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Costs and Benefits of Undertaking BEAM (Building Environment Assessment Method)-Plus New Building Assessments in Hong Kong

綠建環評新建築評估實施的成本與效益

Final Report

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Executive summary

1 Abstract

BEAM-Plus is a voluntary tool for assessing the sustainability and performance of buildings across the entire lifecycle of buildings. Since its first launched as a premiere assessment method in Hong Kong, BEAM-Plus has been undergoing continuously updating and refinement in scope and details. This study identified both the economic and non-economic benefits and obstacles in obtaining certification under BEAM-Plus New Building Version 2.0 in Hong Kong. However, only economic costs and benefits associated with individual credits as well as achieving various BEAM-Plus performance grading requirements were monetarized in this study. In addition, the study also investigated whether the current BEAM-Plus performance grading scheme could provide adequate economic incentives for developers and designers to pursue building sustainability beyond the threshold level.

Energy simulation models were constructed for a baseline case high-rise office building for revealing the costs incurred and benefits accrued for pursuing higher performance levels. A number of sustainable strategies that can provide economic benefits have been identified to facilitate property investors, owners, architects and engineers in making decisions in pursuing higher BEAM-Plus performance grades. The amounts of willingness-to-pay by developers for various BEAM-Plus performance grades were elicited and examined in light of performance-based and market-driven benefits. Implementation practicability of strategies had also been revealed through focus group meetings. All in all, this study provides valuable insights for policymakers by providing multiple analytical perspectives to help them gain a better understanding of the economic, environmental and social values of energy efficiency, lifecycle cost and building performance in sustainable development with a view to enhancing adoption of BEAM-Plus.

The following are the objectives of this study, all of which have been fulfilled:

I. To identify and estimate the economic, environmental and social benefits as well as non-economic obstacles of reaching the threshold BEAM-Plus rating and pursuing higher ratings for a new sustainable building development.
II. To estimate the costs and benefits of complying various credit requirements under BEAM-Plus v2.0 with due regards to initial investment costs, lifecycle costs and operational savings associated with a new sustainable building development.
III. To investigate the extent to which various performance grading under BEAM-Plus can provide adequate economic incentives for developers and designers in terms of energy efficiency, building performance, and other social and environmental aspects of sustainability.
IV. To explore whether developers have higher intentions to adopt the BEAM-Plus assessment schemes with the informed costs and benefits for adoption of BEAM-Plus assessment and their willingness-to-pay (WTP) for obtaining different

performance grades.

V. To develop effective sustainable design strategies for developers and designers to obtain different BEAM-Plus performance grades for a new building development or a major work of addition or alteration.

In this study, the additional costs and benefits as well as the performances of various sustainable measures required for earning individual BEAM-Plus credits were evaluated by comparing against those of the baseline building. Statistical analyses of priced bills of quantities (BQs) and cost data books for Hong Kong were used as references for cost estimation. The quantities of various materials used were determined from statistical analysis of BQs of previous office building projects, while the performances were determined by referencing to energy simulation results and other relevant literature.

To ensure the findings derived from this study are reasonable, a focus group meeting comprising major market players from different building development and design professions was organized. The meeting helped to solicit their views on the findings from the benefit-cost analysis and the proposed strategies for obtaining various BEAM-Plus performance grades. The amounts of willingness-to-pay of developers for achieving various BEAM-Plus grades were also discussed. In addition, the practicability of implementing various sustainable measures to earn BEAM-Plus credits was also listed as a major agenda item.

Major research findings

Benefits and costs of implementing various sustainable measures to earn BEAM-Plus credits have been revealed in this study. By assuming that private developers will pursue the least cost approach, the best strategies of selecting credits to attain various BEAM-Plus grades have been determined together with their associated costs and benefits.

Costs of various sustainable measures to earn BEAM-Plus credits

Considering from the perspective of initial costs, some sustainable measures that can be used to fulfil the BEAM-Plus credit requirements have been found to be able to provide monetary savings. Reuse of building structure was found to be able to provide the largest monetary saving (with a maximum potential saving of \$562.9 /m^2/credit for reusing 90% of existing building structure). However, this measure is not always feasible for all building projects. It can be applied to projects like revitalization of historical building, and conversion of industrial buildings to hotels. Besides, use of pre-fabricated internal building elements (primarily interior wall partitions) can also yield a monetary saving of \$169.9 /m^2/credit. It is also possible to acquire monetary savings by lowering the lighting power intensity by 10% via adopting LEDs. The saving in initial cost was found to be \$40.0 /m^2/credit.

Meanwhile, there were also measures that require high initial cost premiums. When pursuing the performance path of the EU 2 Section of the Energy Use category in BEAM-Plus, the initial cost premium could be as high as \$3350.0 /m^2/credit. High initial cost premiums were also required for incorporating pre-fabricated building structural elements (c.f. MW 3; \$228.0 /m^2/credit) and make building services flexible (c.f. MW 11; \$228.0 /m^2/credit).

Lifecycle costs (LCC) of building sustainability measures have also been estimated in this study. Similar to initial costs, reuse of existing building structure could yield high monetary saving (i.e. annualized LCC saving of \$13.9 /m^2/credit). Adoption of energy saving measures could also provide savings in LCC through lowering electricity bills. The monetary savings in annualized LCC was estimated to be \$3.18 /m^2/credit.

Costs of achieving various BEAM-Plus performance grades

Basically, there are four performance grades within BEAM-Plus, namely, Bronze, Silver, Gold and Platinum, with Bronze as the lowest and Platinum as the highest grade. Assuming the least cost approach was adopted, no additional initial capital outlay was determined to be required for achieving Bronze grade. For Silver, Gold, and Platinum grades, the initial cost premiums of implementing sustainable measures were of insignificant impacts (< HK\$12 /m^2; i.e. < 0.05% of total initial cost of the building). Additional initial cost premiums required for upgrading from Bronze to Silver, from Silver to Gold, and from Gold to Platinum were found to be \$1.06/m^2, \$1.89/m^2 and \$3.80/m^2 respectively.

In terms of LCC, it was found that monetary savings could be obtained in achieving a Bronze grade if the least cost approach had been pursued. The savings were mainly attributed to reuse of building structure and the reduction in electricity bills due to the implementation of energy saving measures.

Benefits arising from earning BEAM-Plus credits

The benefits of the implementation of various building sustainability measures for earning BEAM-Plus credits can be broadly categorized into tangible and intangible benefits. Tangible benefits are primarily monetary savings due to reduction in electricity bills as a result of implementing various energy saving measures. Examples of intangible benefits include enhancement of productivity due to adoption of natural lighting, health benefits resulting from improving indoor air quality, and change of occupants' behavior in pursuing a more sustainable living style.

Social benefits arising from earning BEAM-Plus credits

In addition to the tangible benefits discussed above, there will social benefit gains arising from earning BEAM-Plus credits. However, they are generally intangible, more difficult to identify, quantify or monetarize, e.g. those associated with health, safety,

and well-being of building occupants and neighbourhood aspects within the Health and Wellbeing (HWB) Category in BEAM-Plus. Other benefits can be gained by individuals and the society through earning credits related to (1) enhancement of indoor air quality (IAQ), (2) thermal, acoustic and visual comfort, (3) adoption of daylighting, (4) views to nature, (5) family friendly and barrier free designs.

In addition, there are credits within other BEAM-Plus sections that can also provide social benefits. For example, there are credits related to the encouragement of use of public transport and enhancement of walkability of neighborhood (SS1 and SS2). Better connection to public transportation hubs can improve the accessibility to and from home and workplace. Walkability enhancement can indirectly improve the health and well-being of building occupants through enhancing individual physical activity levels. Also, improvement of outdoor thermal comfort (SS10) can enhance the walkability of outdoor spaces, thus reduce the chance of overweight and obese, and health risks. Besides, there are credits which help preserve the cultural and historical values of site / neighbourhood.

Benefit-cost analysis of earning BEAM-Plus credits

In this study, only tangible benefits are monetized in the benefit-cost analysis. Benefit-cost ratio, which is the ratio of benefit to the additional initial costs or LCC, was determined for individual building sustainability measures. A higher benefit-cost ratio suggests a more economically beneficial measure to be implemented. Of all the energy saving measures considered in this study, it was found that increase the lighting power intensity to 9 W/m^2 via LED was the most beneficial measure (with a benefit-cost ratio of 6.8), followed by increasing the COP of HVAC system to 3.5 (with a benefit-cost ratio of 3.0), and adoption of water-cooled system (with a benefit-cost ratio of 2.3). Glazing with lower shading coefficient value was found to be the least beneficial energy saving measure.

Practicality of sustainable measures to earn BEAM-Plus credits

During the focus group meeting, the practicality of implementing various sustainable measures to earn BEAM Plus credits was discussed. The ease of earning a number of credits have been found to be linked directly with site conditions. Provision of neighborhood amenities to building users is one of the examples. Basically, it is not feasible to earn such credits by implementing sustainable measures which are restricted by the given site conditions. Although it is theoretically possible to obtain huge savings in initial cost by reusing existing building structure, it is not a measure which is always feasible to be implemented. Indeed, it is often feasible for projects like revitalization of historical buildings, and conversion of industrial buildings into hotels. Also, it is possible to acquire some monetary savings in initial costs by recycling of construction and demolition wastes. However, there may be hidden costs (e.g. cost of provision of documents documenting the recycling of materials) borne by contractors which may hinder the implementation of recycling measure. The structure of current recycling market also makes it challenging to recycle wastes. A more mature market is thus needed for fully implementing this sustainable measure.

Motivation and willingness-to-pay for achieving higher BEAM-Plus grades

The motivation and willingness-to-pay for achieving higher BEAM-Plus grades were also discussed during the focus group meeting. For most developers, the primary driver of pursuing higher BEAM Plus grades was to secure GFA concession. However, some developers, mostly large developers, who might attempt to achieve higher BEAM-Plus grades in order to pursue their corporate sustainable policies. Meanwhile, some high sustainability awareness tenants were keen to rent office spaces in buildings with higher sustainable performance (i.e. with performance grades within BEAM-Plus, LEED etc.). In order to attract this type of tenants, some developers were eager to pursue higher BEAM-Plus grades. For the willingness-to-pay for BEAM-Plus grades, it was generally agreed that many developers did lay down their own budget plans for achieving different BEAM-Plus grades although the participants did not give exact figures on the amount that developers were willing to pay. This is especially true for developers who had experiences in the BEAM-Plus certification for their previous building development projects.

2 Layman's summary on policy implications and recommendations

Policy recommendations in general

GFA concession should be of the first priority in terms of formulating policies to promote construction of sustainable buildings. The current policy allows developers to just register and obtain an "unclassified" grade for their development projects so as to fulfil the minimum requirement for obtaining the GFA concessions. Although the current regulation requires disclosure of information regarding energy performance / BEAM-Plus assessment for the development project granted with GFA concession, this type of information can be disclosed in a very opaque manner such that the tenants or buyers may not easily realise the sustainable performance level attained by buildings. Thus, it is recommended to stipulate mandatory disclosure of performance grades to the public in a more explicit manner, regardless of whether GFA concession have been granted or not. Also, it is proposed that the percentages of GFA concession granted should be directly linked to the BEAM-Plus performance grades achieved.

Policy recommendations concerning different stakeholders

Different stakeholders have different concerns and interests on sustainable buildings. Thus, different types of policies should be formulated to cater for the characteristics of different stakeholders. It is recommended to formulate policies that can target at addressing the interests and concerns of developers, and tenants and buyers separately.

Developers

Although initial cost premiums are often incurred, energy saving measures can usually lead to savings in lifecycle cost. Developers may not be able to benefit from

savings in electricity bills if they are not going to operate the building. Additional incentives are needed to encourage them to implement energy saving measures. Provision of low interest green loans or subsidies can be one of the policies to be formulated. Tax rebates linked to the energy performance of buildings are worth deeper considerations.

Tenants and buyers

It has been suggested in the focus group meeting that developers might not be keen to promote buildings awarded with high BEAM-Plus performance grades. One of the reasons might be that the general public was not fully aware of the existence or benefits of BEAM-Plus as an eco-label. Conceivably, one of the motivations for developers to pursue higher BEAM-Plus grades should come from the demands for sustainable performances of buildings from tenants or buyers. Consequently, policies should also be geared towards education of the public on the benefits of sustainable buildings and BEAM-Plus certification. Also, incentives can be provided to tenants or buyers as an indirect way to promote sustainable building construction even though HK is a developer dominated property market. Monetary incentives such as tax reduction can be granted to tenants or buyers who have rented / bought properties of higher BEAM-Plus grades.

Policy recommendations for individual sustainable measures

Some policy recommendations for encouraging the implementation of individual sustainable building measures are discussed in the followings:

Recycling of construction and demolition (C&D) wastes can provide some monetary savings in initial cost. However, lack of a mature recycling market may be one of the important deterrent factors. Information flow is an important element for developing a mature recycling market. An online system for information exchange between developers / contractors and recycling companies for C&D wastes should be developed in Hong Kong for enhancing the information flow. Support (e.g. in terms of provision of spaces for storing the C&D wastes) can also be provided to recycling companies. Besides, mandatory use of recycled materials in construction may also help to develop a more mature recycling market. A higher landfill dumping charges may act as a catalyst to force developers / contractors to consider the option of recycling instead of dumping.

On the other hand, the payback period of PV was estimated to be longer than 10 years after considering both the savings in electricity bills and feed-in-tariff. Even for owner-developers, the long payback period may become a strong barrier for PV installations. Promoting the concept of Energy Services Companies (ESCOs), which will install PV panels without upfront charges but collect the share of savings after installation, may help to encourage developers to install PV panels.

Higher window-to-wall (WWR) ratios will lead to higher energy consumption levels and construction costs. However, most developers will still adopt higher WWRs to enlarge the viewing areas from the building to outside, which may further enhance

the saleability of buildings. Policies can be formulated to deal with such issues with an objective to enhance the energy performance of building. Adoption of lower WWRs (e.g. 0.5) should be advocated as a best practice for building design. More education campaigns should also be organized to educate the public about the advantages of adopting lower WWRs, which may exert indirect influences on the decisions of developers.

Besides, the construction of green roofs and green facades can help to reduce cooling load of buildings and the ambient temperature of the open spaces surrounding buildings. This will in turn help to enhance the thermal comfort and hence walkability of the open spaces, which is one of the social benefits arising from sustainable buildings. In this regard, code of practices or even incentives can be provided to developers for promoting their construction.

摘要

BEAM-Plus是用於評估建築全生命周期可持續性以及性能的自願性工具。 自從 BEAM-Plus 於香港首次作為評估方法被推出以來，一直在不斷更新和完善其評估範圍和細節。本研究確立了在香港獲得 BEAM-Plus 新建建築 2.0 版認證的經濟和非經濟效益及其阻礙。在本研究中只有與個體積分以及達到不同 BEAM-Plus 性能評級要求相關的經濟成本和收益被貨幣化。此外，本研究還調查了當前的 BEAM-Plus 性能評級方案是否可以為開發商和設計師提供足夠的經濟激勵，從而鼓勵他們追求超越閾值水準的建築可持續性。

本研究構建了基準高層辦公樓的能耗模型，以便揭示為達到更高性能水準所產生的成本和收益。方案中已經確立了部分具有經濟效益的可持續戰略，以便促進房地產投資者、業主、建築師和工程師做出傾向於更高 BEAM-Plus 性能等級的決策。與此同時，方案檢視了績效型和市場利益驅動的開發商對各類 BEAM-Plus 性能等級的支付意願。通過焦點小組會議也揭示了這些戰略的實施可行性。總而言之，這項研究為決策者提供了多視角的寶貴見解，促進他們瞭解能源效率、生命週期成本和建築性能在可持續發展中的經濟、環境和社會價值，並進一步確立 BEAM-Plus 的實施價值。

以下羅列出了本研究所實現的各類目標:

I. 識別並且評估了達到 BEAM-Plus 閾值水平以及追求更高評級的可持續性建築開發所產生的經濟、環境、社會效益和非經濟阻礙。
II. 估算了基於 BEAM-Plus 2.0 版本各種積分要求的成本和收益，並考慮與新的可持續建築開發相關的初始投資成本、生命週期成本和運營效益。
III. 調查了 BEAM-Plus 的各種性能評級在多大程度上可以在能源效率、建築性能和可持續性的其他社會和環境方面為開發商和設計師提供足夠的經濟激勵。
IV. 探討了發展商在獲知 BEAM-Plus 評估成本和收益后，是否傾向於採用 BEAM-Plus 方案，以及他們對獲得不同評級的支付意願（WTP）。
V. 為開發商和設計師制定了有效的可持續設計策略，促進獲得新建築開發或大型加建和改建工程的不同 BEAM-Plus 性能等級。

本研究通過與基準建築的比較，評估了額外成本和收益以及獲得個體 BEAM-Plus 積分所需的各種可持續措施的績效。香港的定價工程量清單（BQ）和成本數據手冊的統計分析被用作成本估算的參考。各類材料的用量根據以往辦公樓專案工程量清單統計分析確定，而性能則參考能源類比結果及相關文獻確定。

為確保本研究得出結論的合理性，我們組織了一次焦點小組會議，會議成員由來自不同建築開發和設計專業的主要市場參與者組成的。 在會議上，研究者徵求了他們對收益成本分析的結果和獲得各類 BEAM-Plus 表現等級的擬議策略

的意見，並且討論了開發商為獲得各類 BEAM-Plus 評級而願意支付的金額。 此外，會議的另外一個主題是推行各項可持續措施以取得 BEAM-Plus 積分的可行性。

1 主要的研究成果

本研究揭示了實施各種可持續措施以獲得 BEAM-Plus 積分的收益和成本。通過假設私人開發商將追求最小化成本，研究確立了獲得不同 BEAM-Plus 等級的最佳積分選擇策略及其相關成本和收益。

獲取 BEAM Plus 積分的各種可持續措施的成本

從初始成本的角度考慮，一些滿足 BEAM-Plus 積分要求的可持續措施被證明能夠節省資金。研究發現，建築結構的再利用能夠實現節約資金效益最大化（再利用 90%的現有建築結構，則最多可能節省 $562.9/平方米/積分）。 此項措施可應用於歷史建築活化、工業建築改建為酒店等專案。 然而並非適用於所有建築專案。此外，使用預製內部建築構件（主要是內牆隔斷）也可以節省 $169.9/平方米/積分的資金。還可以通過採用 LED 燈將照明功率強度降低 10%的措施來節約資金，這項措施可節省$40. 0 /平方米/積分的初始成本。

與此同時，還有一些措施需要較高的初始成本溢價。在追求 BEAM-Plus 中能源使用類別的 EU 2 部分的性能路徑時，初始成本溢價可高達 $3350.0/平方米/積分。 合併預製建築結構元素（參見 MW 3; $228.0/平方米/積分）和靈活性的建築服務（參見 MW 11; $228.0/平方米/積分）也需要高額的初始成本溢價。

本研究還估算了建築可持續性措施的生命週期成本（LCC）。與初始成本類似，現有建築結構的再利用可以節省大量資金（生命週期成本每年資金節約為 $13.9/平方米/積分）。還可以通過降低電費的節能措施來節省生命週期成本，其生命週期成本每年資金節約估計為 $3.18 /平方米/積分。

達到各種 BEAM-Plus 性能評級的成本

基本上，BEAM-Plus 有四個性能評級，即銅、銀、金和鉑金，其中銅為最低等級，鉑金為最高等級。假設採用最低成本法，即達到銅級不需要額外的初始成本。 那麼，實施可持續措施對於銀、金和鉑金等級的初始成本溢價影響不大（小於 $12/平方米; 即小於建築初始總成本的 0.05%）。從銅升級到白銀、從白銀升級到黃金、從黃金升級到白金的額外初始成本溢價分別為 $1.06/平米、$1.89 /平米 和 $3.80 /平米。

就生命週期成本而言，如果採用最低成本方法，則可以在獲得銅級時節省資金。節餘主要歸因於建築結構的再利用以及因實施節能措施而減少的電費。

獲得 BEAM-Plus 積分的好處為獲得 BEAM-Plus 積分而實施各種建築可持續性措施的好處可大致分為有形和無形兩類。有形效益主要是由於實施各種節能措施而減少了電費，從而節省了資金。無形效益的例子包括由於採用自然採光而提高生產力，改善室內空氣質量帶來的健康益處，以及由於在建築物中實施可持續教育元素而改變居住者追求更可持續生活方式的行為。

獲得 BEAM-Plus 積分的社會效益

除了上述討論的有形收益之外，獲得 BEAM-Plus 積分還會帶來社會效益的增益。然而，這些效益通常是無形的，更難以確定、量化或貨幣化，例如與建築內部人員健康、安全和福祉以及 BEAM-Plus 中健康與福祉類別中的社區方面相關的效益。通過獲得與以下方面相關的積分，個人和社會可以獲得其他好處：（1）改善室內空氣質量（IAQ）；（2）提高熱、聲音和視覺舒適度；（3）採用自然採光；（4）欣賞自然景色；（5）家庭友好和無障礙設計。

此外，BEAM-Plus 的其他部分中也有一些能提供社會效益的積分。例如，鼓勵使用公共交通和提升社區可步行性的積分（SS1 和 SS2）。更好地連接到公共交通樞紐可以改善往返家庭和工作場所的便利性。提升可步行性可以間接地通過增加個人體育活動水平改善房屋住戶的健康狀況。此外，改善室外熱舒適度（SS10）可以提高室外空間的可步行性，從而降低超重和肥胖的機會，減少健康風險。此外，還有一些積分有助於保護場地/社區的文化和歷史價值。

獲得 BEAM-Plus 積分的效益成本分析

在這項研究中，只有有形的收益在收益成本分析中被貨幣化。效益成本比被定義為效益與額外初始成本或生命週期成本的比率，為個體建築可持續性措施。高效益成本比代表所實施措施具有更高的經濟績效。在本研究考慮的所有節能措施中，通過 LED 將照明功率強度提高到 9 瓦/平方米是最佳的措施（效益成本比為 6.8）；其次為提高 HVAC 的 COP 系統至 3.5（效益成本比為 3.0）和採用水冷系統（效益成本比為 2.3）。採用具有較低遮陽係數值的玻璃被證明是最低效益的節能措施。

獲得 BEAM-Plus 積分的可持續措施的實用性

在焦點小組會議上，討論了實施各種可持續措施以獲得 BEAM-Plus 積分的實用性。人們發現，獲得大量積分的難易程度與場地條件直接相關。為建築使

用者提供社區便利設施就是例子之一。 基本上，通過實施受特定場地條件限制的可持續措施來獲得此類積分是不可行的。雖然理論上可以通過重用現有的建築結構來節省大量的初始成本，但這並不總是一個可行的措施。一般來說，它常用於歷史建築的活化和將工業建築改建為酒店等專案。 此外，通過回收建築和拆除廢物，可以節約部分初始成本。然而，承建商可能會承擔隱性成本（例如提供材料回收檔的成本），從而阻礙回收措施的實施。當前回收市場的結構也使得回收廢物具有挑戰性。因此，需要一個更成熟的市場來全面實施這一可持續措施。

取得更高 BEAM-Plus 評級的動機和支付意願

焦點小組會議還討論了獲得更高 BEAM-Plus 評級的動機和支付意願。 對於大多數開發商而言，獲得更高 BEAM-Plus 評級的主要驅動力是獲得建築面積特許權。然而，一些開發商，特別是大型開發商，可能會嘗試獲得 更高 BEAM-Plus 評級以便推行其企業可持續發展政策。與此同時，一些具有高度可持續意識的租戶熱衷於在可持續性能更高的建築物中租用辦公空間（即性能評級在 BEAM-Plus、LEED 等範圍內）。為了吸引這類租戶，一些發展商也會追求更高的 BEAM-Plus 評級。 雖然參與者們並沒有給出開發商達到更高評級所願意支付的確切費用，但大家普遍認為許多開發商會 制定達到不同 BEAM-Plus 評級的所需預算。這對於在之前的建築開發專案中有過 BEAM-Plus 認證經驗的開發商來說更加適用。

