analysis.

Where the Client can demonstrate through appropriate analysis that the construction of the main elements of the assessed building reduces the embodied energy by the percentages specified then credit(s) shall be awarded.

#### Cost Premium:

<b>Office</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>
<b>Residential</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>

#### Basis for Estimate:

It is difficult to decrease the embodied energy of building structural element by 10 or 15%. The building material should be large amount in construction process; concrete will be the only choice for cost estimation. Concrete with PFA has the lower embodied energy content and gives an insignificant difference in cost as compared with conventional one according to the latest cost estimates from an experienced contractor. In view of this, concrete with PFA will be in favour for obtaining these credits without an additional cost.

#### Benefits:

Less burden of PFA's dumping and production of sodium lime can benefit to environment. Environmental benefits could be up to HK\$352/m<sup>2</sup> and HK\$429/m<sup>2</sup> for office and residential buildings, respectively.

#### Office Building: 10% reduction

CFA of the base building = 42,840m<sup>2</sup>.

Density of 35D/20 concrete = 2200kg/m<sup>3</sup>.

Density of cement = 1,440kg/m<sup>3</sup>

Embodied energy of cement<sup>58</sup> = 5.85 MJ/kg.

Embodied energy of regular concrete<sup>59</sup> = 9.9 MJ/kg.

Total maximum embodied energy of building structure = 35,887 x 2200 x 9.9 = 781,618,860MJ.

Refer to California report, net monetary benefit provided by recycled construction materials =

<sup>58</sup> Venkatarama Reddy 2003

<sup>59</sup> Chen et al 2001

\$451/ton or \$1082/m<sup>3</sup>

Refer to our statistical survey, range of total volume of concrete = 17,162 to 35,887 m<sup>3</sup>.

A 10% reduction in embodied energy for above = 781,618,860 x 0.1 = 78,161,886MJ

Monetary benefit for 10% reduction of embodied energy per CFA (upper estimate) = ((78,161,886 / (5.85 x 1,440)) x 1082) / 42,840 = \$234.3/m<sup>2</sup>

Minimum of total embodied energy for the building structure = 17,162 x 2200 x 9.9 = 373,788,360MJ

A 10% reduction in embodied energy for above = 373,788,360 x 0.1 = 37,378,836MJ

Monetary benefit due to a 10% reduction of embodied energy per CFA (lower estimate) = ((37,378,836 / (5.85 x 1,440)) x 1082) / 42,840 = \$112.1/m<sup>2</sup>

#### *Office Building: 15% reduction*

15% reduction in the maximum of total embodied energy = 781,618,860 x 0.15 = 117,242,829 MJ

Monetary benefit for 15% reduction of embodied energy per CFA (upper estimate) = ((117,242,829 / (5.85 x 1,440)) x 1082) / 42,840 = \$351.5/m<sup>2</sup>

A 15% reduction in the minimum of total embodied energy = 373,788,360 x 0.15 = 56,068,254 MJ

Monetary benefit due to a 15% reduction of embodied energy per CFA (lower estimate) = ((56,068,254 / (5.85 x 1,440)) x 1082) / 42,840 = \$168.1/m<sup>2</sup>

#### *Residential Building: 10% reduction*

CFA of the base building = 36,750m<sup>2</sup>

Refer to bills of quantities<sup>32</sup>, volume range of total concrete = 31,987 to 37,603m<sup>3</sup>

Maximum total embodied energy of building structure = 37,603 x 2200 x 9.9 = 818,993,340 MJ

A 10% reduction of embodied energy for above = 818,993,340 x 0.1 = 81,899,334MJ

Monetary benefit due to a 10% reduction of embodied energy per CFA (upper estimate) = ((81,899,334 / (5.85 x 1,440)) x 1082) / 36,750 = \$286.2/m<sup>2</sup>

Minimum of total embodied energy of building structure = 31,987 x 2200 x 9.9 = 696,676,860 MJ

10% reduction of embodied energy for above = 696,676,860 x 0.1 = 69,667,686MJ

Monetary benefit due to a 10% reduction of embodied energy per CFA (lower estimate) = ((69,667,686 / (5.85 x 1,440)) x 1082) / 36,750 = \$243.5/m<sup>2</sup>

#### *Residential Building: 15% reduction:*

15% reduction in the maximum of total embodied energy = 818,993,340 x 0.15 = 122,849,001MJ

Benefit for 15% reduction of embodied energy per CFA (upper estimate) = ((122,849,001 / (5.85 x 1,440)) x 1082) / 36,750 = \$429.4/m<sup>2</sup>

15% reduction in the minimum of total embodied energy = 696,676,860 x 0.15 = 104,501,529MJ

Benefit for 15% reduction of embodied energy per CFA (lower estimate) = ((104,501,529 / (5.85 x 1,440)) x 1082) / 36,750 = \$365.2/m<sup>2</sup>

### **4.2.4 Hot Water Supply Systems**

- |                     |   |
|---------------------|---|
| Exclusions:         | Buildings where the estimated energy used for supplying hot water is less than 10% of total estimated building annual energy use. |
| Objectives:         | Promote the use of energy efficient hot water supply systems to conserve energy.  |
| Pre-requisites:     | Design of systems shall comply with recommendations in respect of the control of legionella bacteria.                             |
| Credit requirement: | 1 credit for installing energy efficient hot water supply system(s) and equipment that can save 20% or more energy.               |

Assessment: Design of systems shall comply with the local Code of Practice<sup>60</sup> where applicable. The Client shall provide evidence in the form of detailed calculations demonstrating the energy saving potential of the installed equipment when compared to systems/equipment not designed for energy efficiency/conservation, i.e., the baseline/benchmark. The submission shall include specifications of both the installed systems/equipment and the equipment representing the baseline/ benchmark systems/equipment, with justification for the selected baseline/benchmark data used in the analysis. The gains may be demonstrated in terms of conversion efficiency, reduced energy losses, and/or energy conserving controls. However, the estimates of energy saving shall be independent of the quantity of hot water produced. Where it can be demonstrated that the hot water supply equipment/systems installed demonstrate a saving of 20% over the applicable and appropriate baseline/benchmark the credit shall be awarded.

**Cost Premium:**

<b>Residential</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>
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**Basis for Estimate:**

The cost estimates are based on the cost difference of water heaters with or without energy-labelling, which amount up to HK\$1,500 per unit.

CFA of the base building = 36,750m<sup>2</sup>

Total nos. of residential units = 799

Additional cost for providing an energy efficient water heater = \$1,000 – 1,500.

Upper bound estimate = 1,500 x 799 / 36,750 = \$32.6/m<sup>2</sup>.

Lower bound estimate = 1,000 x 799 / 36,750 = \$21.7/m<sup>2</sup>.

**Benefit:**

Lower energy bills are expected depending on consumption and usage pattern.

**4.2.5 Lift and Escalator Systems (1 credit)**

Exclusions: Building with one or no elevators.  
 Objectives: Encourage the use of energy efficient lift and escalator installations in buildings with significant provisions for vertical transportation.  
 Pre-requisites: Compliance with the Building (Construction) Regulations Chapter 123b Regulation 9a.  
 Credit requirement: 1 credit for complying with the Code of Practice for Energy Efficiency of Lift and Escalator Installations.  
 Assessment: To qualify for the credit the Client shall provide a report prepared by a suitably qualified person detailing the systems and equipment installed and confirming compliance with the code<sup>61</sup>. Certification under EMSD’s Energy Efficiency Registration Scheme for Buildings<sup>62</sup> will also satisfy the requirement.  
 Alternative: Where the lift and/or escalator systems are not in strict compliance with the Code but it can be demonstrated that energy performance (through conversion efficiency or intelligent controls) is enhanced to a similar degree the credit shall be awarded.

**Cost Premium:**

<b>Office</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>
<b>Residential</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>

<sup>60</sup> Prevention of Legionnaires’ Disease Committee, Electrical and Mechanical Services Department, Hong Kong Government. Code of Practice for the Prevention of Legionnaires’ Disease in Hong Kong. 2000. [http://www.emsd.gov.hk/emsd/e\\_download/pps/code.doc](http://www.emsd.gov.hk/emsd/e_download/pps/code.doc)  
<sup>61</sup> Electrical and Mechanical Services Department. Code of Practice for Energy Efficiency of Lift and Escalator Installations. [http://www.emsd.gov.hk/emsd/e\\_download/pee/lift\\_escopp.pdf](http://www.emsd.gov.hk/emsd/e_download/pee/lift_escopp.pdf)  
<sup>62</sup> Electrical and Mechanical Services Department. Energy Efficiency Registration Scheme for Buildings. [http://www.emsd.gov.hk/emsd/e\\_download/pee/sch\\_c\\_v19.pdf](http://www.emsd.gov.hk/emsd/e_download/pee/sch_c_v19.pdf)

#### *Basis for Estimate:*

Although manufacturers offer various models lifts and escalators are not mass-produced commodities. Whilst they have familiar characteristics, each installation is engineered for a specific application. Typically, the architect provides specifications in terms of number of stops, expected traffic, and willingness to pay for premium features, such as marble interiors and advanced controls. These are most likely influenced by the grade of building and quality of service, rather than green features, suggesting little or no cost premium.

#### *Benefits:*

Energy used for vertical transportation in high-rise buildings can be a significant part of the total energy use for the building owner (landlord), with estimates in the range 5-15%. The proportion generally depends on building height (as it dictates lift power and speed), quality of service (number of lifts), control strategies (from simple 'up' - 'down' collective, to intelligent traffic management). The CoP's requirements entail the following aspects:

- Maximum allowable electrical power of lifts, escalators & passenger conveyors;
- Energy management of lifts, escalators & passenger conveyors; and
- Total harmonic distortion and total power factor.

The first two of these items provide for improved energy performance, through efficiency of the drive and control of the cars. The third item contributes to a reduction in harmonic distortion (which can be a problem in buildings) and improvement in overall power factor. For users the added advantage of efficient car controls is reduced waiting time.

#### **4.2.6 Electrical Systems (1 credit)**

Exclusions:	None.
Objectives:	Encourage the design of energy efficient electrical installations in high-rise buildings.
Pre-requisites:	Compliance with the Electricity (Wiring) Regulations Chapter 406E.
Credit requirement:	1 credit for complying with the Code of Practice for Energy Efficiency of Electrical Installations.
Assessment:	To qualify for the credit the Client shall provide a report prepared by a suitably qualified person detailing the systems and equipment installed and confirming compliance with the code <sup>63</sup> . Certification under EMSD's Energy Efficiency Registration Scheme for Buildings <sup>64</sup> will also satisfy the requirement.

#### *Cost Premium:*

<b>Office</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>
<b>Residential</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>

#### *Basis for Estimate:*

This Code sets out the minimum requirements for achieving energy efficient design of electrical installations in buildings without sacrificing the power quality, safety, health, comfort or productivity of occupants or the building function. The requirements for energy efficient design are classified into four categories:

- Minimising losses in the power distribution system.
- Reduction of losses and energy wastage in the utilisation of electrical power.
- Reduction of losses due to the associated power quality problems.
- Appropriate metering and energy monitoring facilities.

Since the Code sets out only the minimum standards, that good design should easily meet, it is

<sup>63</sup> Electrical and Mechanical Services Department. Code of Practice for Energy Efficiency of Electrical Installations. [http://www.emsd.gov.hk/emsd/e\\_download/pee/eleccop.pdf](http://www.emsd.gov.hk/emsd/e_download/pee/eleccop.pdf)

<sup>64</sup> Electrical and Mechanical Services Department. Energy Efficiency Registration Scheme for Buildings. [http://www.emsd.gov.hk/emsd/e\\_download/pee/sch\\_c\\_v19.pdf](http://www.emsd.gov.hk/emsd/e_download/pee/sch_c_v19.pdf)

not expected that compliance will involve a cost premium.

**Benefits:**

Proper design of energy efficient electrical installations can lower the electricity consumption.

**4.2.7 Renewable energy of systems (3 bonus credits)**

- Exclusions: None
- Objectives: Encourage the wider application of renewable energy sources in buildings.
- Credits attainable: 3 BONUS
- Pre-requisites: None
- Credit requirement: Credits will be given on a 3-point sliding scale to building developments for which the predicted energy supply from renewable sources meets the following criteria:
  - a) Densely populated urban centres:
    - o 1 credit where 2% or more of building energy is obtained from renewable energy sources.
    - o 2 credits where 4% or more is obtained from renewable energy sources.
    - o 3 credits where 6% or more is obtained from renewable energy sources.
  - b) Less densely populated areas:
 

Less densely populated areas means areas where buildings are separated by the height of the tallest adjacent building on at least two sides.

    - o 1 credit where 4% or more of building energy is obtained from renewable energy sources.
    - o 2 credits where 8% or more is obtained from renewable energy sources.
    - o 3 credits where 12% or more is obtained from renewable energy sources.
- Assessment: The Client shall submit a report providing details of the installations, and calculations showing the estimated energy use provided from renewable energy sources.  
 In the case of systems that generate electricity from renewable sources (e.g. photovoltaic panels), the estimated amount of electricity that will be generated by the system for use by equipment in the building, either instantaneously or from an associated storage system  
 In the case of using systems that produce services direct from renewable sources, which will otherwise require the use of fuel or electricity to produce those services (e.g. hot water supply from solar panels or chilled water supply from absorption chillers powered by solar heat), the equivalent amount of electricity use that will be avoided  
 The calculation shall take due account of the diurnal and seasonal variations in the external environmental conditions (e.g. solar intensity and wind speed and direction) and in the demand for the electricity and/or services generated by the systems. Any energy use and losses by the systems shall be discounted from their output.

**Cost Premium:**

<b>Office</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>
<b>Residential</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>

**Basis for Estimate:**

PV system could be the most potential renewable energy source among all of renewable energy systems. It shall be due to densely populated nature in Hong Kong. There are likely many constraints to development of large scale facilities in urban areas. PV system therefore could be adopted due to its smaller scale and ease of installation. Current study has estimated that PV electricity generation cost is at between \$2.2/kWh and \$4.1/kWh. This high generation cost is due primarily to the high cost of solar panels. Indeed, the financial viability of PV system depends mostly on the initial cost and the efficiency of the solar panels.

**Office Building:**

Annual energy consumption (AEC) of the air-cooled A/C building = 280 – 342 kWh/m<sup>2</sup>

Annual energy consumption (AEC) of the water-cooled A/C building = 240 – 282 kWh/m<sup>2</sup>

PV electricity generation cost<sup>65</sup> = \$2.2 – 4.1/kWh

Range of the total initial cost for PV electricity generation for air-cooled A/C building = 280 x 2.2 = \$616 and 342 x 4.1 = \$1,402

Range of the total initial cost for PV electricity generation for water-cooled A/C building = 240 x 2.2 = \$528 and 282 x 4.1 = \$1,156

*For air-cooled A/C buildings:*

2% reduction of the total (upper estimate) = 1,402 x 0.02 = \$28.0/m<sup>2</sup>

2% reduction of the total (lower estimate) = 616 x 0.02 = \$12.3/m<sup>2</sup>

12% reduction of the total (upper estimate) = 1,402 x 0.12 = \$168.2/m<sup>2</sup>

12% reduction of the total (lower estimate) = 616 x 0.12 = \$73.9/m<sup>2</sup>

*For water-cooled A/C buildings:*

2% reduction of the total (upper estimate) = 1,156 x 0.02 = \$23.1/m<sup>2</sup>

2% reduction of the total (lower estimate) = 528 x 0.02 = \$10.6/m<sup>2</sup>

12% reduction of the total (upper estimate) = 1,156 x 0.12 = \$138.7/m<sup>2</sup>

12% reduction of the total (lower estimate) = 528 x 0.12 = \$63.4/m<sup>2</sup>

*Residential Building:*

Average annual energy consumption (AEC) of the base building = 110 kWh/m<sup>2</sup>

PV electricity generation cost<sup>65</sup> = \$2.2 – 4.1/kWh

Range of total initial cost for PV electricity generation = 110 x 2.2 = \$242 and 110 x 4.1 = \$451

2% reduction of the total (upper estimate) = 451 x 0.02 = \$9.0/m<sup>2</sup>

2% reduction of the total (lower estimate) = 242 x 0.02 = \$4.8/m<sup>2</sup>

12% reduction of the total (upper estimate) = 451 x 0.12 = \$54.1/m<sup>2</sup>

12% reduction of the total (lower estimate) = 242 x 0.12 = \$29.0/m<sup>2</sup>

Custom-made solar panels may be promoted as alternative curtain wall materials with the added benefit of power generation; they are more costly than conventional building materials. A typical example could be the commercial building at Peking Road No. 1. Current study suggests that the BIPV schemes adopted so far have tended to have a pay-back period far longer than those usually considered acceptable by the private sector – a major barrier to the wider uptake of BIPV by the private sector.

*Benefits:*

The Department of Community Medicine of the University of Hong Kong has recently estimated that, based on its Year 2000 data, 5% renewable energy in Hong Kong energy is mixed, there will be a reduction of 8,150 tonnes (14% of total sulphur dioxide emission from power plants) of SO<sub>2</sub>, 7,150 tonnes (13%) of nitrogen oxides, 440 tonnes (13%) of particulates, and 1,834,400 tonnes (5%) of carbon. This reduction in emissions would lead each year to the avoidance of 200 deaths and 2,102 hospital admissions relating to cardiovascular and respiratory illness.

*Office Building:*

Annual health benefits to the owners-occupiers and the society by operating with different reduction in building energy consumption due to application of renewable systems (i.e. PV cells)

Reduction in building energy consumption	Benefits conferred to Owners-Occupiers (\$/m <sup>2</sup> )	Benefits conferred to the Society (\$/m <sup>2</sup> )
2 – 4%	Low:	0.07
	High:	0.14
4 – 8%	Low:	0.14
	High:	0.28

<sup>65</sup> Agreement No. : CE36/2000, study on the potential applications of renewable energy in Hong Kong, stage 1, executive summary, Dec. 2002, EMSD, HKSAR



8 – 12%	High:	0.28	High:	230.2
	Low:	0.28	Low:	18.6
	High:	0.55	High:	460.4

(based on CE36/2000<sup>65</sup>, 200 deaths from cardiovascular and respiratory causes, 2102 hospital admissions relating to cardiovascular and respiratory illnesses to Hospital Authority hospitals)

#### *Residential Building:*

Annual health benefits to the owners-occupiers and the society by operating with different reduction in building energy consumption due to application of renewable systems (i.e. PV cells)

Reduction in building energy consumption	Benefits conferred to Owners-Occupiers (\$/m <sup>2</sup> )	Benefits conferred to the Society (\$/m <sup>2</sup> )
2 – 4%	Low:	0.01
	High:	0.02
4 – 8%	Low:	0.02
	High:	0.04
8 – 12%	Low:	0.04
	High:	0.08

(based on CE36/2000<sup>65</sup>, 200 deaths from cardiovascular and respiratory causes, 2102 hospital admissions relating to cardiovascular and respiratory illnesses to Hospital Authority hospitals)

#### **4.3.1 Air-conditioning Units (3 credits)**

- Exclusions: Buildings not using window and/or split-type air-conditioners.
- Objectives: Ensure the installation of air-conditioning units provides for near optimum performance.
- Pre-requisites: Proper disposal system for the drainage of the condensation shall be provided in accordance with Buildings Department requirements [<sup>66</sup>].
- Credit requirement: a) Positioning of units: 1 credit for complying with the recommended installation positions for air-conditioning units with regard to internal spaces. 1 credit for complying with the minimum width of any external recess with regard to heat rejection.  
b) Additional installation requirements: 1 credit for complying with the items listed in the assessment check-list.

##### **a) Positioning of units**

- Assessment: i) Window type air-conditioning units  
The Client shall provide relevant drawings and specifications demonstrating that the air-conditioning units installed comply with the installation requirements given in Tables 8.10 and 8.11 in Section 8.6.
- ii) Split-type air-conditioning units  
The Client shall provide relevant drawings and specifications demonstrating that the air-conditioning units installed comply with the relevant dimensions given in Table 8.10 in respect of internal unit, and with the relevant dimensions given in Table 8.11 in respect of the external unit.  
Compliance with the requirements shall be demonstrated for each type of domestic unit in a block, or each type of space or room in other types of premises, unless the Client can demonstrate either that circumstances mitigate against compliance in not more than 10% of installations, or that non-compliance will not affect the performance of air-conditioning units in respect of room cooling, or heat rejection.

