RESEARCH SUMMARY Costs and Financial Benefits of Undertaking Green Building Assessments

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GREEN BUILDING

Costs and Financial Benefits of Undertaking Green Building Assessments

Construction Industry Institute
HONG KONG
香港建造業研究學會

Construction Industry Institute - Hong Kong

Summary Report of the CII-HK Research Project

Costs and Financial Benefits of Undertaking Green Building Assessments

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Green buildings are those which go beyond regulatory requirements and usual practice and meet Environment Assessment Standards as well. This persuasive research is a most useful exposition of what needs to be done when designing new buildings and how to improve the built environment through the 'efficient use of energy, water and other resources whilst reducing to the minimum possible related emissions, waste and effluent.'

It points the way for our Government to take the lead, to live up to its proclaimed status as Asia's world city by improving the quality and performance of our entire building stock. If the Government does this all architects, engineers and other professions involved in building Hong Kong will fall into line and follow this good example.

Here then is yet another valuable research document from the Construction Industry Institute and I congratulate the team and authors in showing Hong Kong the way.

The Hon Sir David Akers-Jones, GBM, JP
Chairman
Construction Industry Institute – Hong Kong

Recent increases in oil prices and the potential threat of peak oil will change the supply and demand equation of energy and have significant impact on the economy. Global warming and climate change will add more pressure to reduce consumption of fossil fuels. These issues are high on the economic, social, environmental and political agenda of all countries. There is no exception for Hong Kong.

Typical of metropolises, energy used in buildings accounts for most of the total energy consumption. In Hong Kong, this number for residential and commercial buildings is approximately 56% of the total primary energy used. This offers lots of opportunities for energy conservation in our building stock to reduce our excessive dependence on fossil fuels.

Some of the principal missions of CII are to promote and encourage the real building construction industry to be more cost effective, to minimise energy consumption, to reduce pollution loading and to improve of the built environment. I am therefore delighted to see this research paper on 'Cost and Financial Benefits of Undertaking Green Building Assessments' which uses HK-BEAM as the assessment guide to demonstrate the marginal financial benefit to go green significantly outweighs the margin costs in both commercial and residential buildings.

The paper recommends that HK-BEAM can be further enhanced taking hint from the CEPAS method to provide certification at various stages of project development, the HKSAR Government to implement more robust regulatory framework and to enforce compulsory building labeling for all workplaces, and integration of the testing and commissioning systems throughout the design and build process.

Taking the continuous escalation of energy costs, mitigation of climate change, provision of a more pleasant and healthy living environment into consideration, I agree with the paper that additional tangible and intangible benefits could be gained by greening of Hong Kong building stock with life cycle approach.

I would wish to congratulate CII in sponsoring this research paper and compliment CII for their foresight and effort in carrying research work not only for the improvement of the construction industry but also for the long term well being of Hong Kong.

Ir Otto Poon
Member of the Sustainable Development Council, HKSAR

The word 'green' is oftentimes a misnomer in the language of laymen infesting the concrete and steel habitats of today. The belief that 'green' buildings are of necessity costing a lot more to erect could easily be another fallacy common to many uninformed developers contributing unwittingly to an unsustainable built environment. This collaborative research with the Hong Kong Polytechnic University aims to dispel some of the fundamental misconceptions in the industry and attempts to chart an educated course, with concerted efforts by regulators and building professionals from the industry alike, to combat responsibly the grave issues of environmental pollution and global warming in a rational and practical manner albeit belated and minimal on a global scale.

Findings of the research confirm the worldwide realization that quality of the process is the key to the production of 'greener' and more sustainable buildings rather than any particular 'green' features or attributes. It is also revealed that, to achieve a 'green' label for a new building, the associated premium is indeed within very tolerable limits.

CII-HK acknowledges the valuable contribution by Davis Langdon & Seah Hong Kong Limited and the Housing Authority for their real cost data inputs to the research. The industry should be pleased to note that HK-BEAM is now the recognised 'green' assessment model for new developments in Hong Kong with clearly identified criteria for improvement after years of application. CII-HK encourages the introduction of similar 'green' labels relevant to occupied buildings of the existing stock, the number of which far exceeds any new buildings we have on the drawing board.

The Executive Board
Construction Industry Institute – Hong Kong

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RESEARCH HIGHLIGHTS

Green Building Assessments

This study has examined the costs and financial benefits of green building assessments for new buildings in Hong Kong. The estimates are based on two case studies:

- an air-conditioned office building of 'generic' design, and
- a low-cost (public sector) high-rise residential building, assessed using the Hong Kong Building Environmental Assessment Method (HK-BEAM), which has been widely employed for assessing the environmental performance of residential and commercial buildings in Hong Kong.

Cost Premiums

The following table summarises the minimum premiums on construction cost (excluding fit-out) for the generic office building assessed under HK-BEAM version 1/96R 'New Offices' (1999) and version 4/04 'New Buildings' (2004).

Grade	% Credits	% Premium
	HK-BEAM 1/96R - 59 credits*	
'Good'	55%+	0%+
'Very Good'	65%+	< 1%
'Excellent'	75%+	1%+
	HK-BEAM 4/04 – 112+ credits*	
'Silver'	55%+	0.8%+
'Gold'	65%+	1.3%+
'Platinum'	75%+	3.2%+

* Number of credits varies depending on particular circumstances for a project.

The following table summarises the minimum premiums on construction cost for the high-rise residential building assessed under HK-BEAM version 3/99 'Residential' (1999) and version 4/04 'New Buildings'. The percentages for private sector buildings are about half of the values given for public sector (low-cost) buildings as the construction cost for private sector buildings is about double that for public sector buildings.

Grade	% Credits	% Premium
	HK-BEAM 3/99 - 75 credits*#	
'Good'	45%+	0.5(1.1)%+
'Very Good'	60%+	1.6(3.3)%+
'Excellent'	70%+	3.3(7.3)%+
	HK-BEAM 4/04 – 104+ credits*#	
'Silver'	55%+	0.8(1.7)%+
'Gold'	65%+	1.7(3.7)%+
'Platinum'	75%+	3.4(7.5)%+

* Number of credits varies depending on particular circumstances for a project.
# The percentages are based on the construction cost for a typical private sector apartment building. Percentages in parenthesis apply to low-cost residential building.

In both cases the cost of financing, additional design time/fees, and assessment fees are excluded from these estimates.

The estimates for HK-BEAM versions 1/96R and 3/99 provide historical data as both assessment methods have been replaced by version 4/04.

Caveat

Given the variability of site conditions, building scale and design, as well as the currency of the data used in this study projecting these estimates to particular project would not be appropriate. Rather, the cost premiums should be seen as indicative for a stock of new 'green' buildings in Hong Kong.

Potential Benefits

Green building assessments can lead to better quality and better performing buildings. The higher the assessment grade the better the likely performance although, within a given grade, performance can vary depending on which criteria are satisfied.

- Benefits depend on the enhancements to performance that are a consequence of the assessment, and the persistence over time.
- Tangible benefits, such as reduced energy consumption, ensue from investment in energy efficient design, system and equipment selection and installation, appropriate commissioning and provisions for consequent operation & maintenance.
- Intangible benefits such as improved health, comfort and productivity are recognised, yet are difficult to quantify, although it is clear that green buildings reduce the risks associated with poor quality indoor environments.

Air-conditioned Buildings

In air-conditioned office buildings energy performance is a responsibility shared between the owner/operator and the tenants/users.

- Significant energy performance gains accrue from right-sizing and well-controlled HVAC systems.
- Efficient and well-controlled lighting systems and equipment installed in occupied areas save energy, including a reduction in air-conditioning energy use.

However, reasonably accurate estimates of potential financial benefits from reduced energy use depends on the accuracy of the estimates, i.e. the energy modelling technique employed, the appropriate design data and assumptions about occupancy and use.

Residential Buildings

In the case of high-rise residential buildings the design has somewhat less impact on life-cycle energy performance although, subject to the immediate external environment, can improve indoor environmental quality in individual units through improved daylighting and use of natural ventilation. Ultimately, however, the activities and lifestyle choices of residents have greatest impact on both indoor environments and energy performance.

Whilst price and location dominates purchases decisions there is some evidence that building quality and site amenities are also valued.

Enhanced Process

A growing realisation world-wide is that the quality of process is the key to the production of greener and more sustainable buildings, in particular:

- An integrated design approach whereby all stakeholders are involved in decision making at the earliest stages of planning and design.
- Employment of sophisticated energy modelling techniques using appropriate design data and projected usage patterns.
- Enhanced quality assurance during construction, particularly with regard to the testing and commissioning of building systems.

Recommendations

Hong Kong should live up to its proclaimed status as Asia's World City by taking more tangible steps to reduce its environmental footprint by improving the quality and performance of the entire building stock. Better quality buildings add value and are an asset to supporting the development of the HKSAR's economy.

HKSAR Government

In moving towards this goal the HKSAR Government should:

- Include energy performance criteria for new and refurbished buildings within the building regulations based on the existing voluntary performance-based energy code, but with performance targets of at least 20% improvement over the minimum requirements.
- Include the requirement for full testing and commissioning of non-residential air-conditioned buildings within the building regulations.
- Endorse and provide incentives for green buildings by including requirements for minimum performance, i.e. HK-BEAM 'Silver' grade within the planning and approvals framework, including non-residential government funded buildings.
- Introduce mandatory energy performance declarations for all existing non-residential buildings.

HK-BEAM Society

To align and support new initiatives HK-BEAM should be modified such that:

- Assessment criteria for new buildings reinforce the quality of process, from planning through to handover, by following the CEPAS approach in providing pre-certification of the building design.
- Strengthen assessment outcomes by including pre-requisites for energy performance.
- Change to weighting and scoring system to reflect growing concerns about external environmental impacts, particularly global warming.
- Provide a certification method that conveys the assessed performance in the areas of indoor environmental quality and energy efficiency.

Further Studies

Further studies should be undertaken into refining the data presented in this study, including:

- Impacts on the economy as a consequence of sub-standard building performance.
- Estimating the costs and benefits of green buildings assessments for existing non-residential buildings.

1

INTRODUCTION

Background

More often than not investment decisions for building projects tend to be based on considerations of initial cost. Consequently, any investment in green attributes for a building is likely to depend on the additional cost, i.e. the cost premium over conventional construction practice. Many clients and consultants worldwide, including Hong Kong, have a perception that environmentally friendly buildings cost substantially more to build than conventional designs, with premiums of the order of 5-15% or more being quoted.

This study has sought to reduce the uncertainty by providing data on the premiums over the cost of standard construction, and to outline the potential 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). In essence, the analysis is intended to enable stakeholders to determine the likely cost premiums to obtain the desired HK-BEAM rating.

Green Buildings

A green building is characterised as providing the required building performance over its life-cycle whilst minimising consumption of non-renewable resources and the environmental loadings to land, air and waters. This notion provides a focus for improving the eco-efficiency of buildings and, by emphasising performance requirements that impact on human health, also embraces economic and social dimensions of sustainability.

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.

However, quantifying the life-cycle performance and impacts of large buildings is very difficult with changing use, refurbishment, redecoration, etc, impacting on performance. In the case of heavily-serviced buildings, the significance of the building structure diminishes in comparison to the cumulative impact of several generations of major equipment, upgrades to building systems, and changes to space layout, etc.

Certified Green Buildings

In practice, green buildings are generally regarded as those that have been assessed and certified under a building environmental assessment method (BEAM) such as HK-BEAM. Currently over twenty schemes are in use worldwide.

Generally speaking, BEAM assessments embrace global, regional, local and indoor aspects of building performance, requiring implementation of practices, techniques and technologies which go beyond regulatory requirements and usual practice. Assessments define performance criteria (benchmarks, features and provisions), the required approach to demonstrate compliance, and the evidence to be submitted for certification. The outcome of an assessment is a certified grade or rating (e.g. Very Good', 'Silver') depending on which performance criteria have been satisfied. The higher the number of points or credits obtained the better the grade. However, within a given grade, the overall outcome can vary depending on which particular criteria have been met. For example, emphasis could be on meeting indoor environmental performance criteria as opposed to energy performance criteria.

Furthermore, an assessment for a new building covers only enhancements to planning, design, construction, and handover phases. Performance during subsequent use depends on the design enhancements and the 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.

HK-BEAM

The HK-BEAM scheme has been under development since the publication in 1996 of two versions for office buildings. HK-BEAM 1/96 (New Offices) and HK-BEAM 2/96 (Existing Offices) were updated in 1999 as versions 1/96R and 2/96R, respectively. HK-BEAM 3/99 (Residential) was published in 1999. Pilots for new expanded versions were developed in 2003 to be revised and released in December 2004 as HK-BEAM 4/04 'New Buildings' and HK-BEAM 5/04 'Existing Buildings. Well over one hundred major projects have undergone a HK-BEAM assessment.

HK-BEAM Assessments

The earlier versions of HK-BEAM covered a somewhat limited range of performance issues. Version 1/96R included 59 credits, and version 3/99 around 75 credits, with variations depending on the particular circumstances of a project.

In keeping with the international trends the current versions seek to provide for a more comprehensive assessment, especially for large and complex buildings. HK-BEAM 4/04 for new buildings includes a wider range of issues (over 110 credits), some of which are performance-based, and some prescriptive, i.e. the inclusion of particular features, and provisions that help to enhance subsequent building management, operation and maintenance.