2 外行人對政策影響和建議的總結

一般政策建議

在制定促進可持續建築建設的政策方面，應將建築面積特許權放在首位。目前的政策只允許開發商為其開發專案註冊並獲得「未分類」等級，以滿足獲得建築面積特許權的最低要求。 雖然現行法規要求披露有關獲得總建築面積特許權的開發專案的能源績效/BEAM-Plus 評估的資訊，但此類資訊可以以非常隱蔽的方式披露，以至於租戶或買家很難瞭解 到可持續績效建築物達到的水準。因此，建議以更明確的方式規定向公眾強制披露性能等級，無論是否授予建築面積特許權。此外，建議授予的特許建築面積百分比應與所達到的 BEAM-Plus 表現等級直接挂鉤。

涉及不同利益攸關方的政策建議

不同的利益相關者可能對可持續建築有不同的關注點。因此，應針對不同利益相關者（開發商、租戶和購房者）的特點制定不同類型的政策。

發展商

雖然節能措施通常會產生初始成本溢價，但是從生命週期成本來說是它仍然節省了資金。 如果發展商不打算運營大樓，他們可能無法從節省的電費中受益。 那麼則需要額外的激勵措施來鼓勵他們實施節能措施，例如提供低息綠色貸款或補貼。此外，與建築物能源性能相關的退稅策略也值得更進一步的考慮。

租戶和買家

在焦點小組會議上有人提議，發展商可能不會熱衷於推廣已達到高 BEAM-Plus 性能評級的建築物。其中一個原因可能是公眾並未深入意識到 BEAM-Plus 作為生態標籤的存在或好處。發展商追求更高 BEAM-Plus 等級的動機之一應該來自租戶或買家對建築物可持續性能的需求。因此，政策也應針對可持續建築和 BEAM-Plus 認證的好處對公眾進行教育。此外，儘管香港的房地產市場是以發展商為主導，但是也可以向租戶或買家提供激勵措施，作為促進可持續建築建設的間接方式。租用/購買高 BEAM-Plus 評級的租戶或買家可獲減稅等金錢獎勵。

<u>個別可持續措施的政策建議</u>

以下討論了一些鼓勵實施個別可持續建築措施的政策建議:

回收建築和拆除 （C&D） 廢物可以節省一些初始成本。然而，缺乏成熟的回收市場可能是主要的阻礙因素之一。資訊流是發展成熟的回收市場的重要因素。 香港應開發拆建廢物開發商/承建商與回收公司之間的網上資訊交換系統，以加強資訊流通。也可向回收公司提供支援（例如提供存放拆建廢物的空間）。此外，在建築中強制使用回收材料也可能有助於發展更成熟的回收市場。同時，高昂的垃圾填埋場傾倒費也不失為一種手段，它能夠迫使開發商/承包商傾向於選擇回收而不是傾倒。

另一方面，綜合考慮到節省的電費和上網電價，光伏發電的投資回收期估計超過 10 年。即使對於業主開發商而言，較長的投資回報期也可能成為光伏安裝的重大障礙。推廣能源服務公司 （ESCO） 的概念，即可安裝無需預付費用的光伏面板，但在安裝後收取節約資金的份額，這種概念可能有助於鼓勵開發商安裝光伏面板。

更高的窗牆比（WWR）將導致更高的能源消耗水準和建築成本。 不過，大部分發展商仍會採用較高的窗牆比，以擴大建築物向外的觀景面積，可進一步提升建築物的可售性。制定相關政策能夠處理此類問題，以便提高建築物的能源性能。應提倡採用較低的窗牆比（如 0.5）作為建築設計的最佳實踐。 此外，組織更多的教育活動促進公眾認識到採用低窗牆比的好處，這可能會對發展商的決策產生間接影響。

此外，建造绿色屋顶和绿色立面可以帮助减少建筑物的冷却负荷和周围开放空间的环境温度。这将进一步提高开放空间的热舒适度，从而增强其可步行性，这是可持续建筑所带来的社会效益之一。在这方面，可以制定规范或提供激励措施，以促进开发商建造绿色屋顶和绿色立面。

1 Introduction

1.1 Background

Buildings not only consume a vast amount of resources but also produce a large amount of environmental loadings. Buildings are responsible for 37% of the global carbon emissions (United Nations Environment Programme, 2022). They also consume 30% of raw materials, as well as 25% of water globally (Giannetti et al., 2018). In developed countries, buildings generate 40% of solid waste (Yılmaz & Bakış, 2015). Thus, the built environment has been and is one of the major foci of sustainable policies of governments worldwide. In Hong Kong, buildings contribute to 90% of electricity consumption and 60% of total carbon emission (The HKSAR Government, 2021). In recognition of the above staggering statistics, creating a sustainable built environment (SBE) is an indispensable element of the current and future policies for promoting energy saving and GHG emission reduction in Hong Kong. In recent years, the Hong Kong Green Building Council (HKGBC) has been leading the sustainable building movement in Hong Kong via development and monitoring of operation of BEAM-Plus, which is a voluntary assessment and rating scheme for building sustainability and performance (HKGBC, 2021).

Sustainable buildings do not only lead to energy saving or reduction in carbon emission alone, but also provide a number of co-benefits. For example, improved indoor environmental quality (IEQ) is usually associated with the notion of sustainable buildings. Sustainable assessment schemes such as LEED (USGBC, 2019) and BEAM-Plus (HKGBC, 2021) also include IEQ as a part of their assessment criteria. It has been suggested that health problems such as respiratory illness can be reduced by the improvement of IEQ inside buildings (Fisk, 2002). Studies also found that productivity of occupants was higher if the thermal condition in office buildings was more satisfactory (Geng et al., 2017). Besides, studies also suggested that sustainable buildings could yield financial benefits due to the savings in energy and water consumption (Reddy, 2016).

However, evidence also suggested that an additional upfront cost of up to 21% can be incurred in sustainable building construction (Dwaikat & Ali, 2016). This brings out the question of benefits and costs of sustainable buildings. What will the more cost-effective sustainable building designs be? How different stakeholders will make the decisions on sustainable buildings with respect to their own benefits and costs? Answers to these questions will provide insights on formulating more effective public polices to promote more sustainable, and ultimately zero-emission, buildings. This study attempts to answer all these questions by reference to the credits and grades stipulated within BEAM Plus as the benchmarks of sustainable buildings. Findings from the study will provide valuable insights when formulating sustainable building policies.

1.2 Sustainable Building Assessment

With an aim to minimize the environmental impacts of the built environment, more than 600 of rating systems for comprehensive assessment of building sustainability with various scopes, scales of incentive-weighting, and extents of

application have been developed and undergone continuous updating and refinement (Doan et al., 2017). Such sustainability assessment aims to provide decision makers including property developers as well as prospective buyers and renters of the properties with evaluations of the environmental, economic, and social dimensions of building sustainability (Crawley & Aho, 1999). The credits and ratings awarded to scheme participants also serve as a measure of green investment for social responsibility (Chau et al., 2000). From the investors' standpoint, acting sustainably is no longer at odds with profitmaking because the failure of newly built properties to deliver economic return with both environmental and social performance has been gradually considered as a risk of losing the competitive edge in the market (Lorenz & Lützkendorf, 2008). Launched in 1990, the first sustainable building assessment method is BREEAM (Building Research Establishment's Environmental Assessment Method) under the aegis of the UK government (Prior, 1991). It comprises nine assessment criteria, which are management, wellbeing and health, energy, transport, water, material, land use, ecology and pollution. Pre-completion assessments in construction and commissioning phases are covered in the BREEAM regime, which has been adopted by more than 80 countries (Zhang et al., 2019). In particular, Canada and Australia used BREEAM as the point of departure for developing their own building rating tools (Berardi, 2012).

Following the success of BREEAM, LEED (Leadership in Energy and Environmental Design) certificate scheme was introduced to the building construction industry by the US Green Building Council in the late 1990s (Banani *et al*, 2013). The latest version of LEED comprises six categories, which are sustainable sites, water efficiency, energy and atmosphere, materials and resources, indoor environment quality, and innovation and design processes. LEED assesses the performance of new building in terms of site aspects, materials use, water use, energy use and indoor environmental quality (IEQ). Building performance is based on objective targets such as lifecycle costs and energy consumption. Although LEED has been adopted in more than 30 countries (including Hong Kong) due to its simplicity, the limited categories of credit-criteria are a major hindrance to adequately addressing regional variations of the built environment (Alyami and Rezgui, 2012; Mao, *et al*, 2009).

1.3 BEAM-Plus in Hong Kong

The first building assessment method in Hong Kong, HK-BEAM (Hong Kong Building Environmental Assessment Method), was developed by HK-BEAM Society Limited in 1996 based on the BREEAM in the UK. In this year, HK-BEAM for New Office Design (Version 1/96) and Existing Office Premises (Version 2/96) were launched as a voluntary certified sustainable building performance assessment scheme. Since then, HK-BEAM constantly evolved and HK-BEAM for New (Version 4/04) and Existing (Version 5/04) Buildings were launched in 2004.

BEAM rating system has since evolved into BEAM-Plus, which covers seven aspects consisting of site, management, water use, energy use, material and waste, health and well-being, and innovations (HKGBC, 2021). The main goal of BEAM-Plus is to minimise the adverse impact of buildings on the environment while raising the quality of living and satisfaction of building occupants. Similar to LEED, a new

building is assessed in two stages under BEAM-Plus. The first stage is provisional assessment for which certification is based on design specifications and predicted performance. The second-stage is the final assessment carried out during the operation phase and requires actual performance data to be submitted. In order to achieve the targets set out in Energy Saving Plan by 2025 in Hong Kong, it is worthwhile improving the efficiency of building energy consumption through the implementation of BEAM-Plus. BEAM-Plus has been evolved into a mature rating tool over the years with adoptions by more than 1,600 buildings.

Figs. 1 and 2 show the total number of projects that have undergone the assessment of BEAM-Plus New Buildings V1.1 and 1.2 respectively. As V2.0 has only recently been launched, we have not had a chance to acquire the updated statistics on the total number of projects adopted this version yet.

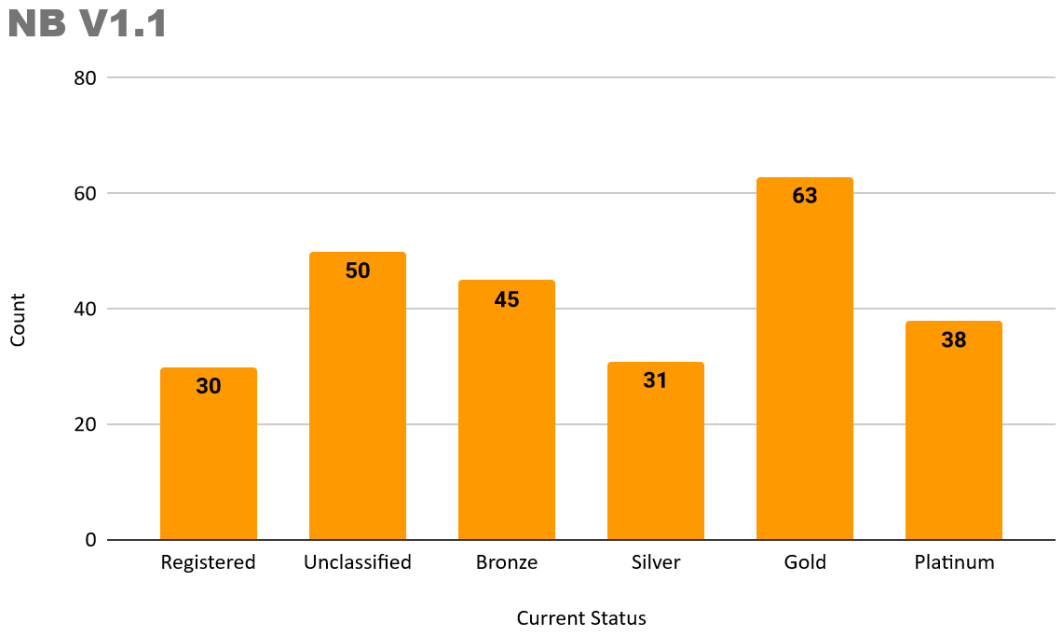

Figure 1 Number of projects which have undergone BEAM-Plus assessment for New Buildings V1.1

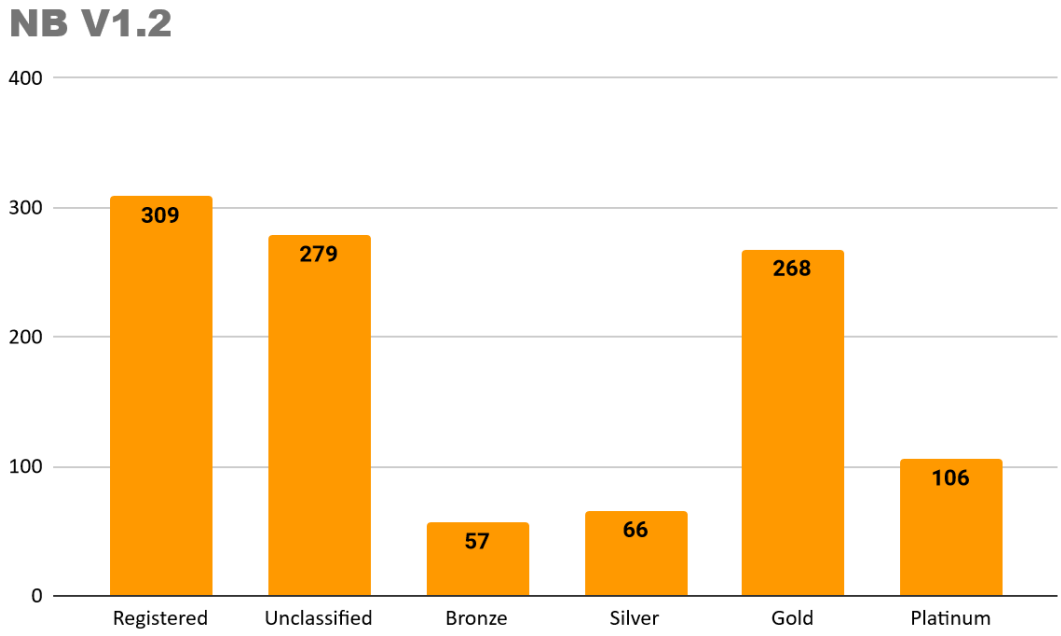

Figure 2 Number of projects which have undergone BEAM-Plus New Buildings V1.2

1.4 Costs and Benefits of Sustainable Buildings

Earlier sustainability studies focusing on the built environment revealed that the interpretation of what constitutes a sustainable development in this unique compact city of mixed land-use and blurred boundaries between life and work could be extensive ranging from reduction in domestic wastes to improvements in healthy living (Planning Department, 2000; ARUP, 2006). The aforementioned rating schemes have shared the common path to gaining credibility in the community at large while creating demand for sustainable buildings across sectors associated with construction and real estate (Chau, *et al*, 2000a). A questionnaire-survey found that although the majority of building designers in Hong Kong perceived that building values in terms of lower lifecycle costs were significant to property development, they acknowledged that the rating systems (including LEED) in the industry were not strong motivators of the market demand for improvement in building energy efficiency (Chan, *et al*, 2009). As a marketable product, the demands for a property with a sustainability label are tied up with the added values such that the rating scheme furthers the interests of those who make financial or creative investments in the building. It has been established that for the measures of pro-environmental potentials of newly developed buildings elucidating the ratings in cost-and-benefit terms is a viable alternative to expressing the weightings on the relative importance of building criteria as an index of impact-equivalent factors. Based on lifecycle costing, an upfront investment as low as 2% of the design and construction costs yields long-term operational and energy savings over ten times of the premium (Kats, 2003). Locally, the modelled extra costs for the top two BEAM-Plus ratings were found to be in the range from 5 to 10% of the total costs (Fan, *et al*, 2018). The findings are consistent with similar costs and benefits analyses (Kats, 2010; Gabay,

et al, 2014). Other cost-value studies also suggested that the front-end capital could be recovered from benefits in reduced maintenance costs, improved building performance, and potentially enhanced work productivity (Madew, 2006; Nicolay, 2007; World Green Building Council, 2013). Further, green-labelled office buildings were found to command premiums in rent (Kok & Jennen, 2012; Fuerst & van de Wetering, 2015) as well as sale price (Miller, *et al*, 2008; Newell, *et al*, 2014). Due to the pre-requisites of building setback and building separation, BEAM-Plus-certified new developments ensured the environmental benefits of the improvement in outdoor air quality at the pedestrian level (Chan, 2018). Cost-benefit analysis has been successfully employed as a decision-aiding tool to convert the multitude of accredited criteria into a range of monetary values for developers joining the rating scheme to square up to their environmental priorities with net economic gain (Chau, *et al*, 2000a, 2000b). The paradigm shift from financial modelling based on capital cost reduction to those based on lifecycle costs and benefits is essential in reflecting more accurately the values of going green with new developments (Davis Langdon, 2007).

It was estimated that the *minimum* premium on total construction cost for buildings certified as 'green' under the previous version of Hong Kong Building Environmental Assessment Method (HK-BEAM) was likely to be of the order of 0-4%, depending on the certified performance grade achieved (e.g. HKBEAM 'Gold'). However, the migration from HKBEAM to BEAM Plus embraces substantial changes in assessment categories, credit structure and provisions, which warrants a detailed study of costs and benefits of various credit provisions. As the cost implication of individual credits varies widely, an in-depth analysis of the costs and benefits of the baseline buildings as well as high performance buildings will certainly be an immense value to the design teams to set their targets.

Previous cost-value studies on green buildings and green rating schemes for new building developments focused on return on investment in terms of energy savings (Gabay, *et al*, 2014), running-cost reductions (Nicolay, 2007), rental and sale premiums (Wiley *et al*, 2010; Newell, *et al*, 2014), tax rebates (Brotman, 2014; Rana, *et al*, 2021), and bonus floor area (Qian, *et al*, 2016; Chan, 2018). Few studies have investigated decision strategies that furnish building developers and design consultants with information such as markers on the costs and benefits of implementing the specific aspects of a green building assessment. This study should be of values to decision makers in both government and industry when several cost-and-benefit alternatives can be provided by the analysis, which points in the direction of encouraging developers to go for a higher performance grade perceived to be difficult to obtain. By revealing the cost implications of each and every aspect of the seven BEAM-Plus categories, the analysis will be useful for policymakers to adjust the assessment weights and criteria for the avoidance of greenwashing (Matisoff, *et al*, 2014; Doan, *et al*, 2017) or leverage government incentives with more stringent conditions for the improvement of sustainable building performance, given that at the present moment a minimum passing rating is not a pre-requisite for granting scheme-participants GFA concessions. The decision strategies to be developed in the study aim to help developers and designers to identify their environmental priorities for achieving a maximum number of credits under BEAM Plus New Buildings Version 2.0 (NB v2.0).

Specifically, this study attempts to address the following questions:

1) Which is the optimal set of accredited criteria that is the most economically beneficial for developers to obtain their target BEAM Plus performance grade?
2) Apart from costs and benefits, which is the optimal set of accredited criteria that achieves a minimum environmental impact in terms of carbon footprint and energy consumption with maximum cost-benefits?

1.5 Objectives of the current study

There are 5 objectives in the current study:

I. To identify and estimate the economic, environmental and social benefits as well as non-economic obstacles of reaching the threshold BEAM-Plus rating and pursuing higher ratings for a new sustainable building development;
II. To estimate the costs and benefits of complying various credit requirements under BEAM-Plus v2.0 with due regards to initial investment costs, lifecycle costs and operational savings associated with a new sustainable building development;
III. To investigate the extent to which various performance grading under BEAM-Plus can provide adequate economic incentives for developers and designers in terms of energy efficiency, building performance, and other social and environmental aspects of sustainability;
IV. To explore whether developers have higher intentions to adopt the BEAM-Plus assessment schemes with the informed costs and benefits for adoption of BEAM-Plus assessment and their willingness-to-pay (WTP) for obtaining different performance grades;
V To develop effective sustainable design strategies for developers and designers to obtain different BEAM-Plus performance grades for a new building development or a major work of addition or alteration.

2 Credits within BEAM-Plus V2.0

As it is expected that BEAM-Plus V2.0 will be increasingly used for future new office building project assessments, only the costs and benefits associated with this updated version will be evaluated and presented here. In this study, the costs and benefits of individual credits within various categories have been evaluated. Prior to discussions of our findings, it is worthwhile acquiring a basic understanding of operation and structure of BEAM-Plus. Table 1 lists the breakdown of credits within BEAM-Plus New Buildings V2.0. In addition to credits, there are percentage weightings assigned to individual categories, which are the percentage of scores obtainable in each section. Table 2 shows the weighting of each section within BEAM-Plus. It can be seen that the number of credits and percentage weighting of the Energy Use (EU) category are the highest among all the categories within BEAM-Plus. On the contrary, the number of credits and the percentage weight of the Water Use (WU) category are the lowest.