<sup>66</sup> Buildings Department. Practice Note for Authorised Persons and Registered Structural Engineers. PNAP 238. Disposal of Condensation from Air-Conditioning Units. <http://www.info.gov.hk/bd/english/documents/pnap/Pnap238.pdf>

*Cost Premium:*

<b>Residential</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>
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*Basis for Estimate:*

The installation positions and heat rejection space requirement are normally decided by Architects. Due to the façade requirement, Architects will try to dispose the A/C units into recess locations of buildings, i.e. light-well, or end-sides of walls which may not meet the space requirement of these credits.

**b) Additional installation requirements**

- Assessment: The Client shall confirm that the installation conforms with any four of the following items that are relevant to the type of air-conditioning units used:
- o to reduce penetration of noise units shall be located on walls which do not face major noise sources (road traffic, major pedestrian walkways, playgrounds, etc);
  - o to reduce intake of polluted air units shall be located in walls such that air is not drawn in from pollution sources such as roads, commercial activities, etc;
  - o for improved acoustics properties and better circulation, the internal discharge shall be close to the centre of the wall in which it is located;
  - o for the purpose of reducing noise from rain, and to reduce the potential for water dripping on to lower units, slabs shall be provided to as support and as cover;
  - o to encourage proper maintenance, the installation of units shall be such to allow for safe and convenient removal;
  - o where air-conditioning units are provided by the developer, the units selected shall be labelled as Grade 1 or 2 under the Government's energy efficiency labelling scheme for room coolers<sup>67</sup>.

*Cost Premium:*

<b>Residential</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>
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*Basis for Estimate:*

The additional costs for this credit are mainly depended on the features of air conditioning units. More energy efficient air conditioning units, e.g. those labelled with Grade 1 or 2 under the Government's energy efficiency labelling scheme, may incur an insignificant to moderate increase in the first cost.

*Benefits:*

Higher heat rejection efficiency of air conditioning units by proper installation methods can lower the energy consumption level. A study by Bojic et al.<sup>68</sup> revealed that insufficient clearance spaces could cause a significant increase in the temperature of the outdoor air entering the air conditioners, which would also be accompanied by a reduction in the airflow rate. The electricity consumption level of the air conditioners would be increased by 45% over that when the air conditioners were drawing in the discharged hot condenser air from other air conditioners locating at an opposite wall.

**4.3.2 Clothes Drying Facilities (1 credit)**

- Exclusions: Buildings other than residential buildings.
- Objectives: Encourage greater use of natural resources in place of gas or electrical energy for clothes drying purposes.
- Credit requirement: 1 credit for providing suitable clothes drying facilities which utilise the natural environment for the majority of residential units.
- Assessment: The Client shall demonstrate the adequacy of the clothes drying facilities for efficient drying by sun and breeze, which is adequately protected from water droplets and debris falling from higher levels, and not adversely affected by smoke, fumes and

<sup>67</sup> Electrical & Mechanical Services Department, the Government of the Hong Kong SAR. The Hong Kong Voluntary Energy Efficiency Labelling Scheme for Room Coolers.  
[http://www.emsd.gov.hk/emsd/e\\_download/pee/eels\\_room\\_cooler\\_\(jan\\_2003\).pdf](http://www.emsd.gov.hk/emsd/e_download/pee/eels_room_cooler_(jan_2003).pdf)

<sup>68</sup> Bojic M. et al. 2002, Influence of clearances on the energy performance of window-type air-conditioners at the same level outside residential buildings, Building and Environment 37, 713-726.

pollutants emitted from water heaters, cooking exhausts, discharges from air-conditioning units, etc.

**Cost Premium:**

<b>Residential</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>
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**Basis for Estimate:**

Costs are based on common construction practices and estimates provided by experienced surveyors in Hong Kong and the cost range is about \$200 to 500 per unit of clothes drying facilities.

Clothes drying facilities are normally provided in new public residential buildings. New designs have been resolved the problem of water droplets and debris. Removable clothes drying shelf are widely used in new private sector buildings.

CFA of the base building = 36,750m<sup>2</sup>

Nos. of residential units = 799

Additional cost for provision of a clothes drying hanger = \$200 - 500

Upper bound estimate = 500 x 799 / 36,750 = \$10.9/m<sup>2</sup>

Lower bound estimate = 200 x 799 / 36,750 = \$4.3/m<sup>2</sup>

**Benefits:**

Reduced energy consumption from use of gas or electric cloth drying machines and corresponding saving of energy bills could be up to \$40/m<sup>2</sup>.

CFA of the base building = 36,750 m<sup>2</sup>

Total nos. of flat units = 799

Unit electricity charge = \$0.885 per kWh (based on current electric tariff)

Gas charge per MJ = \$0.21 (based on current gas tariff)

Electricity consumption of electric clothes dryer per month for each flat<sup>69</sup> = 106 to 121 kWh

Upper bound estimate for annual saving per CFA if electric clothes dryer was not used = (121 x 0.885 x 12 x 799) / 36,750 = \$27.9

Lower bound estimate for annual saving per CFA if electric clothes dryer was not used = (106 x 0.885 x 12 x 799) / 36,750 = \$24.5

Gas consumption of gas clothes dryer per month for each flat<sup>69</sup> = 671 to 762 MJ

Upper bound estimate for annual saving per CFA if gas clothes dryer was not used = (762 x 0.21 x 12 x 799) / 36,754 = \$41.7

**4.3.3 Energy Efficient Lighting in Public Areas (1 credit)**

- Exclusions: None.
- Objectives: Ensure energy efficient lighting equipment and robust energy conserving controls are used to meet the needs for user safety, security and accessibility in all exterior, public and service areas of buildings.
- Credit requirement: 1 credit for installation of: energy efficient lighting equipment; and control for the lamps in areas where daylight is available.
- Assessment: The Client shall submit a report prepared by suitably qualified person demonstrating that the criteria have been met for lighting systems used.
  - a) Exterior play areas, footpaths, services areas, walkways, etc:
    - o all lamps have luminous efficacy greater than the minimum values specified in the Code of Practice for Energy Efficiency of Lighting Installations;
    - o fluorescent lamp control-gear loss less than the maximum allowable lamp control gear loss specified in the Code of Practice for Energy Efficiency of Lighting

<sup>69</sup> Puget Sound Energy 2004, Common Household Items – Energy Costs Guide

Installations; and

- o the average circuit efficacy for all areas not less than 65 lm/W.

The lamp luminous efficacy, lamp control-gear loss and installed lighting power density for outdoor areas and spaces should be assessed using the method and the standard forms published in the Code of Practice for Energy Efficiency of Lighting Installations<sup>70</sup>. The assessment of the average circuit efficacy shall be based on the method given in the Appendix of the Code, or equivalent alternative.

b) Interior public areas such as lift lobbies, staircases, etc., and service areas such as plant rooms:

lighting power density is less than 85% of the maximum allowable lighting power density specified for "Spaces for Common Activities" (Space Code A) in Table LG4 of the Code of Practice for Energy Efficiency of Lighting Installations; and the average circuit efficacy for all areas not less than 65 lm/W.

The lamp luminous efficacy, lamp control-gear loss and installed lighting power density for indoor spaces should be assessed using the method and the standard forms published in the Code of Practice for Energy Efficiency of Lighting Installations. The assessment of the average circuit efficacy shall be based on the method given in the Appendix of the Code.

c) Controls

Provisions for daylighting controls in all applicable areas demonstrating that lighting will be maintained at a level required for the intended use of the space, and can be dimmed or switched-off when daylight is adequate.

**a) Exterior areas**

Assessment:

Exterior play areas, footpaths, services areas, walkways, etc:

- o all lamps have luminous efficacy greater than the minimum values specified in the Code of Practice for Energy Efficiency of Lighting Installations;
- o fluorescent lamp control-gear loss less than the maximum allowable lamp control gear loss specified in the Code of Practice for Energy Efficiency of Lighting Installations; and
- o the average circuit efficacy for all areas not less than 65 lm/W.

The lamp luminous efficacy, lamp control-gear loss and installed lighting power density for outdoor areas and spaces should be assessed using the method and the standard forms published in the Code of Practice for Energy Efficiency of Lighting Installations<sup>71</sup>. The assessment of the average circuit efficacy shall be based on the method given in the Appendix of the Code, or equivalent alternative.

**Cost Premium:**

<b>Office</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>
<b>Residential</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>

**b) Interior public areas**

Assessment:

Interior public areas such as lift lobbies, staircases, etc., and service areas such as plant rooms:

lighting power density is less than 85% of the maximum allowable lighting power density specified for "Spaces for Common Activities" (Space Code A) in Table LG4 of the Code of Practice for Energy Efficiency of Lighting Installations; and the average circuit efficacy for all areas not less than 65 lm/W.

The lamp luminous efficacy, lamp control-gear loss and installed lighting power density for indoor spaces should be assessed using the method and the standard forms published in the Code of Practice for Energy Efficiency of Lighting Installations. The assessment of the average circuit efficacy shall be based on the method given in the Appendix of the Code.

**Cost Premium:**

<b>Office</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>
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<sup>70</sup> Electrical and Mechanical Services Department, The Government of the Hong Kong Special Administrative Region. Code of Practice for Energy Efficiency of Lighting Installations. [http://www.emsd.gov.hk/emsd/e\\_download/pee/lightingcop.pdf](http://www.emsd.gov.hk/emsd/e_download/pee/lightingcop.pdf).

<sup>71</sup> Electrical and Mechanical Services Department, The Government of the Hong Kong Special Administrative Region. Code of Practice for Energy Efficiency of Lighting Installations. [http://www.emsd.gov.hk/emsd/e\\_download/pee/lightingcop.pdf](http://www.emsd.gov.hk/emsd/e_download/pee/lightingcop.pdf).

<b>Residential</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>
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### c) Controls

Assessment: Provisions for daylighting controls in all applicable areas demonstrating that lighting will be maintained at a level required for the intended use of the space, and can be dimmed or switched-off when daylight is adequate.

#### Cost Premium:

<b>Office</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>
<b>Residential</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>

#### Basis for Estimate:

The total number of ballasts and lighting fittings required for the base building was estimated with reference to the statistical survey data from bills of quantities for residential buildings. The cost difference between conventional and electronic ballasts could be up to HK\$90.

#### Office Building:

CFA of the base building = 42,840m<sup>2</sup>

Number of luminaires in AHU Rooms, Switch Rooms and Toilets of typical floors (assumed size of 4.6 m x 4.6 m) = 10 x 40 = 400

Number of luminaires in staircases = 6 x 40 = 240

Number of luminaires in Sprinkler Pump Room and Intermediate Booster Pump Rooms (assumed size 10 m x 5 m) = 8 x 2 = 16

Number of luminaires in F.S. Pump Rooms, Water Pump Rooms and Fan Rooms (assumed size 4.6 m x 4.6 m) = 2 x 10 = 20

Number of luminaires in Common Lift Lobbies and Corridors (size 15 m x 4 m) = 12 x 40 = 480

Number of luminaires in Lift Machine Room (size 15 m x 15 m) = 25

Number of luminaires in Chiller Plant Room (size 15 m x 10 m) = 20

Number of luminaires in other common area or plant rooms i.e. refuse chamber or workshops etc. = 60

Therefore, total nos. of luminaire required for the base building

= 400 + 240 + 16 + 20 + 480 + 25 + 20 + 60 = 1261

Total additional cost required by using electronic ballasts instead of conventional ballasts (based on cost estimates of quantity surveyors):

Cost of conventional ballast: \$ 80

Cost of electronic ballast: \$ 170

Cost difference between this two types of ballasts: \$ 90

Then, additional cost per construction floor area = 1261 x 90 / 42,840 = \$2.6

#### Residential Building:

CFA of the base building = 36,750m<sup>2</sup>

Nos. of luminaire required for the base building<sup>32</sup> = 358 (based on statistical survey in public housing)

Total additional cost required if electronic ballasts were used instead of conventional ballasts: (based on cost estimates given by quantity surveyors)

Cost of conventional ballast: \$ 80

Cost of electronic ballast: \$ 170

Cost difference between this two types of ballasts: \$ 90

Then, additional cost per construction floor area = 358 x 90 / 36,750 = \$0.9

Lightings with electronic ballasts are widely used nowadays due to the energy consumption of

which could be 30% less than conventional one by the experimental analysis by Electrical and Mechanical Department.

**Benefit:**

Using electronic ballasts for lightings can help reduce energy consumption, and thus the energy bills for owners-occupiers.

**Office Building:**

CFA of the base building = 42,840 m<sup>2</sup>

Unit electricity charge = \$0.815 per kWh (based on current electric tariff)

Average percentage reduction in electricity consumption per efficiency lighting = 30%

Assume the average power wattage of the public lightings was 36W and they operated 17 hours a day

Nos. of lightings in public area = 1260 (by above calculation)

Annual cost saving estimate:  $(36 \times 17 \times 365 \times 1260 \times 0.3 \times 0.815) / (1,000 \times 42,840) = \$1.6/m^2$

**Residential Building:**

CFA of the base building = 36,750 m<sup>2</sup>

Unit electricity charge = \$0.885 per kWh (based on current electric tariff)

Average percentage reduction in electricity consumption per efficiency lighting = 30%

Assume the average power wattage of the public lightings was 36W and they operated 12 hours a day

Nos. of lightings in public area<sup>32</sup> = 358 (based on statistical survey of public housing)

Annual cost saving estimate:  $(36 \times 12 \times 365 \times 358 \times 0.3 \times 0.885) / (1,000 \times 36,750) = \$0.4/m^2$

**4.3.6 Energy Efficient Appliances (1 credit)**

- Exclusions: Buildings where appliances are not provided by the developer.
- Objectives: Encourage the wider use of energy efficient appliances.
- Credit requirement: 1 credit for specifying the use of certified energy efficient appliances.
- Assessment: The Client shall provide details of all the appliances installed in the building and evidence as to the efficiency ratings of each type and size of the appliances.  
Where appliances listed under the Energy Efficiency Labelling Scheme<sup>72</sup> are efficiency Grade 1 or 2, or the appliances conform to similar grades under a recognised energy efficiency labelling scheme, such as USEPA Energy Star Products<sup>73</sup>, the credit shall be awarded.

**Cost Premium:**

<b>Residential</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>
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**Basis for Estimate:**

Evidence suggests that consumers are increasingly conscious of energy efficiency and will seek to purchase the best grade products. The response from manufacturers is to ensure only best grade products are supplied, else they become uncompetitive. The development of EMSD's energy labelling scheme along similar lines to UK and US approaches indicates the same trend applies in Hong Kong. There is unlikely to be a cost premium if only Grade 1 and 2 appliances are sold locally.

**Benefit:**

This is a business decision by developers as to whether or not to supply appliances in residential

<sup>72</sup> Electrical and Mechanical Services Department. Energy Efficiency Labelling Scheme. [http://www.emsd.gov.hk/emsd/eng/pee/eels\\_pub.shtml](http://www.emsd.gov.hk/emsd/eng/pee/eels_pub.shtml)

<sup>73</sup> US Environmental Protection Agency. Energy Star. [http://208.254.22.7/index.cfm?fuseaction=find\\_a\\_product](http://208.254.22.7/index.cfm?fuseaction=find_a_product).

units to boost sales. The types of appliances are likely to be restricted to those that are built-in to kitchen units or suitably sized for utility rooms. Increased sales value or saleability is the major benefit to developers.

Environmental benefits would accrue due to reduced energy consumption. Economic benefits accrue to householders through reduced energy bills.

#### 4.4.1 Testing and Commissioning (4 credits)

- Exclusions: None.
- Objectives: Ensure that commissioning of electrical and mechanical systems that impact on energy use is adequate, that systems perform as specified, and can be operated as intended.
- Credit requirement:
- a) Commissioning specifications: 1 credit for provision of appropriate specifications and cost provisions in contract documents detailing the commissioning requirements for all systems and equipment that impact on energy use and indoor environmental quality.
  - b) Commissioning plan: 1 credit for the appointment of a commissioning authority and provision of a detailed commissioning plan that embraces all specified commissioning work.
  - c) Commissioning: 1 credit for ensuring full and complete commissioning of all systems, equipment and components that impact on energy use and indoor environmental quality.
  - d) Commissioning report: 1 credit for providing fully detailed commissioning reports for all systems, equipment and components that impact on energy use and indoor environmental quality.

##### a) Commissioning specifications

- Assessment: The Client shall submit copies of specifications detailing the commissioning requirements for each system and equipment, and details of the cost provisions for the commissioning work.
- Where it can be shown that the specifications meet the requirements given in Section 8.7.1 as a minimum, and cost provisions are sufficient to carry out the intended work the credit shall be awarded.

##### Cost Premium:

Office	U	0	0+	L	M	H
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##### Basis for Estimate:

Detailed testing and commissioning specifications, mainly for building services systems and equipment, are provided by ArchSD for government buildings, and typically 3% of the contract cost is allowed for T&C. In the private sector the allowance may be as low as 0.5%. The cost premium for specifications is limited to the effort in drawing up the specifications. Whether the costs allowed in contract documents are 'appropriate' as required by HK-BEAM is difficult to judge. The importance of commissioning provisions for green buildings and the likely cost premium is discussed elsewhere in this report.

##### b) Commissioning plan

- Assessment: There shall be appropriate cost provisions for the appointment of an independent commissioning authority and for the commissioning processes. The commissioning authority shall be a Registered Professional Engineer with adequate expertise in the commissioning of electrical and mechanical systems, equipment and components. A suitably qualified member of the organisation that performed the design may act as the commissioning authority; however, such an individual must not be responsible for any aspect of the project design, or construction management or supervision for the subject building. In addition, reporting of all conditions and findings must be immediate and direct from the commissioning authority to the Client. The commissioning authority shall be responsible for:
- o review and approval of commissioning specifications;
  - o the development of a commissioning plan;
  - o determining and documenting whether systems, equipment and components are

functioning in accordance with the design intent and in accordance with the construction documents.

Where the Client can provide evidence that the commissioning plan meets the requirements detailed in Section 8.7.2 as a minimum the credit shall be awarded.

**Cost Premium:**

<b>Office</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>
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**Basis for Estimate:**

The appointment of a commissioning agent or commissioning authority is not common practice in Hong Kong, where T&C by the contractor with oversight by the client's representative the norm. The additional cost for a commissioning authority is taken to add low to moderate cost to a project, depending on the scale and complexity of the project and the scope of work.

**c) Commissioning**

Assessment: Where the Client appoints a commissioning agent to be responsible for performing the functional testing of systems and equipment, as documented by the commissioning authority, using forms approved by the commissioning authority, and all of which meet the requirements of Section 8.7.3 as a minimum, the credit shall be awarded.

**Cost Premium:**

<b>Office</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>
<b>Residential</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>

**Basis for Estimate:**

The requirement in HK-BEAM is for the commissioning authority to perform functional testing of systems and equipment, but in practice it is more likely that the commissioning authority will oversee that T&C undertaken by contractors meets the contract specifications. Cost premium here is linked to item b) above.

**d) Commissioning reports**

Assessment: Where the Client demonstrates that after all commissioning tasks, except seasonally deferred testing have been completed, and a commissioning report is provided covering as a minimum the items given in Section 8.7.4, the credit shall be awarded.

**Cost Premium:**

<b>Office</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>
<b>Residential</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>

**Basis for Estimate:**

The work undertaken by the commissioning authority is to ensure commissioning records are complete and available to the building operator. The cost premium is linked to items b) and c) above.

**Benefits:**

Full and proper commissioning of systems enhances safety, energy efficiency and user comfort and health.

**4.4.2 Operation & Maintenance (3 credits)**

Exclusions: None.

Objectives: Enable building operators to implement the design intent, be able to monitor the performance of the building, and maintain the performance.

Credit requirement: a) Operations and maintenance manual: 1 credit for providing a fully documented operations and maintenance manual to the minimum specified.  
 b) Energy management: 1 credit for providing fully documented instructions that enables systems to operate at a high level of energy efficiency.  
 c) Operator training and operation and maintenance facilities 1 credit for: providing training for operations and maintenance staff to the minimum specified; and demonstrating that adequate maintenance facilities are provided for operations and



maintenance work.