The focus of required performance is on the assessment of indoor environmental quality (IEQ), expressed in terms of thermal comfort, indoor air quality, lighting quality, acoustics and noise, and hygiene, although other 'sustainability' aspects of building performance such as safety and amenities are also included. Given the potential impact on productivity in workplaces and the overall quality of life of citizens, good IEQ is clearly germane to the economic and social performance of buildings of all types.

As Fig. 1 shows the assessed issues (credits) are grouped in different categories covering a wide range of external environmental impacts, at the site, local, regional and global scales.

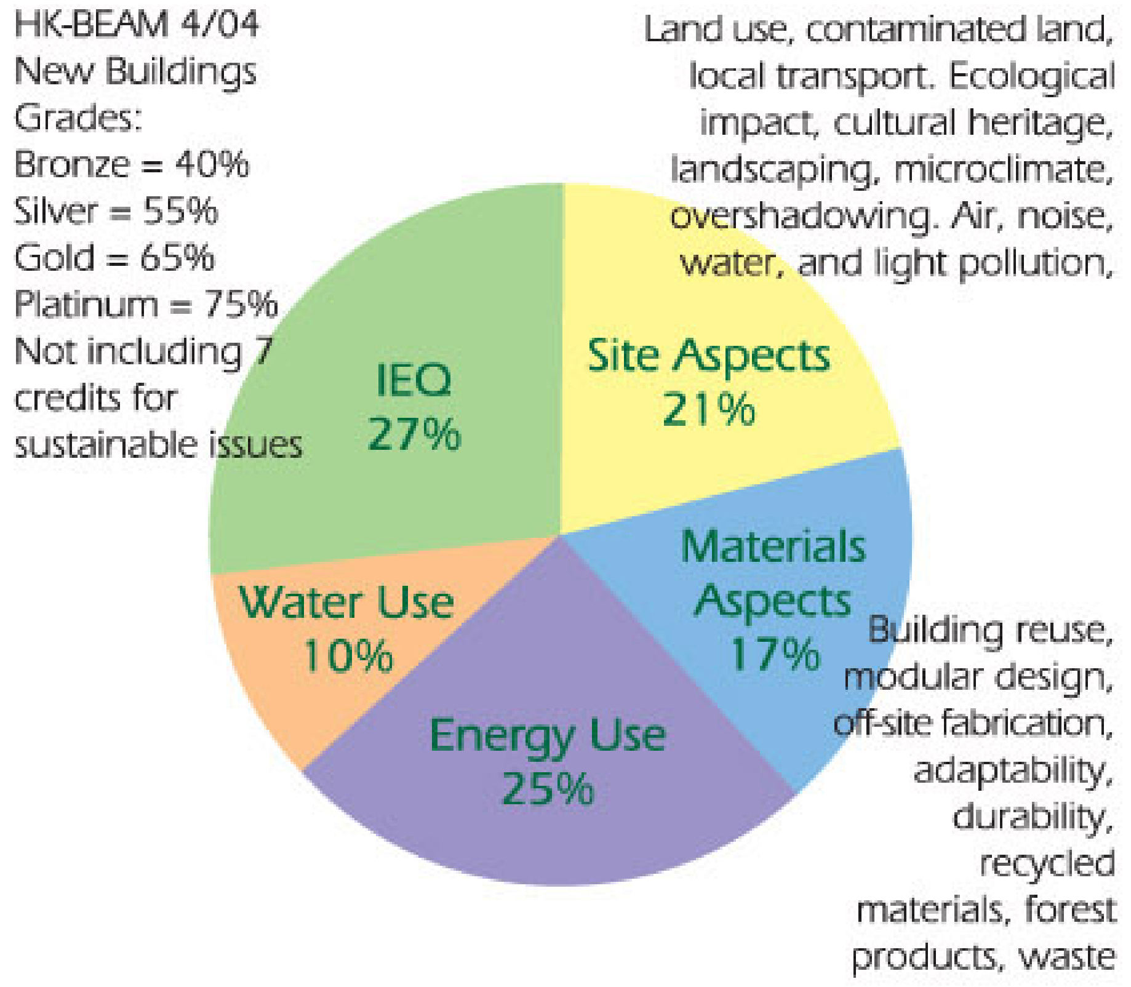


Fig. 1 Performance categories and weightings in HK-BEAM 4/04 (applicable to office buildings)

This Study

Starting in early 2005 the study was undertaken in stages. The focus of Stage I was new air-conditioned office buildings using data from assessments under HK-BEAM version 1/96R. Stage II focused on new high-rise residential developments using data from projects assessed under HK-BEAM 3/99. The Stage III study considered the costs and potential financial benefits of undertaking assessments under HK-BEAM 4/04 applied to both office-type buildings and high-rise residential buildings, respectively.

The 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 and less comprehensive assessments. The final report for this project places emphasis on the Stage III cost-benefit analysis and the potential to enhance the development of greener, and more sustainable buildings in Hong Kong.

The Stage I and Stage II reports, together with the final report following the completion of Stage III are included in the accompanying CD-ROM.

2

METHODOLOGY

Approach

Given that cost data available from HK-BEAM assessed projects are usually incomplete and vary depending on particular circumstances, a bottom-up approach was adopted for estimating the additional cost for different levels of award, i.e. 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 a Client had the capability of accessing all required technical and cost information, and would deploy an investment strategy that would achieve the performance grade at the least cost.

The estimates are based on two case studies:

- an air-conditioned office building of 'generic' design, and
- a low-cost (public sector) high-rise residential building.

Generic Office Building

The generic office building configuration is shown in Fig. 2. The site setting and key design data (Table I) is rather typical of large office buildings as demonstrated by a territory wide survey.

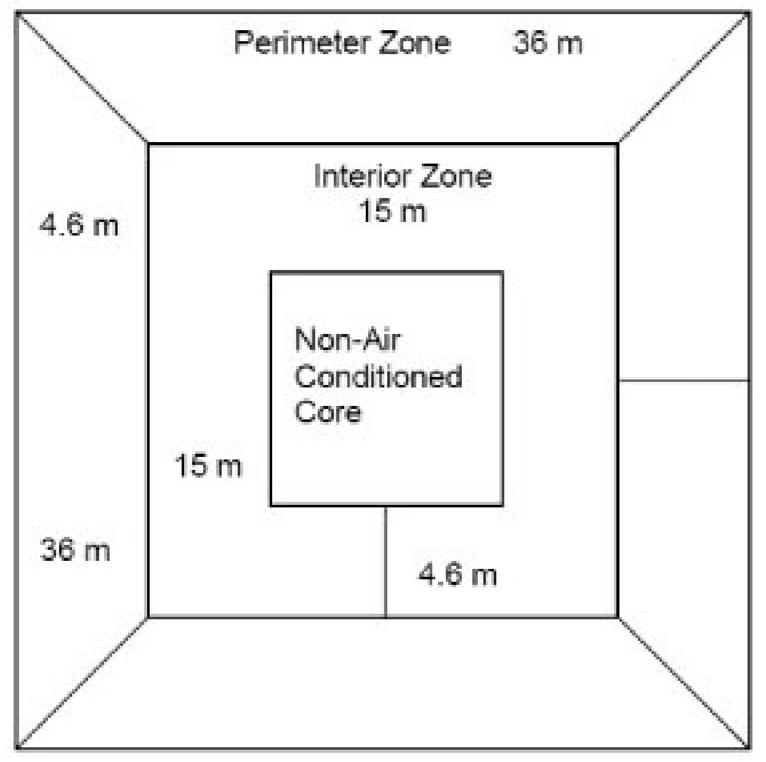
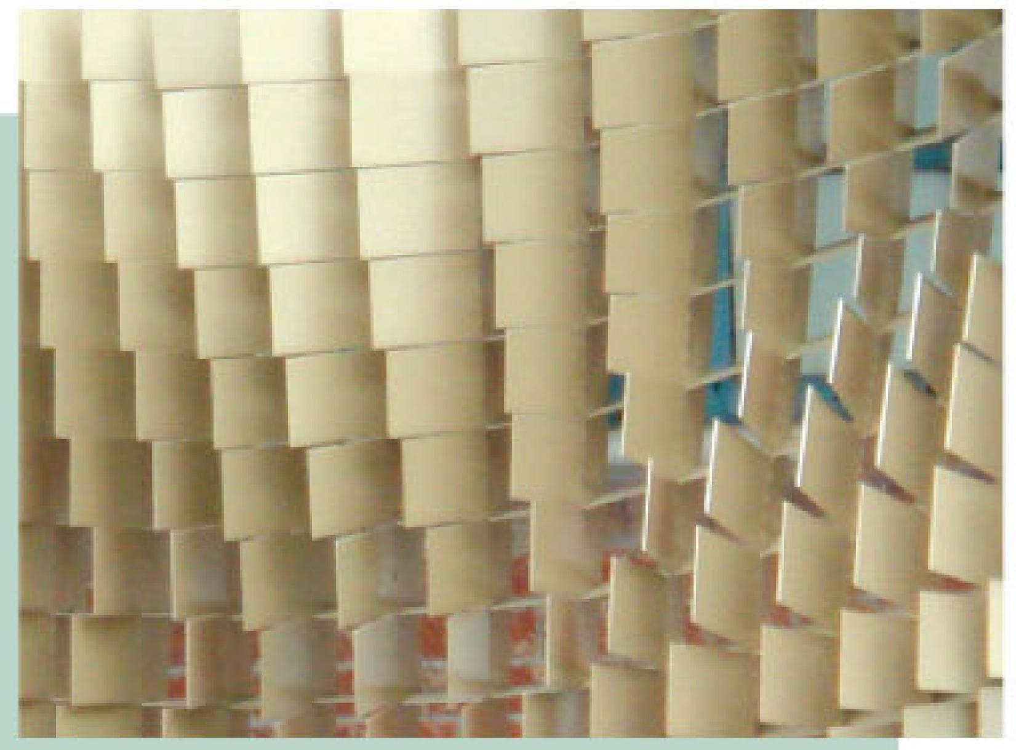


Fig. 2 Generic office building

Table I Key data for generic office building

Parameter	Value
Number of floors	40
Floor to floor height	3.2 m
Perimeter zone (36 x 36 m)	567 m^2
Interior zone (27 x 27 m)	504 m^2
Core – non A/C (15 x 15 m)	225 m^2
Floor area	1,071 m^2
Total floor area	42,840 m^2
Permitted site coverage	65%
Open space/landscape area	700 m^2
Occupation density	9 m^2/person
Total population	4760
Window/wall area ratio	0.50
Shading coefficient	0.45
OTTV	34.7 W/m^2
Installed lighting load	25 W/m^2
Appliances load	25 W/m^2
Pump efficiency	0.6
Fan efficiency	0.55
Annual electricity consumption	280 kWh/m^2 (air-cooled) 240 kWh/m^2 (water-cooled)
Maximum electricity demand	180 VA/m^2 (air-cooled) 138 VA/m^2 (water-cooled)
Ventilation rate	10 l/s/person
Infiltration rates	0.1 air change/hour
Primary filters	60-65% efficiency
Secondary filters	60-65% efficiency



High-rise Residential Building

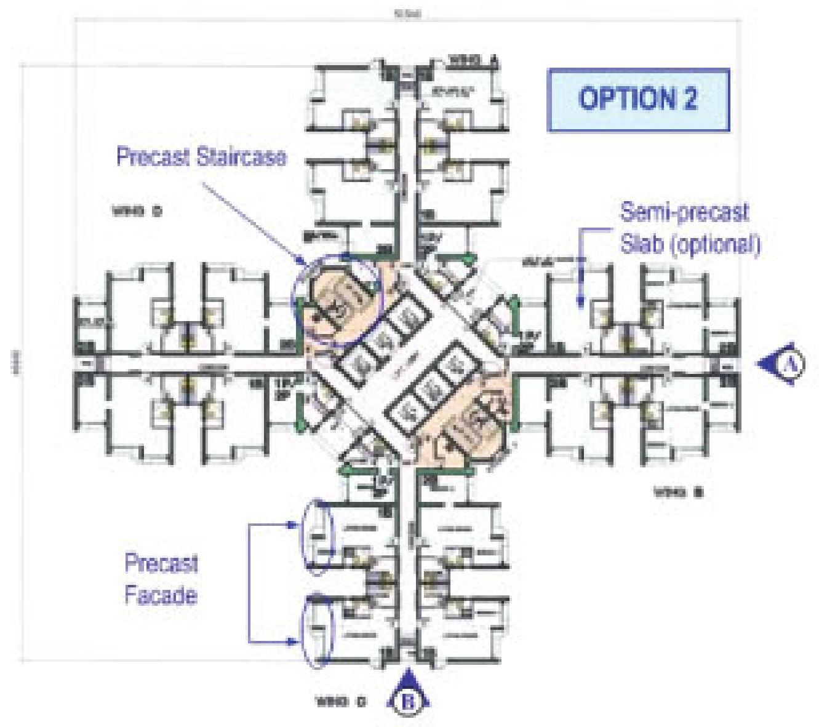


Fig. 3 Layout of Harmony Block

Since it was not feasible to cater for the many different residential building designs in this study the cost and benefit estimates provided have been estimated with reference to a low-cost residential building design. As about one third of the population of Hong Kong lives in public rental housing a Housing Authority Harmony Block (Fig. 3) was selected as the baseline high-rise 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 current regulations and taking into account the practice of local developers. 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 (Table II).