Table 1 A summary of breakdown of credits within BEAM-Plus V2

	Category 2	*Total Credits*	*Total Bonus*
	Integrated Design and Construction Management (IDCM)	**25**	**14**
IDCM P1	Sustainability Champions - Project	**required**	
IDCM P2	Environmental Management Plan	**required**	
IDCM P3	Timber Used for Temporary Works	**required**	
IDCM 1	Sustainability Champions - Design	**1**	**1**
IDCM 2	Complimentary Certification		**3**
IDCM 3	Integrated Design Process	**4**	
IDCM 4	Life Cycle Costing	**1**	
IDCM 5	Commissioning	**4**	
IDCM 6	Sustainability Champions - Construction	**1**	
IDCM 7	Measures to Reduce Site Emissions	**4**	
IDCM 8	Construction and Demolition Waste Recycling	**2**	**4**
IDCM 9	Construction IAQ Management	**1**	
IDCM 10	Considerate Construction	**1**	
IDCM 11	Building Management Manuals	**1**	
IDCM 12	Operator Training plus Chemical Storage Room	**1**	
IDCM 13	Digital Facility Management Interface		**1**
IDCM 14	Occupant Engagement Platform		**1**
IDCM 15	Document Management System	**2**	
IDCM 16	BIM Integration	**1**	**3**
IDCM 17	Design for Engagement and Education on Green Buildings	**1**	**1**
	Category 3	*Total Credits*	*Total Bonus*
	Sustainable Sites (SS)	**20**	**19**
SSP1	Minimum Landscaping Requirements	**required**	
SS1	Pedestrian-oriented and Low Carbon Transport	**2**	**3**
SS2	Neighbourhood Amenities	**2**	
SS3	Building Design for Sustainable Urbanism	**2**	**2**
SS4	Neighbourhood Daylight Access	**1**	
SS5	Noise Control for Building Equipment	**1**	
SS6	Light Pollution Control	**2**	
SS7	Biodiversity	**1**	**5**
SS8	Urban Heat Island Mitigation	**4**	**6**
SS9	Immediate Neighbourhood Wind Environment	**1**	
SS10	Outdoor Thermal Comfort	**2**	
SS11	Stormwater Management	**2**	**1**
SS12	Design for Climate Change Adaptation		**2**

	Category 4	*Total Credits*	*Total Bonus*
	Materials and Waste (MW)	**14**	**21**
MWP1	Minimum Waste Handling Facilities	**required**	
MW1	Building Re-use		**3**
MW2	Modular and Standardised Design	**1**	**1**
MW3	Prefabrication	**1**	**3**
MW4	Design for Durability and Resilience	**1**	**2**
MW5	Sustainable Forest Products	**1**	**1**
MW6	Recycled Materials	**1**	**2**
MW7	Ozone Depleting Substances	**2**	
MW8	Regional Materials	**1**	**2**
MW9	Use of Certified Green Products	**2**	**4**
MW10	Life Cycle Assessment	**1**	
MW11	Adaptability and Deconstruction	**1**	**1**
MW12	Enhanced Waste Handling Facilities	**2**	**2**
	Category 5	*Total Credits*	*Total Bonus*
	Energy Use (EU)	**31**	**13**
EUP1	Minimum Energy Performance	**required**	
EU1	Low Carbon Passive Design	**6**	
EU2	Reduction of CO2 Emissions	**10**	**5**
EU3	Peak Electricity Demand Reduction	**3**	
EU4	Metering and Monitoring	**1**	**2**
EU5	Renewable and Alternative Energy Systems	**6**	**5**
EU6	Air-Conditioning Units	**2**	
EU7	Clothes Drying Facilities	**1**	**1**
EU8	Energy Efficient Appliances	**2**	
	Category 6	*Total Credits*	*Total Bonus*
	Water Use (WU)	**12**	**3**
WUP1	Minimum Water Saving Performance	**required**	
WU1	Annual Water	**3**	**1**
WU2	Water Efficient Irrigation	**2**	**1**
WU3	Water Efficient Appliances	**1**	
WU4	Water Leakage Detection	**1**	
WU5	Twin Tank System	**1**	
WU6	Cooling Tower Water	**1**	
WU7	Effluent Discharge to Foul Sewers	**1**	
WU8	Water Harvesting and Recycling	**2**	**1**
	Category 7	*Total Credits*	*Total Bonus*

	Health and Wellbeing (HWB)	**19**	**10**
HWBP1	Minimum Ventilation Performance	**required**	
HWB1	Healthy and Active Living		**1**
HWB2	Biophilic Design		**2**
HWB3	Inclusive Design	**1**	**1**
HWB4	Enhanced Ventilation	**3**	**1**
HWB5	Waste Odour Control	**1**	
HWB6	Acoustics and Noise	**4**	**1**
HWB7	Indoor Vibration	**1**	
HWB8	Indoor Air Quality	**4**	**1**
HWB9	Thermal Comfort	**2**	**1**
HWB10	Artificial Lighting	**2**	
HWB11	Daylight		**2**
HWB12	Biological Contaminations	**1**	

Table 2 A summary of weightings of various BEAM-Plus sections

Category	Percentage Weighting
IDCM	18%
SS	15%
MW	9%
EU	29%
WU	7%
HWB	22%

In the older HKBEAM versions, the performance grades achieved were directly associated with the total number of credits earned. However, this grade structure has been changed for the new BEAM-Plus versions. Instead of merely counting the total number of credits earned, the final grades achieved are dependent on the total percentage score obtained. In addition, there is a requirement that a minimum of 20% of scores is required to be obtain for each category. Table 3 shows the minimum percentage scores required for individual BEAM-Plus performance grades.

Table 3 A summary of total percentages and minimum scores obtained for achieving different BEAM-Plus performance grades

Grade to be achieved	Minimum percentage of scores obtained in each category	Total percentage score obtained
Platinum	20%	≥ 75%
Gold	20%	≥ 65%
Silver	20%	≥ 55%
Bronze	20%	≥ 40%

3 Methodology

Fig. 3 outlines the methodology flow of this study. The methodology was mainly targeted at evaluating the benefits and costs that could be monetarized for sustainable buildings. Without a formal definition for sustainable building, the specification of a sustainable building is assumed to follow those prescribed for attaining individual performance grades and credits under BEAM-Plus V2.0. In this study, all the major benefits and costs associated with sustainable buildings have been identified and discussed. Benefits examined include economic, environmental and social benefits, while costs include initial, operational, maintenance and disposal costs. However, only the environmental and economic benefits that can be monetarized have been included for computing benefit-cost ratios since majority of social benefits are intangible and difficult to monetarize.

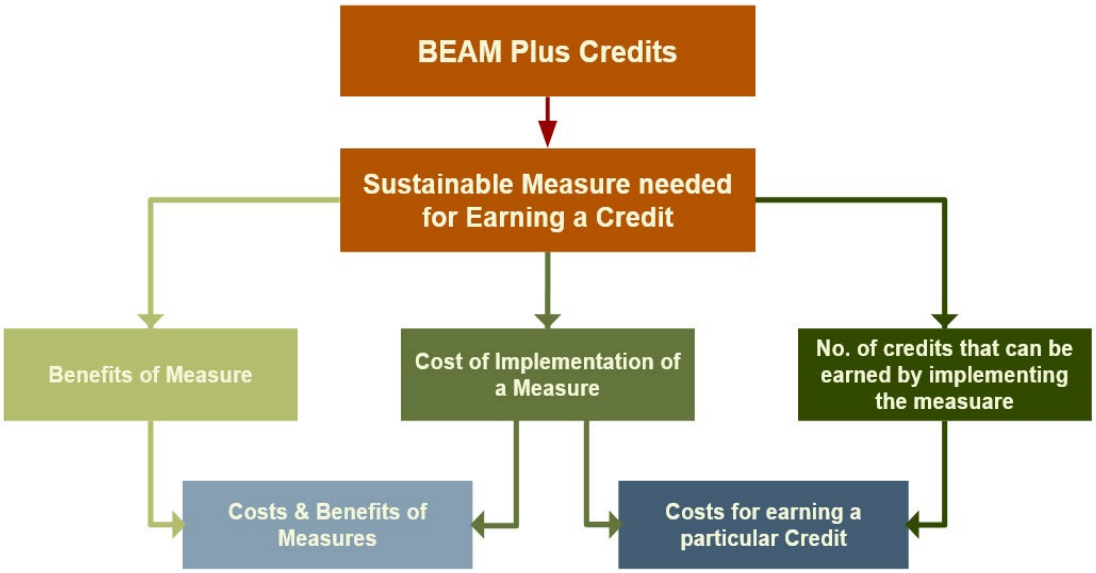

Figure 3 A flowchart showing the methodology adopted in this study

Broadly speaking, the BEAM-Plus credits can be categorized into performance-related and prescriptive credits. Performance credits, which are mainly referred to the credits under the "performance path" in BEAM-Plus, will be awarded when prescribed performance levels of a building are met, regardless of measures implemented. For example, one credit can be earned when 1% of CO_2 emission reduction can be attained when compared to the CO_2 emission of the baseline case (cf. EU 2). Prescriptive credits will be awarded after a prescribed measure has been implemented. For instance, one credit will be awarded for the provision of a digital interface to facilitate facility management teams to review building performance (cf. IDCM 13).

3.1 Major Assumptions

As it is extremely difficult to cater for all different building configurations as well as diverse building design options, a number of major assumptions have been made in relation to the building design and credits to be awarded. They are listed as follows:

- A baseline building, whose configurations were identified from previous surveys in Hong Kong, was adopted as a vehicle for evaluating the costs and benefits of a sustainable building.
- Credits that can only be awarded by acquiring other types of BEAM certificates (e.g. BEAM Plus Neighbourhood) are excluded.
- All the monetarized costs and benefits are expressed in terms of HK$.
- Costs incurred for meetings among developers or various trades of professionals are excluded.
- Credits solely related to conditions outside the site boundary that are beyond the control of developers, are not considered.
- Only the benefits and costs related to a single building are included.
- Life span of the building was assumed 50 years.
- A discount rate of 10% was assumed, without the consideration of inflation.
- The following electricity tariff structure from CLP was assumed for our electricity consumption calculations:

Demand Charge		**Energy Charge**	
Each of the first 650 kVA	$ 68.4	Each of the first 200,000 kWh	$0.757
Each kVA above 650 kVA	$ 65.4	Each unit over 200,000 kWh	$0.737

- Feed-in-Tariff was assumed to be the following according to data from CLP:

RE Generation Capacity	**FiT rate (kWh)**
	After 27 April 2022
≤ 10kW	$4
> 10kW to ≤ 200kW	$3
200kW to ≤ 1MW	$2.5

- Credits related to demolition of building(s) originally in the site are excluded.

3.2 Benefit-Cost Analysis

Net benefits are needed to be estimated before carrying out benefit-cost analysis. In this study, only quantitative benefits that can be converted into monetary terms will be included in the benefit-cost analysis. An example of such benefit is the saving in electricity bills due to implementation of energy saving measures. On the contrary,

qualitative benefits, such as improved satisfaction during building occupation, will not be included in calculation of benefit-cost analysis, but will be outlined in the later sections.

Meanwhile, the net benefits obtained by implementing a particular sustainable building measure are computed by subtracting the costs of its implementation from the benefits accrued over the entire building lifecycle. Generally, a specific measure is considered financially viable if the net benefit is a positive value, and vice versa.

3.2.1 Economic Benefit-Cost Ratio

Benefit-cost ratio, which is the ratio of the net benefit to additional lifecycle cost (LCC) of implementing a sustainable building measure, is adopted to determine its financial viability. In particular, a measure is preferred if the benefit-cost ratio is higher than 1. A specific measure is considered more financially viable if its benefit-cost ratio is higher.

The economic benefit of a sustainable building measure is the monetary return gained from its implementation. Mathematically, the economic benefit-cost ratio of a sustainable building measure is obtained by:

$$\text{Economic Benefit-Cost Ratio}_i = \frac{\Delta B_i^{Econ}}{\Delta C_i} \quad (1)$$

Where ΔB_i^{Econ} and ΔC_i are the net economic benefit and LCC incurred by implementing the *i*th sustainable building measure. Only tangible benefits will be included in the analysis. The economic benefit is often related to the savings in energy costs or earnings in revenue. Meanwhile, the cost considered include operations, maintenance and repair, as well as replacement and final disposal costs.

3.3 Cost-Effectiveness of Energy Efficiency Measures

Apart from benefit-cost analysis, the cost-effectiveness of energy efficiency measures will also be determined. Annualized cost/CO_2 will be determined so as to reveal the cost-effectiveness of various energy efficiency measures:

$$\text{Annualized cost/CO}_2\text{ saving } = \frac{C_{io}-C_i}{E_{io}-E_i} \quad (3)$$

where C_i and C_{io} are costs, including both initial costs and operational electricity costs, with and without implementing the *i*th energy efficiency measure; E_i and E_{io} are the amounts of CO_2 emissions with and without the *i*th energy efficiency measure.

As the initial cost is usually only a fraction of the operating cost, it can be assumed that C_{io} - C_i always carries a positive value. Meanwhile, the value of E_{io} should always be greater than that of E_i. The smaller value of the annualized cost/CO_2, the more cost-effective measure is.

3.4 Performance Prediction

3.4.1 Performance-related Credits

Within BEAM-Plus, all the 24 Performance Credits are embedded within the Energy Use (EU) Section. They are primarily related to the design of buildings and systems targeted at reducing the energy use or CO_2 emissions. As mentioned before, a baseline building was constructed to predict the enhanced performances for various sustainable design options and to estimate the associated additional initial and lifecycle costs and benefits.

Baseline Building

Figure 1 shows the typical floor and Table 1 summarizes the specifications of the baseline building. The baseline building had a square layout plan of 36m x 36m. The core of the building, with dimensions of 15m x 15m, was located at the centre of the building.

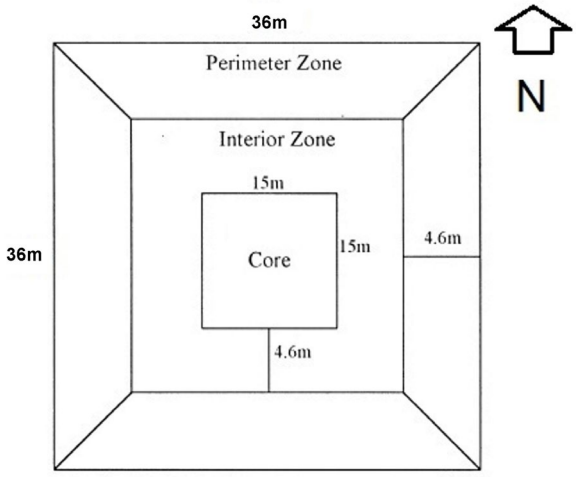

Figure 4 Typical floor of the baseline building

Table 4 Specifications of the baseline building

Description	Parameter	Design Value
Physical details	No. of floor	40
	floor-to-floor height (m)	3.2
	Dimension of floor (L×W) (m)	36×36
	Area per floor (m^2)	1296
	Air-conditioned area per floor(m^2)	1071
Envelope details	Heat transfer coefficient ($W/m^{2\circ}C$)	
	Wall	3.8

	Roof	0.8
	Window	5.5
	Shading coefficient (SC)	0.71
	Window-to-wall ratio (WWR)	0.5
Indoor design conditions	Temperature (°C)	23
	Relative humidity (%)	50
	Ventilation rate (L/s/person)	10
Internal loads	Lighting power density (W/m^2)	9
	Equipment power density (W/m^2)	25
Air-conditioning system	Cooling method	Air-cooled
	Chiller rated COP	3.2
	Pump efficiency	0.85
	Fan efficiency	0.7

The performance, in particular energy consumptions and the costs and benefits of various system or building designs were compared against those of the baseline buildings for estimating the potential reduction of energy use or CO_2 emissions. Table 5 summarizes different options of systems and building designs investigated in this study.

Table 5 Systems and Building Design Options investigated

System Design Options	Levels
Indoor Set Point Temperature (°C)	23; 25.5
Type of Cooling System	Air Cooled; Water Cooled
HVAC Coefficient of Performance (COP)	3.2; 3.5 (Air Cooled); 5.8; 6.2 (Water Cooled)
Pump Efficiency	0.85; 0.9
AHU Fan Efficiency	0.65; 0.7
Use of Centrifugal Fans (for Air Cooled System)	Yes; No
Use of Variable Speed Drive	Yes; No

Lighting Power Density (W/m^2)	6.8; 7.4; 9
Building Design Options	**Levels**
Window-to-Wall Ratio (WWR)	0.5; 0.7; 0.9
Glass Shading Coefficient	0.33; 0.65; 0.71
Building Orientation	0°; 22.5°; 45°

Prediction of Building Energy Consumption

Given that it is a common practice in Hong Kong that the selection of electrical appliances is left to buyers or tenants, the energy consumption level of electrical appliances was assumed constant in this study. With the energy consumption of electrical appliances being excluded, HVAC and lighting systems will become the biggest energy consumers in buildings and their energy consumption/CO_2 emissions will become more important. Energy Plus [1], which is a software for indoor energy consumption simulation, was adopted in this study for predicting the energy consumption due to HVAC systems. The daily operating schedules of HVAC and artificial lighting systems were assumed to be operating from 08:00 to 23:00 daily. The CO_2 emission potential of a specific measure was estimated by multiplying the amount of energy consumption by the equivalent carbon dioxide emission coefficient per kWh electricity consumed, i.e. 0.7kg CO_2 in BEAM.

3.4.2 Prescriptive Credits

For the specific sustainable building measures listed under prescriptive credits, their performances were determined either through estimations or literature review. For instance, the performance of material reuse is mainly related to the embodied energy content of materials. The amount of reduction in embodied energy content due to reuse of a particular material was determined from relevant literature.

3.5 Cost Estimation

To evaluate the costs and benefits of various sustainable building measures, it is necessary to estimate both quantities and initial costs of building materials and equipment. Statistical analyses of priced bills of quantities (BQs) and cost data books for Hong Kong were used as references for cost estimation. While the quantities of various materials used were determined from statistical analysis of BQs of office buildings in previous projects.

3.6 Estimating the costs of achieving various BEAM-Plus performance grades

Within BEAM-Plus, some credits are linked together. For example, one extra bonus credit can be earned if 10% of structural elements (1 credit), façade elements (1 credit) and internal building elements (1 credit) are fabricated off-site. A bonus credit can only be earned after these three credits have been obtained (MW 3). On the contrary, some credits are mutually exclusive within the same section. For instance, within EU 2 Section, the total number of performance path credits is 10 + 5 bonus, while the total number of prescriptive credits is 7. Given that not all the credits are independent of one another, there are many different ways for obtaining a number of combinations of credits from the same or different sections. Taking the MW 2 Section as an example, it is possible to earn 1 credit or 1 credit plus 1 bonus credit. This suggests that there are 2 possible options of earning credits within this section. In MW 3, there are a total of 4 possible options (i.e. 1 credit; 1 credit + 1 bonus credit; 1 credit + 2 bonus credit; and 1 credit + 3 bonus). There is a total of 8 possible options of earning credits when considering MW 2 and MW 3 together. Bearing in mind that there are many possible options for earning credits throughout all the BEAM-Plus categories and sections, it is necessary to identify all the possible combinations of credits before estimating the associated costs and benefits. A protocol has been formulated to identify all the possible credit combinations and estimate the costs of achieving various BEAM-Plus grades. The main rationale behind the protocol is to search for all the possible combinations of BEAM-Plus credits that can be earned. Fig. 5 shows the protocol adopted for searching for different combinations of credits. The search process of credit combinations was performed by using a customized script in Python in a systematic manner. With identification of possible combinations of credits and the costs of each credit, the costs of achieving various performance grades can be estimated.

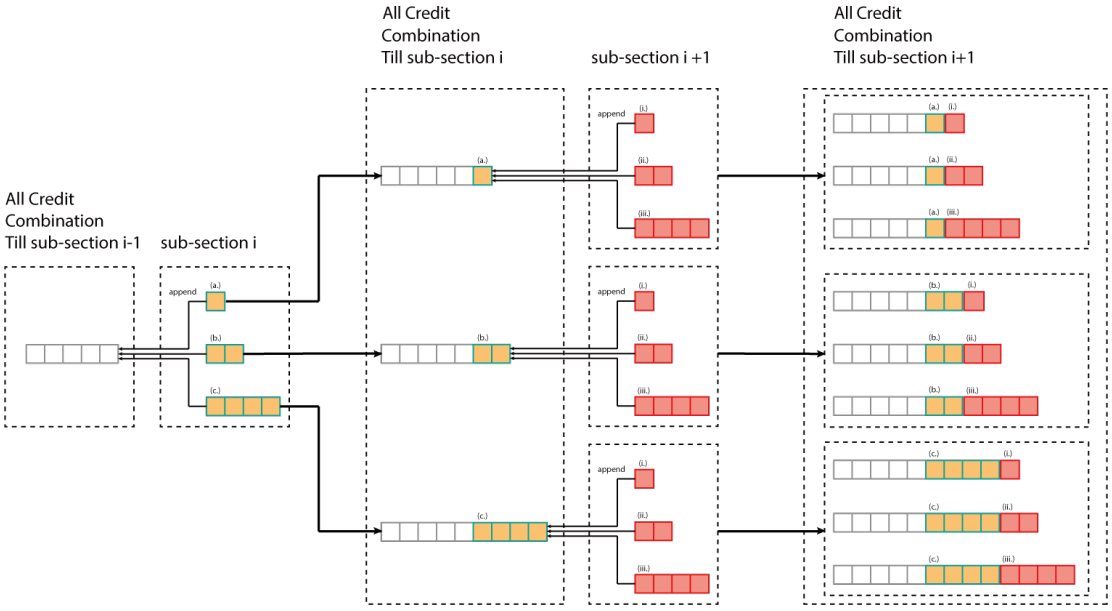

Figure 5 Protocol for identifying various combinations of credits in achieving particular BEAM-Plus performance grades

3.7 Focus Group Meeting

To verify the cost estimates obtained from this study are reasonable and to reveal the practicality of implementation of sustainable building measures, a focus group meeting has been organized. Building professionals, including BEAM-Plus consultants, architects and developers were invited to attend the focus group meeting for discussions.

4 Results

4.1 Percentage score of credits within various BEAM-Plus categories

As the final grade achieved in BEAM-Plus is now based on the percentage score instead of the total number of credits obtained, it is essential to acquire an understanding on how the percentage score can be computed for each category. Fig. 6 shows the percentage scores of individual credits within various BEAM-Plus categories. The percentage scores of individual credits are determined by the total number of credits earned within a particular category as well as the score weighting of that category. Noticeably, the percentage scores of bonus credit are always higher than those of normal credits within the same category and a factor of 1.2 is needed to multiply to the total number of bonus credits to arrive at the corresponding percentage scores. Further, it is noteworthy pointing out that credits within various categories are not equal when considering the percentage scores. The percentage score of individual credits within the Health and Wellbeing (HWB) category is the highest, followed by Energy Use (EU) category. Among all the categories, earning a HWB or EU credit can help attain the highest percentage scores, while earning a Water Use (WU) credit can only obtain the lowest percentage score.

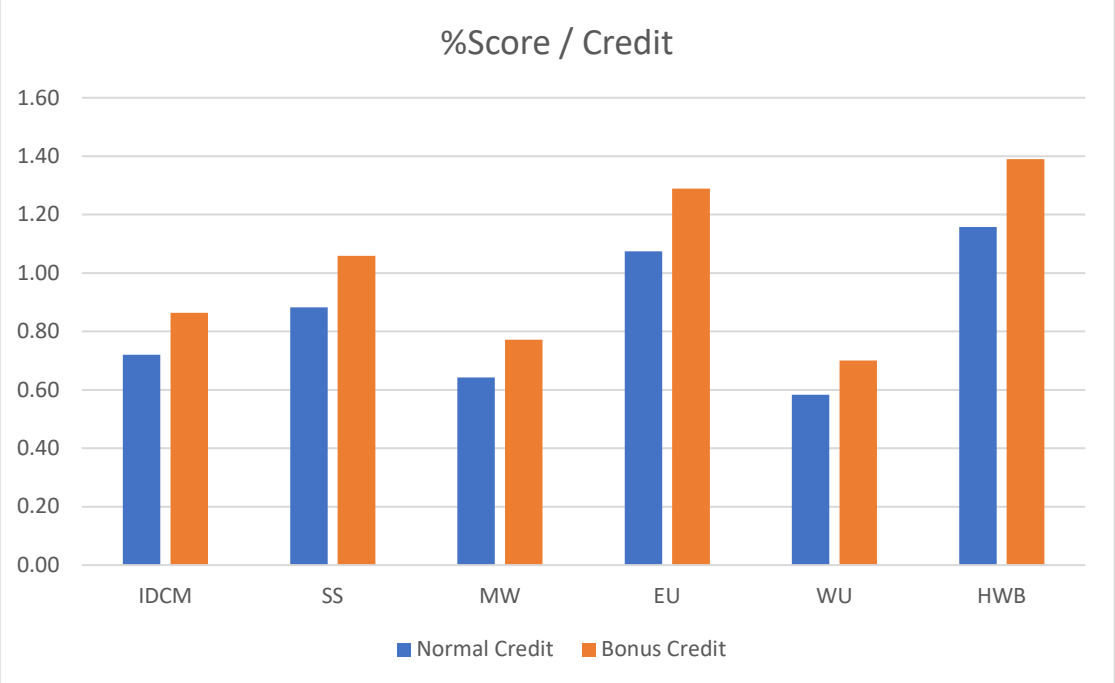

Figure 6 Percentage score per credit of various BEAM-Plus categories

4.2 Cost premiums required for undertaking BEAM-Plus assessments *(Objective II)*

Different stakeholders may have different concerns and interests about the costs and benefits incurred at different stages over whole building life cycle. Developers who sell the buildings after construction may only concern about the initial costs incurred during planning and construction stages. On the other hand, owner-developers, or building owners or tenants will have more concerns and interests about the costs and savings during operational stage. Consequently, it is worthwhile examining the cost impacts of various sustainable building measures from the perspectives of both initial cost and LCC.