#### **a) Operations and maintenance manual**

Assessment: The design intent and basis of design shall be included as a defining part of the operations and maintenance manual and the energy management manual. The manual shall include the details given in Section 8.7.5 as a minimum.  
Where an adequate contract sum was provided for the preparation of comprehensive operations and maintenance manual, and the manual covers adequately the major energy consuming building services systems and equipment the credit shall be awarded.

##### *Cost Premium:*

<b>Office</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>
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##### *Basis of Estimate:*

Like testing and commissioning, the provision of operation and maintenance manuals that allow building operators to optimise building performance is a rare! In most cases it appears that the information provided is incomplete, poorly organised and difficult for O&M staff to understand.

#### **b) Energy management**

Assessment: Where the operations and maintenance manual, or a dedicated energy management manual is provided, and meets the requirements of Section 8.7.6 as a minimum, the credit shall be awarded.

##### *Cost Premium:*

<b>Office</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>
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##### *Basis of Estimate:*

As for a) above.

#### **c) Operator training and operation and maintenance facilities**

Assessment: The training program shall cover as a minimum the items listed in Section 8.7.7. Details of the facilities for operation and maintenance, such as the workshop(s), office accommodation, computing facilities etc., shall be provided, and the case made to demonstrate the adequacy of the facilities in relation to the size and complexity of the building served.  
Where the Client can verify that training of the building's operations and maintenance staff was undertaken for all commissioned systems and major equipment, using the operations and maintenance manual, and the energy management manual as the basis for the training, and demonstrate that the provided operation and maintenance facilities are adequate, the credit shall be awarded.

##### *Cost Premium:*

<b>Office</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>
<b>Residential</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>

##### *Basis of Estimate:*

As for a) and b) above.

##### *Benefit:*

Effective maintenance and operation of the building services can have a significant effect on energy efficiency. It will also help prevent unexpected breakdowns and prolong the life of equipment, avoiding unnecessary use of resources in premature replacement.

#### **4.4.3 Metering & Monitoring (1 credit)**

Exclusions: None.

Objectives: Enable building operators to measure, monitor and develop measures to improve the performance of the building's engineering systems, particularly concerning energy use.

**Pre-requisites:** As a prerequisite metering provisions shall meet the requirements of the Government's energy codes.

**Credit requirement:** 1 credit for installation of: metering that allows monitoring of electricity use by the main chiller plant and auxiliaries; instruments for monitoring building cooling load and operating parameters central chiller plant; metering that allows separate monitoring of electricity use by the air side of the HVAC system; and metering for landlord's electricity consumption in common space/public areas.

**Assessment:** The Owner/Operator shall provide details of the measuring and monitoring equipment installed and commissioning records of consumption and chiller plant performance, to demonstrate that electricity use and performance can be monitored as stipulated. Monitoring of central chiller plant will be assessed on the basis of BSRIA Technical Note TN 7/94<sup>74</sup> or similar specification published by an appropriate authority. The monitoring system shall allow the overall performance of the plant and individual chillers to be determined for all operating modes and range of operating conditions. Electricity metering (for input power, energy and maximum demand), together with associated measuring transducers/transformers for indicating power and energy, shall comply with an appropriate standard such as BS EN<sup>75</sup> and to at least accuracy class 1. Sensors for temperature, flow rate and pressure measurements shall meet the minimum accuracy requirements in ASHRAE Standard 114<sup>76</sup> or similar equivalent. Metering provision shall identify electricity use patterns for major air handling equipment, such as centralised air handling units for floors/zones, large designated areas, etc. Metering provision shall identify the electricity use pattern for each major system fed from the Owner/Operator's main switchboard(s), i.e., landlords lighting and small power, transportation, plumbing & drainage systems, major air handling equipment, such as centralized air handling units for floors/zones, large designated areas, etc.

**Cost Premium:**

<b>Office</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>
<b>Residential</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>

**Basis for Estimate:**

It is difficult to pin down the likely cost of metering as it depends on the systems installed, and number of sub-units, e.g. number of chillers in the central plant. In a well metered office the landlord services may have a score or more of meters or monitoring points<sup>77</sup>, such as.

Supply to chiller and chilled water pump sets, and chiller output monitoring

Public lighting and power for office tower

Supply for passenger lifts and escalators

Car park lighting & power

Essential supply for fan and pump rooms

Essential supply for office tower, car park, etc

Supply to numerous AHUs, etc

Cost depends on accuracy required, robustness of instrumentation, wiring costs, etc.

Additional costs for metering of energy-consumed equipment could be up to HK\$2,700 for office buildings. The cost impact for office buildings in this respect is considered to be low, which was based on the bills of quantities of 11 examined buildings compared with base office building.

Separate electrical meter is normally installed for each apartment in response to the requirements laid down by the public utility company. The separate meters for public facilities, i.e. A/C and powers of club houses could be regarded as negligible provision in residential development. In

<sup>74</sup> K Calder. The Building Services Research and Information Association. Practical Chiller System Monitoring. Technical Note TN 7/94. 1994.

<sup>75</sup> British Standard BS EN 60521:1995. Class 0.5, 1 and 2 alternating-current watt-hour meters.

<sup>76</sup> ASHRAE. Standard 114-1986: Energy Management Control Systems Instrumentation, American Society of Heating, Refrigerating and Air-conditioning Engineers, Inc., USA. 1987.

<sup>77</sup> Yik F W H, Yee K F, Sat P S K, Chan C W H. A Detailed Energy Audit for a Commercial Office Building in Hong Kong. HKIE Trans. Vol. 5, No. 3. pp 84-88.

owner-occupied buildings the cost of basic sub-metering for electricity used on each floor or by each functional unit within an organisation is relatively small.

*Office Building:*

GFA of base building = 42,840m<sup>2</sup>

Additional cost for providing a meter for monitoring non-HVAC energy consumption = \$17,500

Additional cost for providing a meter for monitoring water-side energy consumption = \$2,700

Additional cost for providing a meter for monitoring air-side energy consumption = \$2,700

Number of non-HVAC meters = 4 to 24

Number of water-side meters = 6

Number of air-side meters = 18

Upper bound estimate =  $(17,500 \times 24) + (2,700 \times 6) + (2,700 \times 18) / 42,840 = \$11.3/m^2$

Lower bound estimate =  $17,500 \times 4 / 42,840 = \$1.6/m^2$

*Benefits:*

According to Deng et al<sup>78</sup>, "Instrumentation of central chiller plants in local buildings is, in general, not adequate for carrying out accurate plant monitoring. Reliable transducers and metering equipment that are essential to properly maintain plant and to monitor performance are absent or of inadequate accuracy for temperature, pressure, water flow rate and electrical input (I, V and kW). Plants are operated with the energy performance unknown to building operators, if instrumentation is not available, or misleading information is presented due to poor accuracy". Reasons for poor instrumentation in chiller plants include lack of awareness by designers and installers and minimal investment in good instrumentation. With inadequate sensors and transducers many building management systems do not function satisfactorily and plant operators often change the operating mode from automatic to manual.

Provision of good metering and monitoring facilities are essential in order to allow building operators to audit and monitor energy use, and enhance energy efficient operation.

## 10.4 CREDITS UNDER WATER USE

### 5.1.1 Water Quality (2 credits)

Exclusions:	None.
Objective:	Ensure that the quality of potable water delivered to building users is satisfactory.
Pre-requisites:	Buildings shall be complied with the Waterworks Ordinance (Cap 102) and the Waterworks Regulations (Cap 102 Subsidiary Legislation), the Hong Kong Waterworks Standard Requirements for Plumbing Installation in Building, and relevant Water Supplies Department Circular Letters issued to Licensed Plumbers and Authorized Persons.
Credit requirement:	a) Fresh water plumbing: 1 credit where fresh water plumbing installations comply with the referenced good practice guides. b) Water quality survey: 1 credit for demonstrating that the quality of potable water meets the referenced drinking water quality standards at all points of use.

#### a) Fresh water plumbing

Assessment:	The Client shall submit a report by a suitably qualified person confirming that the plumbing installations comply with all requirements set down by the Water Supplies Department (WSD) that are applicable to the particular installations in the building, and that due account has been taken into account of the design, and future operation and maintenance requirements of the Code of Practice for the Prevention of Legionnaire
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<sup>78</sup> Deng S M, Burnett J. Performance Monitoring and Measurement for Central Air Conditioning Chiller Plants in Buildings in Hong Kong. HKIE Trans. Vol. 4. No. 1, pp 7-12.

Disease<sup>79</sup> and the Fresh Water Plumbing Quality Maintenance Recognition Scheme<sup>80</sup>, or equal equivalent guidance. Where it can be demonstrated that the plumbing system installations comply with the recommendations in the cited documents, or where equal of better solutions are provided, the credit shall be awarded.

**Cost Premium:**

<b>Office</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>
<b>Residential</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>

**Basis for Estimate:**

Prerequisites credit by compliance with the provisions of the Waterworks Regulations.

**b) Water quality survey**

Assessment: The Client shall provide details of the analysis of samples taken from a selection of potable water outlets used to supply human consumption. Sampling should be systematic, such as described in ISO 5667<sup>81</sup>, but as a minimum samples shall be taken at all the furthest point(s) of delivery from the storage tank, and shall include sampling for each water supply tank used in the building. If water quality at all sample points meets with the World Health Organization (WHO) Guidelines<sup>82</sup> the credit shall be awarded.

**Cost Premium:**

<b>Office</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>
<b>Residential</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>

**Basis for Estimate:**

This credit calls for extra maintenance care of the plumbing system within the building. The required standard is considered to be beyond and over the requirements imposed by the existing provisions of the Waterworks Regulations. Many approaches can be used, but one simple approach is to comply with the fresh water plumbing quality maintenance recognition scheme administered by the Water Services Department. A certificate will be awarded to recognize proper maintenance of the plumbing system inside a building if the following criteria have been met:

- i) the plumbing system is inspected at least once every three months by licensed plumbers or qualified building services surveyors or engineers and is found to be in good physical condition.
- ii) all defects identified in the inspections are promptly rectified by licensed plumbers or qualified persons.
- iii) the water tanks are cleaned at least once every three months.
- iv) water samples are taken in accordance with the recommended procedure and tested for items specified at least once a year and the test results comply with the acceptable limits of these water quality indicators.

Additional operating and maintenance costs but no additional initial costs will be incurred due to the compliance with the additional maintenance requirements on the fresh water plumbing system.

**Benefits:**

The above requirement can guarantee the quality of potable water is free from contamination and suitable for building users.

**5.2.1 Annual water Use (3 credits)**

<sup>79</sup> Prevention of Legionnaires' Disease Committee, Hong Kong Government. Code of Practice for the Prevention of Legionnaires' Disease in Hong Kong. <http://www.emsd.gov.hk/emsd/>

<sup>80</sup> Water Supplies Department. Circular Letter No. 4/2002. Fresh Water Plumbing Quality Maintenance Recognition Scheme. <http://www.info.gov.hk/wsd/en/html/pdf/cir/cir0402.pdf>

<sup>81</sup> ISO 5667-5: 1991. Water quality — Part 6: Sampling — Section 6.5 Guidance on sampling of drinking water and water used for food and beverage processing.

<sup>82</sup> World Health Organization. Guidelines for Drinking-water Quality. Vol. 1 - Recommendations 1993. [http://www.who.int/water\\_sanitation\\_health/dwq/gdwq2v1/en/index.html](http://www.who.int/water_sanitation_health/dwq/gdwq2v1/en/index.html)

Exclusions: None.

Objective: Reduce the consumption of fresh (potable) water through the application of water saving devices that has proven performance and reliability.

Pre-requisites: Compliance with relevant section of the Waterworks Ordinance.

Credit requirement: 1 credit for demonstrating that the use of water efficient devices leads to an estimated aggregate annual saving of 15%.  
2 credits for demonstrating an estimated annual saving of 25%.  
3 credits for demonstrating an estimated annual saving of 35%.

Assessment: Given the paucity of available data for Hong Kong and variability of circumstances for different buildings and uses, rather than being prescriptive, HK-BEAM seeks to provide flexibility in the assessment by allowing Clients to submit justification for the award of credits. The estimation of annual water saving shall be based on the following basic equations.

- o Fresh water use (in litres):
- o Flow devices = Frequency of use x duration (sec) x flow rate (litres/sec)
- o Flush/cycle devices = Frequency of use x capacity (litre)

The Client shall submit a report prepared by a suitably qualified person detailing the capacities (volume, flow-rate, etc) of water using equipment for both the assessed building and a similar 'benchmark' (zero credit) building, i.e., a building where water using devices and appliances are not deemed to be efficient in water use.

Justification for capacities of devices and equipment used in the benchmark building shall be provided by making reference to regulations, standards, guides and other publication published by various authorities (e.g. Water Supplies Department, Institute of Plumbing, etc). This would justify maximum capacities/flows allowed by regulations, or where devices not regarded as water efficient/saving are in general use.

Justification for the capacities used in the assessed building shall be in the form of specifications (manufacturers confirmed performance data) for the installed devices and equipment, taking into account any regulatory restrictions.

The estimated frequency of use for each device or equipment installed shall be justified by reference to appropriate published data or surveys conducted by the Client. The frequency of use shall be the same for the calculation for both the assessed building and the benchmark building. All assumptions as to the number and gender of users, duration and frequency of use, etc. shall be stated and used for both the baseline case and the assessed building. Where fresh water is used for flushing purposes it shall be included in the calculations.

The report shall include the following details:

- o type and number of each fresh water using device;
- o frequency, duration and/or water consumption per use, for each type;
- o estimated water used by each type of fixture;
- o sum of water volumes used for each device, use for cleaning, irrigation, etc;
- o defined number of days of use of the facilities (work days, school days, etc) to annualise water consumption;
- o any deduction in annual use of fresh water by using harvested or recycled water.

The submitted report shall contain two tables, one for the assessed building, and one for the benchmark building, with the following format.

Flow	Device/ equipment	Daily Uses	Volume	Users	Water Use
Flush/cycle	Device/ equipment	Daily Uses	Flow rate	Users	Water Use

- o Estimated total daily consumption (litres) – Assessed building and Benchmark building
- o Annual days of use
- o Annual water use less any recycled water
- o Estimated annual savings (litres) and percentage

In the table each type of water using device shall be listed and all data used shall be referenced to the source.

Confirmation of the award of credits shall take into account the appropriateness of the data used and the estimated percentage of fresh water saved.

**Cost Premium:**

<b>Office</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>
<b>Residential</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>

#### *Basis for Estimate:*

The additional costs are estimated with aid of the bills of quantities<sup>31,32</sup> and current price quotes for sanitary fitments.

#### *Office Building:*

CFA of the base building = 42,840m<sup>2</sup>

Range of additional cost for an infra-red sensor water tap = \$450 – 1,150

Total nos. of water taps = 171 – 587

Range of amount of water saving if infra-red sensor or spring type water tap was used = 31 to 69% (data from Daelyu Industry Co., Ltd, water saving depends on water pressure)

Since the majority of fresh water consumption is due to the usage of water taps in office buildings, 2 to 3 credits can be obtained by using these water saving devices.

Upper bound estimate =  $1,150 \times 587 / 42,840 = \underline{\$15.8/m^2}$

Lower bound estimate =  $450 \times 171 / 42,840 = \underline{\$1.8/m^2}$

#### *Residential Building:*

CFA of the base building = 36,750m<sup>2</sup>

Range of additional cost for providing a low-flow shower head = \$450 – 1,150

Total nos. of low flow shower heads = 799

66% total amount of water can be saved by using low flow shower head (data from Daelyu Industry Co., Ltd, water saving depends on water pressure)

Since the majority of fresh water that can be saved by using low-flow shower heads in residential buildings,

2 to 3 credits can be obtained by using these water saving devices.

Upper bound estimate =  $1,150 \times 799 / 36,750 = \$25.0/m^2$

Lower bound estimate =  $450 \times 799 / 36,750 = \$9.8/m^2$

#### *Basis for Cost Assumption*

Additional first costs will be incurred due to installation of the following sanitary fitments:

- Waterless urinals
- Spring type faucets
- Faucets with infra-red sensors
- Dual flush water closets
- Low-flow shower heads
- Ultra low flush water closets

*Basis for Estimate:* Installing a control system for sanitary fitments can help conserve water consumption. Infra-red sensors for water taps is claim to be able to reduce water consumption by up to 50%. Dual flush and valveless cistern water closets are also claimed to be able to save up to 16% of their daily flushing water consumption. The market price of such water saving devices could be up to \$1,150.

It is no cost implication for monitoring water leakage within the fresh water distribution systems, since which is strictly governed by the Waterworks Regulations. Additional costs if monitoring of water flow at main supply branches for audit purpose could be contributed up to HK\$2 – 10/m<sup>2</sup> for office and residential buildings respectively.

*Benefit:*

*Office Building:*

Annual saving of fresh water bills could be up to HK\$1.8/m<sup>2</sup> and HK\$20.0/m<sup>2</sup> for office and residential buildings respectively if water saving fitments were used.

CFA of the base building = 42,840 m<sup>2</sup>

Total no. of occupants in the base building = 4,760

Average estimated percentage of water saving by using infra-red sensor water taps = (31 + 69) / 2 = 50 (with reference to data provided by Daelyu Industry Co., Ltd)

Therefore, with aid of the plumbing engineering services design guide 2002 & technical calculations shown in Xie Shubo et al 2002,

Daily consumption of water tap potable water = 4760 x 15 L = 71,400 L

Daily water saving by using infra-red sensor water taps = 71,400 L x 0.5 = 35,700 L (35.7 m<sup>3</sup>)

Annual fresh water consumption = 35.7 x 365 = 13,030.5 m<sup>3</sup>

Unit Charge on non-residential water consumption = \$ 5.78/m<sup>3</sup> (refer to the website of Water Authority in 2006)

Total annual water bill for fresh water consumption and sewage: 13,030.5 x \$ 5.78 = \$ 75,316 (refer to Water Authority 2006)

Annual cost saving per construction floor area (CFA) = \$ 75,316 / 42,840 = \$ 1.8

*Residential Building:*

CFA of the base building = 36,750 m<sup>2</sup>

Total no. of occupants in the base building = 2431

Average estimated percentage of water saving by using low-flow shower head = 66 (with reference to data provided by Daelyu Industry Co., Ltd)

Therefore, by plumbing engineering services design guide 2002 & technical calculations in Xie Shubo et al 2002,

Daily consumption of shower potable water = 2,431 x 300 L = 729,300 L

Daily water saving by low-flow shower heads = 729,300 L x 0.66 = 481,3 L (i.e. 481.3 m<sup>3</sup>)

Annual fresh water consumption = 481,3 x 365 = 175,675 m<sup>3</sup>

Unit charge on residential water use = \$ 4.16/m<sup>3</sup> (refer to the website of Water Authority in 2006)

Total annual water bill for fresh water consumption and sewage: 175,675 x \$ 4.16 = \$ 730,800 (with reference to to Water Authority 2006)

Annual cost saving per construction floor area (CFA) per year = \$ 730,800 / 36,750 = \$ 20.0

**5.2.2 Monitoring and Control (2 credits)**

Exclusions:	None.
Objective:	Reduce wastage of fresh water and allow for auditing of water use.
Pre-requisites:	Compliance with Waterworks Regulation Chapter 102A Regulation 32.
Credit requirement:	1 credit for installations of any two features 2 credits for installation of all three features: <ul style="list-style-type: none"><li>o automatic shut-off of devices for the purposes of water conservation;</li><li>o monitoring water leakage within the fresh water distribution system;</li><li>o monitoring of water flow at main supply branches for audit purposes.</li></ul>
Assessment:	The assessment will seek to establish if means are in place that can effectively limit the wastage of water by shutting off fixtures automatically when left open, and the

ability to detect water leaks in buried pipework Various approaches are available and HK-BEAM is not intended to be prescriptive as to which should be used. The Client shall submit a report prepared by a suitably qualified person that details:

- o devices installed to reduce the potential wastage of water due to unnecessary operation of taps, etc;
- o details of any system for monitoring water leaks within internal plumbing installations; and
- o evidence to demonstrate that water use is capable of being fully monitored by the building operator.