Table II Key data for the Harmony Block

Parameter	Values
Number of floors	41
Floor to floor height	2.7 m
Floor area	896 m^2
Total floors area	36,750 m^2
Total no. of units	799
Total pupation	2,431person
Window/wall ratio area	0.65
Site coverage	40%
Open space and landscape area	1,590 m^2 & 1,260 m^2
Window/wall area ratio	0.65
Shading coefficient	0.65
OTTV	42.85 W/m^2
Installed lighting load	19 W/m^2
Annual electricity consumption	110 kWh/m^2
Air conditioning system	Window or split-type units

Cost Data

For this study, the additional cost required to implement a specific green measure (credit compliance) has been estimated by using market all-in-rates 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 was based as far as possible on actual data or estimated data for the projects assessed under HK-BEAM 1/96R (New Offices), and was estimated in terms of dollar values. However, given the widely variable circumstances for high-rise residential building designs obtaining relevant cost data for residential buildings in Stage II was more problematic. As the project proceeded it was decided that cost data for Stage II was to be incorporated with cost data for residential buildings in Stage III.

Since HK-BEAM 4/04 has been expanded in scope and number of assessment criteria compared to previous versions estimating cost premiums and potential benefits are subject to even wider variations. 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 4/04 registered projects remain in the assessment stage with cost data and assessment outcomes incomplete. Furthermore, given that a number of alternative design approaches can be adopted to achieve the targeted credits, the cost premiums for achieving the performance based credits can vary significantly.

Cost Premiums for Individual Credits

Given the variability of circumstances that can affect the cost premium, in Stage II and III credits were grouped into 5 categories of cost premium: 'no', 'insignificant', 'low', 'moderate', and 'high' cost (Tables III and IV).

As the outcomes of this study are compared to similar studies conducted elsewhere, the basis for deciding low/moderate/high cost premiums have been guided by comparisons with what others have regarded as low, moderate or high cost bands.

For example in a US GSA study the cost range was based on lump sum premiums. Analysis reveals that this represents a premium of around 0.3% for a moderate cost premium which seems to be reasonably consistent with the overall cost premium of around 2% for a LEED 'Silver' grade as conclude in a California study[1].

Office Building Cost Premiums

Table III Cost premiums for office building

Cost Impact	(%)	HK$/$m^2$
Average standard high-rise office building		
No cost – '0'	0	0
Insignificant cost - '0+'	< 0.1	< 11
Low cost - 'L'	0.1 – 0.3	11 – 34
Moderate cost - 'M'	> 0.3 – 1.0	> 34 – 113
High cost - 'H'	> 1.0	> 113
Unable to estimate - 'U'		

For costs estimates under HK-BEAM version 1/96 the cost basis for the generic office building was HK$10,600 (2005 data), but for version 4/04 the cost basis is HK$11,300/$m^2$ (2006 data), being the mean cost for an 'Average Standard Office' building Davis Langdon & Seah Hong Kong Limited. Construction Cost Handbook (China & Hong Kong 2006 and 2007), not including fit-out costs for each year.

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[1] The Costs and Financial Benefits of Green Buildings. Sustainable Building Task Force. California. October 2003.

Residential Building Cost Premiums

The basis for the baseline residential building is HK$4,000/m^2, the approximate cost of a 'Low-cost Residential' building (not including air-conditioning units), there being little change between 2005 and 2006. For a private sector residential (apartment) building the construction cost for 2006 was HK$8,900/m^2.

Table IV Cost premiums for residential building

Cost Impact	(%)	HK$/m^2
Low cost high-rise residential buildin		
No cost – '0'	0	0
Insignificant cost – '0'	< 0.1	< 4
Low cost – 'L'	0.1 – 0.3	4 – 12
Moderate cost 'M'	> 0.3 – 1.0	> 12 – 40
High cost – 'H'	> 1.0	> 40
Unable to estimate - 'U'		

Site-realted Construction Costs

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

Low cost credits – cost premium falls in the range of HK$0– $0.25m;

Moderate cost credits – cost premium 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.

Excluded Costs

The study focuses on so-called 'hard costs', the premium for implementing a given credit. The soft costs for design are not included. Soft costs, such as the cost of computer simulations or building surveys, 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 finalised 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 additional cost in an assessment.

Also excluded are the 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, and would be classified as being a 'low cost' premium.

Estimation of Overall Cost Premiums

The process for assessing individual credits in order to develop a goal for certification follows the logic shown in the flow chart shown in Fig. 4. 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-cost, insignificant-cost or low-cost, before examining credits that are likely to incur moderate to high cost premiums, thereby warranting a more detailed cost/benefit analysis.

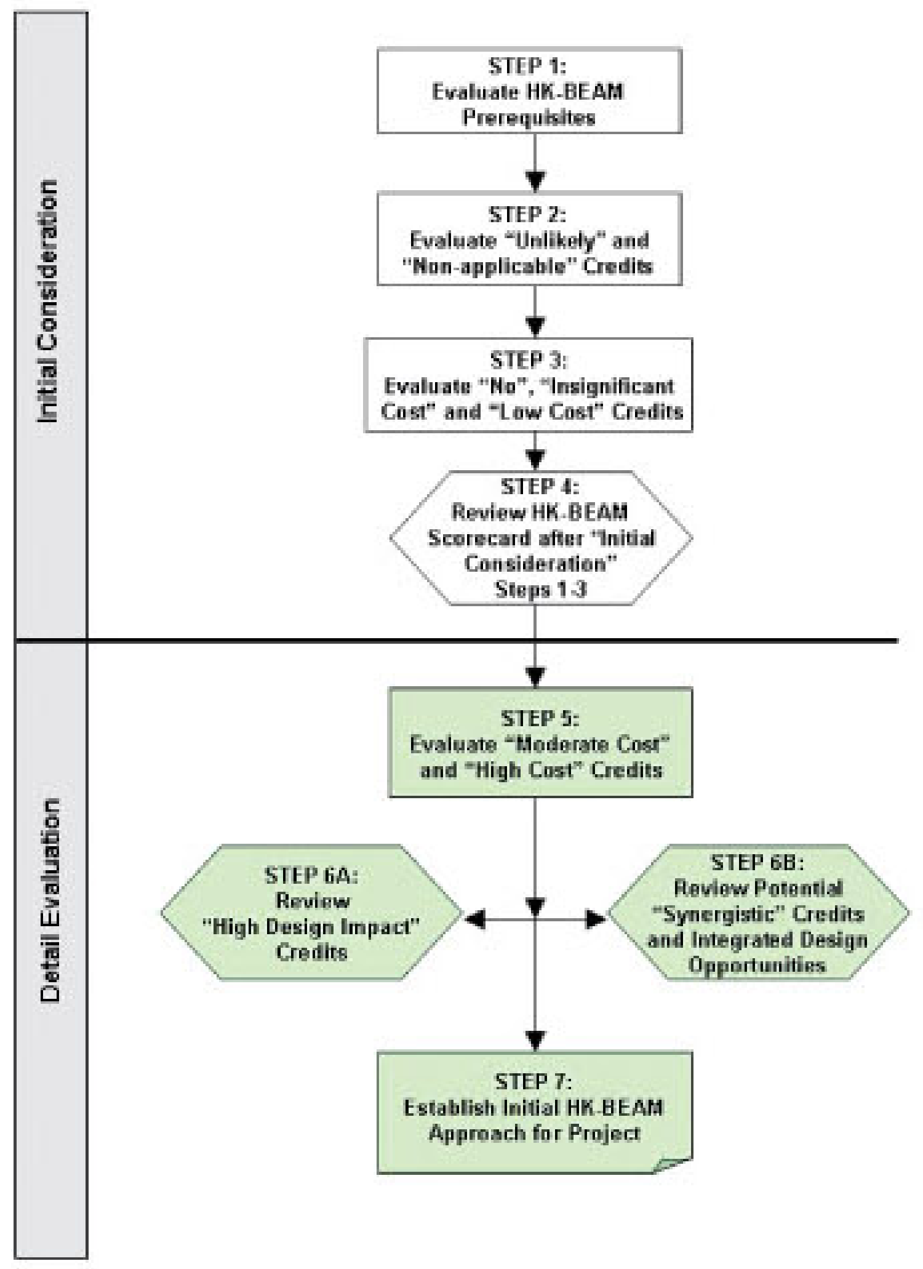

Fig. 4 Process to estimate overall cost premium (based on GSA guide[3])

Table V provides a summary of the cost premiums for each credit for the generic office building, whilst Table VI provides a summary for the high-rise residential building. The tables include only the 'core' credits applicable to an assessment. 'Bonus' credits are not included in the analysis. 'U' identifies credits for which no decision on cost was made for various reasons, such as incomplete or unreliable data.

Key Assumptions

The analysis has been based on the following assumptions:

- Initial material and equipment costs have been estimated by using the all-in rates.
- 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.
- Potential costs and benefits associated with credits have been projected to a period of 5 years after the completion of a building. 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$0.82/kWh for office buildings and HK$0.89/kWh for residential buildings have been used for estimating the monetary benefits associated with energy savings.

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[3] US General Services Agency.GSA LEED® Applications Guide. February 2005)

- A water consumption charge of HK$4.6 per m^3 together with effluent charge of HK$1.2 per m^3 has been used for estimating the monetary benefits gained from water savings.
- No future price escalation has been considered for fuel prices.

Observations

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, 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. For high-rise residential buildings the greater variability in the layout, design and usage patterns increases greatly the uncertainties in estimation of cost premium and the potential outcomes.

Table V Credits and Cost Impacts for HK-Beam 4-04 Assessments - Office Building

Ref:	SITE ASPECTS	C	P
2.1.1	Land Use - Uses reclaimed land	1	0,M>H
	Land Use - Uses Brownfield site	2	
2.1.2	Contaminated Land	1	0,M>H
2.1.3a	Local Transport - Car parking provisions	1	0
2.1.3b	Local Transport - Access to public transport	1	0
2.1.4a	Neighbourhood Amenities - Services	1	0+>L
2.1.4b	Neighbourhood Amenities - Recreational facilities	1	0+>L
2.1.4c	Neighbourhood Amenities - Provided facilities	1	L>M
2.2.1	Site Design Appraisal	1	L
2.2.2	Ecological Impact	1	L>M
2.2.3	Cultural Heritage	1	L
2.2.4a	Landscaping and Planters - Hard landscaping	1	0+
2.2.4b	Landscaping and Planters - Soft landscaping	1	0+
2.2.5a	Microclimate around Buildings - Wind amplify.	1	U
2.2.5b	Microclimate around Buildings - Elevated temp.	1	U
2.2.6a	Overshadowing and Views - Minimum daylight	1	0+
2.2.6b	Overshadowing and Views - Negative impacts	2	
2.2.7	Vehicular Access	1	0
2.2.8	Demolition/ Construction Management Plan	1	0+
2.3.1	Air Pollution During Construction	1	0+
2.3.2	Noise During Construction	1	0
2.3.3	Water Pollution During Construction	1	0+
2.3.4	Emissions from Cooling Towers	1	0+
2.3.5	Noise from Building Equipment	1	0+>L
2.3.6	Light Pollution	1	0+

Note: Bonus credits (B) not included in cost-benefit analysis

Ref:	MATERIALS ASPECTS	C	P
3.1.1	Building Reuse - 15% sub-structure or shell	1	0
	Building Reuse - 30% sub-structure or shell	2	
3.1.2	Modular and Standardized design	1	0
3.1.3	Off-site Fabrication - 50% of listed elements	1	L>M
	Off-site Fabrication - 80% of listed elements	2	
3.1.4a	Adaptability and Deconstruction - Structural	1	M
3.1.4b	Adaptability and Deconstruction - Spatial	1	M
3.1.5	Envelope Durability	1	0
3.2.1	Rapidly Renewable Materials	1	L>M
3.2.2a	Sustainable Forest Products - Temporary works	1	L>M
3.2.2b	Sustainable Forest Products – Used in building	1	0+
3.2.3a	Recycled Materials - Outside surface works	1	0
3.2.3b	Recycled Materials – Building structure	1	0+
3.2.4a	Ozone Depleting Substances – Refrigerants	1	0
3.2.4b	Ozone Depleting Substances – Materials	1	0>L
3.3.2a	Construction Waste - Waste management	1	0+
3.3.2b	Construction Waste - Sorting and recycling	1	0+
3.3.2c	Construction Waste - Quantity of recycled waste	1	0+
3.3.3	Waste Disposal and Recycling Facilities	1	0+

Ref:	ENERGY USE	C	P
4.1.1a	Annual Energy Use - Annual energy consumption	1>4 5>6 7>10	0+>L M H
4.1.1b	Annual Energy Use - Maximum electricity demand	1 2>3	0+>M H
4.2.1	Embodied Energy in Building Structure	2	0
4.2.5	Lift and Escalator Systems	1	0
4.2.6	Electrical Systems	1	0
4.3.3	Energy Efficient Lighting in Public Areas	1	0+
4.4.1a	Testing and Commissioning – Specifications	1	0+
4.4.1b	Testing and Commissioning – Commissioning plan	1	L>M
4.4.1c	Testing and Commissioning – Commissioning	1	0+
4.4.1d	Testing and Commissioning – Report	1	0+
4.4.2a	Operation & Maintenance - O & M manual	1	0+
4.4.2b	Operation & Maintenance - Energy management	1	0+
4.4.2c	Operation & Maintenance - Training & facilities	1	0+
4.4.3	Metering & Monitoring	1	L