Figs. 7 and 8 show the ranges of additional initial cost incurred and changes in lifecycle costs in order to earn the BEAM-Plus 2.0 credits. Of all the credits within BEAM-Plus, 51 of them were found to not incur any additional initial cost (i.e. cost 0) or even negative additional initial cost premiums (where negative values denote that there can be savings in monetary terms in earning the associated credits). Of all the categories within BEAM-Plus, sustainable building measures related to Energy Use (EU) incurred the highest initial costs when compared to other categories. Specifically, changes in window-to-wall ratio of building incur very high initial cost impact. On the other hand, there could be savings accrued when implementing sustainable building measures related to the Materials and Waste (MW) category. The savings in initial cost were largely derived from reusing building structure despite the strategy of reusing building structure not being always feasible.

From the perspective of LCC, the annualised LCC of sustainable building measures of earning EU credits was the highest. Unlike the initial cost, some measures, however, could provide savings in LCC since savings in the electricity costs could offset the additional initial cost outlays. Besides, LCC savings could be accrued by implementing measures within the MW category, and the savings mainly came from reusing building structure in construction phase.

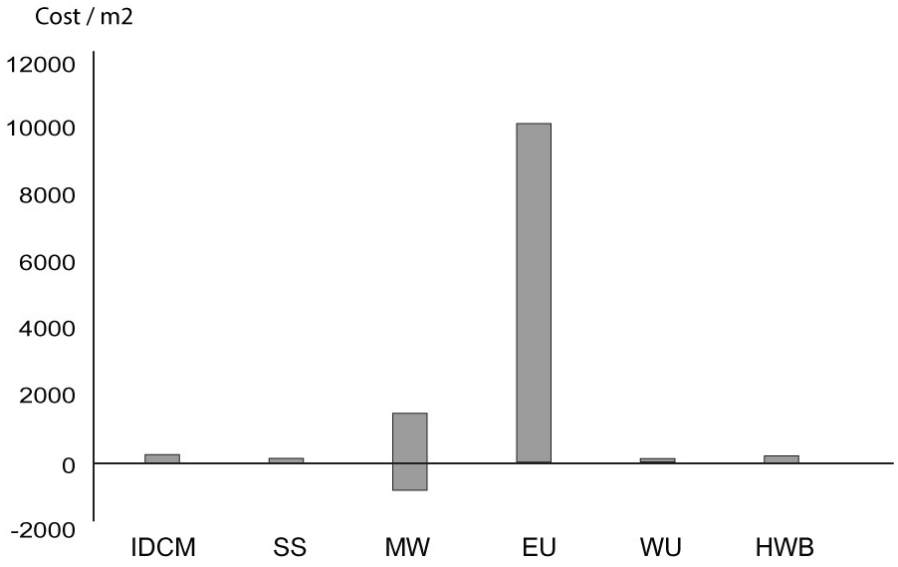

Figure 7 Ranges of initial costs in earning credits within various BEAM-Plus categories

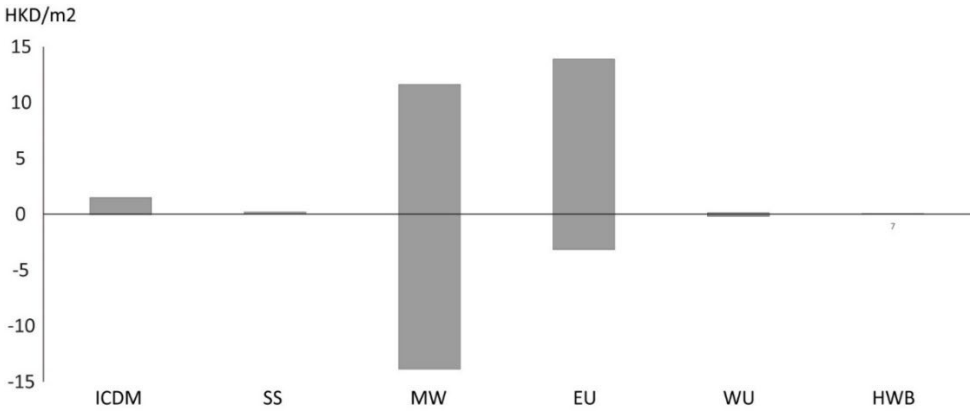

Figure 8 Ranges of changes in annualised LCC in earning credits within various BEAM-Plus categories

Figs. 9 and 10 show the initial cost premium and the change in LCC attributed by implementation of various sustainable building measures. It can be seen that many measures did not require additional initial capital outlays. In addition, a number of measures, which mainly related to reuse of building materials, off-site fabrication and energy saving, could provide monetary savings. Specifically, reuse 90% of building structure (cf. MW 1) could yield the largest possible monetary saving. The potential saving was estimated to \$562.9 /m^2/credit. With 20% of internal building elements (primarily interior wall panels) being fabricated off-site (cf. MW 3), a monetary saving of \$169.9 /m^2/credit could be obtained. LEDs could help reduce the lighting power density by 10% (cf. EU 2 prescriptive path) could lead to an initial cost saving of \$40.0 /m^2/credit.

Conversely, a number of sustainable measures incurred exceptionally high initial cost premium, e.g. sustainable measures mainly related to the performance path in EU 2 Section. The initial cost premium could be as high as \$3350.0 /m^2/credit. High initial cost premiums were required for incorporating pre-fabricated building structural elements (cf. MW 3; \$228.0 /m^2/credit) and make building services flexible (cf. MW 11; \$228.0 /m^2/credit), although they were not comparable in the order of magnitude with those of the performance path credits within the EU 2 Section.

From the LCC perspective, reusing 90% of building structural element could provide the highest monetary saving (with annualised LCC saving of \$13.9/m^2/credit). The LCC saving obtained was mainly due to large saving in initial costs. Monetary saving could also be obtained by adopting energy saving measures to reduce electricity bills. The monetary savings in annualised LCC was \$3.18/m^2/credit. Similar to the case of initial cost premium, many measures also did not incur significant impacts on LCC.

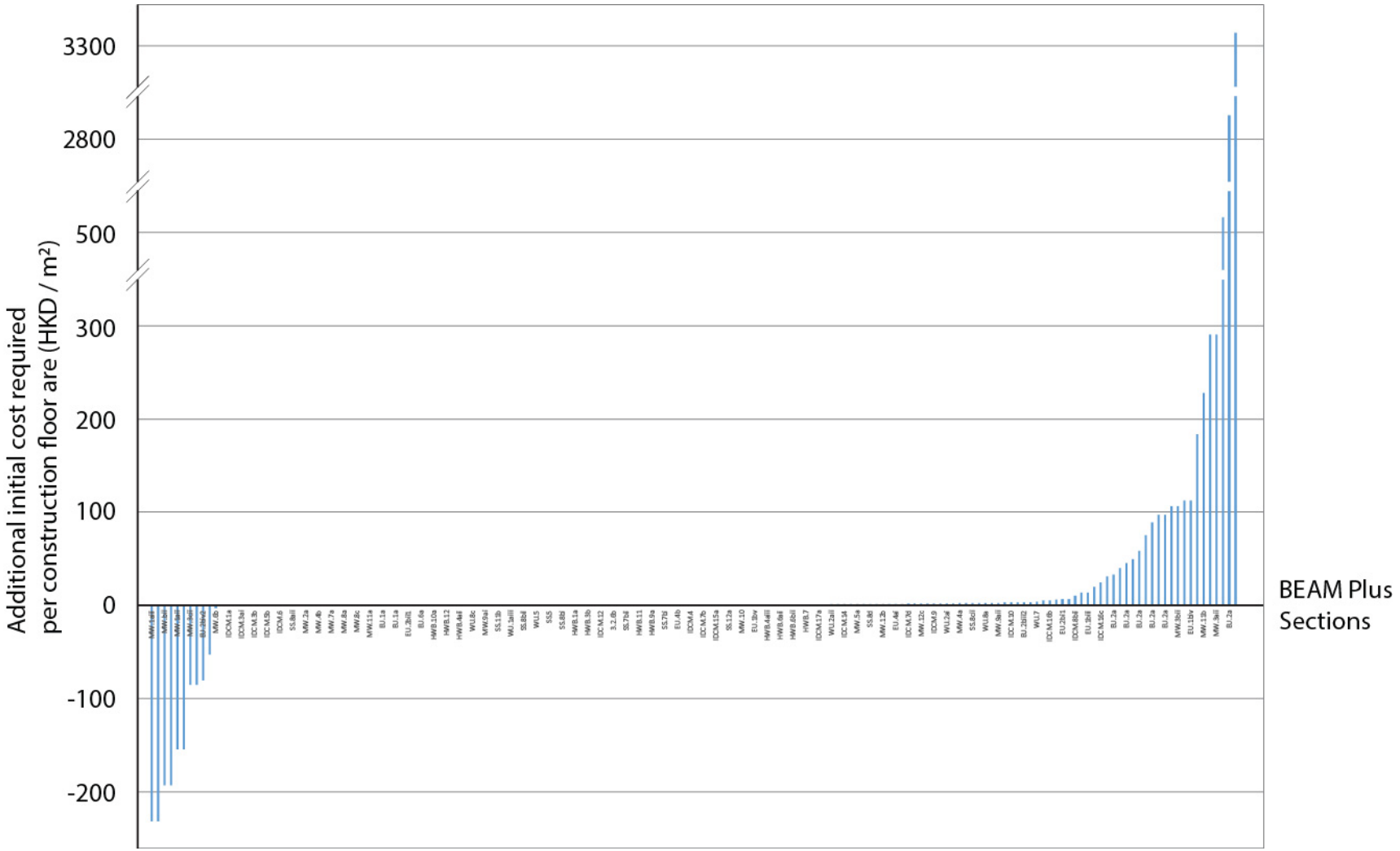

Figure 9 Initial cost premiums for earning credits within different BEAM-Plus sections

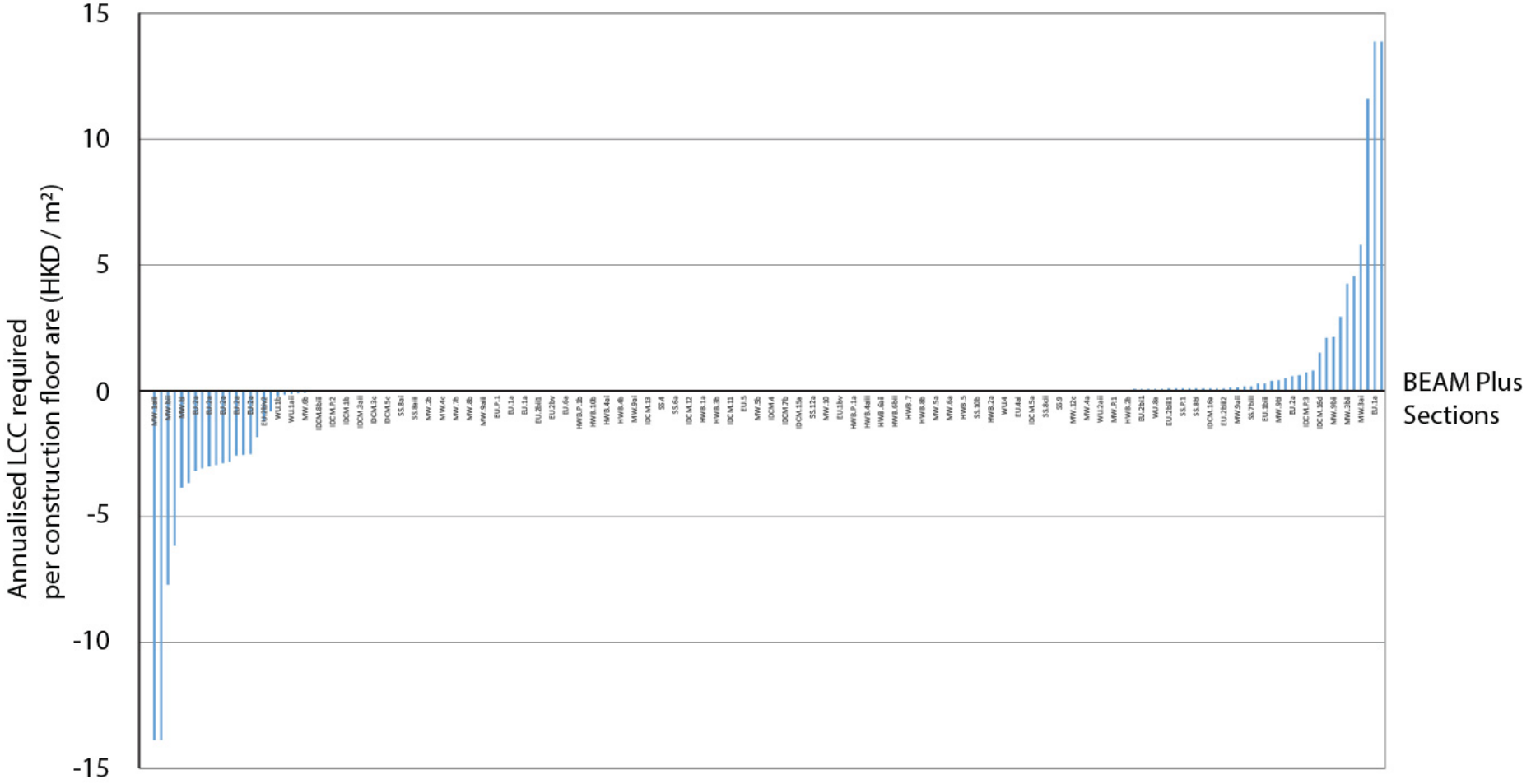

Figure 10 Additional Annualised LCC for earning credits within different BEAM-Plus sections

One of the main objectives of this study is to estimate the cost premium required for attaining various BEAM-Plus performance grades. For this study, the least initial cost approach was assumed as many developers in Hong Kong are speculative and they will most likely consider initial cost first. Under the least cost approach, credits with the lowest initial cost will be targeted first in pursuing specific BEAM-Plus performance grades. However, unlike the older HKBEAM versions, attaining a specific final BEAM-Plus performance grade is not solely dependent on the total number of credits earned, but also on the percentage scores obtained. Within this report, the initial cost implications of various BEAM-Plus credits are broadly grouped into 5 major categories: (i) Negative cost premium (cost saving); (ii) Insignificant cost premium, (cost premium < 0.05% of the total cost of the building); (iii) Low (0.05% ≤ cost premium < 0.25%); (iv) Moderate (0.25% ≤ cost premium < 1%); and (v) High (1% ≤ cost premium). Table 6 shows the classification of the cost implication categories defined within this study for individual BEAM-Plus credits.

Table 6 Classification of the cost implication categories defined within this study

U	-VE	0	0+	L	M	H
NA / Unable to Estimate	Negative Cost Premium	No Cost Premium	Insignificant Cost Impact (<0.05%)	Low (0.05-0.25%)	Moderate (>0.25-1.0%)	High (>1.0%)
-	-	0	<$12.3/m^2	$12.3-61.5/m^2	>$61.5-246/m^2	>$246/m^2

Fig. 11 shows the initial cost premium required to achieve various BEAM-Plus performance grades. Given that reuse of building structure may not always be practical for all building development projects and its impact is quite substantial, the results of both the scenarios of including and excluding the provision of reusing building structure reuse are going to be presented. Basically, 40%, 55%, 65% and 75% of scores are needed in order to attain Bronze, Silver, Gold and Platinum grades respectively. In addition, 20% of scores are required to attain for the prerequisites, irrespective of the performance grades attained. Interestingly, some monetary savings (i.e. negative initial cost premium) is found to be able to be obtained by fulfilling the prerequisites. The maximum potential saving was found to be $562.9 /m^2. The savings in initial cost were mainly attributed by reusing building structure and lower window-to-wall ratios. Meanwhile, if the least cost approach has to be strictly followed, a Bronze grade could be awarded without additional initial costs. Conversely, attaining Silver, Gold or Platinum grades would incur some initial cost implications. Additional initial cost premiums for upgrading to Silver from Bronze, Gold from Silver and Platinum from Gold grades were found to be $1.06/m^2, $1.89/m^2 and $3.80/m^2 respectively, and all of them were classified under 'insignificant cost impact' within this report.

Although the maximum percentage score attainable within BEAM-Plus is 100, it is possible to obtain percentage scores beyond 100. The cost implications of sustainable building measures turn to be low, moderate or high cost impacts for attaining the percentage score higher than 130. Even if reuse of structure is excluded, it is still possible to acquire some savings in initial cost by fulfilling the prerequisites. A lower window-to-wall ratio incurs a lower initial cost and at the same time help to earn CO_2 Emission credits. On the contrary, in the case of reuse of building structure is possible, additional cost premium required for attaining the Bronze grade will become minimal, and the cost impacts of attaining Silver, Gold or Platinum grade fall within insignificant cost categories.

Fig. 12 shows the lifecycle costs of attaining various BEAM-Plus performance grades. Similar to the initial cost premium, there could be savings in lifecycle cost due to fulfilment of the prerequisites, e.g. reuse of building structure and lower window-to-wall ratio. Interestingly, there could also be LCC savings in attaining a Bronze grade. The LCC savings were mainly attributed by the annual savings in electricity cost resulting from implementation of operational energy saving measures.

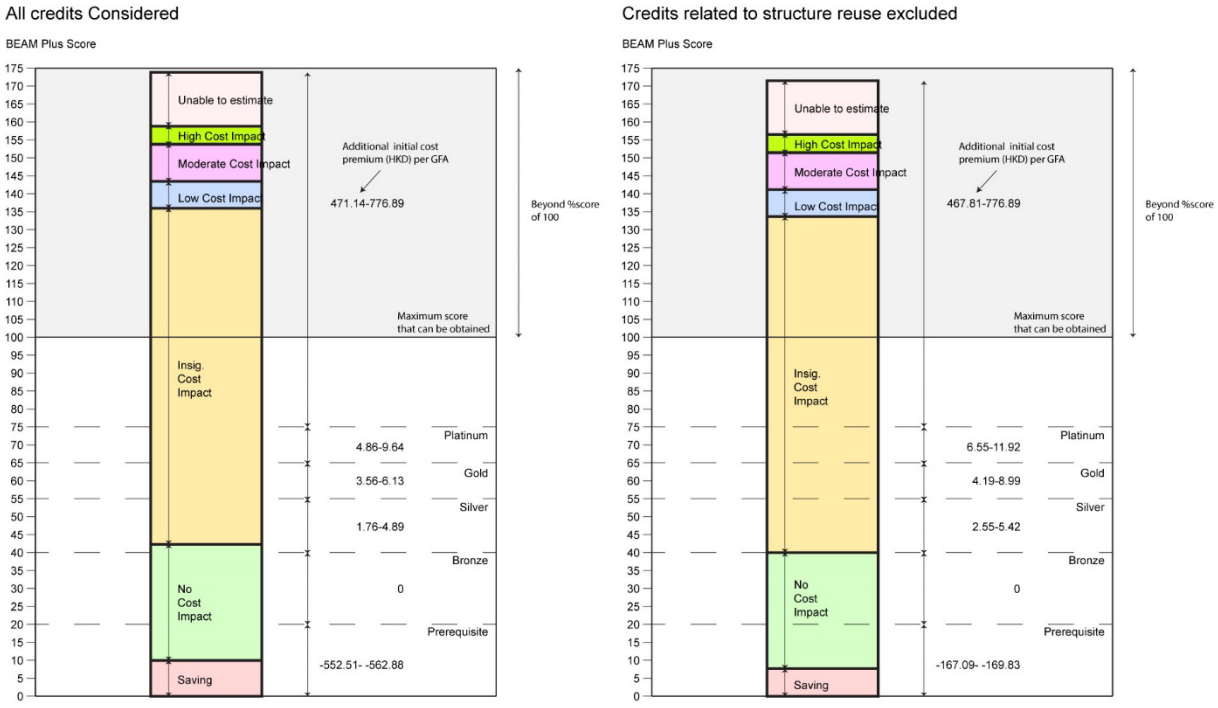

Figure 11 Initial costs required for attaining various BEAM-Plus performance grades

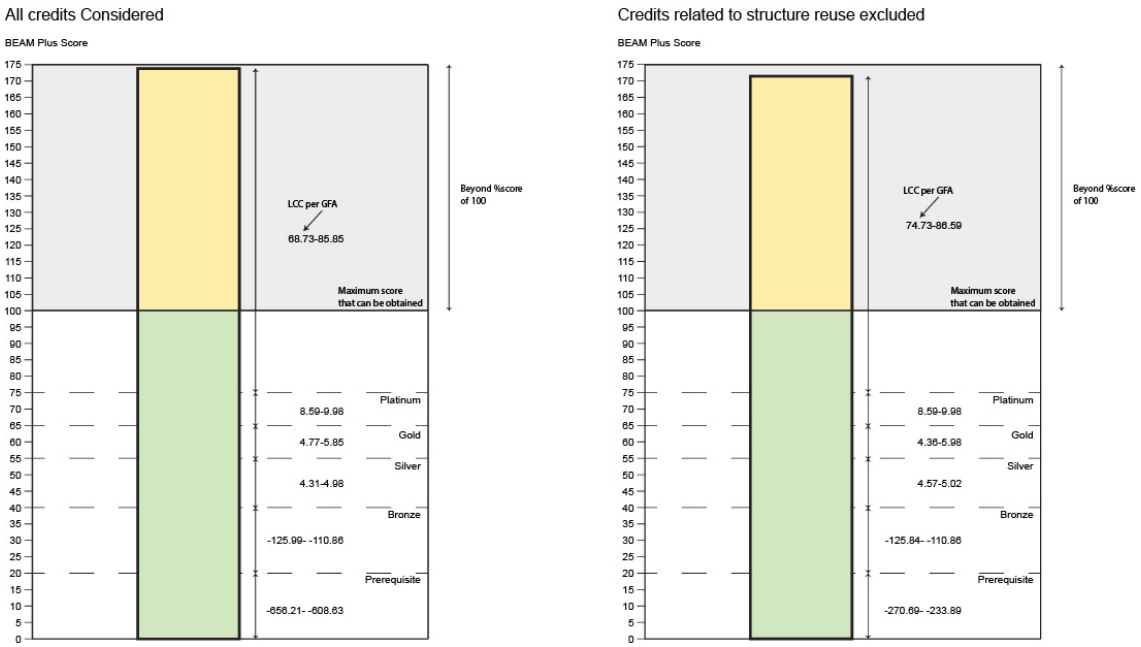

Figure 12 LCC for attaining various BEAM-Plus performance grades

4.3 Cost premiums for earning credits in various BEAM-Plus categories *(Objective II)*

In order to achieve Bronze grade or above in BEAM-Plus, 20% of the scores in each category are needed to be earned. As such, it is essential to reveal the costs of individual credits within each of the categories. Table 7 shows a summary of the cost impacts of individual BEAM-Plus credits.

Integrated Design and Construction Management (IDCM)

For the IDCM category, the cost implications of most of the credits are categorized as no or insignificant, with only a few credits being categorized as low, moderate or high. Specifically, the adoption of BIM in the construction process will incur insignificant to low costs (IDCM 16). Theoretically, it is also possible to obtain monetary savings by adopting a high rate of demolition (if applicable) and construction waste recycling (IDCM 8). However, it may not be practical as there may not be so much wastes for recycling. In addition, there can be some hidden costs due to substantial time resources incurred by both contractors and BEAM consultants in collecting the relevant documents.

Sustainable Site (SS)

For the SS category, a number of credits can only be earned when the prescribed conditions surrounding the site can be complied, which quite often are beyond the control of developers. The credits for accessibility to public transport (SS 1) and having shaded / covered route connecting the site and nearby amenities

(SS 10) are examples of such credits. Meanwhile, retention and planting of tree (SS 7) are considered inapplicable, as it is usually impractical to plant trees for only a single building development. Other than these credits, the cost implications of credits within this category (e.g. provision and share of amenities to the neighbourhood (SS 2)) are estimated to be no or insignificant.