The provision of water flow measuring devices to measure consumption by the Owner/Operator for each of the major water-using sectors (excluding the provisions required for metering individual users) shall be identified by a review of drawings and specifications, or other evidence provided by the Client. Where it can be demonstrated that the provisions of equipment meets the intent, the credit(s) shall be awarded.

**Cost Premium:**

<b>Office</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>
<b>Residential</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>

**Basis for Estimate:**

The additional costs are estimated with aid of the bills of quantities<sup>31,32</sup> and current price quotes for sanitary fitments.

**Office Building:**

Requirement 1: Additional cost for automatic shut-off devices = \$1.8 to 15.8/m<sup>2</sup> (refer to 5.2.1)

Requirement 2: Since individual water meter had been provided for each office unit and no effective leakage detection system other than metering for fresh water distribution system, it is considered to have no cost implication (with reference to the website of Water Authority in 2006)

Requirement 3: Additional cost for providing a water flow meter at main stream = \$10,000 or \$0.2/m<sup>2</sup> (by current price quotes)

Upper bound estimate (1 credit) = \$15.8/m<sup>2</sup>

Lower bound estimate (1 credit) = \$0.2/m<sup>2</sup>

Upper bound estimate (2 credits) = 15.8 + 0.2 = \$16.0/m<sup>2</sup>

Lower bound estimate (2 credits) = 1.8 + 0.2 = \$2.0/m<sup>2</sup>

**Residential Building:**

Requirement 1: Additional cost for automatic shut-off devices = \$9.8 to 25.0/m<sup>2</sup> (refer to 5.2.1)

Requirement 2: Since individual water meter had been provided for each domestic unit and no effective leakage detection system other than metering for fresh water distribution system, it is considered to have no cost implication (with reference to the website of Water Authority in 2006)

Requirement 3: Additional cost for providing a water flow meter at main stream = \$10,000 or \$0.3/m<sup>2</sup> (by current price quote)

Upper bound estimate (1 credit) = \$25.0/m<sup>2</sup>

Lower bound estimate (1 credit) = \$0.3/m<sup>2</sup>

Upper bound estimate (2 credits) = 25.0 + 0.3 = \$25.3/m<sup>2</sup>

Lower bound estimate (2 credits) = 9.8 + 0.3 = \$10.1/m<sup>2</sup>

**Benefit:**

Detection of water leaks in services pipework also presents an opportunity to save water, and perhaps more importantly, reduce the potential for structural damages as well as the creation of unhygienic conditions.



### 5.2.3 Water Efficient Irrigation (1 credit)

- Exclusions: Where soft landscaping and planting coverage is less than 50% of the area of the building footprint.
- Objective: Reduce the reliance on potable water for irrigation.
- Credit requirement: 1 credit for the use of an irrigation system which does not require the use of municipal fresh water after a period of establishment is complete.
- Assessment: The Client shall provide a report prepared by a suitably qualified person describing the soft landscaping design, species of plants, etc, and confirm that, after a period of establishment of the plants and vegetation is complete, irrigation will not require the use of municipal potable (fresh) water supply.

*Cost Premium:*

<b>Office</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>
<b>Residential</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>

*Basis for Estimate:*

The decisions on the selection of trees and plantings are mostly rested on developers and architects. Given a large varieties of species of trees and plants, it is difficult to come up a reasonable cost estimate.

The simplest and inexpensive ways of fulfilling the requirements of credit is to use local and / or adapted landscape plantings that can eliminate the need for a permanent irrigation system.

*Benefits:*

It can lower fresh water consumption and water bills.

### 5.2.4 Water Recycling (1 credit + 2 bonus credits)

- Exclusions: None.
- Objective: Encourage harvesting of rainwater and recycling of grey water in order to reduce consumption of fresh water.
- Pre-requisites: Compliance with the water quality standards appropriate to the use of the recycled water.
- Credit requirement: a) Harvested rainwater: 1 credit for harvesting of rainwater which will lead to a reduction of 10% or more in the consumption of fresh water.  
 b) Provisions for grey water recycling: 1 credit for the provision of plumbing and drainage systems that provide for separation of grey water from black water.  
 c) Recycled water: 1 additional credit where recycled grey water will lead to a reduction of 10% or more in the consumption of fresh water.
- Assessment: Harvested and/or recycled water shall satisfy the water quality requirements for the intended reuse, e.g., cleaning, irrigation, use in heat rejection systems, toilet flushing, etc.  
 Where there is provision for separating grey and black water the credit shall be awarded.

**a) Harvesting of rainwater**

- Assessment: The Client shall provide a report detailing the system or systems installed for the purpose of harvesting rainwater, the details of the expectations in respect of savings in the consumption of fresh water, and shall demonstrate that the rainwater is of a quality appropriate to the end use. Where it can be demonstrated that the expected savings in fresh water use will be 10% or more, either based on baseline building estimates (see Section 5.2.1) or any other appropriate estimation, the credit shall be awarded.

*Cost Premium:*

<b>Office</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>
<b>Residential</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>

*Basis for Estimate:*

Rain water collection for interior uses generally incurs a high initial cost due to the requirement of

additional storage tank and piping system for water distribution. With additional components and systems, higher operation and maintenance costs will also be incurred. Based on price quoted by contractor, the additional first cost was estimated to around HK\$100 per m<sup>2</sup> of landscape area, which amount up to HK\$1.6 and 4.3/m<sup>2</sup> for office and residential buildings respectively.

**Benefits:**

**Office Building:**

CFA of the base building = 42,840m<sup>2</sup>

Saving in annual water bill by installing a rain water recycling system = 10,681 / 42,840 = \$0.2/m<sup>2</sup> (by Yang et al. 2006)

**Residential Building:**

CFA of the base building = 36,750m<sup>2</sup>

Saving in annual water bill by installing a rain water recycling system = 10,681 / 36,750 = \$0.3/m<sup>2</sup> (by Yang et al. 2006)

**b) Provisions for grey water recycling**

Assessment: c) Recycled water  
 The Client shall provide a report detailing system or systems installed for the purpose of recycling grey water, details of the expectations in respect of savings in the consumption of potable water and shall demonstrate that the treated grey water is of a quality appropriate to the end use. Where it can be demonstrated that the expected savings in fresh water use will be 10% or more, either based on baseline building estimates (see Section 5.2.1) or any other appropriate estimation, the credit shall be awarded.

**Cost Premium:**

<b>Office</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>
<b>Residential</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>

**Basis for Estimate:**

The cost estimates were derived based on the unit prices and the estimated additional amount of pipework that was used for separation of grey water from black water. The additional costs could be up to HK\$4 – 19/m<sup>2</sup> for office and residential buildings respectively.

**Office Building:**

CFA of the base building = 42,840m<sup>2</sup>

Additional length of uPVC pipe for separating grey water from black water = 532 – 1,064m

Unit price of uPVC pipe = \$320 (based on cost estimates given by quantity surveyors)

Upper bound estimate = 320 x 1064 / 42,840 = \$7.9/m<sup>2</sup>

Lower bound estimate = 320 x 532 / 42,840 = \$4.0/m<sup>2</sup>

**Residential Building:**

CFA of the base building = 36,750m<sup>2</sup>

Additional length of uPVC pipe for separating grey water from black water = 2,200 – 2,220m

Unit price of uPVC pipe = \$320 (based on cost estimates given by quantity surveyors)

Upper bound estimate = 320 x 2220 / 36,750 = \$19.3/m<sup>2</sup>

Lower bound estimate = 320 x 2200 / 36,750 = \$19.2/m<sup>2</sup>

**c) Recycled water**

Assessment: The Client shall provide a report detailing system or systems installed for the purpose of recycling grey water, details of the expectations in respect of savings in the consumption of potable water and shall demonstrate that the treated grey water is of a quality appropriate to the end use. Where it can be demonstrated that the expected savings in fresh water use will be 10% or more, either based on baseline building estimates (see Section 5.2.1) or any other appropriate estimation, the credit shall be

awarded.

**Cost Premium:**

<b>Office</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>
<b>Residential</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>

Grey water recycling for interior uses generally incurs a high initial cost due to the requirement of additional grey water treatment plant and piping system for water distribution. With additional components and systems, higher operation and maintenance costs will also be incurred. Based on price quoted by contractor, the additional first cost will be higher than the rain water recycling system for the more expense on the water treatment facilities.

**Benefits:**

It may lower fresh water consumption and water bills.

**5.2.5 Water Efficient Facilities & Appliances (2 credits)**

- Exclusions: Buildings in which facilities and/or appliances are not installed by the developer.
- Objectives: Encourage the wider use of water efficient facilities and appliances.
- Pre-requisites: None.
- Credit requirement: a) Water efficient facilities (pools, spas, fountains, etc): 1 credit for demonstrating that installed water facilities are more efficient than otherwise.  
b) Water efficient appliances: 1 credit for installing water efficient appliances that are at least 20% more efficient than otherwise.

**a) Water efficient facilities**

Assessment: The Client shall provide details of all the facilities installed on site or in the building and evidence as to how fresh water use is reduced through design innovations. Where it can be demonstrated that water savings for pools, spas and other water features is 20% or better than the case when water conservation measures are not included, the credit shall be awarded.

**Cost Premium:**

<b>Office</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>
<b>Residential</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>

**Basis for Estimate:**

Water re-circulating systems are normally applied into water efficient facilities i.e. pools, spas, and fountains, etc. Insignificant cost implication incurred for the negligible loss of water or water consumption due to evaporation or soil absorption.

**b) Water efficient appliances**

Assessment: The Client shall provide details of all the appliances installed in the building and evidence as to the water use ratings of each type and size of appliance. Where it can be demonstrated that water use efficiency is high, typically 20% better than appliances not marketed as water efficient, the credit shall be awarded.

**Cost Premium:**

<b>Office</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>
<b>Residential</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>

**Basis for Estimate:**

Model by 5.2.1

**Benefits:**

It can lower fresh water consumption and water bills.

### 5.3.1 Effluent Discharge to Foul Sewers (1 credit)

Exclusions: None.

Objective: Reduce the volumes of sewage discharged from buildings thereby reducing burdens on municipal sewage supply and treatment facilities.

Pre-requisites: Compliance with the Water Pollution Control Ordinance, and the Building (Standards of sanitary fitments, plumbing, drainage works and latrines) Regulations Chapter 123 Regulation 17.

Credit requirement: 1 credit for demonstrating a reduction in annual sewage volumes by 25% or more.

Assessment: The Client shall submit a report prepared by a suitably qualified person detailing the capacities (volume, flow-rate, etc) of water using equipment for both the assessed building and a similar 'benchmark' (zero credit) building, i.e., a building where flushing devices and appliances are not deemed to be efficient in water use.

Justification for capacities of devices and equipment used in the benchmark building shall be provided by making reference to regulations, standards, guides and other publication published by various authorities (e.g. Water Supplies Department, Institute of Plumbing, etc). This would justify maximum capacities/flows allowed by regulations, or where devices not regarded as water efficient/saving are in general use. Justification for the capacities used in the assessed building shall be in the form of specifications (manufacturers confirmed performance data) for the installed devices and equipment, taking into account regulatory restrictions.

The estimated frequency of use for each device or equipment installed shall be justified by reference to appropriate published data or surveys conducted by the Client. The frequency of use shall be the same for the calculation for both the assessed building and the benchmark building. All assumptions as to the number and gender of users, duration and frequency of use, etc. shall be stated and used for both the baseline case and the assessed building. The report shall follow a format that details:

- o type and number of devices using flushing water;
- o frequency, duration and water consumption per use for each;
- o sum of water volumes used for each for male and female users;
- o estimated daily flushing water use;
- o defined number of days of use of the facilities (work days, school days, etc) to annualise effluent discharge;
- o any deduction for annual use of recycled water.

The submitted report shall contain two tables, one for the assessed building, and one for the benchmark building, with the following format.

Flow	Device/equipment	Daily Uses	Volume	Users	Flushing Water Use
Flush/cycle	Device/equipment	Daily Uses	Flow rate	Users	Flushing Water Use

Estimated total daily consumption (litres) – Assessed building and Benchmark building

- o Annual days of use
- o Annual flushing water use less any recycled water
- o Estimated annual reduction in flushing water (litres) and percentage

In the table each type of device shall be listed and all data used shall be referenced to the source.

Confirmation of the award of credit shall take into account the appropriateness of the data used and the estimated percentage of effluent reduction.

#### Cost Premium:

<b>Office</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>
<b>Residential</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>

#### Basis for Estimate:

Under the current Waterworks Regulations<sup>83</sup>, flushing cisterns shall be valveless symphonic type and the capacity of cisterns decreased from 9 litres to 7.5 litres, which equivalent to a 17% reduction in discharge volume of water closets. In addition with other water saving appliance, i.e.

<sup>83</sup> Part V, Flushing Apparatus. Waterworks Regulation, Chapter 102, Subsidiary Legislation, [http://www.wsd.gov.hk/en/html/info\\_publ/regulate.htm](http://www.wsd.gov.hk/en/html/info_publ/regulate.htm)

water taps and urinal bowls with infra-red sensors, it is no doubt to obtain a or more 25% reduction in sewage discharge volume. Since the water closets with low capacity cisterns have about the same price in current market, this credit has insignificant cost impact.

**Benefits:**

It helps reduce the sewage charge for building users.

## 10.5 CREDITS UNDER IEQ

Credits under this category include those that provide for comfort and health, as well as those that provide for improved building amenity.

Credits common to both the Office Building and the Residential Building:

Credits that apply only to the Office Building:

Credits apply only to the Residential Building:

Bonus credits that are not included in the overall cost premium:

The following credits are excluded from the cost-benefit analysis as they are not applicable to the baseline building designs used in this study:

6.3.4 IAQ in Car Parks

6.3.5 IAQ in Public Transport Interchanges

### 6.1.1 Fire Safety (2 credits)

Exclusions:	None
Objective:	Ensure that the designs of fire safety systems are integrated with other building systems and to provide for enhanced fire safety management.
Pre-requisites:	All fire services provisions (both passive construction designs and active protection systems) shall comply with the Fire Services Ordinance and the Building Ordinance, covering the means of escape <sup>84</sup> , access for fire fighting <sup>85</sup> , and fire resistant construction <sup>86</sup> .
Credit requirement:	a) Design integration: 1 credit for demonstrating design integration between fire services systems, and non-fire services systems. b) Fire safety manual: 1 credit for provision of a fire safety manual based on a fire risk assessment for the building.

#### a) Design integration

Assessment	<p>The Client shall submit a report detailing the provision of passive and active fire safety systems provided for the building:</p> <ul style="list-style-type: none"><li>o highlighting compliance with the relevant regulations;</li><li>o interaction with non-fire systems in the event of an alarm or fire event;</li><li>o interaction with security and communications systems that will support safe egress of occupants in the event of a fire.</li></ul> <p>The credit shall be awarded where it can be demonstrated that the following aspects of whole building performance and fire safety design have been taken into account:</p> <ul style="list-style-type: none"><li>o the stability of the structure will be maintained under all assumed uses of the building (i.e. adequate fire resistance period);</li><li>o integration between security and fire safety;</li><li>o the extent that any provisions for natural ventilation, or the degree of air-tightness,</li></ul>
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<sup>84</sup> Building Authority. The Provision of Means of Escape in Case of Fire 1996. [http://www.info.gov.hk/bd/english/documents/code/e\\_moe.htm](http://www.info.gov.hk/bd/english/documents/code/e_moe.htm)

<sup>85</sup> Building Authority. Code of Practice for the Provision of Means of Access for Fire Fighting and Rescue Purposes. 1995. [http://www.info.gov.hk/bd/english/documents/code/moa\\_code1995.PDF](http://www.info.gov.hk/bd/english/documents/code/moa_code1995.PDF)

<sup>86</sup> Building Authority. Fire Resisting Construction. 1996. [http://www.info.gov.hk/bd/english/documents/code/e\\_frc.htm](http://www.info.gov.hk/bd/english/documents/code/e_frc.htm)

- will influence the movement of smoke;
- the interactions between air handling and smoke movement;
- air quality in refuges during a fire event;
- adequacy of emergency warning systems in the acoustical environment;
- signage and way finding in the event of poor visibility due to smoke, including provisions for the visibility impaired and disabled;
- door opening where pressurisation systems are employed;
- durability of fire safety systems, equipment and components.

*Cost premium:*

<b>Office</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>
<b>Residential</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>

***b) Fire safety manual***

- Assessment: The Client shall submit a fire safety manual, written in appropriate language for the end-user, which describes the specific aspects of fire safety management for the building. The manual shall be based on risk assessment, and shall include the following:
- a set of relevant documents (standards, codes, guides, etc) covering fire safety, fire safety system design, and on-going certification requirements;
  - relevant details of building design, construction and layout;
  - details of hydrants, access for fire appliances, exits from the building, exterior lighting, hazards, etc;
  - location of significant ignition sources;
  - presence and influence of inter-spatial openings;
  - characteristic responses of occupants to fire emergencies;
  - techniques of fire detection employed;
  - communications and warnings systems;
  - provisions for smoke management;
  - emergency lighting, signs and notices for way finding;
  - provisions for fire fighting by building operators and users; and
  - operation and maintenance requirements for all systems.

*Cost Premiums:*

<b>Office</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>
<b>Residential</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>

*Basis for Estimate:*

Essential provisions and facilities for fire safety are governed by regulations. However, fire safety systems are often treated as an isolated set of technical systems that have limited interaction with other systems. Design of fire services installations need to take into account the important links between systems, and provisions for security and communications systems serving a building. Operation and maintenance manuals should make it clear to building operators how systems interact in the event of an alarm or fire situation. An aspect of relationships between FSI and the normal operation of a building is a fire risk assessment (which for workplaces is matter covered by legislation throughout Europe).

The cost premium (if any) is a 'soft cost' for ensuring design integration based on risk assessment, plus a cost of providing a section in the building's O&M manual or a separate fire safety manual in a format and language that is easily understood by facility management staff. Cost and effort for large commercial buildings will be higher than for residential buildings but similar in proportion to total fire services design costs.

*Benefits:*

Enhancing design and management aspects of fire safety will no doubt reduce the risks of injury and damage. Given that safety and security are important considerations for building users the enhancements could enhance sales or leasing.

**6.1.2 Electromagnetic Compatibility (1 credit)**

Exclusions: None.

- Objective: Reduce occupant exposure and the potential interference of susceptible devices to interference from power distribution equipment.
- Credit requirement: 1 credit for designs that meet the electromagnetic compatibility requirements in respect of power quality and low frequency magnetic fields.
- Assessment: The Client shall submit a report prepared by a suitably qualified person detailing the design of the electrical distribution system in the building. The report submitted shall demonstrate that the designs of the installations are such as to avoid excessive external magnetic fields, and the selection of power consuming equipment is such as to mitigate the impact of non-linear loads. As a minimum the report shall confirm compliance with:
- Section 6 of the Code of Practice for Energy Efficiency of Electrical Installations<sup>87</sup> in respect of power quality; and
  - the occupational exposure in the ELF frequency range from 1 to 300 Hz not exceed the ceiling value given by:  $B_{TVL} = 60/f$ ; where  $f$  is the frequency in Hz, and  $B_{TVL}$  is the magnetic flux density in millitesla (mT)<sup>88</sup>.

#### Cost Premiums:

<b>Office</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>
<b>Residential</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>

#### Basis for Estimate:

Electromagnetic compatibility or, in another sense, electromagnetic interference (EMI), is major issues in respect of safe and reliable operation of sensitive equipment in buildings<sup>89</sup>. Problems caused by harmonics, which affects both power quality, and power factor, are not uncommon in buildings in Hong Kong<sup>90</sup>. The tendency is to seek solutions to any problems through power conditioning, rather than treating the problems at sources, through the proper selection of equipment.

Interest in magnetic fields has been stimulated in recent years by concern over the physiological effects they may have on humans and animals and the deleterious effects they have on the performance of some electrical equipment, particularly video display units. Investigations have yielded results which are presented in an IEC report<sup>91</sup> as reference values.