Ref:	WATER USE	C	P
5.1.1a	Water Quality - Fresh water plumbing	1	0
5.1.1b	Water Quality – Water quality survey	1	0+
5.2.1	Annual Water Use - Less 15%	1	0+
	Annual Water Use - Less 25%	2	0+>L
	Annual Water Use - Less 35%	3	0+>L
5.2.2	Monitoring and Control - 2 features	1	0+>L
	Monitoring and Control - all 3 features	2	0+>L
5.2.3	Water Efficient Irrigation	1	U
5.2.4a	Water Recycling - Harvesting rainwater	1	0+
5.2.4b	Water Recycling - Greywater recycling	1B	0+
5.2.4c	Water Recycling - Recycled water	1B	L
5.2.5a	Water Efficient Facilities & Appliances - Facilities	1	0+
5.2.5b	Water Efficient Facilities & Appliances	1	0+>L
5.3.1	Effluent Discharge to Foul Sewers	1	0+

Ref:	INDOOR ENVIRONMENTAL QUALITY	C	P
6.1.1a	Fire Safety - Design integration	1	0
6.1.1b	Fire Safety - Fire safety manual	1	0
6.1.2	Electromagnetic Compatibility	1	0+
6.1.3	Security	1	0
6.2.1	Plumbing & Drainage	1	0
6.2.2	Biological Contamination	1	0+
6.2.3	Waste Disposal Facilities	1	0+
6.3.1a	Construction IAQ Management - Implementation	1	0+
6.3.1b	Construction IAQ Management - Filter /flush out	1	0
6.3.2a	Outdoor Sources of Air Pollution - CO	1	0+
6.3.2b	Outdoor Sources of Air Pollution – NO_2	1	0+

6.3.2c	Outdoor Sources of Air Pollution – Ozone	1	0+
6.3.2d	Outdoor Sources of Air Pollution – RSP	1	0+
6.3.3a	Indoor Sources of Air Pollution – VOCs	1	0+
6.3.3b	Indoor Sources of Air Pollution - Formaldehyde	1	0+
6.3.3c	Indoor Sources of Air Pollution - Radon	1	0+
6.3.4	IAQ in Car Parks	1	0+
6.3.5	IAQ in Public Transport Interchanges	1	0+
6.4.1a	Ventilation in air-conditioned premises - Rate	1	0+
6.4.1b	Ventilation in air-conditioned premises - Air change	1	0+
6.4.4a	Localised Ventilation - Source control	1	0+
6.4.5a	Ventilation in Common Areas - Provided	1	0+
6.4.5b	Ventilation in Common Areas - Natural vent.	1B	0+
6.5.1a	Thermal Comfort - Temperature (no-load)	1	0+
	Thermal Comfort - Temperature (full-load)	1	
6.5.1b	Thermal Comfort - Room air distribution	1	0+
6.6.1	Natural Lighting - VDF or 0.5% DF	1	0+
	Natural Lighting - 1% DF	2	0+
	Natural Lighting - 2% DF	3	0+
6.6.2a	Interior Lighting in Occupied Areas - Illuminance	1	0+
6.6.2b	Interior Lighting in Occupied Areas - Glare	1	0+
	Interior Lighting in Occupied Areas - Modulated	1	0+
6.6.3	Interior Lighting in Areas not Occupied	1	0
6.7.1	Room Acoustics	1	0+
6.7.2	Noise Isolation - Airborne noise isolation	1	L>M
	Noise Isolation - Impact noise isolation	1	I.>M
6.7.3	Background Noise	1	0>H
6.7.4	Indoor Vibration	1B	0+>L
6.8.1	Access for Persons with Disability	1	0+
6.8.2a	Amenity Features - For building users	1	U
6.8.2b	Amenity Features - For improved O & M	1	U
6.8.3	IT Provisions	1	U

Ref:	INNOVATION AND ENHANCEMENTS	C	P
7.1	Innovation Techniques	5B	U
7.2	Performance Enhancements		

Table VI Credits and Cost Impacts for HK-Beam 4-04 Assessments – Residential Building

Ref:	SITE ASPECTS	C	P
2.1.1	Land Use - Uses reclaimed land	1	0,M>H
	Land Use - Uses Brownfield site	2	
2.1.2	Contaminated Land	1	0,M>H
2.1.3a	Local Transport - Car parking provisions	1	0
2.1.3b	Local Transport - Access to public transport	1	0
2.1.4a	Neighbourhood Amenities - Basic services	1	0+>L
2.1.4b	Neighbourhood Amenities - Recreational	1	0+>L
2.1.4c	Neighbourhood Amenities - Provided facilities	1	L>M
2.2.1	Site Design Appraisal	1	L
2.2.2	Ecological Impact	1	L>H
2.2.3	Cultural Heritage	1	L
2.2.4a	Landscaping and Planters - Hard landscaping	1	0+
2.2.4b	Landscaping and Planters - Soft landscaping	1	0+
2.2.5a	Microclimate around Buildings - Wind	1	U
2.2.5b	Microclimate around Buildings - Elevated temp	1	U
2.2.6a	Overshadowing and Views - Minimum daylight	1	0+
2.2.6b	Overshadowing and Views - Negative impacts	2	
2.2.7	Vehicular Access	1	0
2.2.8	Demolition/ Construction Management Plan	1	0+
2.3.1	Air Pollution During Construction	1	L
2.3.2	Noise During Construction	1	0
2.3.3	Water Pollution During Construction	1	0+
2.3.4	Emissions from Cooling Towers	1	0+
2.3.5	Noise from Building Equipment	1	0+
2.3.6	Light Pollution	1	0+

Ref:	MATERIALS ASPECTS	C	P
3.1.1	Building Reuse - 15% sub-structure or shell	1	0
	Building Reuse - 30% sub-structure or shell	2	
3.1.2	Modular and Standardized design	1	0
3.1.3	Off-site Fabrication - 50% of listed elements	1	L>M
	Off-site Fabrication - 80% of listed elements	2	
3.1.4a	Adaptability and Deconstruction - Structural	1	M>H
3.1.4b	Adaptability and Deconstruction - Spatial	1	M>H
3.1.5	Envelope Durability	1	0
3.2.1	Rapidly Renewable Materials	1	L>M
3.2.2a	Sustainable Forest Products - Temporary works	1	M
3.2.2b	Sustainable Forest Products – Used in building	1	0+
3.2.3a	Recycled Materials - Outside surface works	1	0
3.2.3b	Recycled Materials – Building structure	1	0+>L
3.2.4a	Ozone Depleting Substances – Refrigerants	1	0
3.2.4b	Ozone Depleting Substances – Materials	1	0>L
3.3.2a	Construction Waste - Waste management	1	0+
3.3.2b	Construction Waste Sorting and recycling	1	0+>L
3.3.2c	Construction Waste - Quantity of recycled waste	1	0+
3.3.3	Waste Disposal and Recycling Facilities	1	0+>L

Ref:	ENERGY USE	C	P
4.1.4a	Annual Energy Use - Annual energy use	8	L>H
4.1.4b	Annual Energy Use - Maximum electricity demand	3	0+>M
4.2.1	Embodied Energy in Structural Elements	2	0
4.2.4	Hot Water Supply Systems	1	M
4.2.5	Lift and Escalator Systems	1	0
4.2.6	Electrical Systems	1	0
4.2.7	Renewable Energy Systems	3B	L>H
4.3.1a	Air-conditioning Units - Positioning of units	1	U
	Air-conditioning Units - Heat rejection	1	U
4.3.1b	Air-conditioning Units - Installation requirements	1	0+>M
4.3.2	Clothes Drying Facilities	1	L
4.3.3	Energy Efficient Lighting in Public Areas	1	0+
4.3.6	Energy Efficient Appliances	1	0>L
4.4.1c	Testing and Commissioning – Commissioning	1	0+
4.4.1d	Testing and Commissioning – Report	1	0+
4.4.2c	Operation & Maintenance - Operator training	1	0+
4.4.3	Metering & Monitoring	1	0+

Ref:	WATER USE	C	P
5.1.1a	Water Quality - Fresh water plumbing	1	0
5.1.1b	Water Quality – Water quality survey	1	0+
5.2.1	Annual Water Use - Less 15%	1	L
	Annual Water Use - Less 25%	2	L>M
	Annual Water Use - Less 35%	3	L>M
5.2.2	Monitoring and Control - 2 features	1	M
	Monitoring and Control - all 3 features	2	M
5.2.3	Water Efficient Irrigation	1	U
5.2.4a	Water Recycling - Harvesting rainwater	1	L
5.2.4b	Water Recycling - Greywater recycling	1B	M
5.2.4c	Water Recycling - Recycled water	1B	M
5.2.5a	Water Efficient Facilities & Appliances - Facilities	1	0+
5.2.5b	Water Efficient Facilities & Appliances	1	L>M
5.3.1	Effluent Discharge to Foul Sewers	1	0+

Ref:	INDOOR ENVIRONMENTAL QUALITY	C	P
6.1.1a	Fire Safety - Design integration	1	0
6.1.1b	Fire Safety - Fire safety manual	1	0
6.1.2	Electromagnetic Compatibility	1	0+
6.1.3	Security	1	0
6.2.1	Plumbing & Drainage	1	0
6.2.3	Waste Disposal Facilities	1	L>M
6.3.2a	Outdoor Sources of Air Pollution - CO	1	0+
6.3.2b	Outdoor Sources of Air Pollution – NO_2	1	0+
6.3.2c	Outdoor Sources of Air Pollution – Ozone	1	0+
6.3.2d	Outdoor Sources of Air Pollution – RSP	1	0+
6.3.3a	Indoor Sources of Air Pollution – VOCs	1	0+
6.3.3b	Indoor Sources of Air Pollution - Formaldehyde	1	0+
6.3.3c	Indoor Sources of Air Pollution - Radon	1	0+
6.3.4	IAQ in Car Parks	1	0+
6.3.5	IAQ in Public Transport Interchanges	1	0+
6.4.2	Background Ventilation - Windows closed	1	M
	Background Ventilation Natural means	1	M
6.4.3	Uncontrolled ventilation - Air tightness	2B	0+
6.4.4a	Localised Ventilation - Source control	1	L
6.4.5a	Ventilation in Common Areas - Provided	1	L
6.4.5b	Ventilation in Common Areas - Natural vent.	1B	L
6.5.2a	Thermal Comfort - With natural ventilation - >80%	1	0+
	Thermal Comfort - With natural ventilation - >90%	2	0+
6.5.2b	Thermal Comfort - With air conditioning	1	0+
6.6.1	Natural Lighting - VDF or 0.5% DF	1	0+
	Natural Lighting - 1% DF	2	0+
	Natural Lighting - 2% DF	3	0+
6.6.3	Interior Lighting in Areas not Occupied	1	0
6.7.1	Room Acoustics	1	0+
6.7.2	Noise Isolation - Airborne noise isolation	1	L>M
	Noise Isolation - Impact noise isolation	1	L>M
6.7.3	Background Noise	1	0>H
6.7.4	Indoor Vibration	1B	0+
6.8.1	Access for Persons with Disability	1	0+
6.8.2a	Amenity Features - For building users	1	U
6.8.2b	Amenity Features - For improved O & M	1	U
6.8.3	IT Provisions	1	U

Ref:	INNOVATION AND ENHANCEMENTS	C	P
7.1	Innovation Techniques	5B	U
7.2	Performance Enhancements		

Note: Bonus credits (B) not included in cost-benefit analysis

3

COST PREMIUMS

Introduction

In order to appreciate the cost premium for certified green buildings, i.e. the cost premium for a given grade over a conventional building, it is necessary to evaluate the number and nature of issues being assessed, the performance criteria for each, and the weighting/scoring method that determines the overall grade.

Cost premiums largely depend on which credits are obtained. 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 higher if a client has preference for particular green features, and/or circumstances are such that their inclusion adds significant cost.

For the generic office building assessed under HK-BEAM 1/96R it was possible to provide both minimum (lower bound) and upper bound dollar value estimates. For the high-rise residential building assessed under version 3/99 only minimum dollar value costs were estimated. For assessments under HK-BEAM 4/04 only minimum cost premiums were estimated.

The detailed costs and benefits data provided in the final report are mainly for assessments under HK-BEAM 4/04, i.e. cost premiums and potential benefits for each applicable core credit in version 4/04.