Material and Waste (MW)

For the MW category, reuse of building structure (MW 1) can provide substantial amount of savings in the initial costs (cf. maximum potential saving = \$562.88 /m^2). However, it is not always possible to reuse building structure. Quite often, reuse of existing building structure is only applicable to projects such as revitalization of historical buildings or conversion of industrial buildings to hotels. Meanwhile, use of prefabricated elements (MW 3) for structure and façade will incur moderate or high cost implication. On the contrary, use of prefabricated interior elements, e.g. prefabricated wall partitions, can provide some monetary savings. Although use PFA or GGBS as partial replacement for cement (MW 6) can theoretically provide monetary savings, this practice has already become an industrial norm nowadays. As such, such credit is assumed to bear no cost implication within this study.

Conceivably, enhancing the flexibility of structural adaptability of the building (MW 11) incur moderate cost implication as it requires higher-grade concrete for both building foundation and structure.

Energy Use (EU)

The EU category is mainly focused on enhancing the energy performance of buildings and in the meantime reducing carbon emission. For the prescriptive path in EU 1, measures that can help achieve low carbon passive design comprises optimum spatial planning, cross ventilation provision, public space natural ventilation, daylighting provision, fixed or movable overhangs (with a cost premium of \$13.9/m^2) and vegetated building envelope (with a cost premium of \$112.5/m^2). Of these six prescriptive measures, the latter two will incur some additional initial costs, while the other credits are design related measures of insignificant or no cost implications. Above all, the cost implications of the 4 credits are moderate. For the perspective path in EU 2, improvement in OTTV can provide monetary savings by reducing the window-to-wall ratio.

Water Use (WU)

Most of the WU credits are of insignificant cost implications. The only exception is the measures prescribed for reducing potable water consumption for irrigation (WU 2), whose cost implication is determined to be low.

Health and Wellbeing (HWB)

All the HWB credits bear no or insignificant cost implication.

Table 7 A summary of cost impacts of earning individual BEAM-Plus credits

Credit Ref:	Integrated Design and Construction Management (IDCM)	Credits	Bonus	Cost Implication	Comments
IDCM.P.1	Inclusion of BEAM Pro in the consultant Team	-	-	0+	
IDCM.P.2	Preparation of environmental management plan	-	-	0	
IDCM.P.3	No virgin forest products are used for temporary work	-	-	L	
IDCM.1a	2 members from at least 2 core design disciplines be BEAM professionals	1	N	0 to 0+	
IDCM.1b	One addition BEAM profession / 2 BEAM Affiliates	1	Y	0 to 0+	
IDCM.2a	Certified by BEAM Plus Neighbourhood	1	Y	-	Excluded as they depend on other BEAM Plus certificates
IDCM.2b	Certified by BEAM Plus Interiors	1	Y	-	
IDCM.2c	Certified by BEAM Plus Existing Buildings	1	Y	-	
IDCM.3ai	Consideration of the integrated design process regarding whole-system thinking	1	N	0	
IDCM.3aii	Organising at least one multi-disciplinary design charrette	1	N	0	
IDCM.3b	Early design consideration of buildability / constructability	1	N	0	
IDCM.3c	Design consideration for operation and maintenance	1	N	0	
IDCM.4	List cycle costing	1	N	0+	
IDCM.5a	Appointment of CxA before tender and provision of commissioning plan	2	N	0 to 0+	Assuming that CxAs are a part of contractor or construction manager team
IDCM.5b	Commissioning review report	1	N	0	
IDCM.5c	Commissioning report	1	N	0	

Credit Ref:	Integrated Design and Construction Management (IDCM)	Credits	Bonus	Cost Implication	Comments
IDCM.6	Engagement of 2 BEAM Professionals or Affiliates by contractors	1	N	0 to 0+	For projects aiming at achieving Bronze grade or above. Assuming that they are already a part of the contractor team
IDCM.7a	Minimisation of air pollution	1	N	0+	
IDCM.7b	Minimisation of noise pollution	1	N	0+	
IDCM.7c	Minimisation of water pollution	1	N	0+	
IDCM.7d	Minimisation of light pollution	1	N	0+	
IDCM.8ai	Demolition waste management plan and recycling of at least 15% of demolition waste	1	N	L	
IDCM.8aii	Recycling of at least 30% of demolition waste	1	Y	0+	
IDCM.8aiii	Recycling of at least 60% of demolition waste	1	Y	Negative	
IDCM.8bi	Construction waste management plan and recycling of at least 15% of construction waste	1	N	L	
IDCM.8bii	Recycling of at least 30% of construction waste	1	Y	0+	
IDCM.8biii	Recycling of at least 60% of construction waste	1	Y	Negative	
IDCM.9	Construction IAQ management plan; undertaking flush out and bake out, replacement of all filters prior to occupancy	1	N	0+	
IDCM.10	Considerate construction	1	N	0+	
IDCM.11	Fully documented operations manual	1	N	0+	
IDCM.12	Operator training plus chemical storage room	1	N	0+	
IDCM.13	Digital facility management interface	1	Y	0+	
IDCM.14	Digital platforms to connect building occupants and building status to drive behaviour change	1	Y	0+	
IDCM.15a	Project team document management system	1	N	0+	

Credit Ref:	Integrated Design and Construction Management (IDCM)	Credits	Bonus	Cost Implication	Comments
IDCM.15b	Facility management team document management system	1	N	0+	
IDCM.16a	Coordinated use of BIM within design teams	1	N	0+	
IDCM.16b	Coordinated use of BIM within design and construction teams	1	N	0+	
IDCM.16c	BIM for time (cost, quantity and schedules preparation)	1	Y	0+	
IDCM.16d	BIM for facility management use (as-built)	1	Y	0+ to L	
IDCM.17a	Provide 2 of the 4 green building education elements listed in BEAM Plus	1	N	0+	
IDCM.17b	Provide all 4 green building education elements listed in BEAM Plus	1	Y	0+	
SS.P.1	Minimum planting provisions and site coverage of greenery of at least 20% of the site	-	-	0+	
SS.1a	Accessibility to public transport	1	N	-	Out of control of the developer
SS.1bi	Achieving 50% or more of the applicable pedestrian-oriented transport planning measures	1	N	-	Not applicable for a relatively small site with only one single building.
SS.1bii	Achieving 100% of the applicable pedestrian-oriented transport planning measures	1	Y	-	Not applicable for a relatively small site with only one single building.
SS.1c	Cycling facilities and network integration	1	Y	-	Out of control of the developer
SS.1d	Charging facilities for electric vehicle	1	Y	0+	
SS.2a	Amenities for building users	1	N	-	Out of control of the developer
SS.2b	Shared amenities for neighbourhood	1	N	0	Differences in the rents

Credit Ref:	Integrated Design and Construction Management (IDCM)	Credits	Bonus	Cost Implication	Comments
					for various amenities and offices are not considered
SS.3ai	At least 30% of applicable sustainable urbanism measures achieved	1	N	U	Unable to estimate the cost
SS.3aii	At least 60% of applicable sustainable urbanism measures achieved	1	N	U	Unable to estimate the cost
SS.3aiii	At least 90% of applicable sustainable urbanism measures achieved	1	Y	U	Unable to estimate the cost
SS.3b	Conservation of cultural heritage	1	Y	0+ to M	
SS.4	Neighbourhood daylight access	1	N	0+	
SS.5	Noise control for building equipment	1	N	0+	
SS.6a	Control of obtrusive artificial light	1	N	0+	
3.2.6b	Control of external light reflection from building	1	N	0+	
SS.7ai	Identified habitat types are of low or negligible indicative ecological value / medium to high value unaffected by the development	1	N	-	Not applicable for a relatively small site with one single building
SS.7aii	Retain tree at least 20% or more of total girth of existing trees on site	1	Y	-	Not applicable for a relatively small site with one single building
3.2.7aiii	Retain tree at least 40% or more of total girth of existing trees on site	1	Y	-	Not applicable for a relatively small site with one single building
SS.7bi	Physical connectivity between areas with ecological values	1	Y	-	Out of control of the developer
SS.7bii	Increase diversity and complexity of planting	1	Y	0+	
SS.7biii	Wildlife-friendly building features	1	Y	0	

Credit Ref:	Integrated Design and Construction Management (IDCM)	Credits	Bonus	Cost Implication	Comments
SS.8ai	Providing shade on at least 5% of the site area and at least 50% of non-roof impervious surfaces on the site	1	N	0+	
SS.8aii	Demonstrating compliance with prescribed requirements of the SBD Guidelines	1	N	0	Assuming that building separation and setback do not have cost implication and there is no podium in the baseline building
SS.8aiii	Demonstrating compliance with prescribed requirements of the SBD Guidelines with enhanced performances	1	Y	0	
SS.8bi	Demonstrating that at least 10% of the total Site Area is provided with tree coverage	2	Y	0+	
SS.8bii	Demonstrating that at least 20% of the total Site Area is provided with tree coverage	1	Y	0+	
SS.8ci	Demonstrating annual wind condition (CFD or wind tunnel)	1	N	0+	
SS.8cii	Demonstrating summer wind condition (CFD or wind tunnel)	1	N	0+	
SS.8d	Conducting an Intra Urban Heat Island Study demonstrating that a maximum Intra-Urban Heat Index	2	Y	0+	
SS.9	Demonstrating that no pedestrian areas will be subject to excessive wind velocities caused by amplification due to the site layout design and/ or building design (CFD / wind tunnel)	1	N	0+	
SS.10a	At least one shaded or covered route, connecting the site with nearby amenities/ site main entrance/transport hub	1	N	-	Out of control of the developer
SS.10b	50% or more of the passive open spaces and pedestrian	1	N	0+	

Credit Ref:	Integrated Design and Construction Management (IDCM)	Credits	Bonus	Cost Implication	Comments
	zones achieve thermal comfort				
SS.11a	Demonstrating that adequate stormwater management design measures have been provided to cater the total volume of runoff for one hour corresponding to a design rainfall of at least 30mm/event for the site in its post-developed conditions	2	N	0+	
SS.11b	Demonstrating that adequate stormwater management measures have been provided to cater the total volume of runoff corresponding to a design rainfall of at least 40mm/event for the site in its post-developed conditions	1	Y	0+	
SS.12a	Studying the projected variation in temperature and rainfall and water level rise/ storm surge of adjacent water bodies due to climate change and its impact on the development and prepare mitigation proposal to improve the climate resilience of the building	1	Y	0+	
SS.12b	Including quantitative calculation to support the resilience design which is technically eligible and cost effective	1	Y	0+	
MW.P.1	Provision of waste recycling facilities	-	-	0+	
MW.1ai	Reuse of 20% or more (by mass or volume) of existing structures	1	Y	Negative	
MW.1aii	Reuse of 40% or more (by mass or volume) of existing structures	1	Y	Negative	
MW.1aiii	Reuse of 90% or more (by mass or volume) of existing structures	1	Y	Negative	
MW.bi	Reuse of 25% or more (by surface area) of superstructure elements	1	Y	Negative	
MW.bii	Reuse of 50% or more (by surface area) of superstructure elements	1	Y	Negative	

Credit Ref:	Integrated Design and Construction Management (IDCM)	Credits	Bonus	Cost Implication	Comments
MW.biii	Reuse of 90% or more (by surface area) of superstructure elements	1	Y	Negative	
MW.2a	Designing modular element contributes to at least 50% of major elements of the project	1	N	0	
MW.2b	Designing modular element contributes to at least 90% of major elements of the project	1	Y	0	
MW.3ai	10% prefabricated structural elements	1	N	H	
MW.3aii	20% prefabricated structural elements	1	Y	H	
MW.3bi	10% prefabricated facade elements	1	N	M	
MW.3bii	20% prefabricated facade elements	1	Y	M	
MW.3ci	10% prefabricated architectural / internal building elements	1	N	Negative	
MW.3cii	20% prefabricated architectural / internal building elements	1	Y	Negative	
MW.3di	Compliance with requirements in MW.3ai, MW.3bi and, MW.3ci	1	Y	H	
MW.3dii	50% or more prefabricated elements listed in MW.3ai, or MW.3bi, or MW.3ci	1	Y	Negative or H	
MW.4a	Building material selection appraisal	1	N	0+	
MW.4b	Protecting vulnerable parts of the building from damage	1	Y	0+	
MW.4c	Protecting exposed parts of the building from material degradation	1	Y	0+	
MW.5a	At least 50% of all the timber and composite timber products are from sustainable sources / recycled timber	1	N	0+	
MW.5b	At least 90% of all the timber and composite timber products are from sustainable sources / recycled timber	1	Y	0+	
MW.6a	At least 10% of materials for site exterior surface works, structures and features with recycled content	1	N	0+	

Credit Ref:	Integrated Design and Construction Management (IDCM)	Credits	Bonus	Cost Implication	Comments
MW.6b	Use of PFA (not less than 25%) or GGBS (not less than 40%) as partial cement replacement in concrete	1	N	0	Consider as an industrial norm
MW.6c	At least 10% of all materials used for interior non-structural components are with recycled content	1	N	M	
MW.6di	Compliance with the requirements in 4.2.6a, b and c	1	Y	-	Dependent on 4.2.6a, b and c
MW.6dii	At least 50% of materials in 4.2.6a, or b, or c are with recycled content	1	Y	Negative to H	
MW.7a	Use of refrigerants of low ozone depletion or global warming potential	1	N	0+	
MW.7b	Use of products in the building fabric and services that avoid using ozone depleting substances	1	N	0+	
MW.8a	At least 10% of materials in the project are regional materials	1	N	0	Use of materials from mainland China
MW.8b	At least 20% of materials in the project are regional materials	1	Y	0	
MW.8c	At least 50% of materials in the project are regional materials	1	Y	0	
MW.9ai	At least 5% certified green products in one listed category	1	N	0+	
MW.9aii	At least 5% certified green products in two listed categories	1	N	0+	
MW.9aiii	At least 5% of certified green products under CIC Green Product Certification, Carbon Labelling Scheme / HK G-Pass in one listed category	1	Y	0	
MW.9aiv	At least 25% of certified green products under CIC Green Product Certification, Carbon Labelling Scheme / HK G-Pass in one listed category	1	Y	0+	
MW.9bi	5% of building materials / products of interior non-structural components are rapidly renewable materials	1	Y	0+	
MW.9bii	25% of building materials / products of interior non-	1	Y	L	

Credit Ref:	Integrated Design and Construction Management (IDCM)	Credits	Bonus	Cost Implication	Comments
	structural components are rapidly renewable materials				
MW.10	Study and optimize embodied energy in major elements of building structure through LCA	1	N	0+	
MW.11a	Spatial adaptability	1	N	0	
MW.11b	Flexible engineering services	1	N	M	
MW.11c	Structural adaptability	1	N	H	
MW.11d	Compliance with requirements in 4.3.11a, b and c	1	Y	-	Dependent on 4.3.11a, b and c
MW.12a	Additional recyclables collection	1	N	0+	
MW.12b	Additional facility provisions to enable enhanced municipal solid waste charging scheme	1	N	0+	
MW.12c	Waste treatment equipment	1	Y	0+	
MW.12d	Alternatives to recycling facilities	1	Y	0+	
EU.P.1	Demonstrate performance improvement against the latest edition of Building Energy Code (BED)	-	-	L	
EU.1a	Low carbon passive design	4	N	M	Prescriptive path
EU.1bi	Built form and orientation	1	N	0+	Performance path. Assuming that change in orientation does not incur cost
EU.1bii	Optimal spatial planning	1	N	0+	Performance path
EU.1biii	External shading device	1	N	0+	Performance path
EU.1biv	Vegetated building envelope	1	N	M	Performance path
EU.1bv	Space layout for natural ventilation	1	N	0+	Performance path. Assuming that change in space layout does not incur cost
EU.1bvi	Space layout for daylight penetration	1	N	0+	Performance path. Assuming that change in space

Credit Ref:	Integrated Design and Construction Management (IDCM)	Credits	Bonus	Cost Implication	Comments
					layout does not incur cost
EU.2a	Reduction of annual CO2 emission from 1% to 29%	15	N,Y	Negative to H	Performance path
EU.2bi1	OTTV Reduction (Wall 5%)	0.5	N	Negative	Perspective path (by decreasing WWR)
EU.2bi2	OTTV Reduction (Wall 10%, roof 50%)	0.5	N	Negative	Perspective path (by decreasing WWR)
EU.2bii1	20% of normally occupied space satisfies ventilation requirements	1	N	0	Perspective path. Assuming spatial planning does not incur costs
EU.2bii2	40% of normally occupied space satisfies ventilation requirements	1	N	0	Perspective path. Assuming spatial planning does not incur costs
EU.2biii1	Improve COP at full load by 3%	1	N	L	Perspective path
EU.2biii2	Improve COP at full load by 6%	1	N	L	Perspective path
EU.2biv1	Increase performance of lighting power by 5%	0.5	N	Negative	Perspective path
EU.2biv2	Increase performance of lighting power by 10%	0.5	N	Negative	Perspective path
EU.2bv	20% reduction from the maximum allowable electrical power of lifts	1	N	0+	Perspective path
EU.3a	Reduction of peak electricity demand by following of energy saving percentage from 5% to 15%	3	N	-	Dependent on EU.2a
EU.3bi	Achieving 4 credits in 5.1.2b	1	N	-	Dependent on EU.2b
EU.3bii	Achieving 7 credits in 5.1.2b	1	N	-	Dependent on EU.2b
EU.4ai	Energy monitoring system for equipment and systems in spaces	1	N	0+	
EU.4aii	Performance auditing monitoring system for equipment and systems in spaces	1	Y	0+	
EU.4b	Monitoring provision of tenant energy consumption	1	Y	0+	

Credit Ref:	Integrated Design and Construction Management (IDCM)	Credits	Bonus	Cost Implication	Comments
EU.5a	Evaluating potential for harnessing solar energy on roof	1	N	0+	
EU.5bi	0.2% of annual energy consumption offset by renewable source	1	N	0+	By using PV
EU.5bii	0.4% of annual energy consumption offset by renewable source	1	N	0+	By using PV
EU.5biii	0.6% of annual energy consumption offset by renewable source	1	N	0+	By using PV
EU.5biv	0.8% of annual energy consumption offset by renewable source	1	N	0+	By using PV
EU.5bv	1% of annual energy consumption offset by renewable source	1	N	-	Unable to attain due to the roof area
EU.5bvi	1.2% of annual energy consumption offset by renewable source	1	Y	-	Unable to attain due to the roof area
EU.5bvii	1.4% of annual energy consumption offset by renewable source	1	Y	-	Unable to attain due to the roof area
EU.5bviii	1.6% of annual energy consumption offset by renewable source	1	Y	-	Unable to attain due to the roof area
EU.5bix	1.8% of annual energy consumption offset by renewable source	1	Y	-	Unable to attain due to the roof area
EU.5bx	2% of annual energy consumption offset by renewable source	1	Y	-	Unable to attain due to the roof area
EU.6a	Air-conditioning units	2	N	-	Assume that there is no window or split-type air-conditioners
EU.6b	Clothes drying facilities	2	N + Y	-	Assume that there is no drying facility
EU.6c	Energy efficient appliances	3	N	-	Assume that there is no appliance
WU.P.1	10% Annual potable water saving by the use of water efficient flow devices	-	-	0+	
WU.1ai	20% Further potable annual water saving	1	N	0+	
WU.1aii	25% Further potable annual water saving	1	N	0+	
WU.1aiii	30% Further potable annual water saving	1	N	0+	

Credit Ref:	Integrated Design and Construction Management (IDCM)	Credits	Bonus	Cost Implication	Comments
WU.1b	40% Further potable annual water saving	1	Y	0+	
WU.2ai	25% reduction of potable water consumption for irrigation	1	N	0+ to L	
WU.2aii	50% reduction of potable water consumption for irrigation	1	N	0+ to L	
WU.2b	100% reduction of potable water consumption for irrigation	1	Y	0+ to L	
WU.3	Installing water efficient appliances that achieve Grade 1 under WDS's Water Efficiency Labelling Scheme	1	N	0+	
WU.4	Installing water leakage detection system	1	N	0+	
WU.5	Twin tank for water supply	1	N	0+	
WU.6	Achieving 7 or more cycles of concentration with acceptable quality	1	N	0+	
WU.7	Reduction in annual sewage volumes by 20% or more	1	N	0+	
WU.8a	Harvesting of rainwater that achieve a reduction of 5% or more in potable water consumption	1	N	0+	
WU.8b	Recycled grey water that achieve a reduction of 5% or more in potable water consumption	1	N	0+	
WU.8c	10% reduction in potable water by (harvesting or rain water, recycled grey water, or both)	1	Y	0 to 0+	Mainly dependent on 6.3.8a and b
HWB.P.1a	Measure outdoor air pollutants on-site prior to building design to understand the site conditions	-	-	0+	
HWB.P.1b	Demonstrate the project is in compliance with the minimum ventilation quantity with respective to its designed ventilation mode	-	-	0	Assuming the attaining this level is the baseline
HWB.1	Compliance of at least 3 relevant applicable design measures for healthy and active living	1	Y	0+	
HWB.2	Visual connection with nature or biophilic design features	2	Y	0+	Partly out of control of the developer

Credit Ref:	Integrated Design and Construction Management (IDCM)	Credits	Bonus	Cost Implication	Comments
HWB.3a	Universal accessibility	1	N	0+	
HWB.3b	Weather protection and family friendly features	1	Y	-	NA for single building with relatively small site.
HWB.4ai	Fresh air provision in normally occupied spaces	1	N	0	Assuming that this is the baseline
HWB.4aii	Fresh air provision in not normally occupied spaces	1	N	0	Assuming that this is the baseline
HWB.4aiii	On-site measurements to verify the ventilation performance for all normally occupied spaces	1	N	0+	
HWB.4b	Effective ventilation system for spaces where significant indoor pollution sources are generated	1	Y	0	Assuming that this is the baseline
HWB.5	Installing odour sensor at discharge points from enclosed waste disposal and recycling spaces	1	N	0+	
HWB.6ai	Demonstrating that mid-frequency reverberation time in applicable spaces of landlord's-controlled area meets the prescribed criteria of different types of premises.	1	N	0+	
HWB.6aii	Demonstrating that mid-frequency reverberation time in applicable rooms of non-landlord meets the prescribed criteria of different types of premises.	1	N	0+	
HWB.6bi	Demonstrating airborne noise isolation between spaces fulfils the prescribed criteria.	1	N	0+	
HWB.6bii	Demonstrating impact noise isolation between floors fulfils the prescribed criteria.	1	N	0+	
HWB.6c	Demonstrating background noise levels within the prescribed criteria (including traffic noise and external building services equipment that are within the project boundary)	1	Y	M	
HWB.7	Demonstrating vibration levels not exceeding the prescribed criteria.	1	N	0+	

Credit Ref:	Integrated Design and Construction Management (IDCM)	Credits	Bonus	Cost Implication	Comments
HWB.8a	Indoor air quality in occupied spaces	3	N	0+	
HWB.8b	Air quality in car park	1	N	0+	
HWB.9a	Conduct thermal comfort analysis	2	N	0+	
HWB.9b	On-site measurement to verify thermal comfort	1	N	0+	
HWB.10a	Achieving the prescribed lighting performance in normally occupied spaces.	1	N	0+	Mainly the cost for computer simulation. Assuming that attaining the required level is the baseline
HWB.10b	Achieving the prescribed lighting performance in not normally occupied spaces and unoccupied spaces.	1	N	0+	Mainly the cost for computer simulation. Assuming that attaining the required level is the baseline
HWB.11	Demonstrating at least 55% of the total area of the studied normally occupied spaces achieves spatial Daylight Autonomy300/50% (sDA300/50%) and no more than 10% of the same area receives Annual Sunlight Exposure1000,250 (ASE1000, 250).	2	Y	0+	Mainly cost for computer simulation. Essentially a spatial planning task
HWB.12	Complying with the recommendations given in the Code of Practice for Prevention of Legionnaires' Disease 2016 Edition in respect of Water Supply Systems, HVAC Systems and other Water Features.	1	N	0	

4.3 Cost premium required for enhancing energy performance *(Objectives I, II)*

Given that the weighting of the Energy Use category and the initial cost premium of earning credits are the highest among all the seven BEAM-Plus categories, it is also of particular interest to evaluate the costs and benefits of

various energy saving measures associated with credits within this category. Since performance path does not prescribe any specific measures required for earning performance credits, the main focus of this part is to estimate the costs of various combinations of measures that can be applied to earn the Energy Use performance credits. It is apparent that a performance-based design is preferred and encouraged by the HKGBC given that the assigned total number of obtainable credits within the performance-based route is higher than that of the perspective-based route. Thus, the focus of the following analysis is on EU2 Reduction of CO_2 Emission in BEAM-Plus.