The cost premium depends on the design approach to reducing such problems. EMI should be addressed by proper design of electrical systems to avoid generation of excessive external fields. Harmonics can be reduced by proper selection of equipment, e.g. using lighting systems controlled by electronic ballasts, may result in higher costs, but can provide other benefits, such as improved lighting quality. Alternatively, compliance could be achieved by applying harmonic filtering devices at appropriate locations, which cost little compared to the whole of the electrical installations in a building.

#### Office Building:

CFA of the base building = 42,840m<sup>2</sup>

Cost required for conducting an electromagnetic test = \$30,000 – 50,000

Upper bound estimate = 50,000 / 42,840 = \$1.2/m<sup>2</sup>

Lower bound estimate = 30,000 / 42,840 = \$0.7/m<sup>2</sup>

<sup>87</sup> Electrical and Mechanical Services Department. Code of Practice for Energy Efficiency of Electrical Installations. [http://www.emsd.gov.hk/emsd/e\\_download/pee/eleccop.pdf](http://www.emsd.gov.hk/emsd/e_download/pee/eleccop.pdf)

<sup>88</sup> American Conference of Government Industrial Hygienists. Threshold Limit Values for Chemical Substances and Physical Agents & Biological Exposure Indices.

<sup>89</sup> Wu M K T. Interference Problems of Fluorescent Lamps Operating on High Frequency Electronic Ballasts with Infrared Remote Control Equipment and Infrared Simultaneous Interpretation System. Electrical and Mechanical Services Department. August 2003. [http://www.emsd.gov.hk/emsd/e\\_download/pee/infrared\\_interference\\_emsdweb.pdf](http://www.emsd.gov.hk/emsd/e_download/pee/infrared_interference_emsdweb.pdf)

<sup>90</sup> Wu M K T. Standards of Power Quality with reference to the Code of Practice for Energy Efficiency of Electrical Installations. Energy Efficiency Office, Electrical & Mechanical Services Department. September 2003. [http://www.emsd.gov.hk/emsd/e\\_download/pee/EEC&harmonic.pdf](http://www.emsd.gov.hk/emsd/e_download/pee/EEC&harmonic.pdf)

<sup>91</sup> International Electrotechnical Commission. Technical Report 6100-2-7. Electromagnetic compatibility (EMC) – Part 2: Environment – Section 7: Low frequency magnetic fields in various environments. 1998.

### *Residential Building:*

CFA of the base building = 36,750m<sup>2</sup>

Cost of conducting an electromagnetic test for the building = \$30,000 – 40,000

Upper bound estimate = 40,000 / 36,750 = \$1.1/m<sup>2</sup>

Lower bound estimate = 30,000 / 36,750 = \$0.8/m<sup>2</sup>

### *Benefits:*

There have been incidences in both office and residential buildings where EMI and harmonics that have caused malfunction of equipment and IT systems or raised concerns amongst occupants. Given the concerns an assurance that such problems have been minimised such enhancements could enhance sales or leasing.

### **6.1.3 Security (1 credit)**

Exclusions:	None.
Objective:	Engender a feeling of well-being amongst building users.
Pre-requisites	Burglar alarm systems shall comply with the Noise Control Ordinance.
Credit requirement:	1 credit for scoring at least 75% of the applicable security measures and facilities for the building.
Assessment:	<p>The Client shall submit a report prepared by a suitably qualified person which includes: a completed checklist of the security measures and facilities provided, justification for each checked item, details of the physical security systems provided, and a detailed security manual explaining how the physical provisions (hardware) integrates with the management system (software) for the building.</p> <p>Where 75% compliance of applicable items is demonstrated the credit shall be awarded. Alternatively, the Client may provide detailed rationale and arguments to demonstrate that security systems are integrated and an enhanced standard of security can be provided.</p> <p>Note: the criteria are listed under Site perimeter controls, Surveillance, Building Security, Site/Building Layout</p>

### *Cost Premium:*

<b>Office</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>
<b>Residential</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>

### *Basis for Estimate:*

Contracted-out or in-house security management in better quality Hong Kong buildings is likely to satisfy the applicable security measures and facilities for the buildings.

### *Benefits:*

It can provide the safety environment for the building users.

### **6.2.1 Plumbing & Drainage (1 credit)**

Exclusions:	None.
Objective:	Reduce the potential for contamination of plumbing and drainage systems, the ability of systems to carry infections, and the likelihood of odours.
Pre-requisites:	Compliance with the provisions of the Building (Standards of Sanitary Fitments, Plumbing, Drainage Works and Latrines) Regulations.
Credit requirement:	1 credit for designs that reduce the potential for transmission of harmful bacteria viruses, and odours.
Assessment:	<p>The Client shall submit details in the form of drawings and specifications for the plumbing and drainage systems, and confirmation that installation of the systems was carried out according to the specifications. A summary report shall be submitted highlighting where appropriate means have been included to allow for safe and hygienic operation over the expected lifespan of the systems and components. The 'appropriate means' shall include, but is not limited to, reference to the following:</p>



- adequacy of flushing water supply to meet the pattern of demand;
- design of drainage stacks of adequate capacity for peak loading;
- venting of stacks;
- access to pipework and ducts for maintenance purposes;
- installation of buried pipework that pays attention to leaks at joints, seals, etc. for the expected life of the installation;
- design of floor drains; and
- maintenance of water seals.

Where it can be demonstrated that the design and installation of the plumbing and drainage systems, and any other provisions that can impact on performance (e.g. ventilation of bathrooms) have been given due attention, e.g. comply with the recommended practices promoted by various authorities, then the credit shall be awarded.

**Cost Premium:**

<b>Office</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>
<b>Residential</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>

**Basis for Estimate:**

Prerequisites credit by compliance with the provisions of the Building and Waterworks Regulations.

**Benefits:**

It can reduce the potential for contamination of plumbing and drainage systems, the ability of systems to carry infections, and the likelihood of odours.

**6.2.2 Biological Contamination (1 credit)**

- Exclusions: Residential buildings.
- Objective: Ensure that the design, installation and facilities for operation and maintenance of air conditioning systems, and water systems and features, are such as to reduce the risk of biological contamination.
- Credit requirement: 1 credit for complying with the recommendations given in the Code of Practice - Prevention of Legionnaires Disease, in respect of air-conditioning and ventilation systems, and water systems.
- Assessment: The Client shall submit a report prepared by a suitably qualified person detailing how the design and installation of the air-conditioning and ventilation systems and equipment meet with the requirements and recommendation contained in the Code of Practice - Prevention of Legionnaires Disease [92], or at least equal equivalent code. The report shall also detail how water supply, particularly hot water supply, and water use in features such as spas, fountains, etc., are designed and installed in compliance with the Code or Practice.

**Cost Premium:**

<b>Office</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>
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**Basis for Estimate:**

Similar to credit 2.3.4

**Benefit:**

Similar to credit 2.3.4

<sup>92</sup> Prevention of Legionnaires' Disease Committee, Electrical and Mechanical Services Department, Hong Kong Government. Code of Practice for the Prevention of Legionnaires' Disease in Hong Kong. 2000. [http://www.emsd.gov.hk/emsd/e\\_download/pps/code.doc](http://www.emsd.gov.hk/emsd/e_download/pps/code.doc)

### 6.2.3 Waste Disposal Facilities (1 credit)

Exclusions:	None.
Objective:	Ensure that the design, installation and facilities waste disposal and recycling are such as to reduce the risk of odours entering occupied areas or public areas.
Pre-requisites:	Compliance with the Building (Refuse Storage Chambers and Material Recovery Chambers and Refuse Chutes) Regulations.
Credit requirement:	1 credit for the provision of a hygienic refuse collection system.
Assessment:	<p>The Client shall submit details of the refuse collection system to demonstrate that refuse is disposed of in an hygienic manner and prevents any significantly discernable odours from entering occupied areas or public areas in or immediately adjacent to the building development.</p> <p>The system shall comply with those recommendations contained in PNAP 98<sup>93</sup> in respect of refuse storage and recovery chambers appropriate to the given circumstances.</p> <p>The provision of a purpose designed automated/mechanical system for waste disposal is deemed to meet the requirements.</p>

#### Cost Premium:

<b>Office</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>
<b>Residential</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>

#### Basis for Estimate:

The objective of this credit, which is substantially different from that of 3.3.3, is to ensure that the design, installation and facilities waste disposal and recycling are such as to reduce the risk of odours entering occupied areas or public areas. PNAP 98 has made a number of recommendations that are able to meet the requirement of this credit. A single air purifier may be installed before the final discharge into the atmosphere if a centralized ventilation system is adopted. Alternatively where there is no particular odour problem a mechanical fan coupled with a particulate filter at each RS &MRR/MRC may be considered. Air purifying devices such as 'Chemical Air Scrubber', 'Bio-oxygen Generator', 'Photo-oxidation Generator' or other appropriate devices should be provided with a RS&MRC.

#### Office Building:

CFA of the base building = 42,840m<sup>2</sup>

Cost of providing air purifying devices = \$ 150,000 – 200,000 (quoted from experienced contractor)

Upper bound estimate = 200,000 / 42,840 = \$4.7/m<sup>2</sup>

Lower bound estimate = 150,000 / 42,840 = \$3.5/m<sup>2</sup>

#### Residential Building:

CFA of the base building = 36,750m<sup>2</sup>

Cost of providing air purifying devices = \$ 400,000 – 500,000 (quoted from experienced contractor)

Upper bound estimate = 500,000 / 36,750 = \$13.6/m<sup>2</sup>

Lower bound estimate = 400,000 / 36,750 = \$10.9/m<sup>2</sup>

#### Benefits:

Provide a healthy environment for building users so as to reduce the rate of absenteeism of the employee workers, and reduce the risk and liability of lawsuits caused by poor indoor air quality.

### 6.3.1 Construction IAQ Management (2 credits)

Exclusions: Residential and similar buildings not provided with central air-conditioning and

<sup>93</sup> Buildings Department. Practice Note for Authorized Persons and Registered Structural Engineers, PNAP 98. Refuse Storage and Collection Building (Refuse Storage and Material Recovery Chambers and Refuse Chutes) Regulations. <http://www.info.gov.hk/bd/english/documents/pnap/Pnap098.pdf>

ventilation systems.

Objective: Ensure that building ventilation systems are not contaminated as a result of residuals left over from construction activities.

Credit requirement: a) Construction IAQ management: 1 credit for implementing a Construction IAQ Management Plan.  
b) Filter replacement and flush-out: 1 credit for:  
o a building 'flush out' or 'bake out'; and  
o replacement of all filters prior to occupancy.

**a) Construction IAQ management**

Assessment: To demonstrate compliance the Client shall submit a report prepared by a suitably qualified person documenting effective implementation of a Construction IAQ Management Plan appropriate to the scale and extent of the development including, but not limited to, the following:  
o a copy of the Plan;  
o evidence of measures showing protection of ducts, on-site storage or protection of installed absorptive materials, etc;  
o checklists, worksheets, notifications, deficiencies, resolutions, etc., related to construction IAQ issues;  
o documentation that demonstrates implementation of construction IAQ management measures during construction;  
o details of filtration media used during construction and installed immediately prior to occupancy; and  
o documentation for duct cleaning and testing.  
Where due attention has been paid to construction IAQ management as detailed in the check-list below, the credit shall be awarded.

*Cost Premium:*

Office	U	0	0+	L	M	H
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*Basis for Estimate:*

Measures and documentation for IAQ lead an insignificant cost implication.

**b) Filter replacement and flush out**

Assessment: The Client shall submit a report prepared by a suitably qualified person detailing the technical information for the filtration media used during construction and installed immediately prior to occupancy. The report shall also detail building flush-out procedures including actual dates of the flush-out.  
Where it can be demonstrated that filtration media used had a Minimum Efficiency Reporting Value (MERV) of 13 as determined by ANSI/ASHRAE 52.2-1999(94) or equivalent performance specification, and a minimum one-week building flush-out with new filtration media at 50% outside air was carried out after construction ended and prior to occupancy, the credit shall be awarded.

*Cost Premium*

Office	U	0	0+	L	M	H
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*Basis for Estimate:*

Nowadays, it is regarded as a common practice in construction industry. Thus, no additional cost will be incurred.

*Benefit:*

It can provide a healthy environment for building users so as to reduce absenteeism of the workers occupants, and reduce the risk and liability of lawsuits caused by poor indoor air quality.

<sup>94</sup> American Society of Heating, Refrigerating and Air-conditioning Engineers. ANSI/ASHRAE Standard 52.2-1999. Method of Testing General Ventilation Air-cleaning Devices for Removal Efficiency by Particle Size. Atlanta, 1999. www.ashrae.org.

A study in Singapore conducted by Kosonen and Tan<sup>95</sup> revealed that there is a productivity gain of about 0.5 to 2% if using better ventilation system, i.e. displacement ventilation.

### 6.3.2 Outdoor Sources of Air Pollution (4 credits)

- Exclusions:** None.
- Objective:** Demonstrate that airborne contaminants from outside sources will not give rise to unacceptable levels of indoor air pollution in normally occupied spaces.
- Credit requirement:**
- a) Carbon monoxide (CO); 1 credit for demonstrating compliance with appropriate criteria for CO.
  - b) Nitrogen dioxide (NO<sub>2</sub>); 1 credit for demonstrating compliance with the appropriate criteria for NO<sub>2</sub>.
  - c) Ozone (O<sub>3</sub>); 1 credit for compliance with the appropriate criteria for O<sub>3</sub>.
  - d) Respirable suspended particulate (RSP, PM<sub>10</sub>); 1 credit for compliance with the appropriate criteria for RSP.
- Assessment:**
- The Client shall provide a report prepared by the suitably qualified person detailing the criteria adopted for indoor air quality for each type of normally occupied premises within the building development.
- Where the Client does not offer criteria, HK-BEAM aligns with the HKSAR IAQ Certification Scheme<sup>96</sup>. The criteria for air-conditioned buildings shall be those defined under Good Class in Table 1 of the scheme Guide. For other occupied areas and habitable rooms the criteria can be that defined in the Guide, in ASHRAE 62-2001<sup>97</sup> or equivalent standard.
- Compliance shall be demonstrated by measurement. The report shall identify the measurement protocol. i.e., the measuring equipment used, duration of measurements, number and details of the sampling points, the measurement results, and overall conclusions from the measurements survey.
- For RSP the instrument type used shall be of gravimetric type, such as cyclone elutriator or impactor. An instrument based on the optical scattering method is acceptable with a referenced calibration curve with respect to a gravimetric instrument. In a zone where it can be demonstrated that CO, NO<sub>2</sub>, ozone and RSP are solely from outside, measurements can be taken at the outdoor air intake locations where CO, NO<sub>2</sub>, ozone and RSP are likely to infiltrate.
- The objective of sampling is to ensure that the building will not suffer unduly from outside sources of pollution. The sampling protocol (number and locations of samples) shall follow as a minimum that given in Appendix 8.8. Any other protocol demonstrated to be of equal rigour appropriate to the nature of the premises surveyed would be acceptable.
- In the case of occupied/habitable rooms in air-conditioned/naturally ventilated buildings the measurement of indoor air pollutants shall take place whilst operating in the naturally ventilated mode. Given that air and pollutant exchange with the outside depends on prevailing climatic conditions, particularly wind speed and direction, it is expected that due account is taken and that measurements will be taken under typical or average climatic conditions.
- Where it can be demonstrated that the identified pollutants are unlikely to exceed the limits prescribed, and as determined from an appropriate sample of measurements the relevant credit(s) shall be awarded.

#### Cost Premium:

<b>Office</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>
<b>Residential</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>

<sup>95</sup> Kosonen R. and Tan F. 2004, The effect of perceived indoor air quality on productivity loss, Energy and Buildings 36, 981- 986.

<sup>96</sup> Indoor Air Quality Management Group. A Guide on Indoor Air Quality Certification Scheme for Offices and Public Places. <http://www.iaq.gov.hk/cert/doc/CertGuide-eng.pdf>

<sup>97</sup> American Society of Heating Refrigeration and Air Conditioning Engineers. ASHRAE Standard 62. Ventilation for Acceptable Indoor Air Quality, Atlanta 2001.

### *Basis for Estimate:*

Credits will be given for demonstrating that airborne contaminants from outside sources will not give rise to unacceptable levels of indoor air pollution in normally occupied spaces. Specifically, one credit will be given for demonstrating compliance with appropriate criteria for CO, NO<sub>2</sub>, O<sub>3</sub>, RSP, PM<sub>10</sub>. The requirements for number of sampling points and protocol can be considered to be similar to those laid down in the Guidance Note issued by EPD on the management of indoor air quality for offices and public places in Hong Kong. It was estimated that the total number of sampling points required for the base building was 36 (i.e. 1 per 1,200 m<sup>2</sup>), and the additional initial cost for carrying out all these measurement was equivalent to HK\$1.2/m<sup>2</sup>.

### *Office Building:*

CFA of the base building = 42,840m<sup>2</sup>

Total nos. of sampling points = 36 (based on GN issued by EPD<sup>98</sup> 1 sampling point per 1200m<sup>2</sup>)

Total nos. of air pollutants are required to be measured = 4 (CO, NO<sub>2</sub>, O<sub>3</sub>, RSP, PM<sub>10</sub>)

Cost per sampling test = \$330 - \$350 (estimated from experienced environmental consultants)

Upper bound estimate = 350 x 36 x 4 / 42,840 = \$1.2/m<sup>2</sup>

Lower bound estimate = 330 x 36 x 4 / 42,840 = \$1.1/m<sup>2</sup>

### *Residential Building:*

Similar figures apply to high-rise residential buildings.

### *Benefits:*

It can provide a healthy environment for building users. Hui indicated that apartments located in better air quality areas would also attract higher sale prices. From historical transaction records, the sale price of an apartment was approximately 1.3% higher than that of an identical one located in a neighbourhood whose annual average air pollution index was one percent smaller than the one under examination.

### **6.3.3 Indoor Sources of Air Pollution (3 credits)**

Exclusions:	None.
Objective:	Demonstrate that airborne contaminants, predominantly from inside sources, do not give rise to unacceptable levels of indoor air pollution in normally occupied spaces.
Pre-requisites:	None.
Credit requirement:	a) Volatile organic compounds (VOCs): 1 credit for compliance with the appropriate criteria for VOCs. b) Formaldehyde (HCHO): 1 credit for compliance with the appropriate criteria for formaldehyde. c) Radon (Rn): 1 credit for compliance with the appropriate criteria for radon.
Assessment:	The Client shall provide a report prepared by the suitably qualified person detailing the criteria adopted for indoor air quality for each type of normally occupied premises within the building development. Where the Client does not offer criteria, HK-BEAM aligns with the HKSAR IAQ Certification Scheme [ <sup>98</sup> ]. The criteria for air-conditioned buildings shall be those defined under Good Class in Table 1 of the scheme Guide. For other occupied areas and habitable rooms the criteria can be that defined in the Guide, in ASHRAE 62-2001 [ <sup>99</sup> ] or equivalent standard. a) Measurement method Where compliance is demonstrated by measurement the report shall identify the measurement protocol. i.e., the measuring equipment used, duration of measurements, number and details of the sampling points, the measurement results,

<sup>98</sup> Indoor Air Quality Management Group. A Guide on Indoor Air Quality Certification Scheme for Offices and Public Places. <http://www.iaq.gov.hk/cert/doc/CertGuide-eng.pdf>

<sup>99</sup> American Society of Heating Refrigeration and Air Conditioning Engineers. ASHRAE Standard 62. Ventilation for Acceptable Indoor Air Quality, Atlanta 2001.

and overall conclusions from the measurements survey.

A sample at the lowest outdoor air intake location can help to identify the relative contribution of VOCs from indoor and outdoor. However, the common alpha track detector and gamma ray detector for radon detection are not regarded as suitable for measurement. Scintillation cells and electronic monitors are more suitable for both grab sampling and continuous measurements.

The objective of sampling is to ensure that the building will not suffer unduly from outside sources of pollution. The sampling protocol (number and locations of samples) shall follow as a minimum that given in Appendix 8.8. Any other protocol demonstrated to be of equal rigour appropriate to the nature of the premises surveyed would be acceptable.