Office Building - Premiums for HK-BEAM/96R

Fig. 5 gives the profile of minimum additional construction cost premiums for each of the 59 applicable credits in HK-BEAM 1/96R (a similar graph was obtained for the upper bound estimate) identified as follows:

AC	Air-conditioning equipment electricity load
BC	Biological contamination
CP	Contents of paints
ED	Electricity maximum demand
EL	Electrical energy consumption
EN	External noise levels
FR	Facility for recycling materials
HM	Specification of hazardous materials
HR	Heat recovery
IE	Position of outdoor intake and exhausts
LB	Legionella bacteria from wet cooling tower
LD	Specification of lighting devices
LG	Compliance of lighting guidelines
LP	Office lighting power density
NB	Noise from building

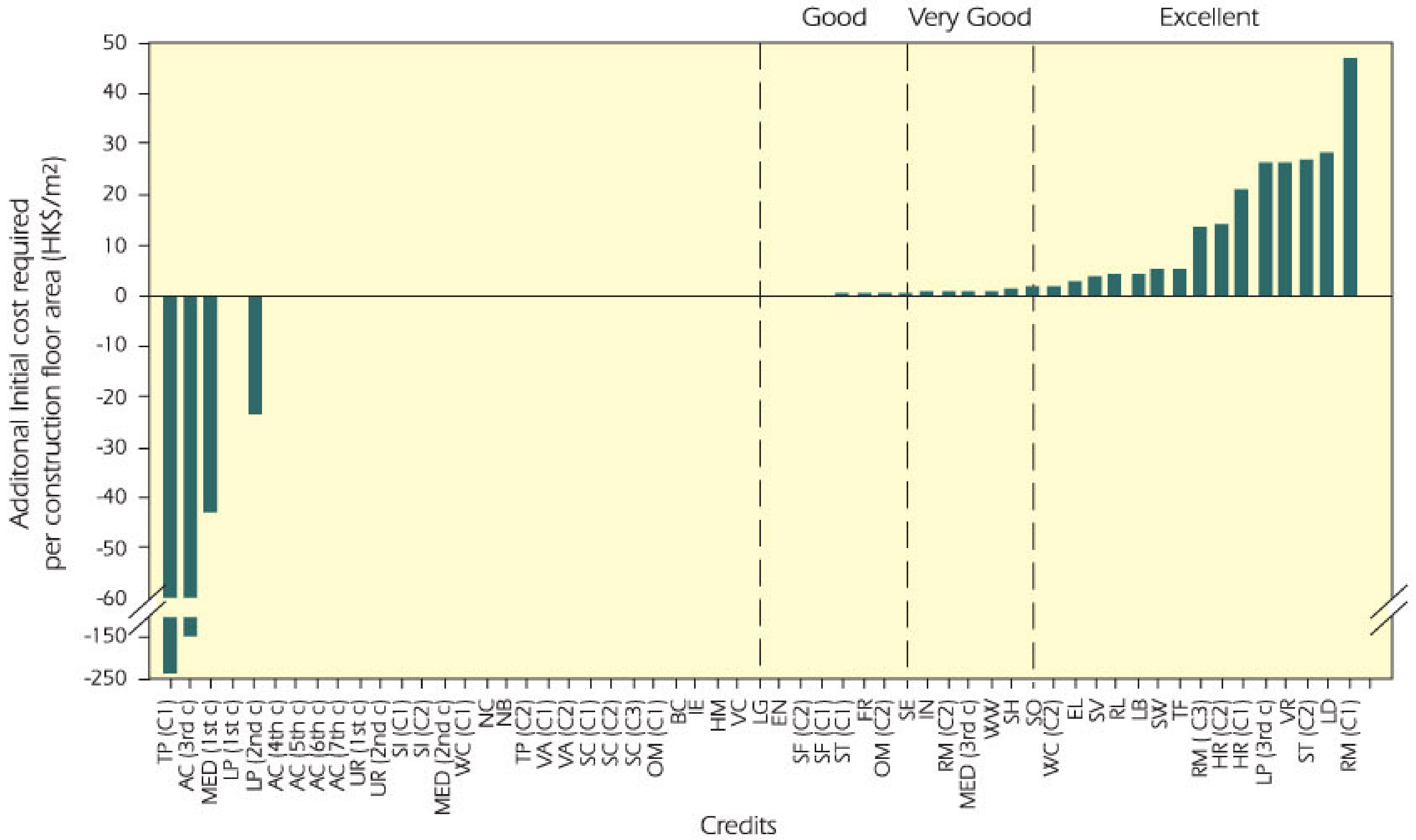
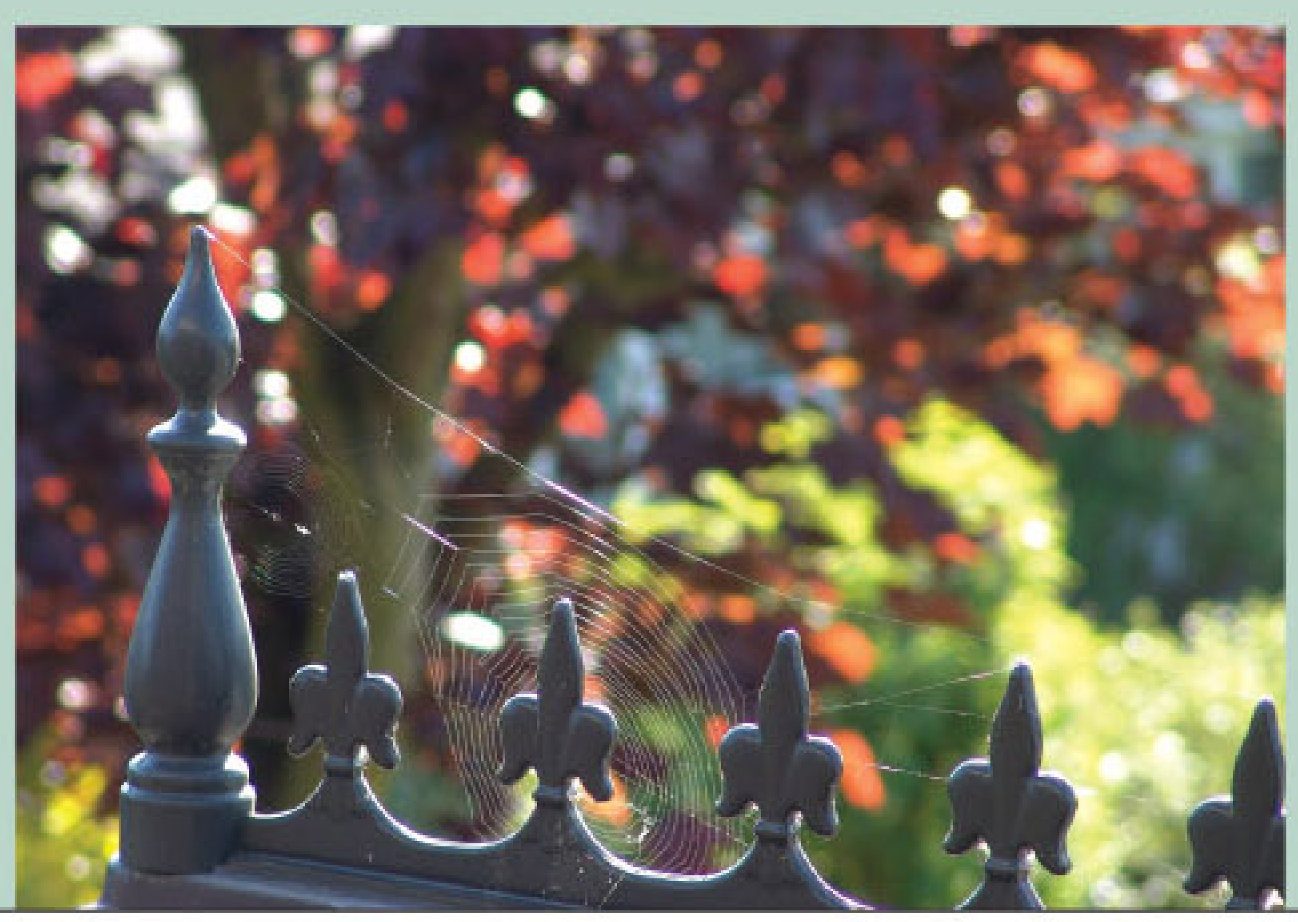


Fig. 5 Minimum construction cost premiums for credits under HK-BEAM 1/96R (New Offices)

NC	Noise during construction
OM	Operations and maintenance
C1 – C3	Credits 1 to 3
RL	Automatic refrigerant leakage detection
RM	Specification of recycled materials
SC	HVAC system commissioning
SE	Separate monitoring of electricity use
SF	Specification of filters
SH	Separate monitoring of electricity use
SI	Specification for insulation
SO	Specification of electricity use (Owners)

ST	Solid timber
SV	Separate ventilation systems
SW	Sorting of waste on site
TF	Timber formwork
TP	Transport and pedestrian access
UR	Use of refrigerants
VA	Vehicular access for servicing, etc
VR	Design of ventilation rate
WC	Water conservation
WW	Construction wastewater discharge
1st - 7th c	1st to 7th credit



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.

Based upon the lower bound estimates, $1.8/m^2 and $8.6/m^2 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^2 for initial construction costs.

Similarly, based upon upper bound estimates, $17.7/m^2 and $64/m^2 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.

Residential Building - Premiums for HK-BEAM 3/99

Fig. 6 shows the percentages of total number of credits required for achieving a particular performance grade under 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^2 to HK$84/m^2 based on the average total construction costs for 'low cost' high-rise housing is about HK$4,000/m^2.

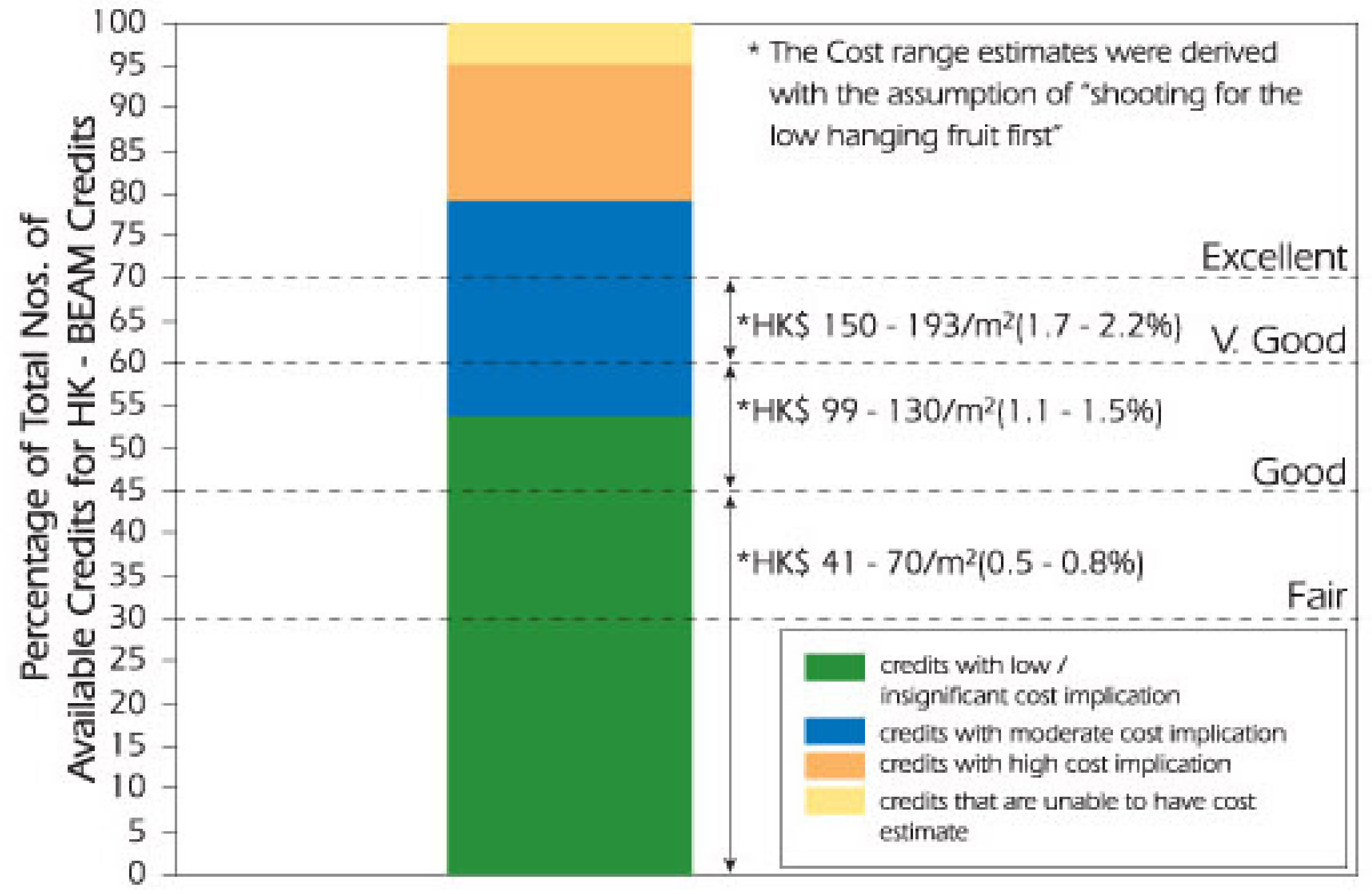


Fig. 6 Minimum construction cost premiums for credits under HK-BEAM 3/99 (Residential)

The attainment of 'insignificant' and 'low cost' credits secures an overall performance grade of 'Good', which is reasonable given the budget constraints on public sector 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. 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^2, i.e. around 3.4% of the construction cost for a private sector residential building.

Cost Premiums for Version 4/04

Fig. 7 shows the percentage of available credits with different cost impact categories to the total number of credits assessed under HK-BEAM 4/04 (excluding the bonus credits). For the office building credits with no, insignificant or low cost premiums together provide 75% of the total credits thereby achieving Platinum rating, at a premium of HK$361/m^2 or about 3.2% of the HK$11,300 construction cost (for an 'average standard office building').

For the residential building credits with no, insignificant or low cost premiums together provide 67% of the total credits thereby achieving Gold rating, at a premium of HK$152/m^2 or about 3.7% of the construction cost of HK$4,000. A Platinum rating requires a minimum of HK$301/m^2 or 7.5% for a low-cost residential building, which is about 3.4% for the construction cost (HK$8,900) for a private sector apartment

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 to meet with these requirements.