4.3.1 Carbon emission reduction potential of various energy efficient measures

Table 8 shows the initial cost premium (\$/ton CO_2/m^2/year) of implementing various energy saving measures. Based on the least cost approach, measures with lower initial cost premiums should be given higher priority orders in implementation. When comparing different options of improving the energy efficiency of artificial lighting system, reducing the lighting power intensity to 7.4W/m^2 required a lower initial cost premium (\$ -16.1 / ton CO2-e / m^2 /year) than reducing to 6.8W/m^2 (\$ 35.0 / ton CO2-e / m^2 /year). Thus, lowering the lighting power intensity of an artificial lighting system to 7.4 W/m^2 was preferred from the perspective of cost-effectiveness. Similarly, glazing having a shading coefficient value of 0.65 required a lower initial cost premium than that of 0.33 (\$ 63.90 vs. 74.25 / ton CO2-e / m^2 /year), which also suggests that shading coefficient value of 0.65 was more preferred for glazing, from the perspective of cost-effectiveness to reduce carbon emission.

Fig. 13 shows the CO_2 abatement potential of implementing various energy saving measures. As discussed, lowering the lighting power intensity to 7.4 W/m^2 and glazing of shading coefficient value of 0.65 were more preferred to other options within the same energy saving measure category. They are included in Fig. 14 to compare with other energy saving measures. Reducing the lighting power intensity to 7.4 W/m^2 could lower the initial cost. Accordingly, this energy saving measure should be given the first priority when attempting to earn EU2 credits. Adjusting the indoor set-point temperature from 24 to 25.5°C is also recommended as it does not incur any additional cost. Although 25.5°C is not the most preferred set-point temperature for individuals given the current thermal behaviour of majority of occupants in Hong Kong, it was argued that it could still satisfy a majority of occupants in buildings (Kam, 2004). For building orientation, rotating the base building plan by 45 degrees should also be preferred as it could produce energy savings but without incurring additional initial costs.

Additional cost premiums are incurred for adopting other energy efficient measures considered in the study. In terms of cost-effectiveness, improving energy efficiency of HVAC system should be considered after exhausting all the energy options that can produce initial savings or incur insignificant additional costs. Improving the COP of chillers should be the first option to be considered when attempting to enhance the energy efficiency of HVAC system, followed by

replacing an air-cooled system by a water-cooled system and installation of capacitor banks. Meanwhile, decreasing the shading coefficient value of glazing to 0.65 and installation of PV panels on rooftop should be of the lowest priority in terms of cost-effectiveness of measures to reduce carbon emission.

Table 8 Initial cost premiums of implementing various energy efficient measures

Energy Efficiency Measure		Initial Cost Premium ($ / ton CO_2-e / m^2 /year)
Building Orientation	Rotate the building plan by 45 degrees	0
Artificial Lighting	Change Lighting Power Intensity to 6.8 W/m^2	34.97
	Change Lighting Power Intensity to 7.4 W/m^2	-16.12
HVAC	Set-point Temperature to 25.5°C	0
	Change COP to 3.5	11.54
	Change to water-cooled system	35.33
	Installation of Capacitor Bank	43.26
Glazing	Use Glazing of SC 0.65	63.60
	Use Glazing of SC 0.33	74.25
Renewable Energy	Installation of PV Panels on roof top	150.28

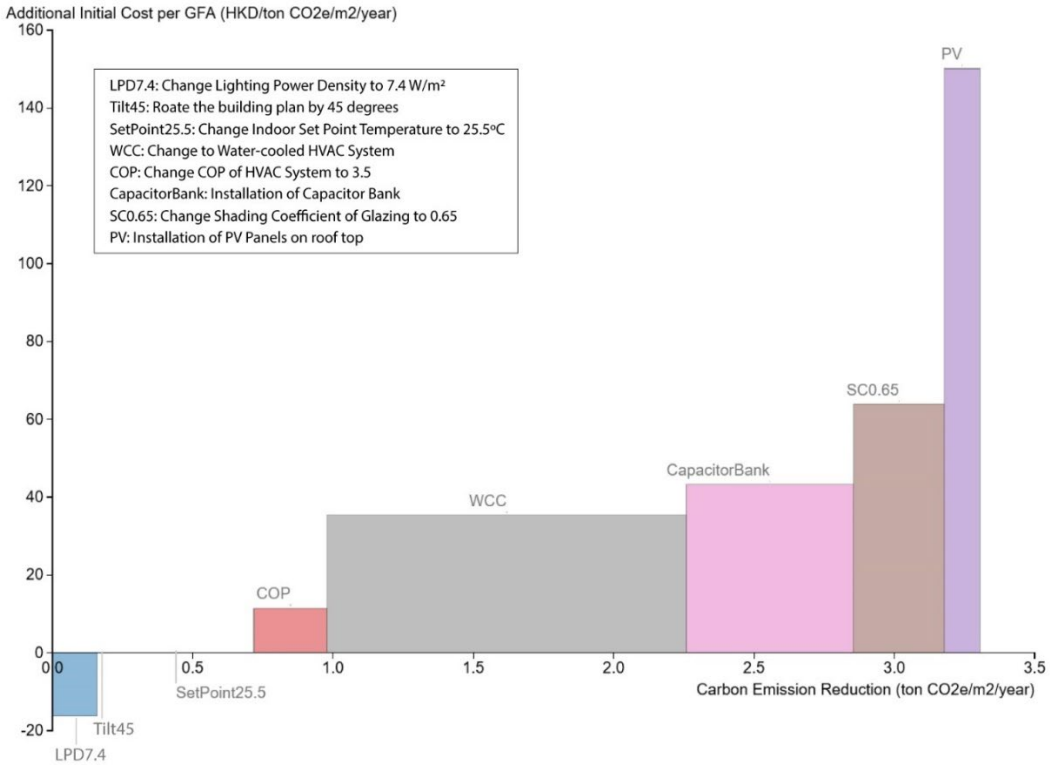

Figure 14 Abatement potential of various energy efficient measures

4.3.2 Payback Period of energy efficient measures

It is also of paramount interest to reveal the payback period required to recoup all the initial capital outlays. Fig. 15 shows the payback periods of all the examined energy efficiency measures. The payback periods of reducing lighting power intensity to 7.4W/m^2, rotating the building plan by 45 degrees and changing the set-point temperature to 25.5°C were 0 as they either could provide initial cost savings without exert any significant impact on the initial costs. The payback period of improving the COP to 3.5 was found to be the lowest (1.2 years), followed by decreasing the lighting power intensity to 6.8 W/m^2 (i.e. 2.3 years), installation of capacitor banks (i.e. 3.3 years), replacing air-cooled chiller by water-cooled (i.e. 3.4 years), and installation of PV panels on roof top (7.1 years). Meanwhile, the payback periods of using glazing of different shading coefficient values were found to be the highest (i.e. 9.9 years of SC of 0.65 and 15.5 years of SC of 0.33).

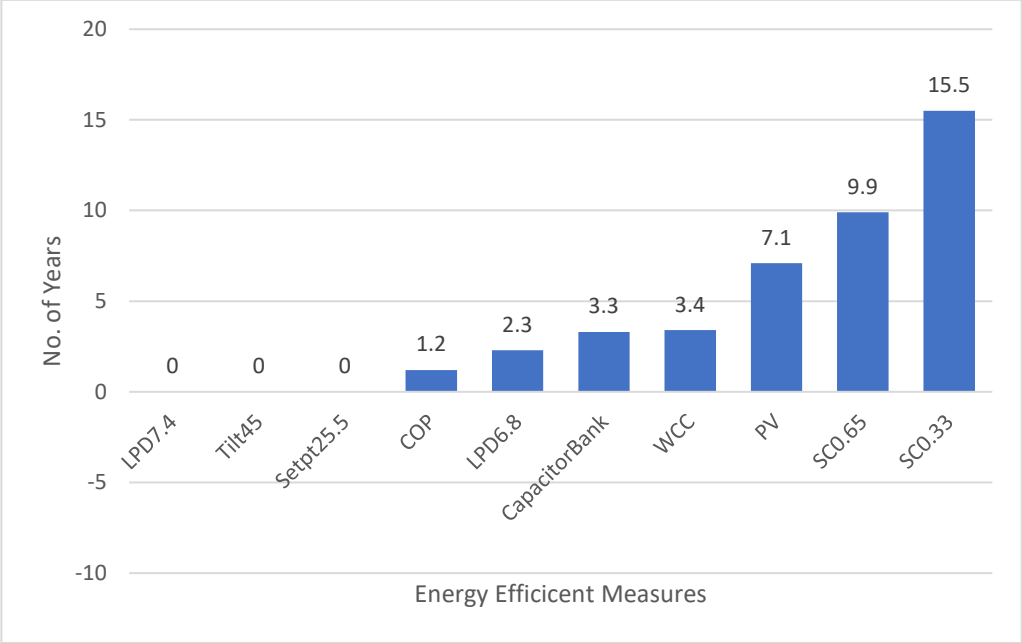

Figure 15 Payback periods of various energy saving measures

4.3.3 Cost premiums and energy saving potentials of combinations of energy efficient measures

The cost premiums and energy saving potentials of different combinations of energy efficient measures were also estimated. To provide a broader view of the relationship between energy saving potential and initial cost premium, a quadrant analysis has been performed and the resulting quadrant graph is shown in Fig. 16. The data points lie above the x-axis are combinations that will not lead to reduction in energy consumption. Meanwhile, the initial cost premium is higher if a data point positions farther to the right. As the primary aim of this study is to evaluate the costs and benefits of various sustainable measures and in turn for attaining different

BEAM-Plus performance grades, the following analyses are going to focus on cases that can help reduce energy consumption (i.e. changes in annual energy consumption with negative values, which are the data points below the x-axis in Fig. 16). All the combinations of energy saving measures could lead to savings in initial costs. This is mainly because the lowest WWR while highest glazing shading coefficient value had been adopted for the baseline building (i.e. glazing of lower shading coefficient values were more expensive). Besides, it can be seen that similar annual energy savings could be achieved by adopting energy saving measures requiring different initial cost premiums. In fact, the amount of initial cost premium is mainly affected by the choices of WWR and glazing shading coefficient value. However, it should be noteworthy pointing out that, under normal practice, the decision of choosing a particular WWR usually is not purely based on the amount of energy savings or reduction in carbon emission. Instead, there may be considerations for aesthetics or views from the building. Thus, it may be more valuable for estimating the energy saving potentials and cost premium after WWR has been fixed.

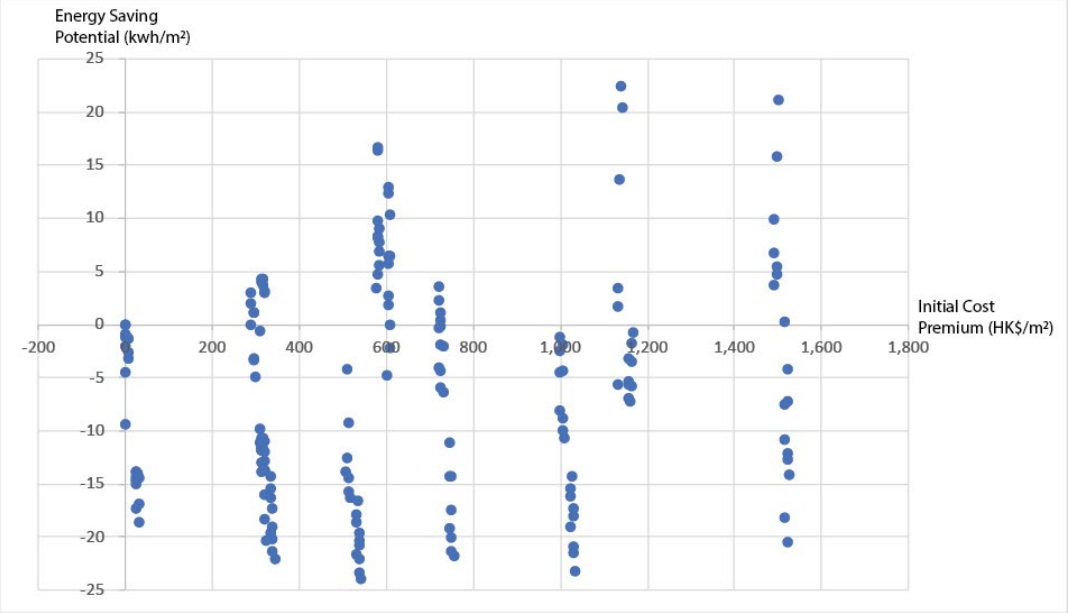

Figure 16 Changes in annual energy consumption and initial cost premium of implementing various energy efficient measures

Table 9 shows the initial cost premiums and energy saving potentials for various WWR and glazing shading coefficients. It can be seen that when the WWR and glazing shading coefficient have been fixed, the differences between the upper bound and lower bound of the initial cost premium always fall between \$29 and 35/m^2. However, the difference in initial cost premium between different combinations of WWR and glazing shading coefficient were within an order of \$100/m^2. In terms of initial cost, a lower WWR and a higher glazing shading coefficient value was considered to be more beneficial in reducing the energy consumption required for space cooling in Hong Kong.

Table 9 Initial cost premiums and annual energy saving potential for different WWRs and shading coefficient values of glazing

WWR	Glazing Shading Coefficient	Initial Cost Premium ($/m^2)	Annual Energy Saving (kwh/m^2)
0.5	0.71	-0.64 to 29.80	-18.68 to 0
0.5	0.65	307.17 to 342.36	-22.06 to -0.66
0.5	0.33	506.86 to 542.06	-23.90 to -4.23
0.7	0.71	288.39 to 323.58	-20.43 to -0.06
0.7	0.65	719.31 to 754.51	-21.87 to -0.20
0.7	0.33	998.89 to 1034.08	-23.29 to -1.17
0.9	0.71	578.04 to 607.85	-4.76 to -2.19
0.9	0.65	1131.46 to 1166.65	-7.33 to -0.84
0.9	0.33	1490.91 to 1526.10	-21 to -1

Fig. 17 shows a quadrant analysis displaying the relationships between changes in energy saving potential and the change in annualised lifecycle costs after implementing various combinations of building energy saving measure. Unlike the case of initial cost premium, it is possible to acquire both energy saving and monetary saving in lifecycle saving at the same time (bottom-left quadrant). Similarly, only cases with energy savings (data points below x-axis) are considered in this study. The savings in lifecycle cost were mainly attributed by lower electricity bills after implementing building energy saving measures.

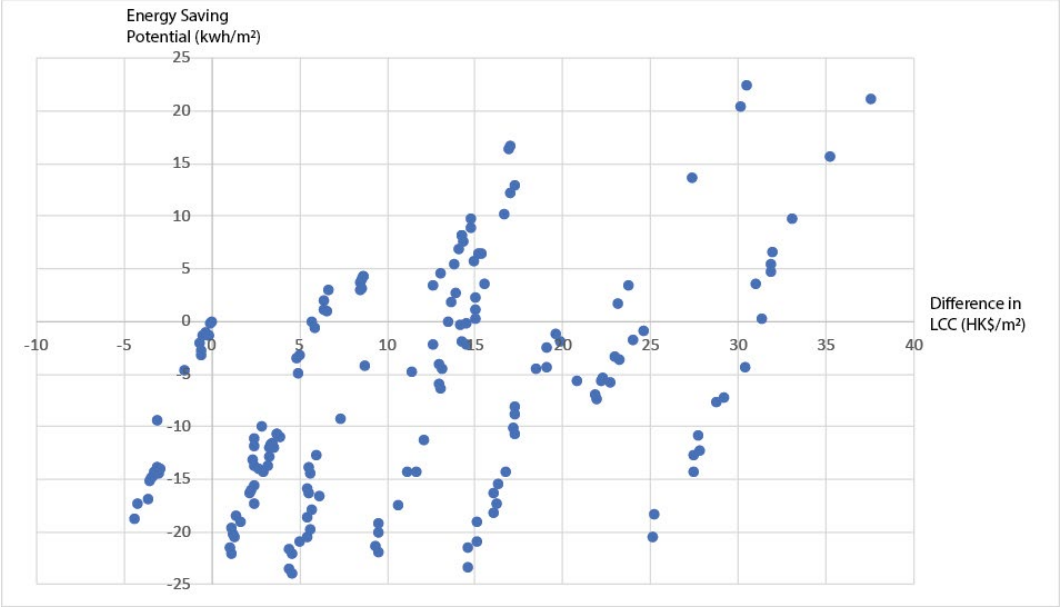

Figure 17 Changes in annual energy consumption and changes in LCC of implementing various energy efficient measures

Table 10 shows the change in lifecycle cost with respect to those of the baseline building and energy saving potentials due to adopting different WWRs

and glazing shading coefficient values. It can be seen that savings in lifecycle cost could only be yielded when WWR = 0.5 and glazing shading coefficient value = 0.71. To this end, it is anticipated that more saving in lifecycle cost could be achieved by further reducing WWR. Interestingly, it is observed that, given that the WWR had been fixed, the change in annualised lifecycle cost with respect to that of the baseline building was always the smallest when the shading coefficient value = 0.71. Glazing of lower shading coefficient values might not be a viable option in terms of lifecycle cost. Instead, focusing on the strategy of adopting a lower WWR would be a better option.

Table 10 Change of annualised lifecycle cost from that of base building and annual energy saving potential for different WWRs and shading coefficient values of glazing

WWR	Glazing Shading Coefficient	Change of annualised lifecycle cost from that of the base building ($/m^2)	Annual Energy Saving (kwh/m^2)
0.5	0.71	-4.37 to 0	-18.68 to 0
0.5	0.65	1.10 to 5.94	-22.06 to -0.66
0.5	0.33	4.44 to 8.76	-23.90 to -4.23
0.7	0.71	1.35 to 5.76	-20.43 to -0.06
0.7	0.65	9.38 to 14.55	-21.87 to -0.20
0.7	0.33	14.62 to 19.87	-23.29 to -1.17
0.9	0.71	11.42 to 13.53	-4.76 to -2.19
0.9	0.65	20.80 to 24.64	-7.33 to -0.84
0.9	0.33	25.10 to 30.41	-21 to -1

4.4 Social Benefits arising from higher BEAM-Plus grades *(Objective I)*

Many economic, environmental and social benefits can be gained by pursuing higher BEAM-Plus grades. Some benefits are easier to be identified and quantified, and even monetarized, e.g. those related to economic and environmental benefits, while some benefits are intangible and cannot be easily monetarized, e.g. social benefits.

Examples of tangible economic and environmental benefits that can be more readily identified, quantified and monetarize include those energy related credits within EU section as the benefits associated with implementation of energy efficiency measures can be readily reflected through changes (i.e. decrease) in annualised life-cycle costs and energy saving potentials.

Examples of intangible social benefits that are difficult to identify, quantify or monetarize are mainly associated with health, safety, and well-being of building occupants and neighbourhood aspects within the Health and Wellbeing (HWB) Category in BEAM-Plus. Some benefits can be gained by individuals and society through earning credits related to (1) enhancement of indoor air quality (IAQ), (2)

thermal, acoustic and visual comfort, (3) adoption of daylighting, (4) views to nature, (5) family friendly and barrier free designs.

(1) IAQ - Deteriorated IAQ can cause a higher risk of allergies and airway infections in buildings. For instance, low ventilation rate in buildings can lead to higher incidences of airborne disease infections (Li et al., 2007). A questionnaire survey conducted in the U.S. revealed that 45%, 23% and 39% building occupants perceived that productivity; absenteeism and health had been improved after the enhancement of IAQ in the buildings (Hamilton et al., 2016). Better air quality can help reduce the number of premature death, i.e. mortality (e.g. Wong et al, 2002), number of hospital admissions, i.e. morbidity (e.g. Ballester et al., 2006; Oftedal et al., 2003) and restricted activity days (e.g. Ostro and Rothschild, 1989), which can reduce the heavy financial burdens of individuals, employers as well as the government. It was estimated on 2006 for HK that the estimated monetary gains by the society per incident of mortality were $1,928,000-52,300,000, and $19,000-38,000 per incidents of hospital admissions (Chau et al, 2008).
(2) Thermal, acoustic and visual comfort – It is vital to provide occupants with a comfortable indoor environment. Wu et al. (2020) suggested that the probability for an individual to feel dissatisfied with the overall environment was between 65 - 83% when he/she felt dissatisfied in any one of the thermal, acoustic, visual environments. Thus, it is important to provide all of thermal, acoustic and visual comfort so as to help enhance the overall satisfaction of building occupants.
(3) Adoption of daylighting – Daylighting can instill positive effects on health, performance and mood of people (Veitch et al., 1993; Veitch & Gifford, 1996). In an office environment, daylight access can affect the productivity of building occupants. It was determined from recent questionnaire survey results that individuals working in an office with little daylight tended to have a higher prevalence of eyestrain (35% for office environment with little daylight vs 26% for office environment with daylight), fatigue (32% vs 21%), tension and irritability (20% vs 16%), and forgetfulness (25% vs 18%) (Woo et al., 2021).
(4) Views to nature – Having views to nature can help build a visual connection between building occupants and nature. Previous findings suggested that visual connection to nature could help reduce stress, improve concentration etc. (Ryan et al., 2014).
(5) Family friendly and barrier free design – The benefits of family friendly and barrier free facilities or design are primarily the enhancement of individuals' satisfaction when using the building.

There are also credits within other BEAM-Plus sections that can provide social benefits. For example, there are credits related to the encouragement of use of public transport and enhancement of walkability of neighborhood (SS1 and SS2). Better connection to public transportation hubs can improve the accessibility to and from home and workplace. Walkability enhancement can indirectly improve the health of building occupants through enhance individual physical activity levels. Meanwhile, improvement of outdoor thermal comfort (SS10) can also enhance the walkability of the outdoor spaces. Enhancing physical activity levels can reduce the chance of overweight and obese, thus lower the risks of Type 2 diabetes (Burchfiel

et al., 1995; Katzmarzyk, Church, Craig, & Bouchard, 2009), osteoporosis (Schmitt, Schmitt, & Dören, 2009), metabolic syndrome (Healy et al., 2008; Swinburn & Shelly, 2008), high blood cholesterol level (Craig, Bandini, Lichtenstein, Schaefer, & Dietz, 1996; Healy et al., 2008; Katzmarzyk et al., 2009; Swinburn & Shelly, 2008), and chronic diseases as a result of increasing blood lipids and blood pressure (Dunstan et al., 2010; Healy et al., 2008; Katzmarzyk et al., 2009). Also, it can lower risks of colon cancer (Dunstan et al., 2010) and ischemic heart disease (Sesso, Paffenbarger, & Lee, 2000) and even the possibility of premature death (Blair, 1989; Inoue et al., 2008).