In the case of occupied/habitable rooms in air-conditioned/naturally ventilated buildings the measurement of indoor air pollutants shall take place whilst operating in the background ventilation mode, or where there is no specific provision for background ventilation, with all windows and doors closed.

Where it can be demonstrated that the identified pollutants are unlikely to exceed the limits prescribed, and as determined from an appropriate sample of measurements the relevant credit(s) shall be awarded.

b) Design method

As an alternative to measurements on the completed building the Client shall provide a report prepared by the suitably qualified person detailing how indoor air pollution has been taken into account through detailed design. The report shall detail the computations and data used in the design approach used, especially the assumption in respect of emissions. Where it can be demonstrated that compliance with Good Class in Table 1 of the scheme Guide based on the 'Indoor Air Quality Procedure given in ASHRAE 62 or the methodology outlined in CEN Report CR 1752<sup>100</sup>, the relevant credits shall be awarded.

*Cost Premium:*

<b>Office</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>
<b>Residential</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>

*Basis for Estimate:*

Credits will be given for demonstrating that airborne contaminants predominately from inside sources will not give rise to unacceptable levels of indoor air pollution in normally occupied spaces. Specifically, one credit will be given for demonstrating compliance with appropriate criteria for VOCs, formaldehyde, and radon. The requirements for number of sampling points and protocol can be considered to be similar to those laid down in the Guidance Note issued by EPD on the management of indoor air quality for offices and public places in Hong Kong. It was estimated that the total number of sampling points required for the base building was 36 (i.e. 1 per 1,200 m<sup>2</sup>), and the additional initial cost for carrying out all these measurement was equivalent to HK\$0.9/m<sup>2</sup>.

*Office Building:*

CFA of the base building = 42,840m<sup>2</sup>

Total nos. of sampling points = 36 (based on GN issued by EPD, 1 sampling point for 1200m<sup>2</sup>)

Total nos. of air pollutants to be measured = 4 (VOCs, HCHO, Rn)

Cost per sampling test = \$330 - \$350 (estimated from experienced environmental consultants)

Upper bound estimate = 350 x 36 x 3 / 42,840 = \$0.9/m<sup>2</sup>

Lower bound estimate = 330 x 36 x 3 / 42,840 = \$0.8/m<sup>2</sup>

*Residential Building:*

Similar figures apply to high-rise residential buildings.

*Benefit:*

Similar to credit 6.3.1

<sup>100</sup> European Committee for Standardization. CEN Report CR 1752. Ventilation for buildings – Design criteria for the indoor environment. December 1998.

### 6.4.1 Ventilation in air-conditioned premises (2 credits)

- Exclusions: Residential and similar buildings using window units and/or split units.
- Objective: Ensure that ventilation systems provide for effective delivery to support the well being and comfort of occupants in normally occupied spaces.
- Pre-requisites: Compliance with CAP 123J Building (Ventilating Systems) Regulations.
- Credit requirement: a) Outdoor air ventilation rate: 1 credit for demonstrating that the corrected design ventilation rate meets the design intent for normally occupied spaces, and the corresponding outdoor air flow rate is achieved.  
b) Air change effectiveness: 1 credit for demonstrating that the air change effectiveness in normally occupied areas meets the specified performance.

#### a) Outdoor air ventilation rate

- Assessment: The calculations/simulations shall cover at least one representative sample of each type of premises (normally occupied spaces). Calculations should be based on guidance from recognised authorities such as ASHRAE 62 [101] or equivalent that take into account ventilation required to provide adequate indoor air quality for odour comfort.
- The outcome of measurements shall demonstrate that the required amount of outdoor air corresponding to the corrected design ventilation rate is actually provided. Air flow measurements may be made using conventional procedures, such as described in ASHRAE 111<sup>102</sup>, or by tracer gas techniques in accordance with ASTM E 741<sup>103</sup> or equivalent.
- Where the corrected ventilation rate is achieved in a minimum of 90% of premises, and the design ventilation rate is achieved in a sample of each type of premises the credit shall be awarded

#### b) Air change effectiveness

- Assessment: Compliance may be demonstrated either through measurement of the completed building in accordance with ASHRAE 129 (RA 2002)<sup>104</sup> or equivalent, or in cases where measurement may be difficult using CFD simulations produced by a suitable airflow model.
- The measurement locations shall include at least one representative sample of each type of premises (normally occupied spaces) as defined by the type of HVAC system used, design occupancy density, nature of usage, zoning, etc. Measurements are required at the occupied zone in each representative test space in accordance with ASHRAE 129. The measurements shall be undertaken under simulated full occupancy conditions. All airstreams of the air-side system serving the test space shall have a constant flow rate to the degree practical (e.g. the difference between the maximum and minimum should be within 10%).
- Where the air change effectiveness is demonstrated to be equal or greater than 1, and matches the design intent in all sampled premises, the credit shall be awarded.

#### Cost Premium:

Office	U	0	0+	L	M	H
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#### Office Building:

One credit will be given for demonstrating that the corrected design ventilation rate meets the design intent for normally occupied spaces, and the corresponding outdoor air flow rate is achieved. One credit will also be given for demonstrating that the air change effectiveness in normally occupied areas meets the specified performance.

<sup>101</sup> American Society of Heating Refrigeration and Air Conditioning Engineers. ASHRAE Standard 62. Ventilation for Acceptable Indoor Air Quality, Atlanta 2001.

<sup>102</sup> American Society of Heating Refrigeration and Air Conditioning Engineers. ASHRAE Standard 111. Practices for Measurement, Testing, Adjusting and Balancing of Building Heating, Ventilation, Air Conditioning and Refrigeration Systems, Atlanta 1998

<sup>103</sup> American Society for Testing and Materials. ASTM Standard E 741-00, Standard Test Methods for Determining Air Change in a Single Zone by Means of a Tracer Gas Dilution. Philadelphia, 2000.

<sup>104</sup> American Society of Heating Refrigeration and Air Conditioning Engineers. ANSI/ASHRAE Standard 129 (RA 2002). Measuring Air-change Effectiveness. Atlanta 1997.

Design calculations can be used for demonstrating a given design did comply with the corrected ventilation rate, corresponding outdoor air flow rate, and the air change effectiveness. In some cases, a test on a model layout would also be arranged for demonstration. The additional cost incurred is insignificant.

**Benefits:**

Annual health benefits that could be gained by the owners-occupiers and the society when the base building was operating at different ventilation rates are shown as follows:

Ventilation rate (l/s)	Benefits gained by Owners-Occupiers (\$/m <sup>2</sup> )		Benefits gained by the Society (\$/m <sup>2</sup> )	
8	Low:	6.7	Low:	0.47
	High:	18.48	High:	10.86
10	Low:	10.35	Low:	0.79
	High:	31.01	High:	18.23

The benefit gains by the owners-occupiers included reduced rate of absenteeism of their employee-workers, and avoidance fees of doctors' consultation. The benefit gains by the society included reduced costs associated with reduced mortality rates, reduced hospitalisation costs, and reduced restricted activity days. However, the effect on workers' productivity had been excluded in the cost estimation due to its controversial nature.

**6.4.2 Background Ventilation (2 credits)**

- Exclusions: Buildings not designed to utilise natural ventilation.
- Objective: Ensure that normally occupied premises designed to utilise natural ventilation are provided with a minimum of background ventilation to control indoor air pollutants.
- Pre-requisites: Compliance with the Building (Planning) Regulations (B(P)Reg.) 30, 31 and 32.
- Credit requirement: 1 credit for demonstrating the adequacy of ventilation in all normally occupied or habitable rooms with windows closed.  
1 additional credit where it can be demonstrated that adequate ventilation can be achieved by natural means.
- Assessment: The Client shall provide evidence in the form of a report by a suitably qualified person stating the ventilation criteria adopted in the design of normally occupied and/or habitable spaces, and that the appropriate analysis or measurements have been undertaken to verify the adequacy of background ventilation (minimum air change rate). Compliance should be demonstrated using any suitably verified or scientifically validated method, for at least one representative worst case sample of each occupied space for average wind conditions under 'windows closed' conditions, but with any purpose designed ventilators 'open'.  
The minimum ventilation rate required to maintain known contaminants below recognised limits can be calculated using recognised procedures, for example, Appendix D of BS 5925<sup>105</sup> or similar.  
Ventilation performance may be simulated using wind tunnel tests, computational fluid dynamics (CFD) or other appropriate modelling techniques<sup>106, 107</sup>.  
The modelling technique shall show a boundary layer as appropriate for the site, and the model will include any significant buildings and site obstructions within a distance of approximately 6 building heights. The pressure data will be used with recognised calculation procedures (e.g. BS 5925) to estimate flows through the habitable areas. Buoyancy or turbulence driven flows need not be considered. Ventilation rates can be predicted using either CFD or approaches that range in complexity from simple single zone models to elaborate multi-zone models. Principles of model operation are

<sup>105</sup> BS 5925:1991 (Inc. Amendment No 1), Code of Practice for Ventilation principles and designing for natural ventilation. British Standards Institute, London. December 1995.

<sup>106</sup> American Society for Testing Materials. ASTM E 2267-03. Specifying and Evaluating Performances of Single Family Attached and detached Dwellings – Indoor Air Quality. 2003.

<sup>107</sup> American Society of Heating, Refrigerating and Air Conditioning Engineers. ASHRAE Fundamentals Handbook Chapter 26. Atlanta 2001.



discussed in the ASHRAE Handbook<sup>108</sup>.

Alternatively, a suitable commissioning test may be performed, for example a tracer gas decay test<sup>109</sup>. The test should be carried out in representative units as defined above and performed under average wind conditions with windows closed and purposely designed ventilators open.

Where it can be demonstrate that background ventilation in normally occupied and/or habitable rooms under conditions when windows are closed meets minimum levels as prescribed in standards and guidelines from a recognised authority the credit shall be awarded. Where this can be achieved wholly by natural means the second credit shall be awarded.

*Cost Premium:*

<b>Residential</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>
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*Basis for Estimate:*

One credit will be given for demonstrating the adequacy of ventilation in all normally occupied or habitable rooms with windows closed. Another credit will be given where it can be demonstrated that adequate ventilation can be achieved by natural means. To demonstrate ventilation performance, wind tunnel tests, computational fluid dynamics (CFD), or other appropriate modelling techniques can be used. Alternatively, a suitable commissioning test, for instance a tracer gas decay test, may be performed. As a rough estimate from an experienced environmental consultant, \$12.2/m<sup>2</sup> - \$13.6/m<sup>2</sup> would be required for such tests and modelling, and which has moderate cost impact on the initial construction cost.

*Residential Building:*

CFA of the base building = 36,750m<sup>2</sup>

Cost of CFD modelling = \$450,000 – 500,000

(based on estimates from environmental consultants)

Upper bound estimate = 500,000 / 36,750 = \$13.6/m<sup>2</sup>

Lower bound estimate = 450,000 / 36,750 = \$12.2/m<sup>2</sup>

*Benefit:*

Similar to credit 6.3.1

**6.4.3 Uncontrolled Ventilation (2 bonus credits)**

Exclusions:	Air-conditioned and mechanically ventilated buildings.
Objective:	Reduce uncontrolled air movement in or out of premises, thereby provide better control over background ventilation through purposely provided openings and reduce infiltration of contaminated air.
Credit requirement:	1 credit for undertaking tests in multi-zone buildings using a non-balanced test method on a representative sample of units, to demonstrate that the air tightness is within recognized limits. OR 2 credits for undertaking tests using either a whole building test method or, in the case of multi-zone buildings (e.g. apartment blocks) a 'guarded cell' (or balanced) test method, on a representative sample of units, to demonstrate that the air tightness is within recognized limits.
Assessment:	The Client shall provide evidence in the form of a report prepared by a suitably qualified person that defines the targets for air leakage rate for the various types of premises in the development, demonstrating that the appropriate testing and analysis has been undertaken, and that the outcomes demonstrate compliance.

<sup>108</sup> American Society of Heating, Refrigerating and Air Conditioning Engineers. ASHRAE Fundamentals Handbook Chapter 26. Atlanta 2001.

<sup>109</sup> ASTM E 741-00. Standard Test Method for Determining Air Change in a Single Zone by means of a Tracer Gas Dilution. American Society for Testing Materials. Pasadena USA. 2000.

The defined air leakage rates should conform to recognised good practice targets e.g.<sup>110</sup>.

Fan pressurisation measurements can be based on a whole building test such as described in ASTM E 779<sup>111</sup>, or a method demonstrating similar rigour. In the case of high rise multi zone (or multi unit) buildings it is permissible to pressurise individual units using a guarded cell technique<sup>112,113</sup>.

A less stringent test is to perform an un-balanced test on individual units, i.e. pressurise individual units in isolation. These tests are influenced by the degree of cross leakage by neighbouring units (to the sides, above and below) and therefore the air leakage rate measured is not only the air leakage through the building envelope.

For all test methods, the arithmetic mean of the air leakage rates measured under pressurisation and depressurisation at 50 Pa should be normalised to the external surface area of the whole building or unit to give the air leakage rate in  $\text{m}^3 \text{m}^{-2} \text{h}^{-1}$  of external envelope.

Where the tests and analysis have been properly undertaken in a sample of each type of premises and the air leakage rate(s) conform to recognised good practice/standards then the appropriate bonus credit(s) shall be awarded.

**Cost Premium:**

<b>Residential</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>
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**Basis for Estimate:**

Two bonus credits will be given for reducing uncontrolled air movement in or out of premises, thereby provide better control over background ventilation through properly provided openings and reduce infiltration of contaminated air. As these two are bonus credits, they are excluded from the calculation of 'overall cost premium'. As a rough estimate from an experienced environmental consultant, \$1.4/m<sup>2</sup> - \$2.7/m<sup>2</sup> would be required for providing fan pressurisation measurements throughout the entire building.

**Residential Building:**

CFA of the base building = 36,750m<sup>2</sup>

Cost of conducting fan pressurization measurements for whole building = \$50,000 – 100,000

(based on estimates from environmental consultants)

Upper bound estimate = 100,000 / 36,750 = \$2.7/m<sup>2</sup>

Lower bound estimate = 50,000 / 36,750 = \$1.4/m<sup>2</sup>

**Benefit:**

Similar to credit 6.3.1

**6.4.4 Localised Ventilation**

- Exclusions: Item b) is excluded for residential buildings.
- Objective: Prevent exposure of building occupants to concentrated indoor sources of pollutants.
- Pre-requisites: Compliance with CAP 123J Building (Ventilating Systems) Regulations
- Credit requirement:
  - a) Source control: 1 credit for the provision of an adequate ventilation system for rooms/areas where significant indoor pollution sources are generated.
  - b) Local exhaust: 1 credit for the provision of a system of local exhaust of premises undergoing fit-out and redecoration.
- Assessment: Where it can be demonstrated that source control measures can meet the performance requirements the credit(s) shall be awarded.

<sup>110</sup> Chartered Institute of Building Services Engineers. TM23:2000. Testing Buildings for Air Leakage, London. 2000.

<sup>111</sup> ASTM International. E 779. Standard Test Method for Determining Air Leakage Rate by Fan Pressurization. 1999.

<sup>112</sup> International Energy Agency. Air Infiltration and Ventilation Centre (AIVC. Guarded Cell Pressurisation Measurements.

<sup>113</sup> Bahnfleth W P, Yuill G K, Lee B W. Protocol for field testing of tall buildings to determine air leakage rate. ASHRAE Transactions. 1999. pp 27-38.

**a) Source control**

Assessment: The Client shall provide evidence in the form of a report prepared by a suitably qualified person detailing the design criteria that has been adopted and details of the ventilation system designs providing local exhaust where concentrated pollutant sources are likely to be present. The report shall provide details of tests and the results demonstrating that the design performance is achieved. Where the design ventilation rate specified is lower than that specified in a recognised international or national standard the client shall demonstrate through appropriate testing that there is 99% isolation between areas with concentrated pollutant sources and occupied areas. Where it can be demonstrated that source control measures can meet the performance requirements the credit(s) shall be awarded.

**Cost Premium:**

<b>Office</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>
<b>Residential</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>

**Basis for Estimate:**

One credit will be given for the provision of an adequate ventilation system for rooms/areas where significant indoor pollution sources are generated. In order to fulfil the requirement, separate air ducts and electrical accessories will be provided for ventilating the rooms/areas with significant indoor pollution sources are generated, e.g. printing room. The quantities of air ducts and electrical accessories required depend on the building design, configuration and actual circumstances. As a rough estimate, it requires \$3.6/m<sup>2</sup> - \$4.4/m<sup>2</sup> for the separate air duct provision, which is considered to have a low cost impact on the overall construction cost.

**Office Building:**

CFA of the base building = 42,840m<sup>2</sup>

Unit price of 600mm x 600mm galvanized steel air duct = \$576/m (based on experience surveyors)

Length of 600 x 600mm galvanized steel air duct required = 130m – 150m (measured from base building)

Additional cost of providing mechanical ventilation and electrical accessories = \$80,000

Upper bound estimate = (576 x 150 + 80,000) / 36,754 = \$3.9/m<sup>2</sup>

Lower bound estimate = (576 x 130 + 80,000) / 36,754 = \$3.6/m<sup>2</sup>

**Residential Building:**

CFA of the base building = 36,750m<sup>2</sup>

Unit price of 600mm x 600mm galvanized steel air duct = \$576/m (based on experience surveyors)

Length of 600 x 600mm galvanized steel air duct required= 120m – 140m (measured from base building)

Additional cost of providing mechanical ventilation and electrical accessories = \$80,000

Upper bound estimate = (576 x 140 + 80,000) / 36,754 = \$4.4/m<sup>2</sup>

Lower bound estimate = (576 x 120 + 80,000) / 36,754 = \$4.1/m<sup>2</sup>

**b) Local exhaust**

Assessment: The report shall provide technical details to demonstrate how the ventilation system design(s) may be temporarily adapted so that air from any areas undergoing fit out or renovation can be exhausted to the outside without re-circulation or entrainment to occupied areas. The ventilation provisions shall be adequate to exhaust to outside air any material off-gassing, combustion products, excess moisture, etc., and the exhaust is discharged such that it does not re-enter the premises or enter adjacent premises under typical wind conditions. Compliance may be demonstrated by conducting appropriate tests in a sample of units.

**Basis for Estimation:**

Credit will be given for the provision of a system of local exhaust of premises undergoing fit-out

and redecoration. As we are only interested in new office buildings, the cost associated with this credit will be excluded from this report.

*Benefits:*

Similar to credit 6.3.1

#### 6.4.5 Ventilation in Common Areas (1 credit + 1 bonus credit)

Exclusions: Spaces covered under the section on Localised Ventilation.

Objective: Ensure adequate ventilation in common areas and circulation routes within premises and to avoid cross-contamination between areas.

Pre-requisites: Compliance with applicable regulations covering ventilation provisions in buildings.

Credit requirement: a) Ventilation by any means: 1 credit for demonstrating that all enclosed common areas in a building are provided with adequate ventilation.  
b) Use of natural ventilation: 1 BONUS credit where the provision for ventilation is by natural means.

Assessment: The Client shall provide evidence in the form of a report prepared by a suitably qualified person detailing the design criteria that has been adopted for each type of common area included in the development, and the results of calculations, simulations and/or measurements in the specified sample of spaces to demonstrate compliance with the assessment criteria.  
Compliance is conditional that outside air brought in to common areas should be free from known or potential localised sources of pollution (e.g. motor vehicle exhaust, workshops, etc), and exhausted air contain does not contaminate public areas or occupied areas.

##### a) Ventilation by any means

Assessment: Design ventilation rates shall be defined by the Client, but should comply with recommendations from recognised authorities, e.g. BS 5925<sup>114</sup>, ASHRAE 62<sup>115</sup> or equivalent. Compliance shall be demonstrated by measurements on a representative sample of each type of space, including worst cases, under average wind conditions.

##### b) Use of natural ventilation

Assessment: Where natural ventilation is employed it shall demonstrated that the ventilation rate specified is achieved under average wind conditions in at least 80% of the common areas, aggregated by floor area. Compliance may be demonstrated by suitable commissioning measurements such as a tracer gas test<sup>116</sup> on a representative sample of spaces, including worst cases, or by appropriate modelling techniques, such as wind tunnel test, CFD or other computer models<sup>117,118</sup>.