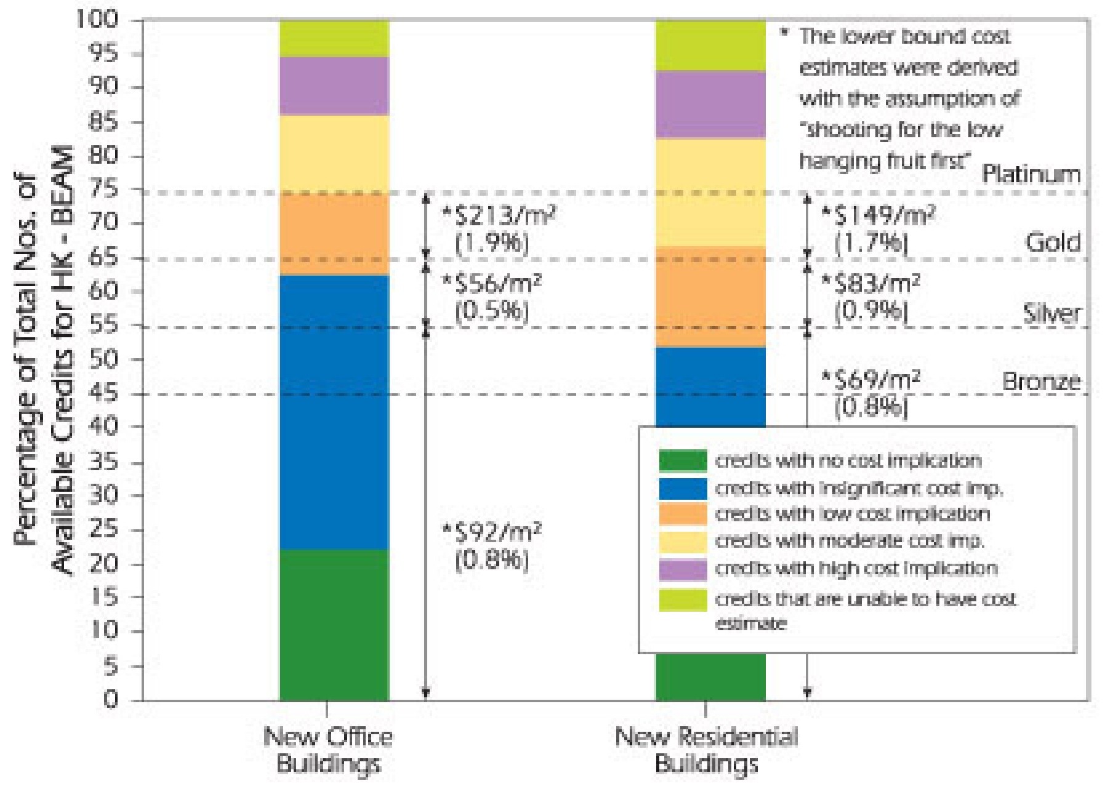


Fig. 7 Minimum construction cost premiums for office and residential buildings under HK-BEAM 4/04 (core credits only)

Summary

Table VII summarises the minimum premiums on construction cost (excluding fit-out costs and additional soft costs) for the generic office building assessed under HK-BEAM version 1/96R 'New Offices' (1999) and version 4/04 'New Buildings' (2004).

Table VII Cost premiums for an office building

Grade	% Credits	% Premium
HK-BEAM 1/96R - 59 credits*		
"Good'	55%+	0%+
'Very Good'	65%+	< 1%
'Excellent'	75%+	1%+
HK-BEAM 4/04 – 112+ credits*		
'Silver'	55%+	0.8%+
'Gold'	65%+	1.3%+
'Platinum'	75%+	3.2%+

* Number of credits varies depending on particular circumstances for a project.

Table VIII summarises the minimum premiums on construction cost for the high-rise residential building assessed under HK-BEAM version 3/99 'Residential' (1999) and version 4/04 'New Buildings'. The percentages for private sector buildings are about half of the values given for public sector (low-cost) buildings.

Table VIII Cost premium for residential building

Grade	% Credits	% Premium
HK-BEAM 3/99 - 75 credits*		
'Good'	45%+	0.5(1.1)%+
'Very Good'	60%+	1.6(3.3)%+
'Excellent'	70%+	3.3(7.3)%+
HK-BEAM 4/04 – 104+ credits*#		
'Silver'	55%+	0.8(1.7)%+
'Gold'	65%+	1.7(3.7)%+
'Platinum'	75%+	3.4(7.5)%+

* Number of credits varies depending on particular circumstances for a project.
# The percentages are based on the construction cost for a typical private sector apartment building. Percentages in parenthesis apply to low-cost residential building.

Caveats

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.

Comparisons with Other Studies

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) 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 conventional practice. Syphers et al Syphers G, Baum M, Bouton D, Sullens W. Kemark. Managing the Cost of Green Buildings. October 2003 quote typical incremental cost of meeting LEED-NC certification (Fig. 8), 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.

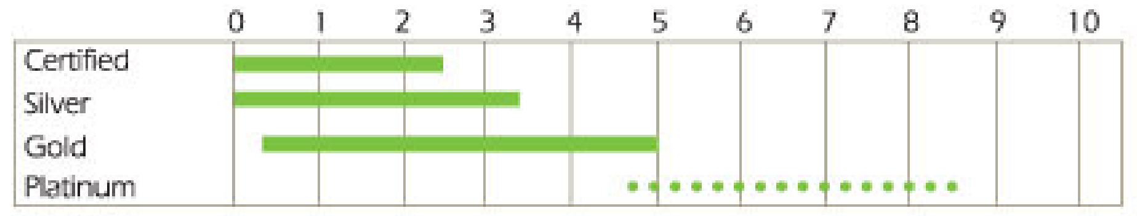


Fig. 8 Cost premiums for LEED (Syphers et al[4])

A Langdon database of US building costs 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.

Table IX indicates the percentage increase in capital cost for an air-conditioned office building assessed using BREEAM 2004. 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 IX Cost premiums for BREEAM[5]

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%	0.19% 3	,3%

Perspectives on Cost

Based on a broad cost database, ball-park ratios for better quality buildings in OECD countries are reported 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 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^2/annum for office space in Hong Kong's CBD, the cost of one workstation of 10m^2 is around HK\$80,000 pa. Based on a HK\$250,000 pa salary, the staff cost is 75%, occupancy cost 25%.

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[4] Syphers G, Baum M, Bouton D, Sullens W. Kemark. Managing the Cost of Green Buildings. October 2003

[5] BRE Information paper IP 4/05. Costing sustainability: How much does it cost to achieve BREEAM and EcoHomes ratings? 2005

In fourth quarter 2005 the approximate total building costs in Hong Kong for a standard office building with air-conditioning ducting and light fittings to tenant areas was HK\$ 10,600/m^2, including services at HK\$2,550/m^2 (average). Fit-out costs are estimated as HK\$5,170/m^2, 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. Over 20 years the occupancy costs are around HK\$ 1.6 million, business costs HK\$6.4 million/10m^2 compared to the construction cost of around HK\$0.16 million/10m^2.

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 significant impact on the much larger business cost.

Office Building Energy Costs

Assuming a lighting power density of 25 W/m^2, equipment power density 25 W/m^2, for a workstation area of 10m^2, 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 (per annum.). From a recent audit of operation and maintenance practices, the average monthly cost for air-conditioning O&M was HK\$17.3/m^2/month, with energy accounting for 87%, i.e. HK\$15/m^2/month. From a previous survey air-conditioning energy accounts for around three-quarters of landlord energy use, so energy costs for landlord services average about HK\$20/m^2/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\$1,800/10m^2. If air-conditioning is charged separately the total energy cost is around HK\$3,000 pa/10m^2 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.

Residential Energy Costs

Energy costs (including water and sewage charges) as a percentage of total household expenditure are given in Table X. 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 X Energy costs as a percentage of monthly household expenditure

Income Group	Energy cost $	Housing %
CPI(A) $4.1-15.8k pm	175-665	29.17
CPI(B) $15.8-28.2k pm	470-830	27.70
CPI(C) $28.2-61.5k pm	615-1340	26.66

Clearly, other than for those with very low incomes, an energy cost of the order of 2-3% of household income is not a significant expenditure.

4

POTENTIAL BENEFITS

Perceived Benefits

Green buildings are perceived to provide tangible benefits such as financial savings from reduced materials, energy and water use, and intangible benefits including improved productivity in workplaces, reduced operation and maintenance costs, lower demands on infrastructure, higher rental or sales value.

For example, from an analysis of international and Australian data, the Green Building Council of Australia reported that green buildings deliver lower annual operating costs and more efficient asset management. According to executives in Australia the added value includes:

- 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.

Furthermore, a survey of architects, engineers, contractors and owners in the US concluded that respondents expected, on average:

- a decrease of operating costs of 8% to 9%;
- increase in building values of around 7.5%;
- ROI to improve 6.6%;
- occupancy to increase by 3.5%; and
- rents to rise by 3%.

However, whilst 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, it is noteworthy that only a proportion of the criteria need be met for certification, e.g. 55% for 'Silver'. Consequently, the additional benefits of a certified green building compared to a conventional building depend on the totality of the performance enhancements put in place, i.e. the assessment criteria (credits) confirmed by the certification, and the persistence of the enhancements measures over a period of building use.

HK-BEAM Standards

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 the higher levels of performance that characterise green buildings. Audits of Hong Kong buildings show that the causes of inefficient operation are not dissimilar to those found elsewhere, and include:

- 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;
- inadequate testing and commissioning of services systems; and
- inadequate provisions for operation and maintenance.

In the assessment of new buildings the criteria (Tables V and VI) includes design based assessments, construction phase environmental performance, and final testing, commissioning and handover of the completed building.

Clearly, the better the certified grade the higher the proportion of criteria satisfied and the better the performance, although within any given grade the final outcome can vary. For instance, a project team may place emphasis on achieving the target grade at the least cost. Design enhancements that score credits, e.g. estimated annual energy use, may not be realised or persist during building use. Construction related credits would benefit only the construction phase.

Building Type

Because of the dissimilarities in design, operation and use, significant differences in performance criteria, costs and benefits exist for office buildings compared to residential buildings. These differences have significant impact on the indoor environmental conditions and consumption of resources, particularly energy and water. Maintaining good performance depends on the available technical expertise.

For office buildings the design principle is 'built tight, ventilate right' with centrally supplied air-conditioning and ventilation systems. Technically complex building systems are under the control of building management, while office areas and equipment are under occupant control. The self-contained units in residential buildings have operable windows to utilise natural ventilation, and appliances that are controlled by occupants who generally have limited technical awareness.

Energy Use Benefits for Office Buildings

Financial benefits typically include reduced investment in major plant from 'right-sizing', and reduction in energy and water consumption during use.

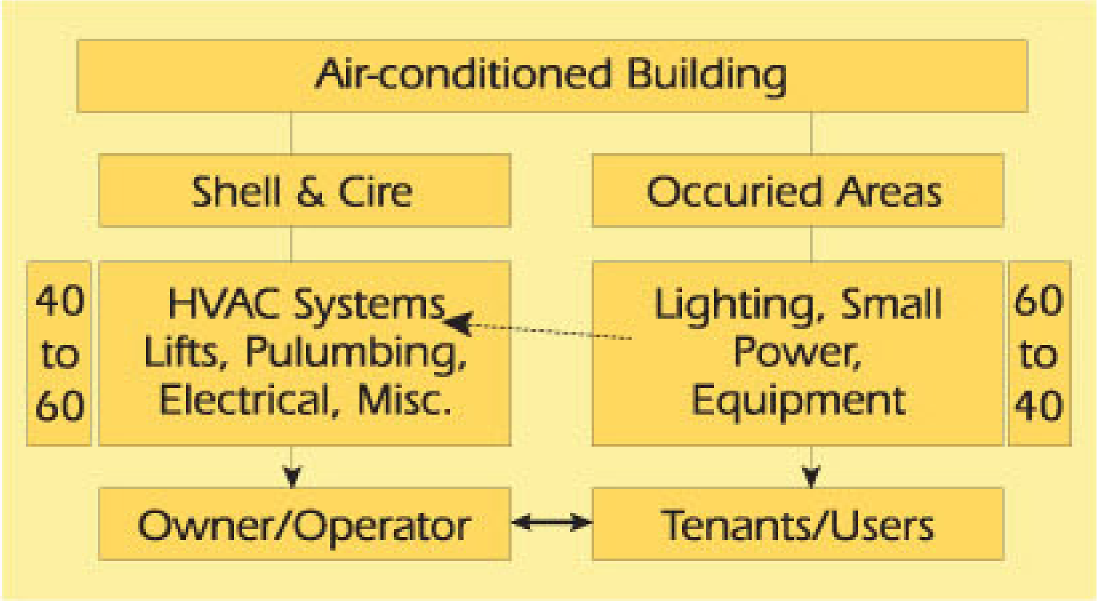


Fig. 9 Breakdown of annual energy use in air-conditioned buildings

Air-conditioned office buildings mainly use electricity, with HVAC, lighting and office equipment the major end-uses (Fig. 9). HVAC system performance is strongly influenced by design, e.g. building envelope, 'right-sizing' and selecting efficient equipment, implementation of robust control strategies, etc., although energy use also depends on the density and usage patterns of installed lighting and equipment. Consequently, the design of office lighting systems and controls, and the selection and use of office equipment, have significant impact on the energy performance of an office building.

HK-BEAM 4/04 awards up to 13 credits for reducing annual energy use and the maximum electricity maximum demand. Additional credits (5) are for efficient 'landlord' systems, and the provisions for energy management (8). The use of renewable energy adds up to 3 bonus credits.