4.5 Benefit-cost analysis of sustainable building measures for fulfilling the BEAM-Plus assessments *(Objectives I, II)*

Integrated Design and Construction Management (IDCM)

IDCM 1: Sustainability Champions – Design

Number of credits attainable: 1 + 1 bonus credit

Initial Cost Premium:

At least two 2 members from 2 applicable core design disciplines are accredited BEAM professionals

U	-VE	0	0+	L	M	H

At least one additional member, who was in a different discipline counted from the above credit, is accredited BEAM professionals (bonus)

U	-VE	0	0+	L	M	H

Or

At least two additional members, who were in a different discipline counted from the above credit, are accredited BEAM affiliates

U	-VE	0	0+	L	M	H

There have to be BEAM professionals in different core design disciplines in the project team in order to obtain these credits. With BEAM professionals in the project team, there can be more thorough thoughts and valuable inputs in terms of sustainable building design during design and construction process. It may also make the implementation of various sustainable measures more smoothly.

IDCM 2: Complimentary Certification

Number of credits attainable: 3 bonus credits

Initial Cost Premium:

The project is certified by BEAM-Plus Neighbourhood certification

Excluded in the cost estimation as obtaining this credit is dependent on other BEAM certifications.

Preparing the project for BEAM-Plus Interiors certification

Excluded in the cost estimation as obtaining this credit is dependent on other BEAM certifications.

Preparing the project for BEAM-Plus Existing Buildings certification

Excluded in the cost estimation as it is out of the scope of this study.

These credits are related to obtaining and preparing for other BEAM certifications. Obtaining other BEAM certifications can ensure that the design and construction of the building is more complete and thorough in terms of building sustainability.

IDCM 3: Integrated Building Design Process

Number of credits attainable: 2

Initial Cost Premium:

Consideration of the integrated design approach so as to explore the relationship between sustainable design strategies and building systems in the conceptual design stage

U	-VE	0	0+	L	M	H

Organising at least one multi-disciplinary design charrette to formulate sustainable design strategies in conceptual design stage

U	-VE	0	0+	L	M	H

These credits are related to the conceptual or schematic design stage. As the cost of making design changes is considered the lowest at this stage, it will be beneficial to explore various sustainable strategies during the conceptual design stage. A thorough sustainable design strategy exploration will also help to ensure the sustainable performance of the completed building.

IDCM 4: Life Cycle Costing

Number of credits attainable: 4

Initial Cost Premium:

Conduction life cycle costing for active systems

U	-VE	0	0+	L	M	H

This credit encourages the use of life cycle costing to investigate various building and system design options. This will help to ensure that the building is not only sustainable but also financially viable/efficient in terms of life cycle cost.

IDCM 5: Commissioning

Number of credits attainable: 4

Initial Cost Premium:

Demonstrating the appointment of commissioning authority before tender stage and providing a commissioning plan (2 credits)

U	-VE	0	0+	L	M	H

Provision of commissioning review report before construction

U	-VE	0	0+	L	M	H

Provision of commissioning report

U	-VE	0	0+	L	M	H

Developer is required to appoint a commissioning authority before tender stage and provide a commissioning plan. The main idea behind this is to ensure the performance of the building systems in a sense that they will be operated as design or intended. This will in turn ensure that the building during operation is as sustainable as it is originally designed.

IDCM 6: Sustainable Champions – Construction

Number of credits attainable: 1

Initial Cost Premium:

At least 2 accredited BEAM professionals are engaged by the main contractor

U	-VE	0	0+	L	M	H

At least 1 accredited BEAM professionals and 2 accredited affiliates are engaged by the main contractor

U	-VE	0	0+	L	M	H

**the above are only applicable to projects intending to achieve a Bronze grade or above*

It is required that BEAM professionals and/or affiliates are engaged by the main contractor in order to obtain these credits. The main benefit of this arrangement is to that it can help ensure (i) the sustainable measures mainly related to contractors (e.g. construction waste recycling) will be implemented smoothly, and (ii) the building sustainability measures will be implemented properly.

IDCM 7: Measures to Reduce Site Emission

Number of credits attainable: 4

Initial Cost Premium:

Minimisation of Air Pollution

U	-VE	0	0+	L	M	H

Minimisation of Noise Pollution

U	-VE	0	0+	L	M	H

Minimisation of Water Pollution

U	-VE	0	0+	L	M	H

Minimisation of Light Pollution

U	-VE	0	0+	L	M	H

The credits are related to minimisation of air pollution, noise pollution, water pollution and light pollution from the site. These will help to ensure a satisfactory neighbourhood environment around the construction site. Controlling wastewater discharge from the site will lower the environmental impact to the neighbourhood environment. Lighting nuisance control can ensure the visual comfort of pedestrian passing by the construction site.

IDCM 8: Construction and Demolition Waste Recycling

Number of credits attainable: 2 + 4 Bonus credits

Initial Cost Premium:

Demonstrating compliance with the demolition waste management plan and recycling at least 15% of demolition waste

U	-VE	0	0+	L	M	H

Recycling at least 30% of demolition waste (Bonus)

U	-VE	0	0+	L	M	H

Recycling at least 30% of demolition waste (Bonus)

U	-VE	0	0+	L	M	H

Demonstrating compliance with the construction waste management plan and recycling at least 15% of construction waste

U	-VE	0	0+	L	M	H

Recycling at least 30% of construction waste (Bonus)

U	-VE	0	0+	L	M	H

Recycling at least 30% of construction waste (Bonus)

U	-VE	0	0+	L	M	H

According to the EPD (2021), construction wastes accounted for 23% of the total weight of the wastes dumped to landfill sites. Considering the limited landfill spaces (Wu et al., 2020), recycling of construction and demolition (C&D) wastes can help relieve the burden of landfill sites in Hong Kong. Given the imposition of dumping charges for construction wastes, monetary saving can be gained by recycling C&D wastes (maximum potential saving: ~ \$2.1 /m^2). However, a more mature recycling industry / market will be required to further enhance this recycling practice.

IDCM 9: Construction IAQ Management

Number of credits attainable: 1

Initial Cost Premium:

U	-VE	0	0+	L	M	H

Developers are required to undertake “Flush out” or “bake out”, and filter replacement prior to occupancy. “Flush out” and “bake out” can help to remove up to 86% VOC of newly built buildings (Park & Park, 2018; Kim et al., 2010). The removal of VOC can help to reduce irritation of nose, eyes etc., and lower the chance of having the problem of asthma, i.e. a major lung infection due to bad air quality. This will help ensure the health of occupants in long term.

IDCM 10: Considerate Construction

Number of credits attainable: 1

Initial Cost Premium:

U	-VE	0	0+	L	M	H

Considerate measures are encouraged to protect both neighbourhood and passers-by, and construction workers. Examples of the measures include provisions of hoardings and covered walkways, tree preservation within the project site and provisions of alternative to reflective vest in hot weather. These measures will help to ensure the safety and satisfaction of passer-by and the safety, health and well-being of construction workers.

IDCM 11: Building Management Manuals

Number of credits attainable: 1

Initial Cost Premium:

U	-VE	0	0+	L	M	H

Provision of fully documented operations and maintenance manual and energy management manual are required, so that building operators will be able to implement the design intents such as the space temperature and humidity criteria and ventilation requirements. These manuals will help to ensure the comfort, health, and well-being of the occupants, as well as the designed energy performance of the building.

IDCM 12: Operator Training plus Chemical Storage Room

Number of credits attainable: 1

Initial Cost Premium:

U	-VE	0	0+	L	M	H

Training programs are needed to be provided to facilities management team for the operations of the building systems. This will help to ensure buildings to be operated smoothly, and assure the health and safety of building occupants.

Meanwhile, the provision of a centralised chemical storage room for storing chemicals such as chiller refrigerants and cleansing chemicals can reduce the risk of environmental pollution due to the leakage of these chemicals.

IDCM 13: Digital Facility Management Interface

Number of credits attainable: 1 bonus credit

Initial Cost Premium:

U	-VE	0	0+	L	M	H

A digital interface in addition to the metering provision is required to be implemented. The digital interface is to facilitate future facility management team to review the building operation performance. This will help ensure the performance of building. On the other hand, it can help to collect data on the building performance with an objective to optimize the performance of other building projects of developers.

IDCM 14: Occupant Engagement Platform

Number of credits attainable: 1 bonus credit

Initial Cost Premium:

U	-VE	0	0+	L	M	H

Provision of digital platforms to connect building occupants and the building status is required in order to obtain this credit. The platform should provide information regarding the sustainable measures implemented in the building, the energy consumption of the space rented by the occupants, recommendations to reduce energy consumption in the building and tips of having a healthy lifestyle. Providing such information to the occupants may help to induce occupant behaviour changes in reducing the energy use in building.

IDCM 15: Document Management System

Number of credits attainable: 2

Initial Cost Premium:

Demonstrating the use of document management systems within the design team

U	-VE	0	0+	L	M	H

Demonstrating the use of document management systems platform by the facility management team

U	-VE	0	0+	L	M	H

It is required to install a document system before earning these credits. Naming and filing rules have to be unified. For project teams, the system should contain information such as project timeline and meeting minutes. For facility management team, information such as approved drawing by government departments, as-built drawings, water management manuals and tenancy green guides have to be included as important components of the system. With unified file systems, different members of the project and/or facility management teams will be able to communicate more effectively, which will help to make the design, construction and operation of the building more smoothly.

IDCM 16: BIM Integration

Number of credits attainable: 1 + 3 bonus credits

Initial Cost Premium:

Coordinated use of BIM within design teams

U	-VE	0	0+	L	M	H

Coordinated use of BIM within design and construction teams (Bonus)

U	-VE	0	0+	L	M	H

Using BIM model for scheduling, cost and quantity (Bonus)

U	-VE	0	0+	L	M	H

Updating BIM model to as-built condition (Bonus)

U	-VE	0	0+	L	M	H

With proper implementation of BIM, difficulties of project management can be reduced (He et al., 2017) as the adoption of BIM can provide a platform for communication and collaborations of different trades and business domain (Alreshidi et al., 2017; Gha, et al., 2015). Integration of BIM facility management can even enhance the efficiency of building operation (Ghosh et al., 2015).

IDCM 17: Design for engagement and education on green buildings

Number of credits attainable: 1 + 1 bonus credits

Initial Cost Premium:

Provide 2 of the 4 green building education elements listed in BEAM Plus

U	-VE	0	0+	L	M	H

Provide all 4 green building education elements listed in BEAM Plus (Bonus)

U	-VE	0	0+	L	M	H

Developers are required to provide (1) manuals for all sustainable measures implemented in the building, (2) an education signage system in communal areas to educate building users about sustainable building, (3) a platform (e.g. a website) for sustainable living showcase demonstration, and/or (4) alternative sustainable building education elements. Provision of these elements helps to educate building users about sustainable buildings, which may affect their behaviour so as to have a more sustainable living.

Sustainable Site (SS)

SS 1: Pedestrian-oriented and low carbon transport

Number of credits attainable: 2 + 3 bonus credits

Accessibility to public transport

Excluded in the cost estimation as it is beyond the control of developers.

50% of applicable pedestrian-oriented access measures achieved

Excluded in the cost estimation as it is not applicable for a single building development.

100% of applicable pedestrian-oriented access measures achieved (Bonus)

Excluded in the cost estimation as it is not applicable for a single building development.

Cycling facilities and network integration (Bonus)

Excluded in the cost estimation as it is out of the control of developer.

Provision of charging facilities for electric vehicles (EV) (Bonus)

U	-VE	0	0+	L	M	H

Different parts of the captioned item include (a) Accessibility to Public Transport, (b) Pedestrian-oriented Access, (c) Cycling Facilities and Network Integration, and (d) Charging Facilities for Electric Vehicles (EV). These measures encourage walking, cycling activities and the use of public transport instead of driving. If driving is necessary, use of electric vehicles will be encouraged.

Accessibility to public transport may improve saleability and easy access to public transport is usually beneficial to tenants or building users. On the other hand, there can also be environmental benefits associated with all (a), (b), (c) and (d). The benefits include reduction in air pollution, fuel use and noise from private cars. Meanwhile, social benefits that can be gained include the accessibility to the workplace. Encouraging the use of public transport may also help to ease the traffic congestion problems.

SS 2: Neighbourhood Amenities

Number of credits attainable: 2

Initial Cost Premium:

Provision of amenities to the building users from the neighbourhood

Excluded in the cost estimation as it is out of the control of the developer.

Provision of amenities in the building and share to the neighbourhood

U	-VE	0	0+	L	M	H

Developers are required to provide amenities for building users, as well as share the amenities of building for neighbourhood. Provision of amenities such as café and shops may improve saleability. Social benefits can also be acquired by provision of amenities as they may help to improve the walkability of neighbourhood (Huang & Khalil, 2022).

SS 3: Building design for sustainable urbanism

Number of credits attainable: 2 + 2 bonus credits

30% applicable sustainable urbanism measures achieved

U	-VE	0	0+	L	M	H

60% applicable sustainable urbanism measures achieved

U	-VE	0	0+	L	M	H

90% applicable sustainable urbanism measures achieved (Bonus)

U	-VE	0	0+	L	M	H

Demonstrating a proper heritage impact assessment mechanism and implementing the recommendations associated (Bonus)

U	-VE	0	0+	L	M	H

The associated credits include (a) Sustainable Urban Design and (b) Conservation of Cultural Heritage. For (a), developers are required to implement measures such as creating visual corridor to water bodies (if applicable) or views to surrounding landscape, designing building forms as high-quality architectural landmark features in public realm, and providing public open spaces for social events. These place-making measures can help to create a sense of place. The provision of visual corridor to water bodies or surrounding landscape may improve the saleability. Meanwhile, (b) is only applicable to sites with culture heritage or not more than 50m from the site. Cultural heritage impact assessment, and the implementation of the recommendations from the assessment are required. These will help to preserve the cultural and historical values of the site / neighbourhood.

SS 4: Neighbourhood daylight access

Number of credits attainable: 1

Initial Cost Premium:

U	-VE	0	0+	L	M	H

Developers are required to ensure the daylight access of sensitive buildings, such as residential buildings, offices, and schools, within the neighbourhood will be preserved. As daylight access can improve mental health of residents (Nagare et al., 2021), productivity of office workers (Turan et al., 2020) and study performances of students (Küller & Lindsten, 1992) etc., the measure required for this item can help ensure well-being, productivities etc. of the occupants of neighbourhood buildings will not be negatively affected due to the lack of daylight access.

SS 5: Noise control for building equipment

Number of credits attainable: 1

Initial Cost Premium:

U	-VE	0	0+	L	M	H

Developers are required to implement measures to reduce the exposure of the neighbours to the noise generated by building services equipment such as chillers and water cooling towers. This will help to reduce the potential noise pollution to the neighbours from the building.

SS 6: Light pollution control

Number of credits attainable: 2

Initial Cost Premium:

Control of obtrusive artificial light

U	-VE	0	0+	L	M	H

Control of external light reflection from building

U	-VE	0	0+	L	M	H

For these credits, it is to ensure that building design or exterior lighting will not cause light pollution. Developers are required to control obtrusive light from exterior lighting, as well as the reflection of light from the building. Obviously, these measures will help to reduce the potential light pollution from the building and mitigate the annoyance and problems such as sleep disturbance.

SS 7: Biodiversity Enhancement

Number of credits attainable: 1 + 5 bonus credits

Initial Cost Premium:

Reduction of Ecological Impact

Excluded in the cost estimation as it may not be applicable to a site with only one single building development.

Retain tree at least 20% of total girth of existing tree on site (Bonus)

Excluded in the cost estimation as it may not be applicable to a site with only one single building development.

Retain tree at least 40% of total girth of existing tree on site (Bonus)

Excluded in the cost estimation as it may not be applicable to a site with only one single building development.

Provision of physical connection between areas with ecological values (Bonus)

Excluded in the cost estimation as it is beyond the control of developers.

Increase diversity and complexity of planting (Bonus)

U	-VE	0	0+	L	M	H

Provision or wildlife-friendly building features (e.g. windows) (Bonus)

U	-VE	0	0+	L	M	H

Developers are required to preserve the identified habitat types of medium to high indicative ecological values, and ensure the habitat types will not be affected by the development. Besides, biodiversity should also be enhanced by implementing measures such as creating physical connectivity to areas with ecological values and increasing the diversity and complexity of planting. These measures mainly help to restore the ecology of the built-up areas in Hong Kong.

SS 8: Urban Heat Island Mitigation

Number of credits attainable: 4 + 6 bonus credits

Initial Cost Premium:

Provision of shading for at least 5% of site area and 50% of non-roof impervious surfaces using light coloured high-albedo materials

U	-VE	0	0+	L	M	H

Demonstrating compliance with prescribed requirements of the Sustainable Building Development Guidelines as in PNAP APP-152

U	-VE	0	0+	L	M	H

Demonstrating compliance with prescribed requirements of the Sustainable Building Development Guidelines as in PNAP APP-152 with enhanced performance (Bonus)

U	-VE	0	0+	L	M	H

Provision of tree coverage for at least 10% of site area (2 Bonus Credits)

U	-VE	0	0+	L	M	H

Provision of tree coverage for at least 20% of site area (Bonus)

U	-VE	0	0+	L	M	H

Air ventilation assessment by wind tunnel or CFD to demonstrate annual wind condition (Bonus)

U	-VE	0	0+	L	M	H

Air ventilation assessment by wind tunnel or CFD to demonstrate summer wind condition (Bonus)

U	-VE	0	0+	L	M	H

Conduct intra urban heat island study and demonstrate maximum intra urban heat island index in summer is smaller than 0.8°C (2 Bonus Credits)

U	-VE	0	0+	L	M	H

To mitigate the urban heat island effect, measures such as using light coloured high-albedo materials for non-roof impervious surfaces, building planting trees, and adopting green façade are needed to be implemented. Mitigation of urban heat island effects can help improve outdoor thermal comfort, as well as avoid the adverse health effect brought by high temperature, which can cause fatalities in extreme cases (Mohajerani et al., 2017).

SS 9: Immediate Neighbourhood Wind Environment

Number of credits attainable: 1

Initial Cost Premium:

U	-VE	0	0+	L	M	H

Due to wind amplification, high-rise buildings can render high wind speed at the pedestrian level. Thus, measures are required to ensure wind environment within the surrounding neighbourhood will not be affected by wind amplification. Pedestrians can in fact feel discomfort due to high wind speed (Blocken et al., 2016). The measures can help to avoid pedestrian discomfort due to the high wind speed.

SS 10: Outdoor Thermal Comfort

Number of credits attainable: 2

Initial Cost Premium:

Provision of at least one shaded route to nearby amenities / site main entrance / transport hub

Excluded in the cost estimation as it is out of control of the developer.

50% or more of passive open spaces and pedestrian zone achieve thermal comfort

U	-VE	0	0+	L	M	H

Developers are required to provide shaded or covered walkways connecting to the site from nearby amenities or public transport hub, and open space or pedestrian zones with outdoor thermal comfort. Providing open spaces and walkways with outdoor thermal comfort can encourage individuals to spend time and enjoy the open spaces, as well as pedestrian to walk. This can also improve the well-being of individuals.

SS 11: Stormwater Management

Number of credits attainable: 2 + 1 bonus credit

Initial Cost Premium:

Provision of adequate stormwater management design to cater for rainfall of 30mm/event (2 Credits)

U	-VE	0	0+	L	M	H

Provision of adequate stormwater management design to cater for rainfall of 40mm/event (Bonus)

U	-VE	0	0+	L	M	H

Design measures are required for stormwater management such as installation of stormwater detention tank system. Implementation of these measures can help to reduce stormwater runoffs and discharge rate, which can in turn reduce the risk of flooding within the neighbourhood and water pollution yielded by flooding.

SS 12: Design for Climate Change Adaption

Number of credits attainable: 2 bonus credits

Initial Cost Premium:

Studying the impact on the development due to climate change and prepare mitigation proposal

U	-VE	0	0+	L	M	H

Inclusion of quantitative calculation to demonstrate that the design is eligible and cost-effective

U	-VE	0	0+	L	M	H

Impacts on the building (such as its structure and facade) due to the projected changes in annual rainfall and temperature are needed to be considered. Due to the relatively long-life cycle of buildings (i.e. 50 years in this study), it is important to design buildings that can adapt to both the current and future climate. Building and building services systems design with the consideration of climate change can avoid the inefficiency or even malfunctions of the building due to the change of operational conditions (De Wilde & Coley, 2012), which may increase the life cycle cost of the building.

Materials and Waste (MW)

MW 1: Building Re-use

Number of credits attainable: 3 bonus credits

Initial Cost Premium:

Reuse of 20% of existing structure or 25% of existing superstructure

U	-VE	0	0+	L	M	H

Reuse of 40% of existing structure or 50% of existing superstructure

U	-VE	0	0+	L	M	H

Reuse of 90% of existing structure or superstructure

U	-VE	0	0+	L	M	H

Reuse existing structure or super structure elements (at least floor, roof decking) and enclosure materials (skin and framing) is highly encouraged. Building reuse can provide monetary savings (potential saving: \$154.17 to 693.75 /m^2, depending on the percentage of reuse). It can also reduce the demolition waste and reduce the burden of landfill sites in Hong Kong. However, building reuse is always considered difficult to implement except for special projects such as the revitalisation of historical buildings.

MW 2: Modular and Standardised Design

Number of credits attainable: 1 + 1 bonus credit

Initial Cost Premium:

Designing modular elements contributing to at least 50% of major elements of the development

U	-VE	0	0+	L	M	H

Designing modular elements contributing to at least 90% of major elements of the development

U	-VE	0	0+	L	M	H

Developers are required to adopt modular and standardised elements for the building project. According to ISO 2848:1984 (ISO, 1984), "the principal objective of modular coordination is to assist the building industry and associated industries, by standardization in such a way that components fit with each other, with other components and with the building assembly on site, thereby improving the economics of building". The adoption of modular and standardised design may also render a faster building completion time and generate less waste.

MW 3: Prefabrication

Number of credits attainable: 1 + 3 bonus credits

Initial Cost Premium:

(a) 10% of structural elements were fabricated off-site

U	-VE	0	0+	L	M	H

20% of structural elements were fabricated off-site (Bonus)

U	-VE	0	0+	L	M	H

or

(b) 10% of façade elements were fabricated off-site

U	-VE	0	0+	L	M	H

20% of façade elements were fabricated off-site (Bonus)

U	-VE	0	0+	L	M	H

or

(c) 10% of internal building elements were fabricated off-site

U	-VE	0	0+	L	M	H

20% of internal building elements were fabricated off-site (Bonus)

U	-VE	0	0+	L	M	H

Compliance with requirements in (a), (b) and (c) (Bonus)

U	-VE	0	0+	L	M	H

50% or more of the elements in (a), (b), or (c) are fabricated off site (Bonus)

U	-VE	0	0+	L	M	H

Developers are encouraged to adopt prefabrication of structural, façade and internal building elements in building projects. Building elements prefabricated in factories can be easily and rapidly assembled at the building site. The buildability of building, as well as speed of construction (Zhang et al., 2014), can be improved. Prefabrication of building elements can render less waste during construction process (Jaillon & Poon, 2010). The process of construction can become less labour intensive (Tam et al., 2015). Nuisances from the site such as noise and dust can be reduced. The cost saving due to the reduction in the use of wooden formwork was estimated to be \$39.79 /m^2 of CFA (Jaillon & Poon, 2008).

MW 4: Design for Durability and Resilience

Number of credits attainable: 1 + 2 bonus credits

Initial Cost Premium:

Demonstrating a proactive approach to evaluate the durability of building materials

U	-VE	0	0+	L	M	H

Provision of proactive measures to prevent damage of vulnerable parts

U	-VE	0	0+	L	M	H

Incorporating measures to limit material degradation due to environmental factors

U	-VE	0	0+	L	M	H

Developers are required to consider the durability of building materials, and implement measures to protect vulnerable parts of building from damage and exposed parts of the building from material degradation. Use products with increase durability and protection of various parts of the building will reduce the number of replacements and may help to lower the life-cycle embodied energy of the building.