##### Cost Premium:

<b>Office</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>
<b>Residential</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>

##### Basis for Estimate:

One credit will be given for demonstrating that all enclosed common areas in a building are provided with adequate ventilation and an additional bonus credit will be given if this ventilation is by natural means. The sampling test for monitoring indoor air quality, i.e. environmental chamber test, are conducted in protective lobbies and common corridors and the associated costs could be accounted for between \$0.9/m<sup>2</sup> and \$4.5/m<sup>2</sup> for office and residential buildings respectively.

##### Office Building:

CFA of the base building = 42,840m<sup>2</sup>

<sup>114</sup> BS 5929: 1991 (Amendment No. 1) Code of practice for Ventilation Principles and designing for Natural Ventilation. British Standards Institute, London, 1995.

<sup>115</sup> American Society of Heating, Refrigerating and Air Conditioning Engineers. ASHRAE 62-2001. Ventilation for Acceptable Indoor Air Quality. American Society of Heating, Refrigerating and Air Conditioning Engineers. Atlanta, 2001.

<sup>116</sup> ASTM International. E 741-00. Standard Test Method for Determining Air Change in a Single Zone by means of a tracer Gas Dilution. 2000

<sup>117</sup> ASTM International. ASTM E 2267-03. Specifying and Evaluating Performances of Single Family Attached and detached Dwellings – Indoor Air Quality. 2003.

<sup>118</sup> American Society of Heating, Refrigerating and Air Conditioning Engineers. ASHRAE Fundamentals Handbook Chapter 26. Atlanta 2001.

Total nos. of sampling points = 40 (based on base building configuration)

Cost per sampling test (environmental chamber test) = \$800 - \$1,000

Upper bound estimate =  $1000 \times 40 / 42,840 = \$0.9/\text{m}^2$

Lower bound estimate =  $800 \times 40 / 42,840 = \$0.7/\text{m}^2$

#### *Residential Building:*

CFA of the base building =  $36,750\text{m}^2$

Total nos. of sampling points = 200 (based on base building)

Cost per sampling test (environmental chamber test) = \$800 - \$1,000

Upper bound estimate =  $1000 \times 200 / 42,840 = \$4.5/\text{m}^2$

Lower bound estimate =  $800 \times 200 / 42,840 = \$3.7/\text{m}^2$

#### *Benefit:*

Similar to credit 6.3.1

### **6.5.1 Thermal Comfort in Air-conditioned Premises (3 credits)**

Exclusions:	Buildings where air-conditioning is provided by window units or split units.
Objective:	Ensure that the air-conditioning system can provide the stated design conditions in occupied spaces under changing load conditions.
Credit requirement:	a) Temperature: 1 credit for sustaining the air temperature at the design value within $\pm 1^\circ\text{C}$ when the air side system is operating at steady state under conditions of zero occupancy. 1 credit for sustaining the air temperature at the design value within $\pm 1^\circ\text{C}$ when the air side system is operating at steady state under simulated full-load conditions. b) Room air distribution: 1 credit where room air diffusers satisfy the Air Diffusion Performance Index.
Assessment:	The Client shall provide evidence in the form of a report prepared by a suitably qualified person detailing the design criteria with respect to thermal comfort conditions for all types of premises included in the building, and the results of the measurements in the specified sample of premises.

#### **a) Temperature**

Assessment:	The measurement locations shall include at least one representative sample of each type of premises (occupied spaces) as defined by the type of HVAC system used, design occupancy density, nature of usage, zoning, etc. The main physical parameters of the indoor climate (air temperature and relative humidity) are undertaken: i) with no occupants, and ii) with simulated full occupancy. The results shall demonstrate compliance with the prescribed design criteria within the prescribed limits, for a minimum of 90% of the prescribed locations. In the case of i) it will demonstrate that the HVAC system is capable of 'turn-down' to the lower limit and for ii) it can demonstrate the ability to meet the design load. The sensors used in the measurement survey shall have an accuracy that complies with ASHRAE 55-1992 <sup>119</sup> , ISO 7726 <sup>120</sup> or equivalent.
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#### **b) Room air distribution**

<sup>119</sup> American Society of Heating, Refrigeration and Air-conditioning Engineers. ASHRAE 55-1992: Thermal Environmental Conditions for Human Occupancy. Atlanta 1992.

<sup>120</sup> International Standard Organization. International standard 7726, Ergonomics of the thermal environment — Instruments for measuring physical quantities. 1998.

Assessment: The measurement locations shall be as for a). The assessment of performance shall be in accordance with ASHRAE 113<sup>121</sup> r equivalent standard method.

**Cost Premium:**

Office	U	0	0+	L	M	H
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**Basis for Estimate:**

One credit will be given for sustaining the air temperature at the design value within +/- 1°C when the air side system is operating at steady state under conditions of zero occupancy. One credit will be given for sustaining the air temperature at the design value +/- 1°C when the air side system is operating at steady state under simulated full load conditions. One credit will be given where room air diffusers satisfy the Air Diffusion Performance Index.

In order to earn these credits, a series of measurement survey has to be conducted so as to measure and monitor the main physical parameters of the indoor climate, e.g. air temperature and relative humidity, under conditions with no occupants and with simulated full occupancy. On the other hand, the air diffusion performance index will be calculated for the room air diffusers at various locations based on the site measurement data. The additional cost incurred for the measurement survey is minimal.

**Benefit:**

Ensure the adequacy of thermal comfort to maintain the productivity in workplaces. Lower the energy consumption by applying energy efficient air-conditioning systems.

**6.5.2 Thermal Comfort in Naturally Ventilated Premises (3 credits)**

- Exclusions: Buildings that are not designed to utilise natural ventilation.
- Objective: Promote the application of measures that reduce elevated temperatures caused by external heat gains, and ensure installed air-conditioning units can provide adequate control of indoor temperature.
- Credit requirement:
  - a) Performance with natural ventilation: 1 credit for demonstrating indoor operative temperatures in occupied/habitable rooms meet the 80% acceptability limits. 2 credits for demonstrating indoor operative temperatures in occupied/habitable rooms meet the 90% acceptability limits.
  - b) Performance with air-conditioning: 1 credit for sustaining the air temperature at the design value within ±1.5°C when the air-conditioning unit is operating at steady state under conditions of zero occupancy.

**a) Performance with natural ventilation**

Assessment: The assessment will seek to establish the extent to which the design of the building envelope can mitigate the effects of external heat gains. Based on the output from a suitable thermal simulation model of the building the predicted indoor operative temperature shall be compared with the criteria given in ASHRAE 55<sup>122</sup> under the 'Optional Method for Determining Acceptable Thermal Conditions in Naturally Conditioned Spaces'.

Assessment may be confined to the 'worst case' scenarios, i.e., for those normally occupied areas of the building most susceptible to external heat gains and/or do not benefit from the prevailing climatic conditions.

The spaces in question must be equipped with operable windows that can be readily opened and adjusted by the occupants. Mechanical cooling for the space shall not be provided, although mechanical ventilation with unconditioned air may be utilized.

The thermal analysis shall be undertaken using dynamic thermal modelling software. The thermal performance within the occupied or habitable space of each type of premises most affected by solar gains shall be determined. The modelling shall be undertaken full annual simulation using standard Hong Kong weather data. The

<sup>121</sup> American Society of Heating, Refrigerating and Air-conditioning Engineers. ASHRAE 113-1990: Method of Testing for Room Air Diffusion. Atlanta, 1990.

<sup>122</sup> American Society of Heating, Refrigeration and Air-conditioning Engineers. ASHRAE 55-2004: Thermal Environmental Conditions for Human Occupancy. Atlanta 2004.

modelling will include the effect of installed solar control features, e.g. glazing, internal or external shading components, fabric and infiltration specifications, and site obstructions. The modelling need not include any internal gains, i.e., simulations for unoccupied premises are required.

Alternatively, compliance may be demonstrated under appropriate summer and winter conditions through the measurement of temperature in suitable locations in a sample of premises most exposed to external heat gains.

The Client shall provide evidence in the form of a report prepared by a suitably qualified person detailing any means used to control the external (solar) heat gains, the specification and details of the thermal simulation software used in the analysis, and the results of the simulations.

Where compliance is demonstrated by measurements the details of measuring equipment, sampling locations, sampling time, time of measurements, external temperature and prevailing weather conditions shall be provided.

Where it can be demonstrated that the predicted indoor temperature lies within the 80% acceptability limits given in ASHRAE 55-2004 a credit shall be awarded. Where the predicted indoor temperature lies within the 90% acceptability limits both credits shall be awarded.

### **b) Performance with air-conditioning**

**Assessment:** The measurement locations shall include at least one representative sample of each type of premises (occupied spaces) as defined by the type of HVAC system used, design occupancy density, nature of usage, zoning, etc. The measurements shall be undertaken with no occupants. The sensors used in the measurement survey shall have an accuracy that complies with ISO 7726<sup>123</sup> or equivalent. To earn credit the results shall demonstrate compliance with the prescribed design criteria within the prescribed limits, for a minimum of 90% of the prescribed locations.

#### **Cost Premium:**

<b>Residential</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>
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#### **Basis for Estimate:**

One credit will be given for demonstrating indoor operative temperatures in occupied/habitable rooms meet the 80% acceptability limits. Two credits will be given for demonstrating indoor operative temperatures in occupied/habitable rooms that meet the 90% acceptability limits. One more credit will be given for sustaining the air temperature at the design value within +/-1.5°C when the air-conditioning unit is operating at steady state under conditions of zero occupancy. Greater acceptability can be achieved through the use of better quality air-conditioning units and better thermostatic controls. To demonstrate compliance, a thermal analysis shall be undertaken using dynamic thermal modelling software. Or alternatively, compliance may be demonstrated under appropriate summer and winter conditions through the measurement of temperature in suitable locations in a sample of premises most exposed to external heat gains. The costs associated with such modelling or sampling test are estimated to be minimal in comparison with the total construction cost.

#### **Benefit:**

Ensure the adequacy of thermal comfort to maintain the productivity in workplaces. Lower the energy consumption by applying energy efficient air-conditioning systems.

### **6.6.1 Natural Lighting (3 credits)**

**Exclusions:** None.

**Objective:** Encourage a holistic examination of site layout, building design, and fenestration design, such as to maximise access to daylight for the purposes of improved health and comfort.

**Credit requirement:** 1 credit where the provision of daylight meets the levels specified in PNAP 278 for vertical daylight factor OR the average daylight factor (DF) is at least 0.5% for all

<sup>123</sup> International Standard Organization. ISO 7726, Ergonomics of the thermal environment — Instruments for measuring physical quantities. 1998.



normally occupied spaces. 2 credits where the average daylight factor in all normally occupied spaces is at least 1%. 3 credits where the average daylight factor in all normally occupied spaces is at least 2%.

**Assessment:**

The Client shall submit evidence in the form of a report prepared by a suitably qualified person demonstrating compliance with the assessment criteria. Daylight availability, based on 'worst case' scenarios, i.e., the most obstructed windows, shall be demonstrated by either one of the following methods.

**a) Measurement of VDF**

On-site measurements for a selection of windows that are shown by design drawings to have the greatest external obstructions. The measurements should be carried out during stable overcast sky conditions.

To assess vertical daylight factor (VDF) an illuminance meter should be placed at the centre of the window and another illuminance meter on a horizontal plane under an unobstructed sky. In practice, a completely unobstructed horizontal plane may be difficult to achieve in the Hong Kong urban environment and the roof of the building may be a good approximation to an unobstructed horizontal plane. The two illuminance meters should be read simultaneously and the ratio of the illuminance on the window and the illuminance on the unobstructed horizontal plane is taken as the vertical daylight factor.

To qualify for credit the glazing visual transmittance, obtained from manufacturer's specification of the glazing product or by measurement, shall be equal or greater than 70%.

**b) Measurement of DF**

Measurement of average daylight factor (DF) shall be by the methods recommended by CIBSE<sup>124</sup>, or equal equivalent.

Given that the specified sky condition can be difficult to obtain in practice the following modelling methods are acceptable alternatives.

**c) Estimation of VDF**

The CIE standard overcast sky shall be used in computer simulations.

Compliance with the VDF criteria can be demonstrated using the method given in PNAP 278<sup>125</sup>, provided application of the method takes account of the limitations stated in the Appendix A. The alternative is to use the HK-BEAM preferred method developed by Cheung and Chung<sup>126</sup> which can be applied without restrictions. (Details of this method with supporting calculation spreadsheet are available from the authors upon request).

**d) Estimation of DF**

The average daylight factor (DF) shall be estimated according to the preferred method [3], that given in the CIBSE design guide<sup>127</sup>, or similar equivalent method. Alternatively, daylighting design software such as Radiance<sup>128</sup> can be used to calculate the average DF provided it can be demonstrated that the method of computation employed by the software used is not inconsistent with the preferred calculation method.

The report submitted shall identify the key parameters used in the computations/modelling, especially with regard to glazing transmittance, and the reflectance's of external and internal surfaces. The values of the parameters shall reflect the nature and type of surfaces on the external vertical obstructions and horizontal surfaces, and likely internal finishes.

The room dimensions shall be taken to be a typical perimeter room for the building, be it a habitable room, office, classroom, etc.

**Cost Premium:**

<b>Office</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>
<b>Residential</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>

<sup>124</sup> The Chartered Institution of Building Services Engineers. Applications Manual – Window design.

<sup>125</sup> Buildings Department Practice Note for Authorized Persons and Registered Structural Engineers, PNAP 278. Lighting and Ventilation Requirements – Performance-based Approach. <http://www.info.gov.hk/bd/english/documents/pnap/Pnap278.pdf>

<sup>126</sup> Cheung H D, Chung T M. Calculation for Mean Daylight Factor in a Building Interior Within a Dense Urban Environment. Department of Building Services Engineering, Hong Kong Polytechnic University.

<sup>127</sup> The Chartered Institution of Building Services Engineers. Lighting Guide LG10. daylighting and window design. CIBSE.

<sup>128</sup> Ward Larson, G. and Shakespeare, R. Rendering with RADIANCE. Morgan Kaufmann. San Francisco.

### *Basis for Estimate:*

One credit will be given where the provision of daylight meets the levels specified in PNAP 278 for vertical daylight factor or the average daylight factor (DF) is at least 0.5% for all normally occupied spaces. Two credits are given where the average daylight factor in all normally occupied spaces is at least 1%, and three credits will be given where the average daylight factor in all normally occupied spaces is at least 2%. To achieve compliance, it is necessary that the design, fenestration, surface finishes of the occupied spaces are needed to be carefully considered, and their compliances are needed to be proven by test or modelling. The costs associated with these types of test or modelling are considered to be very small.

### *Benefit:*

Data from the California reports<sup>45,129</sup> revealed that proper admission of daylight may help save electrical energy by supplementing the artificial lighting system. It can trim a building's lighting energy use by 10 to 30 percent when the spaces are integrated with photosensors that dim electric lighting in daylight areas. A well-designed daylighting system can interact with a building's HVAC system in a way that can deliver even more savings. When daylighting is integrated into building designs, the reduction in lighting load often induces a reduction in the cooling load, making it possible to install a smaller mechanical system. This delivers ongoing energy cost savings and lowers the first cost and replacement cost of the mechanical system. The resulting savings may offset the additional cost of high-performance glazing. On the other hand, the productivity of occupants could conservatively be expected are much less than 26% (which reflects extremes in daylighting), perhaps on the order of 2% to 6%.

## **6.6.2 Interior Lighting in Normally Occupied Areas (2 or 3 credits)**

Exclusions:	Residential buildings, hotels and apartment buildings.
Objective:	Ensure the adequacy and maintenance of visual comfort conditions achieved by the electric lighting provisions in occupied spaces.
Credit requirement:	a) Illuminance: 1 credit where the prescribed lighting performance in each type of premises in respect of maintained illuminance and illuminance variation is achieved. b) Lighting quality: 1 credit for lighting installations in which: the limiting unified glare rating is achieved; and light sources have an appropriate colour rendering index. 1 credit where fluorescent and other lamps with modulating (fluctuating) output are fitted with dimmable high-frequency ballasts in all work areas.
Assessment:	The design criteria for interior lighting shall be at the discretion of the Client but shall embrace both 'quantity' and 'quality' of the lighting system performance including: maintained horizontal, and where appropriate vertical, illuminance, illuminance variation, limiting glare index, colour rendering, and modulation of light output appropriate to the type and use of the premises/indoor spaces. The criteria adopted shall be based on authoritative guidance, such as that provided in CIE <sup>130, 131</sup> , CIBSE <sup>132</sup> and/or IESNA <sup>133</sup> publications, or equivalent. As the focus is on lighting for comfort and productivity, lighting for performing arts, display decoration, ambience. etc., shall normally be excluded from consideration. Compliance with the assessment criteria shall be demonstrated either by measurements using a standardised measurement protocol appropriate to the parameter being assessed, and/or by modelling (calculation), providing the calculation method or software used is based on a standardised method, and uses data/assumptions appropriate to the circumstances. Notwithstanding, demonstration of compliance with a) requires that the maintained illuminance take into account the influence on light output by adjacent air-conditioning or ventilation fixtures, and the

<sup>129</sup> Leary M. et al. 2004, Building and Buying Green In Indian Country, A Practical Guide for California Tribes, The California Integrated Waste Management Board.

<sup>130</sup> Commission Internationale de l'Eclairage (CIE). Lighting of Indoor Work Places. CIE Standard S 008/E.

<sup>131</sup> Commission Internationale de l'Eclairage (CIE). Discomfort Glare in Interior Lighting. CIE 117-1995.

<sup>132</sup> The Chartered Institution of Building Services Engineers. Code for interior lighting. London. CIBSE.

<sup>133</sup> Illuminating Engineering Society of North America. Lighting Handbook, Reference & Applications. 9<sup>th</sup> edition., New York.

<sup>134</sup> Commission Internationale de l'Eclairage (CIE). Maintenance of indoor electric lighting systems. CIE Technical Report - Publication No. 97. Vienna.

lighting maintenance plan (the period for luminaire cleaning and group re-lamping) appropriate to the circumstances [134].

The Client shall submit a report prepared by a suitably qualified person detailing the 'as installed' lighting systems or, for premises/spaces yet to be fitted-out, the technical details of the proposed lighting systems for each type of normally occupied space within the development. The report shall detail the design criteria and the results of measurements or other means demonstrating compliance. For premises to be fitted out by tenants compliance shall be confirmed if the technical details and contractual arrangements with tenants in respect of lighting installations is deemed to meet the assessment criteria.

Measured Performance:

For lighting installations that are already installed, horizontal and vertical illuminance and luminance can be measured using a lux meter and a luminance meter. The colour quality of lamps can be assessed from the lamp specifications. Colour appearance (correlated colour temperature) can be checked from the lamp labels or by measurement using a colour meter. Flicker can be assessed by whether the specified ballasts are magnetic or electronic, and can be tested using a simple 'flicker meter'.

Air diffusers located near to fluorescent luminaires with open lamp compartments may result in cool air blowing over the lamps directly causing decrease light output and lamp efficacy. The design details should demonstrate that the cool air from diffusers will not adversely impact on lamp performance.

Computation

The 'lumen method' can be used to calculate the maintained illuminance over the working plane according to the calculation procedure described in Section 4.5.3 of the CIBSE Code or in Appendix 3 of the CIBSE Lighting Guide<sup>135</sup>. The calculated maintained illuminance will then be checked for compliance with the recommendations given in Section 2.6.4 of the Code, or the recommendations given in Chapter 5 of the Guide.

The illuminance variation consists of 'uniformity' which is concerned with illuminance conditions on the task and immediate surroundings, and 'diversity' which expresses changes in illuminance across a larger space. The uniformity and diversity can be calculated according to that described in Section 4.5.4 of the Code. The calculated uniformity (minimum to average illuminance) over any task area and immediate surround should not be less than 0.8. The diversity of illuminance expressed as the ratio of the maximum illuminance to the minimum illuminance at any point in the 'core area' of the interior should not exceed 5:1. The core area is that area of the working plane having a boundary 0.5 m from the walls.