Annual Energy Use - 10
Max Electricity Demand - 3
For Air-Conditioning, Lighting and
Equipment In Office Areas

Efficient Systems & Equipment
Performance - 5
4.2.1 Embodied Energy - 2
4.2.5 Lifts & Escalators - 1
4.2.6 Electrical Installation - 1
4.3.3 Public Area Lighting - 1

Provisions For Energy Management - 8
4.4.1 Testing & Commissioning - 4
4.4.2 Operation & Maintenance - 3
4.4.3 Metering & Monitoring - 1

Up to 10 credits are awarded for estimated reductions of 10 to 45 % in annual energy use in air-conditioned areas for the assessed building compared to that of the baseline building. The baseline building is one that barely meets minimum regulatory and voluntary code requirements. Variables such as weather data and occupancy patterns used in the computer simulation are the same for

the assessed building and the baseline building. Energy performance improvements will depend on the selected set-points for temperature, etc. system design and equipment selection, the designed lighting and assumed equipment power loads.

Right-sizing

Oversizing of systems and equipment is common, usually a result of inappropriate design assumptions and use of generous safety margins. Oversizing of air-conditioning systems is likely to result in overcooling and discomfort. Where designs are based on realistic data and use of efficient equipment the size of main HVAC plant can usually be reduced (up to 50%) thereby saving in capital cost, more efficient operation (8-20% energy saving), and improved indoor comfort.

Estimated Energy Performance

According to prior research if buildings met local voluntary energy code requirements, on average the energy efficiency would be 8% better. As the codes constitute minimum standards for HK-BEAM's energy use in a new building could be reduced by 8% at no cost premium.

Example calculations for the baseline case and measures required for achieving the maximum number of credits and potential savings are given in Table XI. This example requires efficient lighting systems (12W/m^2), including reductions at the perimeter zone through use of daylight, efficient office equipment (14W/m^2), efficient fans, variable speed drives, modified window-wall ratio, and a set point temperature of 25.5°C. If lighting and office equipment design criteria are not attained the reductions in energy consumption will be roughly halved, so to the number of credits obtained.

Table XI Estimated energy performance enhancements for generic office building

Defaults and Estimates	Baseline	Best
Operating schedule as defined in HK-BEAM 4/04		
Temperature set-point	23˚c	25.5˚c
Occupancy density/person	9m^2	same
Ventilation rate/person	10 l/s	same
Lighting power density W/m^2	25	12
Equipment power density W/m^2	25	14
Lighting energy kWh/m^2/annum	79	38
Equipment energy kWh/m^2/annum	79	44
A/c energy (water cooled) kWh/m^2	83	43
A/c energy (air-cooled) kWh/m^2	123	72
Total energy use for air-conditioned (occupied) areas:		
Water cooled kWh/m^2	240	280
Air cooled kWh/m^2	125	154

Performance in Use

The estimated energy used for air-conditioning, i.e. computer modelling, is based on 'ideal' performance, not least the control of the plant, which is unlikely to exist in actual operation. An allowance of +50% for a/c energy use is more realistic, so water-cooled a/c energy is 124kWh/m^2 and air-cooled becomes 184kWh/m^2. Total consumption for occupied areas increases to 280kWh/m^2 and 340kWh/m^2, respectively.

With the addition of energy use for 'landlord' services such as lifts, lighting in public areas, etc, typically 5-15% of total, these estimates for the baseline building lie within the range of audited data for existing office buildings, i.e. 200-400kWh/m^2.

Investment in Energy Efficient Systems

The estimated cost premium (not including changes to window-wall ratio) for all 'best practice' measures, including office lighting and equipment, is HK$108/$m^2$ for air-cooled a/c and HK$119/$m^2$ for water-cooled a/c, achieving around 40% energy reduction, and an estimated annual saving of HK$87/$m^2$ to HK$110/$m^2$. Improvements in a/c system design can be repaid in about one year. The additional cost for efficient lighting (e.g. T5 luminaires and dimmable electronic ballasts) would also be repaid in about one year. Even if savings are half of those projected the simple payback for energy efficient building systems are of the order of one to three year.

Although based on estimates from detailed computer modelling the data illustrates where energy efficiencies can be achieved, and by which stakeholders.

Energy Use Benefits for Residential Buildings

As Fig. 10 illustrates, the pattern of energy use for residential buildings differs from air-conditioned buildings, with the majority of end uses dictated by the lifestyle and preferences of the occupants, rather than factors that can be influenced through design. With the cost of energy a small part of household expenditure, in an affluent society it is unlikely that households will reduce energy use at the expense of comfort or convenience. With great variations in building designs and usage patterns the benefits are not clear cut and are more difficult to quantify.

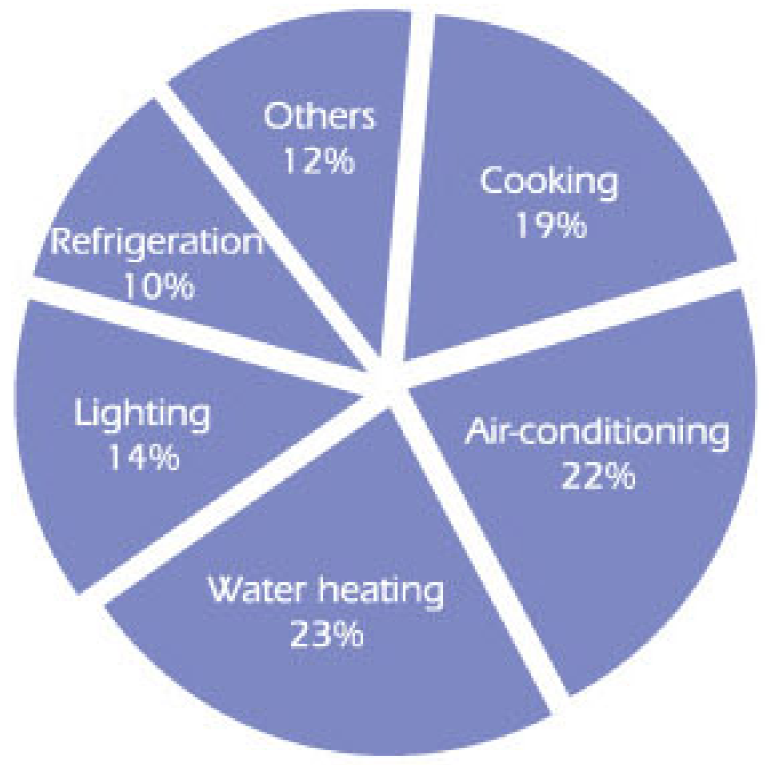


Fig. 10 Energy use in residential segment

The potential to reduce air-conditioning energy use is through utilisation of natural ventilation, and installation of more efficient equipment. Likewise, lighting energy use may be reduced if daylighting is adequate, and efficient lighting sources are installed.

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 is 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. Simulation was used to estimate the impact of an integrated passive design approach to reduce the cooling requirements for a Hong Kong Housing Authority Concord block with window-mounted air-conditioners.

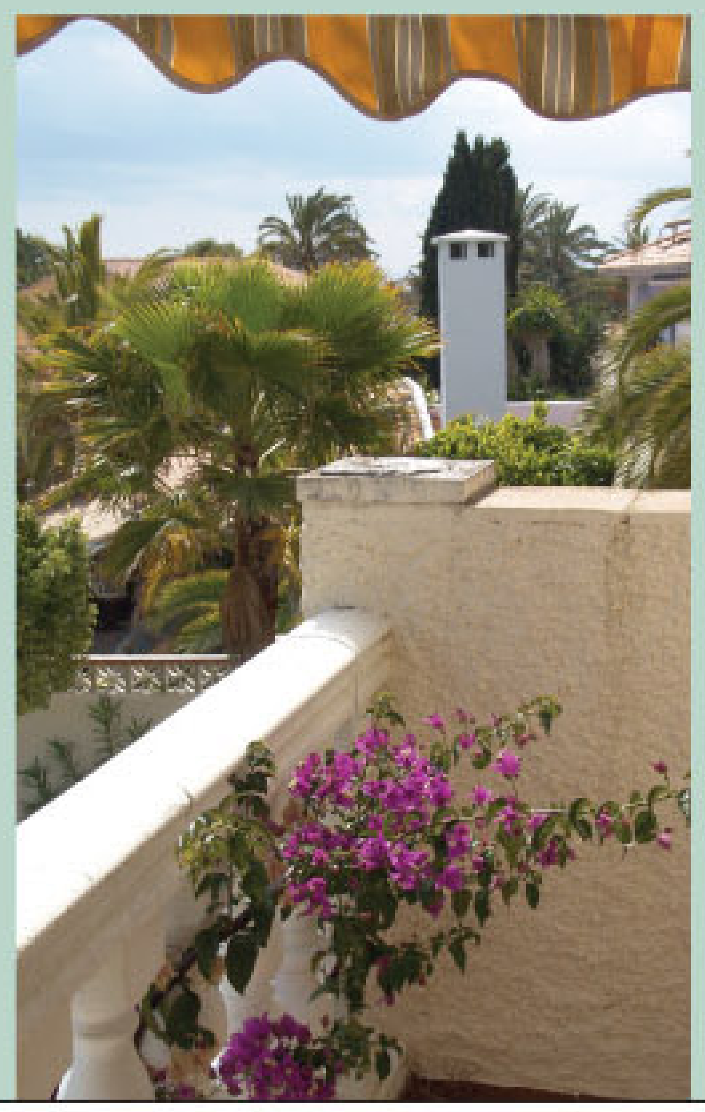
It was found that by modifying the building envelope with design strategies such as changing external wall colour, using more advanced glazing, and introducing solar shading the annual cooling energy saving was 31.4%, with peak cooling load reduced by 36.8%. For a typical floor of an entire block, consisting of all eight flats, the reduction in annual required cooling energy ranged from 26.9% to 27.9%. Even so, this reduction, if achieved in practice would reduce overall energy use by some 5-6%.

Adequacy of daylight is a particular problem for apartments on lower floors that are overshadowed by structures in close proximity. Whilst it is possible to improve matters through design features such as light shelves and increased reflectance of external surfaces, the benefit is during daytime, when occupancy and need for illumination is probably at its lowest. Consequently, whilst penetration of daylight is considered important from a health perspective, it may provide significant energy savings in residential settings.

With the many variations in residential estate and individual building design it is very difficult to generalise outcomes in terms of the costs and benefits of improved design. Quantifying the benefits of solar shading, daylighting and natural ventilation requires sophisticated modelling of a building, particular the envelope design features, and the surroundings, the cost of which is likely to be 'high' and difficult to justify in practice.

Potential for Water Savings

Water is becoming a more precious and high-demand resource in regions adjoining Hong Kong. Fresh water supplies are increasingly affected factors such as contamination of sources and rising demand. In 2005, water piped into the SAR from Dongjiang accounted for 771 million m^3, or 79.7% of Hong Kong's consumption for the entire year, at a cost of HK$2,530 million. With around 53% of fresh



water consumption the domestic sector is dominant, and average freshwater consumption of 200 litre/person/day is high by world standards in spite of the provision of seawater for toilet flushing in most residential buildings (263 million m^3 of seawater being used compared to 82 million m^3 of fresh water).

Whilst water supply standards the quality of potable water delivered at taps is often perceived to be unsatisfactory by consumers, resulting in an average consumption of bottled water of around 50 litre/person/annum in 2003 and rising. The use of bottled water is not an environmentally preferred solution on account of the production and transport requirements. HK-BEAM seeks to ensure that buildings provide potable water that is both safe and acceptable in terms of taste, colour and odour.

HK-BEAM gives credit for the installation of water saving features such as low-flow shower heads and faucets. 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 in the domestic sector is that user ignorance can result in neglect and subsequent dissatisfaction leading to disuse. For developments with significant coverage of soft landscaping, greenery and planters HK-BEAM rewards irrigation by harvested rainwater or recycled water, and/or use of native plants that can survive without additional watering.

Whilst water recycling is given credit HK-BEAM acknowledges that, for Hong Kong's high-rise dense built environments, the potential for collecting rainwater is limited and potentially costly. Similarly, 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.

Where seawater flushing is provided the benefits of savings are limited to a small reduction in water charges, but where this is not the case then reducing the use of potable water is a more significant benefit. Reducing the need for effluent treatment also saves on capital cost for plant and energy cost for treatment.

Intangible Benefits

The intangibles include benefits to the external environment through reduced impacts on the environmental, adjacent properties, infrastructure, etc. and potential for improved comfort, health and productivity through better quality indoor environments, services and amenities.

Immediate benefits to a developer as a result of certification may include an enhanced reputation as a responsible citizen. For office buildings the quality of the indoor environment, services and amenities are appreciated by tenants/users and are an expectation from 'green' building assessments, if not always delivered. Given the lack of awareness amongst the general public, the benefits of a green building assessment for residential buildings is difficult to judge.

A number of studies have focused on occupant satisfaction with housing 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.

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 there estate found that facilities on the estate were highly valued.

Site Aspects

HK-BEAM assessments under Site Aspects mainly relate to urban and estate planning, neighbourhood impacts during construction and use, and reducing the environmental impacts from construction. Credits (Tables IV and V) apply to all 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.

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. Credits 2.2.8 to 2.3.3 seek to reduce the environmental impacts of construction, whilst 2.3.4 to 2.3.6 seek to reduce nuisance to neighbouring properties during building use.

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 the embodied energy in the structural elements of a building.

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. Credits 3.2.4, and 3.3.1 to 3.2.3 seek to reduce environmental impacts and waste from construction phases.