The glare index can be calculated according to either of the two methods described by CIE, or the CIBSE Technical Memoranda<sup>136</sup>. These methods are also summarised in Section 4.5.6 of the CIBSE Code. The calculated glare index shall be checked for compliance with the recommendations given in Section 2.6.4 of the Code or Chapter 5 of the Lighting Guide.

For assessment using the IESNA Lighting Criteria, the calculation methods described in Chapter 9 of the IESNA Lighting Handbook can be used for the calculation of the following parameters:

- o horizontal and vertical illuminance;
- o glare: VCP or UGR; and
- o luminance.

Alternatively, a validated computer program such as RADIANCE, LIGHTSCAPE etc can be used for the calculation. The calculated results will then be checked for compliance with the recommended criteria in the IESNA Lighting Design Guide.

**Cost Premium:**

<b>Office</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>
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**Basis for Estimate:**

One credit will be given where the prescribed lighting performance in each type of premises in respect of maintained luminance and luminance variation is achieved. One credit will be given for lighting installations in which the limiting unified glare rating is achieved and light sources have an appropriate colour rendering index. One credit will be given where fluorescent and other lamps

<sup>135</sup> The Chartered Institution of Building Services Engineers. Lighting Guide LG7: Lighting for offices. London, CIBSE, 1993.

<sup>136</sup> The Chartered Institution of Building Services Engineers. Technical Memoranda TM10. Calculation of glare indices. London, CIBSE, 1985.

with modulating output are fitted with dimmable high-frequency ballasts in all work areas. To demonstrate compliance, measurements using a standardised measurement protocol appropriate to the parameter being assessed, and/or by modelling providing the calculation method or software used is based on a standardised method and uses data/assumptions appropriate to the circumstances. The cost of conducting the modelling, or measurement tests was estimated to be  $\$0.5/\text{m}^2 - 0.7/\text{m}^2$ , and the actual rectification costs could not be estimated would vary according to actual circumstances in case of non-compliance.

*Office Building:*

CFA of the base building =  $42,840\text{m}^2$

Cost of illuminance and lighting quality modelling =  $\$20,000 - \$30,000$

Upper bound estimate =  $30,000 / 42,840 = \$0.7/\text{m}^2$

Lower bound estimate =  $20,000 / 42,840 = \$0.5/\text{m}^2$

*Benefit:*

Ensure the adequacy of visual comfort to maintain the productivity in workplaces. Lower the energy consumption by applying energy efficient lightings.

**6.6.3 Interior Lighting in Areas not Normally Occupied**

Exclusions:	None.
Objective:	Ensure the adequacy of artificial lighting provisions in common areas and service areas such as plant rooms.
Pre-requisites:	Compliance with the Building Regulations for those common areas covered by regulations, e.g. Building (Planning) Regulation (B(P)R) 40 in respect of lighting of staircases.
Credit requirement:	1 credit where the prescribed lighting performance in each type of common or service space in respect of light output and lighting quality is achieved.
Assessment:	<p>Here the focus is on lighting for safety, security and work activities required for operation and maintenance. The design criteria is at the discretion of the Client but shall embrace both 'quantity' and 'quality' of the lighting system performance including: maintained horizontal, and where appropriate vertical, illuminance, illuminance variation, limiting glare index, colour rendering, and modulation of light output appropriate to the type and use of the premises/indoor spaces. The criteria adopted shall be based on authoritative guidance, such as that provided in CIE<sup>137,138</sup>, CIBSE<sup>139</sup> and/or IESNA<sup>140</sup> publications, or equal.</p> <p>The Client shall submit a report prepared by a suitably qualified person detailing the 'as installed' lighting systems or, for spaces yet to be fitted-out, the technical details of the proposed lighting systems for each type common or service space within the development. The report shall detail the design criteria and the results of measurements or other means demonstrating compliance.</p> <p>Compliance with the assessment criteria shall be demonstrated either by measurements using a standardised measurement protocol appropriate to the parameter being assessed, and/or by modelling (calculation), providing the calculation method or software used is based on a standardised method, and uses data/assumptions appropriate to the circumstances. Notwithstanding, demonstration of compliance with a) requires that the maintained illuminance take into account the influence on light output appropriate to the circumstances, such as the recommendations given by CIE<sup>141</sup>.</p>

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<sup>137</sup> Commission Internationale de l'Eclairage (CIE). Lighting of Indoor Work Places. CIE Standard S 008/E.  
<sup>138</sup> Commission Internationale de l'Eclairage (CIE). Discomfort Glare in Interior Lighting. CIE 117-1995.  
<sup>139</sup> The Chartered Institution of Building Services Engineers. Code for interior lighting. London. CIBSE.  
<sup>140</sup> Illuminating Engineering Society of North America. Lighting Handbook, Reference & Applications. New York.  
<sup>141</sup> Commission Internationale de l'Eclairage (CIE). Maintenance of indoor electric lighting systems. CIE Technical Report - Publication No. 97. Vienna.

*Cost Premium:*

<b>Office</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>
<b>Residential</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>

*Basis for Estimate:*

Prerequisites credit by compliance with the provisions of the Building Regulations.

*Benefits:*

It can provide a safety environment for the building users so as to reduce the rate of absenteeism of employee-workers and reduce the risk and liability of lawsuits caused by poor indoor air quality.

### 6.7.1 Room Acoustics

Exclusions: Buildings/premises where speech intelligibility is not important, and rooms of a special acoustical nature.

Objective: Improve the acoustical properties of rooms in which speech intelligibility is important.

Credit requirement: 1 credit for demonstrating that the reverberation time in applicable rooms meets the prescribed criteria for given types of premises.

Assessment: There is no single all-encompassing set of criteria that will define good acoustical properties for all types of rooms and uses. The Client shall define the criteria appropriate to the type and use of the premises/rooms in the building. However, for the purposes of assessment account should be taken of the criteria given below. Where alternative criteria is used the Client shall provide evidence as to the suitability of the alternative, e.g. by making reference to authoritative guidance. Likewise, where criteria appropriate to the type and use of premises/spaces is not stated herein, the Client shall provide evidence as to the suitability of the criteria adopted.

Compliance shall be demonstrated by detailed calculations, or measurement, or both, depending on the Client's preference. The reverberation time shall be assessed using Sabine's formula<sup>142</sup> or similar alternative taking into account the room details and appropriate assumptions about the materials in the space. Measurements during commissioning shall use the method given in ISO 3382<sup>143</sup> or equal equivalent.

The Client shall submit details in the form of a report prepared by a suitably qualified person providing a schedule of the premises and spaces in the building, relevant design details as they impact on acoustical properties, the rooms/premises subject to field tests or for which detailed calculations have been made, the acoustical criteria used, underlying assumptions, and the results of tests or calculations demonstrating compliance with the criteria.

Where it can be demonstrated that the acoustical quality in a sample of each type of room in which speech intelligibility is important, as measured or calculated, meets appropriate performance criteria the credit shall be awarded.

*Cost Premium:*

<b>Office</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>
<b>Residential</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>

*Basis for Estimate:*

One credit will be given for demonstrating that the reverberation time in applicable rooms meets the ISO 3380 or equivalent. For office premises, the reverberation time of A-weighted sound pressure level, in modular (private) office and conference rooms, shall be 0.6s or below. For residential premises, such level in bedrooms and living rooms shall be between 0.4 and 0.6s. To demonstrate compliance, an acoustic test for measuring reverberation time will be conducted. The cost of conducting a test was estimated to be \$0.5/m<sup>2</sup> – 0.8/m<sup>2</sup>, and the actual rectification costs could not be estimated would vary according to actual circumstances in case of non-compliance.

<sup>142</sup> I.Sharland. Woods practical guide to noise control. Colchester, England.

<sup>143</sup> International Standard Organization. ISO 3382. Acoustics - Measurement of the reverberation time of rooms with reference to other acoustical parameters.

*Office Building:*

CFA of the base building = 42,840m<sup>2</sup>

Cost of conducting acoustic tests for measuring reverberation time = \$20,000 – 50,000

(based on estimates from environmental consultants)

Upper bound estimate = 30,000 / 42,840 = \$0.7/m<sup>2</sup>

Lower bound estimate = 20,000 / 42,840 = \$0.5/m<sup>2</sup>

*Residential Building:*

Similar figures apply to high-rise residential building.

**6.7.2 Noise Isolation (2 credits)**

Exclusions: Buildings/premises which are inherently noisy and unaffected by noise from adjacent premises/spaces.

Objective: Improve the noise isolation of normally occupied premises/rooms to reduce impact of unwanted noise.

Credit requirement: 1 credit for demonstrating airborne noise isolation between rooms, spaces and premises meets the prescribed criteria.  
1 credit for demonstrating impact noise isolation between floors meets the prescribed criteria.

Assessment: As there are a number of ways to quantify or classify noise isolation (insulation) in buildings, the exact performance criteria used to define both airborne noise isolation and impact noise isolation shall be stated by the Client. However, for the purposes of assessment account should be taken of the criteria given below. Where alternative criteria is used the Client shall provide evidence as to the suitability of the alternative, e.g. by making reference to authoritative guidance. Likewise, where criteria appropriate to the type and use of premises/spaces is not stated herein, the Client shall provide evidence as to the suitability of the criteria adopted.

Compliance shall be demonstrated by measurement or by detailed calculations, or both, depending on the Client's preference. Measurements shall follow the protocols given in the referenced standards. Calculations should be done with reference to appropriate standards.

The Client shall submit details in the form of a report prepared by a suitably qualified person providing a schedule of the premises and spaces in the building, the noise isolation criteria adopted, relevant structural details as they impact on noise isolation, the rooms/premises subject to field tests or for which detailed calculations have been made, underlying assumptions, and the results of tests or calculations demonstrating compliance with the criteria (expressed in parameters that are consistent with the test and/or calculation methods).

Where it can be demonstrated that airborne noise isolation, as measured or calculated for the most susceptible spaces/rooms/premises, meets appropriate performance criteria the credit shall be awarded. Similarly, where it can be demonstrated that impact noise isolation (insulation) meets appropriate performance criteria in the most susceptible spaces/ rooms/premises, the credit shall be awarded.

*Cost Premium:*

<b>Office</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>
<b>Residential</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>

*Basis for Estimate:*

Similar to Credit 6.7.1, airborne and impact noise reduction is regarded as both a design and construction issue. However, there is no definite guideline being published by the local Hong Kong government on impact noise isolation. Alternatively, we can make reference to the Building Regulations Approved Document E (2003) in the UK. Document E is designed to meet demands for improved acoustic insulation and to combat the problems of noise pollution from neighbours. The Regulations apply to both new build and conversion or refurbishment work and set out standards for; the sound insulation of party walls and floors between dwellings (or rooms used for residential purposes), the sound insulation of internal walls and floors, the control of reverberation

within communal areas and the acoustics of schools (See Building Bulletin 93). Approved Document E can be downloaded at <http://www.planningportal.gov.uk>

The Regulations require the builder to undertake pre-completion sound insulation testing of a sample of party walls and party floors to demonstrate to Building Control that compliance with Part E has been achieved. A series of Robust Standard Details (RSDs), constructions that will provide the required level of sound insulation with a suitable tolerance for workmanship have been developed and adopted as an alternative to pre-completion testing.

In particular, the impact noise reduction between floors can be handled by floating floor construction, or the impact noise reduction between walls or ceilings can be handled by applying specially made acoustic materials that are compliance with Building Regulations Approved Document E (2003). For instance, Acoustilay, Impactafoam can be used for isolating noise between floors. Maxiboard and Soundblockers can be used for isolating noise in ceilings. As a rough estimate, the additional costs of providing better sound absorbent building materials will lie in the range of low to moderate cost impacts.

**Benefit:**

Ensure the adequacy of room acoustics to maintain the productivity and learning ability in workplaces.

### 6.7.3 Background Noise

Exclusions:	Buildings/premises in which speech intelligibility is not important.
Objective:	Control as far as practicable the background noise in premises at levels appropriate to the intended use of the premises.
Credit requirement:	1 credit for demonstrating background noise levels are within the prescribed criteria.
Assessment:	<p>HK-BEAM regards background noise in premises/rooms as a matter having an important bearing on quality and productivity. Given that different criteria maybe used the Client shall define the criteria appropriate to the type and use of the premises/rooms in the building. However, for the purposes of assessment account should be taken of the criteria given below. Where alternative criteria is used the Client shall provide evidence as to the suitability of the alternative, e.g. by making reference to authoritative guidance. Likewise, where criteria appropriate to the type and use of premises/spaces is not stated herein, the Client shall provide evidence as to the suitability of the criteria adopted.</p> <p>Compliance shall be demonstrated by detailed calculations or measurements, or both, depending on the Client's preference. Sufficient numbers of calculations and/or measurements shall be made to ensure that the requirements are met in all specified premises, but in particular for premises near street level and major outdoor sources.</p> <p>Site measurements on the completed building should be on at least one sample of each type of premises/room, taking account the worst case conditions of exposure to noise sources external to the space, and undertaken during periods appropriate to the usage pattern for the space. Measuring equipment shall conform to the accuracy requirements given in IEC 60804 [<sup>144</sup>] to type 2 or better, or equal equivalent standard. For centrally air-conditioned buildings the assessment shall take into account noise from building services equipment.</p> <p>The Client shall submit details in the form of a report prepared by a suitably qualified person providing a schedule of the premises and spaces in the building, relevant design details as they impact on noise isolation, the rooms/premises subject to field tests or for which detailed calculations have been made, the background noise criteria used, underlying assumptions, and the results of tests or calculations demonstrating compliance with the criteria (expressed in parameters that are consistent with the test and/or calculation methods).</p> <p>Where it can be demonstrated that background noise isolation, as measured or calculated for the most susceptible spaces/rooms/premises, meets appropriate performance criteria the credit shall be awarded.</p>

<sup>144</sup> International Electrotechnical Commission. IEC 60804: 2000. Integrating-averaging sound level meters.

*Cost Premium:*

<b>Office</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>
<b>Residential</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>

*Basis for Estimate:*

The growth in the economy during the 1980s and 90s, which brought more construction and more traffic, has also contributed to the noise problem. One million people are affected by excess traffic noise alone, causing it the biggest noise problem in Hong Kong. Noise impacts at the building façade vary to a great extent with the location, e.g. buildings are located in proximity to, or far away from highways. In order to reduce the airborne noise transmission, double glazing windows and noise barriers can be installed at additional initial costs. However, decisions on window to wall ratios, materials and designs for windows and noise barrels are mainly rested on the investors or architects, the additional costs required can impose up to a very high cost impact.

*Benefit:*

Silent neighbourhoods will benefit occupants' health and productivity.

**6.7.4 Indoor Vibration (1 bonus credit)**

- Exclusions: None
- Objective: Avoidance of excessive vibration from building services equipment and external sources.
- Credit requirement: 1 credit for demonstrating vibration levels shall not exceed the prescribed criteria.
- Assessment: The Client shall provide evidence of the investigation in the form of a report prepared by a suitably qualified person demonstrating compliance with the criteria given in ISO 2631-2<sup>145</sup>.

*Cost Premium:*

<b>Office</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>
<b>Residential</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>

*Basis for Estimate:*

Refer to credit 2.3.5 – Noise from Building Equipment.

*Benefit:*

Similar to credit 2.3.5.

**6.8.1 Access for Persons with Disability**

- Exclusions: None.
- Objective: Ensure full access to pertinent building facilities for persons with disability.
- Pre-requisites: Full compliance with Building (Planning) Regulation (CAP 123F) Regulation 72 'Buildings to be planned for use by persons with a disability' and Schedule 3 'Persons With A Disability', and the obligatory design requirements set out in the Code of Practice for Barrier Free Access [146].
- Credit requirement: 1 credit for providing enhanced provisions for access for disabled persons.
- Assessment: The Client shall provide evidence that details the designs to demonstrate full compliance with the pre-requisites, and demonstrate how they provide for enhanced levels of access for disabled persons.  
Credit shall be awarded where, apart from the regulatory requirements the enhanced provisions as identified in the CoP for Barrier Free Access, or similar provisions, are provided where applicable to the type(s) of premises in the building.

<sup>145</sup> International Standard Organization.. ISO2631-2. Evaluation of human exposure to whole-body vibration – Part 2 : Continuous and shock-induced vibration in buildings (1 to 80Hz)

<sup>146</sup> Code of Practice for Barrier Free Access. [http://www.info.gov.hk/bd/english/documents/code/e\\_bfa.htm](http://www.info.gov.hk/bd/english/documents/code/e_bfa.htm)



**Cost Premium:**

<b>Office</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>
<b>Residential</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>

**Basis for Estimate:**

In addition to the obligatory requirements imposed by the Building Regulations, some additional facilities provisions, i.e. public telephones, electronic service points and remote signage system etc, can be provided for the disable people so that they can make full use of the basic facilities in a building without assistance and undue difficulties. The provision of these additional facilities is estimated to have an insignificant cost impact.

**Benefit:**

Ensure full access to pertinent building facilities for persons with disability.

**6.8.2 Amenity Features (2 credits)**

- Exclusions: None.
- Objective: Improve the standard and quality of buildings.
- Pre-requisites: Compliance with the Building Regulations.
- Credit requirement: a) Amenities for the benefit of building users.: 1 credit for providing amenity features that enhance the quality and functionality of a building to the benefit of building users.  
b) Amenities for improved operation and maintenance: 1 credit for providing amenity features that allow for improved operation and maintenance of the building and its engineering services.

**a) Amenities for the benefit of building users**

Assessment: The Client shall submit a report prepared by a suitably qualified person detailing the amenity features provided within the building for the purposes of improving the living and/or working experience of building users. The report shall identify the exempted percentage GFA obtained under regulations, and the additional percentage of GFA provided for the amenities for which no exemption has been allowed.  
Where it can be demonstrated that passive and active recreational facilities, balconies, mail rooms, lift lobbies, common areas, etc., are provided, to at least to the extent described in the referenced documents (see below), and where the Client has included a number of such facilities beyond those giving exemptions in the gross floor area calculations, then the credit shall be awarded.

**b) Amenities for improved operation and maintenance**

Assessment: The Client shall submit a report prepared by a suitably qualified person detailing the amenity features provided within the building for the purposes of improving the flexibility in use and operation and maintenance of the building. The report shall identify the exempted percentage GFA obtained under regulations, and the additional percentage of GFA provided for the amenities for which no exemption has been allowed.  
Where it can be demonstrated that provisions that serve to enhance operation and maintenance exist, to at least to the extent described in the referenced documents (see below), and where the Client has included a number of such facilities beyond those giving exemptions in the gross floor area calculations, then the credit shall be awarded.  
Given that the nature and extent of amenities will vary with the type and scale of the development the Client should provide the rationale if any of the listed amenities is not included.

**Cost Premium:**

<b>Office</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>
<b>Residential</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>

*Basis for Estimate:*

Amenity features are loosely defined as those elements are decided by the investors and Architect. The amount of expenditure may vary to a great extent, i.e. club houses, swimming pools and IT services, and which may be mostly depended on the classes or value of buildings.

*Benefits:*

The Developer may be required to provide the amenity features as part of the conditions of development, and would be factored in with the investment decisions. If such features are provided without conditions, then there would be a premium. The benefit could come from improved saleability if highlighted to potential tenants or owner/occupiers the provision of internal facilities other than public ones.

**6.8.3 IT Services**

- Exclusions: None.
- Objective: Enhance facilities for IT and communications.
- Credit requirement: 1 credit for including the required percentage of serviceability measures and IT facilities identified.
- Assessment: The Client shall submit a report prepared by a suitably qualified person that includes: a completed checklist of the facilities and measures provided, justification for each checked item, and details of the physical systems provided.  
 In the case of offices and similar workplaces the credit shall be awarded for 70% compliance of applicable items. In the case of residential buildings, hotels and apartment buildings the credit shall be awarded for 35% compliance of applicable items.  
 The Client may provide a rationale and arguments to demonstrate additional enhancements to serviceability and IT facilities, which can be submitted within the assessment grid.

*Cost Premium:*

<b>Office</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>
<b>Residential</b>	<b>U</b>	<b>0</b>	<b>0+</b>	<b>L</b>	<b>M</b>	<b>H</b>

*Basis for Estimate:*

Similar to credit 6.8.2 – Amenity Features

*Benefits:*

It can enhance facilities for IT and communications.