Indoor Environmental Quality

Given that on average a person in Hong Kong spends around 85% of their time indoor, indoor environmental conditions have a significant impact on the quality of life. 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'.

Office Buildings

For green office buildings the required performance is to meet or exceed the recognised standards for indoor environmental conditions, so that safety, comfort and health are not compromised, and to provide quality services and amenities that support business activity, thereby attracting tenants and ensuring user satisfaction.

Studies commissioned by the Environmental Protection Department found that one third of Hong Kongs air-conditioned buildings were 'sick', mainly due to unacceptable IAQ. The end result is the IAQ certification scheme, currently operated on a voluntary basis, but with potential for legislative enactment in future. HK-BEAM assessment of indoor air quality (IAQ), ventilation and thermal comfort aligns with the certification scheme in order to prepare for potential certification when the building is occupied. HK-BEAM 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.

A full assessment of IAQ and ventilation performance provides assurance that the building will be healthy and comfortable, reducing the potential for complaints, and increasing tenant/user satisfaction. Whilst it is not possible to fully assess thermal comfort in new premises (HK-BEAM stipulates simulated

loads for tests), the focus of the assessment is on providing adequate control of temperature.

For HK-BEAM 4/04 the client decides which international standards will apply to define comfort, lighting, ventilation and noise criteria. For example, in the energy performance assessment the temperature set point is 23°C and the ventilation rate 10 litre/s/person which are regarded as appropriate for grade A offices, although the HKSAR Government's recommended 25.5°C could be applied, and would result in energy savings.

Assessment of lighting focuses on quality rather than quantity, with the use of daylight whenever feasible. Lighting quality and 'connection' to the outside is of benefit to occupants and can improve workplace satisfaction. Tenants who install their own lighting systems should be aware of the potentially significant impact on productivity as well as the energy used directly for lighting and indirectly for air-conditioning. Tenant fit-out guides and/or contractual arrangements can serve to improve IEQ and energy performance.

Noise and acoustical properties are also important factors influencing workplace performance. Although much depends on the interior design, mitigating noise from outside and from building services equipment is assessed. HK-BEAM also provides performance criteria in respect of airborne noise between rooms, and impact noise between floors, design issues not covered in Hong Kong's building regulations.

Potential Benefits

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 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 maximise the health, satisfaction, and performance of building occupants.

Residential Buildings

The indoor environment in dwellings is very much dependent on the activities and lifestyles of the occupants. Indoor conditions 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 likely increase the use of air-conditioning. With windows closed IAQ depends on the choice of furnishings and decorations, materials used for cleaning, and activities such as smoking and incense burning, etc.

Good design, especially in terms of solar shading, natural ventilation and daylighting can enhance indoor conditions. Subject to site location and the immediate environment, improved access to natural ventilation and daylight would appear to add value to residential buildings.

Garnering the potential benefits available from improved residential building design depends on end user awareness of how some practices can impact on their health and the environment. Unfortunately, Hong Kong residents do demonstrate ignorance when it comes to the use of facilities in their homes. A survey found whilst most respondents were not satisfied with the indoor air quality, 68% did not use the ventilation control devices provided on window type room air conditioners.

Who Pays, Who Benefits

Given the distinct differences in ownership and end use and the potential benefits of green building labelling are markedly different for office buildings compared to residential buildings. The former could be developed either for sale, full or part occupancy, or for letting. Residential buildings may be let (public sector) but the majority are for sale.

The Investor/Developer who completes a building for sale will be more concerned about cost premiums and less concerned about life-cycle performance and operating cost. If a green building label improves sales it becomes attractive.

Whilst location and affordability dominates considerations it is evident that green office buildings do have a marketing advantage, although for residential buildings this remains questionable given the general lack of appreciation of performance enhancements that can result from green building assessments.

Owners of office buildings should be more cognisant of life-cycle costs and the financial benefits that can result from enhanced building performance. Occupiers will be interested in the indoor environmental quality and quality of other services, which is generally understood to be an important factor in workplace productivity.

With increasing concerns about global warming energy performance is likely to come under increasing scrutiny from the public, legislators and investors, suggesting that all developers, owners and occupiers ought to have an interest in ensuring buildings are resource efficient when providing the required level of performance.

Demonstrating corporate responsibility is becoming an important driver for greener and more energy efficient buildings.

Added Value

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 benefits of green buildings accrue to the whole of society, justifying government intervention if the market and economic drivers fail to bring about changes to 'business as usual'.

Minimising Costs and Maximising Benefits

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.
- quality management, operation and maintenance is a requirement to realise the benefits of good design and commissioning.

5

ENHANCING PERFORMANCE

Production of Buildings

According to the CIRC 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.

A conclusion of this study is that enhancements to the performance of new buildings, particularly large air-conditioned buildings, at relatively little additional construction cost depends on investment is quality processes rather than any particular green features or attributes.

Whilst there is little evidence that good processes necessarily produce good outcomes, POE provide evidence demonstrating that bad processes tend to produce poor outcomes. The principles of sustainable development are best implemented within the process rather than by features embedded in a building, process is primary and the technology and product development only secondary in relative importance.

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.

Integrated Design

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 adequate evidence to show that more time spent on planning and design can result in a reduction in construction time and cost through reduced variation (change) orders and aborted work. Involvement of main contractors and building operations and maintenance staff in the early stages of design can improve design outcomes.

Energy 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 to investigate design options are not realised.

Setting up reliable and reasonably accurate building and system models takes time and requires several iterations as the design proceeds from concept to final detailing. However, once a computer model has been established the impact of design changes can be obtained quickly and relatively little cost. Optimising the design of high-rise residential to fully mitigate external impacts whilst capturing the benefits of natural ventilation and daylight is a more difficult task.

As demonstrated in a study for the Housing Authority, modelling a group of high-rise, naturally ventilated buildings requires the use of a number of sophisticated simulation tools. The modelling included the development of a database for annual wind conditions for the site, computational fluid dynamics (CFD) 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. Consequently the whole process may be expensive and too time consuming and may not provide the required answers in a form that can be used by designers.

Building Commissioning

Construction quality is matter of adequate specifications, explicit contractual arrangements, 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. 11 illustrates, the scope of commissioning can be divided in three broad levels of coverage, as follows:

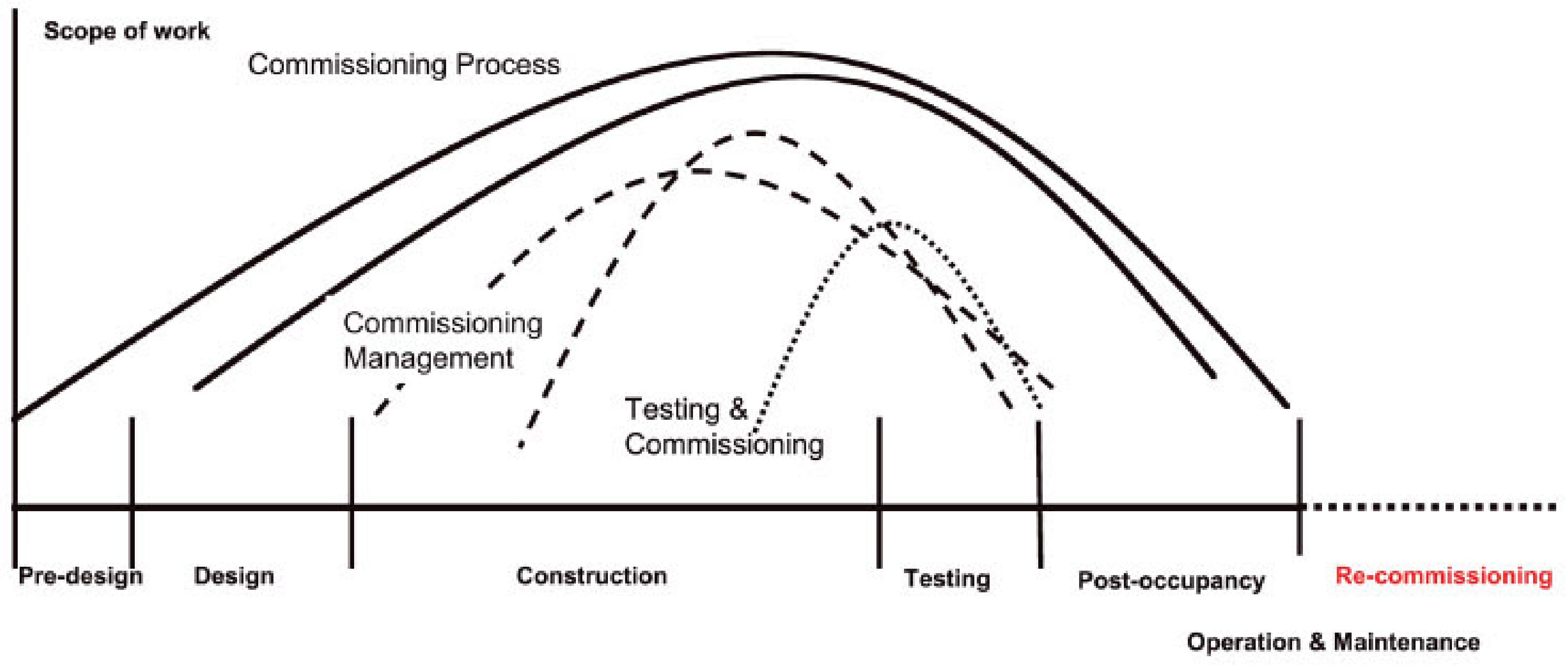


Fig. 11 Scope of commissioning practices

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: overall management process for 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.

Commissioning process: as promoted in the US which, ideally, starts at the earliest stages of planning and design and continues through to post-occupancy.

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 detailed set of T&C procedures published by the Architectural Services Department are widely accepted as standard references for private sector projects. However, 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.

Even mandatory and straightforward T&C of fire services systems has caused delays in obtaining an occupancy permit. 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 commissioned.

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. Whilst provisions in tender documents will ensure that there are resources allowed for commissioning, the 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. 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.

Commissioning management is now addressed by the UK Building Regulations, which requires:

- testing thermal insulation continuity and air-tightness 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.

Provision of a suitable log book is also recognised as being important part of the deliverables to owners and operators of buildings.

The Commissioning Process is defined as a quality-oriented process for achieving, verifying, and documenting that the performance of facilities, systems, and assemblies meets defined objectives and criteria. It 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. The Process includes training for building operators and a period of post-occupancy fine tuning.

Potential Benefits

Inadequate commissioning can reduce the value of the building or cause unexpected capital and O&M expenditure. 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.

However, 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. 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;

- 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. A US study 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.

Provisions for 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, "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, 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".

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RECOMMENDATIONS

Further Studies

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.

HK-BEAM Development

The latest HK-BEAM assessment method for new buildings (Version 4/04) seeks to endorse good practices in the various stages of project development and to assess as far as practicable the performance of the completed building, at which point certification is confirmed.

With the emergence of international standards that define the framework for building environmental assessments, the wider interest in sustainability, and in improving energy performance, it is opportune for the HK-BEAM Society to revise the assessment method.

It is recommended 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. This approach is similar to that adopted in the assessment method CEPAS, recently developed by the Buildings Department. CEPAS overlaps HK-BEAM by around 85% in terms of issues covered, but differs in respect of scoring (weightings) and the provision for certification at various stages of project development.

HK-BEAM 4/04 can be strengthened by requiring minimum performance is key areas such as estimated annual energy use and building commissioning. Pre-requisites should be introduced to ensure key areas of performance are not neglected. Final certification should convey to all interested stakeholders how the performance grade was achieved.

Regulatory Framework

Given that 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. As green buildings aim to provide the required performance, saving energy by reducing the quality of services or indoor environmental quality is a false economy if it results in negative impacts on workplace productivity and occupant comfort.

With the renewed emphasis on reducing carbon dioxide emissions and other 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 30%. 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.

Given the shared responsibility amongst stakeholders, regulations need to address building design and major energy consuming systems and equipment, including user installed equipment. Building commissioning should also be included, similar to the UK's focus on the commissioning of energy consuming systems.

Notwithstanding, promotion, endorsement and incentives for green building labelling by the HKSAR Government in the same way that is now practiced by the US Federal Government and many state and city governments in the US would, over time, provide Hong Kong with a more valuable and sustainable building stock.

Existing Buildings

There is evidence to show that many of Kong Kong's existing buildings do not meet the required performance in terms of IEQ or energy efficiency. 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 and water to end users 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 various incentives, e.g. tax rebates/ penalties, energy taxes.

Investment in fine tuning and recommissioning and is likely to provide energy savings of the order of 10-20% at significantly less cost than investment in renewable energy and new generating capacity.

Task Force Member

- Mr. Michael AMOLD (Chairman)
- Mr. Peter AYRES
- Mr. Toby BATH
- Mr. Cary CHAN
- Mr. Steven HUMPHREY
- Mr. Chi-kwan LAU
- Dr. Ronald LU
- Mr. David ROBERTS
- Mr. Laurie SMITH
- Mr. Gilbert TSANG
- Mr. Derek SMYTH
- Ir. Dr. Nicolas S Y YEUNG

Research Team

- Prof. John BURNETT (Principal Investigator)
- Dr. CHAU Chi-kwan
- Dr. LEE Wai-ling
- Mr. Kevin EDMUNDS

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Construction Industry Institute – Hong Kong

2/F, Dragon Centre, 23 Wun Sha Street,
Tai Hang, Hong Kong
Tel: (852) 2839 7866   Fax: (852) 2839 7326
Email: inquiry@ciihk.org.hk