MW 5: Sustainable Forest Products

Number of credits attainable: 1 + 1 bonus credit

Initial Cost Premium:

50% of all timber products are from sustainable sources / recycled timber

U	-VE	0	0+	L	M	H

90% of all timber products are from sustainable sources / recycled timber (Bonus)

U	-VE	0	0+	L	M	H

Use timber product from sustainable sources (e.g. sustainable forest accredited by Forest Stewardship Council (FSC)) or recycled timber is required in the building project. The reduction in the use of virgin timber help mitigate the problem of deforestation, which contributes to global warming.

MW 6: Recycled Materials

Number of credits attainable: 1 + 2 bonus credits

Initial Cost Premium:

(a) At least 10% of materials used for site exterior surface work, structures and features with recycled content

U	-VE	0	0+	L	M	H

Or

(b) At least 10% of materials used for façade or structural components with recycled content

U	-VE	0	0+	L	M	H

Or
Use of Pulverised Fuel Ash (PFA) partial replacement (at least 25%) of cement in concrete

U	-VE	0	0+	L	M	H

Or

Use of Ground Granulated Blast furnace Slag (GGBS) partial replacement (at least 40%) of cement in concrete

U	-VE	0	0+	L	M	H

(c) At least 10% of materials used for interior non-structural components with recycled content

U	-VE	0	0+	L	M	H

Compliance with requirements of (a), (b) and (c) (Bonus)

U	-VE	0	0+	L	M	H

50% or more of materials in (a), (b), or (c) with recycled content (Bonus)

U	-VE	0	0+	L	M	H

Developers are encouraged to use building materials with recycled content for outside surface works and structure, building façade, or interior non-structural component. The use of Pulverised Fuel Ash (PFA) or Ground Granulated Blast-furnace Slag (GGBS) as partial cement replacement in concrete is also encouraged. Use of recycled products can help to conserve natural resource as the demand for virgin materials. As recycling can be considered as an alternative means of demolition wastes instead of dumping, use of recycled materials can help reduce the burden of landfill sites. Use of PFA and GGBS can reduce the embodied carbon contents of concrete (Kupwade-Patil et al., 2018).

MW 7: Ozone Depleting Substances

Number of credits attainable: 2

Initial Cost Premium:

Use of refrigerants with low combined contributions to ozone depletion and global warming potentials

U	-VE	0	0+	L	M	H

Use of building materials which avoid using ozone depleting substances

U	-VE	0	0+	L	M	H

Use refrigerants with low combined contributions to ozone depletion and global warming potentials, and building materials can minimize the use of ozone depleting substances in their manufacture, composition or use is required. The stratospheric ozone layers help reduce the amount of short-wavelength ultraviolet radiation from the Sun, which can have harmful effects on plants and cause skin cancer, to reach the surface of Earth. Avoiding the ozone depleting substances help to reduce the rate of ozone depletion.

MW 8: Regional Materials

Number of credits attainable: 1 + 2 bonus credits

Initial Cost Premium:

Use of regional materials for at least 10% of the building materials

U	-VE	0	0+	L	M	H

Use of regional materials for at least 20% of the building materials (Bonus)

U	-VE	0	0+	L	M	H

Use of regional materials for at least 50% of the building materials (Bonus)

U	-VE	0	0+	L	M	H

Use of materials originated locally (within an 800km radius of HK by road transportation; or a 1600km radius by rail transportation; or a 4000km radius by sea transportation) is required for the building project. The use of regional materials may reduce the embodied energy of building as well as the energy for transportation. However, care must be taken as the composition of fuel mix in the origin has remarkable impacts on the total carbon emissions.

MW 9: Use of Green Products

Number of credits attainable: 2 + 4 bonus credits

Initial Cost Premium:

At least 5% certified green products in one of the categories: outside surface work, building façade and structure, interior non-structural components, and building services components

U	-VE	0	0+	L	M	H

At least 5% certified green products in two of the categories: outside surface work, building façade and structure, interior non-structural components, and building services components

U	-VE	0	0+	L	M	H

At least 5% of certified green products under Construction Industry Council (CIC) Green Product Certification, Carbon Labelling Scheme / HKGBC Green Product Accreditation and Standard in one of the categories: outside surface work, building façade and structure, interior non-structural components, and building services components (Bonus)

U	-VE	0	0+	L	M	H

At least 25% of certified green products under Construction Industry Council (CIC) Green Product Certification, Carbon Labelling Scheme / HKGBC Green Product Accreditation and Standard in one of the categories: outside surface work, building façade and structure, interior non-structural components, and building services components (Bonus)

U	-VE	0	0+	L	M	H

At least 5% of building materials / interior non-structural components are rapidly renewable materials (Bonus)

U	-VE	0	0+	L	M	H

At least 25% of building materials / interior non-structural components are rapidly renewable materials (Bonus)

U	-VE	0	0+	L	M	H

Use (a) certified green products for outside surface work, building façade and structure, interior non-structural components, or building services components; and (b) rapidly renewable materials is required. Use of certified green products helps to reduce the environmental impact of the building construction. Rapidly renewable materials refer to materials with a harvest cycle of ten years or less. Usually, regeneration of these materials is faster than the market demand for them. To this end, it can render lower impact to the environment (e.g. reduce the risk of deforestation).

MW 10: Life Cycle Assessment

Number of credits attainable: 1

Initial Cost Premium:

U	-VE	0	0+	L	M	H

Life cycle assessment (LCA) is required for demonstrating that the embodied energy of building structure has been studied and optimised. Using the LCA approach can help reveal the life cycle environmental impact of the building structure, which further facilitate comparing design options from the perspective of environmental impact and identify the one with better performance (e.g. lower global warming potential).

MW 11: Adaptability and Deconstruction

Number of credits attainable: 2

Initial Cost Premium:

(a) Designs providing spatial flexibility that can adapt to change in space function

U	-VE	0	0+	L	M	H

or

(b) Design of services that can adapt to change of use

U	-VE	0	0+	L	M	H

or

(c) Provide flexibility such that the building structure allows future change in use of the building

U	-VE	0	0+	L	M	H

Compliance with requirements in (a), (b) and (c) (Bonus)

U	-VE	0	0+	L	M	H

Two items associated with these two credits include providing (a) spatial flexibility that allows expansion according to various spatial requirements, (b) flexible design of services which can adapt to the changes of use layout and use, and (c) flexibility of building structural systems which can allow changes in future use of the building.

Spatial flexibility can provide environmental benefits such as reduced waste when changes, refurbishment and/or deconstruction take place. However, the real benefits will be dependent on how often the function of layout of the internal space has to be altered. The flexibility in design of services can also reduce waste as the services may not have to be changed or replaced due to the change of use layout and use. Similarly, the flexibility of building structural systems enable the potential reuse of building structure, which can help to reduce C&D wastes and provide monetary saving due to the reuse (potential saving in initial cost: \$154.17 to 693.75 /m^2, depending on the percentage of reuse).

MW 12: Enhanced Waste Handling Facilities

Number of credits attainable: 2 + 2 bonus credits

Initial Cost Premium:

Provision of additional facilities for recyclables collections

U	-VE	0	0+	L	M	H

Provision of facilities to enable enhanced Municipal Solid Waste (MSW) Charging Scheme

U	-VE	0	0+	L	M	H

Provide at least one set of waste treatment equipment (Bonus)

U	-VE	0	0+	L	M	H

Provide alternative means of waste collection systems (Bonus)

U	-VE	0	0+	L	M	H

Developers are required to provide facilities for collection, sorting, storage and disposal of recyclable wastes and waste treatment equipment. The provision of these facilities or equipment should aim to reduce the amount of municipal solid waste (MSW) and encourage the recycling waste. These measures will help reduce the pressure of landfill sites by reducing the dumping of MSW.

Energy Use (EU)

EU 1: Low Carbon Passive Design

Number of credits attainable: 6

Initial Cost Premium:

Perspective Path (descriptions in the following paragraphs) (maximum 4 credits)

U	-VE	0	0+	L	M	H

Performance Path (maximum 6 credits)

Reduce building envelope load by rotating the building plan by at least 22.5°

U	-VE	0	0+	L	M	H

Optimum spatial planning to enhance energy conservation with justification by simulation

U	-VE	0	0+	L	M	H

Provision of shading devices with the justification by simulation

U	-VE	0	0+	L	M	H

Provision of vegetated building envelope with justification by calculation

U	-VE	0	0+	L	M	H

Spatial layout to facilitate natural ventilation with justification by simulation

U	-VE	0	0+	L	M	H

Spatial layout to facilitate daylight penetration with justification by simulation

U	-VE	0	0+	L	M	H

Credits can be earned by pursuing either prescriptive path or performance path. For the prescriptive path, developers are required to (a) optimise the internal spatial layout such that at least 5% (for open planned design) to 20% (for non-open planned design) of external wall of the building is occupied by non-conditioned space, (b) provide overhangs at least 0.3 of the window height on the south oriented façade, (c) provide green roof occupying 50% of roof of conditioned spaces or vertical greenery occupying 5% of external walls, (d) provide cross ventilation for normally occupied spaces, (e) provide natural ventilation for public space, and (f) provide daylight access to normally occupied space by windows with height at least 50% of the space depth of normally occupied space. All these measures can lead to potential reduction in energy consumption of buildings. Besides, green roof and vertical greenery may help to mitigate heat island effect and air pollution, as well as provide sound insulation and noise reduction to the building (Berardi et al., 2014). Daylight provision may enhance productivity and well-being of the building occupants.

For the performance path, greater considerations should be placed on the built-form and orientation, spatial planning, shading devices and vegetated building envelope in order to reduce HVAC load. Space layout should be designed to provide natural ventilation and daylight penetration. According to simulation results, rotating the building plan by 22.5° could yield 0.47% to 3.25% saving in annual energy consumption of the building. Depending on the WWR and glazing shading coefficient value, the amount of energy savings acquired from space cooling can be up to 44.1% by installing overhang to buildings in Hong Kong (Huang et al., 2012). For vertical greenery, a maximum of 76% reduction in energy consumption for space cooling could be obtained by designing a “double skin green facade” could yield (Wong & Baldwin, 2016).

Reduction of CO_2 Emission

Number of credits attainable: 10 + 5 bonus credits

Initial Cost Premium:

U	-VE	0	0+	L	M	H

The associated credits can be earned by pursing either prescriptive or performance path. For the prescriptive path, developers may have to reduce the OTTV and RTTV of the building envelope, provide natural ventilation to normally occupied space, improve the COP of the HVAC system, reducing the lighting power, and lowering the maximum allowable electrical power of lift and escalators. Reduction in OTTV and RTTV of building envelopes will reduce the cooling load of the building and hence energy for space cooling. On the other hand, improving the COP of the HVAC system can enhance the energy-efficiency of the system and produce energy saving. Similarly, reducing the lighting intensity, and lowering the maximum allowable electrical power of lift and escalators are also measures that can produce energy saving and hence CO_2 emission reduction.

Meanwhile, there is no prescribed measure for the performance path. Examples of common measures that can be adopted include higher glazing shading coefficient, lower window-to-wall ratio, enhancement of COP of HVAC system, and use of water-cooled instead of air-cooled chiller. The number of credits that can be earned depended on the percentage of reduction in annual CO_2 emission. This requirement of CO_2 emission reduction is itself an environmental benefit.

EU 3: Peak Electricity Demand Reduction

Number of credits attainable: 3

Initial Cost Premium:

Prescriptive Path

Obtain 4 credits in EU 2 (prescriptive path)

U	-VE	0	0+	L	M	H

Obtain 7 credits in EU 2 (prescriptive path)

U	-VE	0	0+	L	M	H

Performance Path – 1 to 3 credits by the saving percentage of 5% to 15% in EU 2 (performance path)

U	-VE	0	0+	L	M	H

The involved credits will be awarded based on the credits obtained from the previous item "*Reduction of CO_2 Emission*". There are two main types of benefits due to peak electricity demand reduction, which occurs during the hottest day of a year when largest amount of electricity is needed for space cooling. Reducing the peak electricity demand can help to ensure the reliability of the electrical grid and reduce the risk of brownouts or blackouts. On the other hand, reducing the peak electricity demand usually mean higher energy efficiency, which in turn leads to reduction in energy consumption. Meanwhile, the cost of these credits are considered "unable to be estimated" as earning these credits is solely dependent on whether EU 2 credits have been earned.

EU 4: Metering and Monitoring

Number of credits attainable: 1 + 2 bonus credits

Initial Cost Premium:

Provision of energy monitoring system for equipment and systems in spaces

U	-VE	0	0+	L	M	H

Provision of performance auditing monitoring system for equipment and systems in spaces

U	-VE	0	0+	L	M	H

Provision of monitoring for tenants' energy consumption

U	-VE	0	0+	L	M	H

Energy monitoring system for equipment and systems in spaces, and performance auditing monitoring system for equipment are required. Provision of monitoring system is also required in tenant area. For building operators or facility managers to monitor the energy use of a building efficiently, it is essential to provide good metering and monitor facility provision. This will help to enhance the energy efficiency of operation of buildings.

EU 5: Renewable and Alternative Energy Generation

Number of credits attainable: 5 + 5 bonus credits

Initial Cost Premium:

Use of on-site renewable energy to offset 0.2% to 2% of energy consumption

U	-VE	0	0+	L	M	H

Developers are required to install renewable energy sources, such as PV panels in buildings. The primary benefit of installing renewable energy sources is obviously reduction in energy consumption. There may be extra monetary savings for the installation of PV panels due to feed-in-tariff (FiT) if feeding the electricity generated to the grid is feasible. The FiT from CLP are $4/kWh for renewable energy system with generation capacity smaller than or equal to 10kW, $3/kWh for capacity between 10kW and 200kW, and $2.5/kWh for capacity higher than 200kW and lower than or equal to 1MW.

EU 6: Air-Conditioning Units

Number of credits attainable: 2

Initial Cost Premiums:

Excluded in the cost estimation as the decisions of installation of window or split-type air conditioner lie on individual tenant / building but not developers.

These credits targeted at buildings with provisions of window or split-type air conditioners. The installation positions of the units have to comply with manufacturer's recommendations for optimal heat rejection. Developers are also required to ensure the operative temperature of the units not exceeding manufacturer's recommendation. Proper installation positions of window or split-type air conditioners may lead to heat rejection efficiency, which will in turn reduce the energy consumption level. Similarly, ensuring that the operative temperature to be in line with manufacturer's recommendation will help to ensure the efficiency of the units.

EU 7: Clothes Drying Facilities

Number of credits attainable: 1 + 1 bonus credit

Initial Cost Premium:

Excluded in the cost estimation as cloth drying is be needed for office buildings.

Provision of permanent clothes drying facilities for residential units is required. When these facilities are provided, energy consumption due to the use of electricity or gas for drying machines can be reduced, with potential annual savings in energy up to $62.3 / m^2.

EU 8: Energy Efficient Appliances

Number of credits attainable: 2

Initial Cost Premium:

Excluded in the cost estimation as the decision of installation of appliances is assumed to lie on individual tenants / building users.

Appliances installed by developers should be certified energy efficient products. It is likely that the appliances to be installed are built-in appliances in kitchen. This may increase the saleability of building. On the other hand, there will be reduction in energy consumption. Reduction in electricity bills will probably be benefited by householders.

Water Use (WU)

WU 1: Annual Water Use

Number of credits attainable: 3 + 1 bonus credit

Initial Cost Premium:

20% further portable annual water saving

U	-VE	0	0+	L	M	H

25% further portable annual water saving

U	-VE	0	0+	L	M	H

30% further portable annual water saving

U	-VE	0	0+	L	M	H

40% further portable annual water saving (bonus)

U	-VE	0	0+	L	M	H

Adoption of water efficient flow devices is required. The use of these devices can provide saving in the use of potable water and in turn water bills.

WU 2: Water Efficient Irrigation

Number of credits attainable: 2 + 1 bonus credit

Initial Cost Premium:

25% reduction of potable water consumption for irrigation

U	-VE	0	0+	L	M	H

50% reduction of potable water consumption for irrigation

U	-VE	0	0+	L	M	H

100% reduction of potable water consumption for irrigation

U	-VE	0	0+	L	M	H

For sites with permanent greenery and permanent irrigation system, use of rainwater and recycled grey water is required for irrigation system. Such irrigation system can help save the use of potable water for irrigation.

WU 3: Water Efficient Appliances

Number of credits attainable: 1

Initial Cost Premium:

U	-VE	0	0+	L	M	H

Developers are required to install water efficient appliances that achieve Grade 1 under the WSD's Water Efficiency Labelling Scheme. Use of such appliances can render saving in the consumption of potable water.

WU 4: Water Leakage Detection

Number of credits attainable: 1

Initial Cost Premium:

U	-VE	0	0+	L	M	H

It is required to install sensors to detect leakage in all potable water tank rooms, such as potable water tank, irrigation and cleansing water tank.

WU 5: Twin Tank System

Number of credits attainable: 1

Initial Cost Premium:

U	-VE	0	0+	L	M	H

Developers are required to provide twin tank system for potable water supply and flushing water supply systems. The use of twin tank system can ensure water can be supplied to occupants continuously when one of the tanks is being cleaned (WSD, 2011). This will help enhance the satisfaction of the occupants when using buildings.

WU 6: Cooling Tower Water

Number of credits attainable: 1

Initial Cost Premium:

U	-VE	0	0+	L	M	H

For cooling towers, 7 or more cycle of concentration with acceptable water quality is required. The primary benefit is reduction in potable water consumption.

WU 7: Effluent Discharge to Foul Sewers

Number of credits attainable: 1

Initial Cost Premium:

U	-VE	0	0+	L	M	H

Developers are required to implement measures such as the installation of low-flow devices on faucets for reducing the sewage volume. Reducing sewage volume can help to reduce the burden of the municipal sewage services and treatment facilities.

WU 8: Water Harvesting and Recycling

Number of credits attainable: 2 + 1 bonus credit

Initial Cost Premium:

Reduction of at least 5% in consumption of potable water by harvesting of rainwater

U	-VE	0	0+	L	M	H

Reduction of at least 5% in consumption of potable water by recycling of rainwater

U	-VE	0	0+	L	M	H

Reduction of at least 10% in consumption of potable water by harvesting of rainwater, recycling grey water, or a combination of both (Bonus)

U	-VE	0	0+	L	M	H

Developers are required to install facilities and systems for harvesting rainwater and recycling grey water. The primary benefit is potable water saving.

Health and Wellbeing (HWB)

HWB 1: Healthy and Active Living

Number of credits attainable: 1 bonus credit

Initial Cost Premium:

Scoring at least 3 items of all applicable design measures for healthy and active living

U	-VE	0	0+	L	M	H

Developers are required to integrate public art in indoor communal areas in the building, install way-finding signage to encourage the use of stairs, install circulation stairs in communal area and provide facilities for physical activities such as exercises stations and jogging tracks in communal areas in the building. Encouraging the use of stairs and the provision of exercise facilities help to enhance the physical health of the occupants.

HWB 2: Biophilic Design

Number of credits attainable: 2 bonus credits

Initial Cost Premium:

Demonstrating visual connection with nature at an assessment space with Visual Quality Score of 2 or above

U	-VE	0	0+	L	M	H

Demonstrating visual connection with nature at an assessment space with Visual Quality Score of 3 or above

U	-VE	0	0+	L	M	H

Provision of visual connection to nature in a normally occupied space with highest occupancy. People tend to seek for connections to nature (Wilson, 1984). Visual connection to nature can help reduce stress, improve concentration etc. (Ryan et al., 2014), which may in turn enhance productivity of occupants. However, whether all these credits can be earned is mainly dependent on existing site conditions. It may not be feasible to earn all the 2 bonus credits if there is no nature scene around the site of the development.

HWB 3: Inclusive Design

Number of credits attainable: 1 + 1 bonus credit

Initial Cost Premium:

Providing at least 10 applicable enhanced provision as stipulated in the "Recommended Design Requirements" of BFA 2008

U	-VE	0	0+	L	M	H

Provision of weather protection and at least two family friendly facilities

Excluded in the cost estimation as it is not applicable for a single building development.

Developers are required to provide barrier-free access with measures such as use of tactile guide path and provision of ramps leading from one level to another, protection features against wind-driven rain in covered semi-outdoor communal areas, and family friendly facilities such as shaded rest areas with seating for caretakers near play equipment for children. These provisions will enhance the satisfaction of occupants, and provision of barrier-free access may improve the saleability of the building.

HWB 4: Enhanced Ventilation

Number of credits attainable: 3 + 1 bonus credit

Initial Cost Premium:

Provision of fresh air in normally occupied spaces

U	-VE	0	0+	L	M	H

Provision of fresh air in not normally occupied spaces

U	-VE	0	0+	L	M	H

On-site measurements to verify the ventilation performance for all normally occupied spaces (bonus)

U	-VE	0	0+	L	M	H

Provision of ventilation system for spaces where significant indoor pollution sources are generated

U	-VE	0	0+	L	M	H

Provision of increased ventilation in normally occupied spaces and adequate ventilation in not normally occupied spaces. Besides, developers are also required to provide effective ventilation system for spaces with significant indoor pollution

sources (e.g. car park). These help improve the IAQ of the building, which is an important factor for the health and wellbeing of occupants.

HWB 5: Waste Odour Control

Number of credits attainable: 1

Initial Cost Premium:

U	-VE	0	0+	L	M	H

Developers are required to install odour sensors at all discharge points from enclosed waste disposal and recycling spaces. This will ensure that actions can be taken when odour is detected. This will help to enhance the satisfaction of building occupants.

HWB 6: Acoustics and Noise

Number of credits attainable: 4 + 1 bonus credit

Initial Cost Premium:

Demonstrating that mid-frequency reverberation time in the landlord controlled rooms meets the prescribed criteria in BEAM-Plus

U	-VE	0	0+	L	M	H

Demonstrating that mid-frequency reverberation time in the non-landlord controlled rooms meets the prescribed criteria in BEAM-Plus

U	-VE	0	0+	L	M	H

Demonstrating that airborne noise isolation between spaces meets the prescribed criteria in BEAM-Plus

U	-VE	0	0+	L	M	H

Demonstrating that impact noise isolation between floors meets the prescribed criteria in BEAM-Plus

U	-VE	0	0+	L	M	H

Demonstrating that background noise levels within the meets the prescribed criteria in BEAM-Plus

U	-VE	0	0+	L	M	H

It is required to demonstrate that the reverberation time in the various rooms, airborne and impact noise isolation and background noise level from external sources and external building services equipment of the building meet the prescribed criteria. Developers are also required to ensure that background noise level is within the prescribed criteria. In the extreme case, developers may even have to install noise barriers to reduce the noise induced by road traffic. Noise can lead to disturbance and annoyance that induce adverse effects on health and well-being of individuals. Controlling the noise in buildings can ensure the well-being and productivity of occupants.

HWB 7: Indoor Vibration

Number of credits attainable: 1

Initial Cost Premium:

Demonstrating that vibration level not exceeding prescribed criteria in BEAM-Plus

U	-VE	0	0+	L	M	H

Developers are required to demonstrate vibration level in buildings does not exceed the prescribed criteria. Vibration can be generated from the operation of building services equipment. Controlling or reducing vibration means that noise generated from the equipment will be inhibited.

HWB 8: Indoor Air Quality

Number of credits attainable: 4 + 1 bonus credit

Initial Cost Premium:

Path 1:

Demonstrating compliance with the prescribed limits of pollutants such as PM10 (2 credits)

U	-VE	0	0+	L	M	H

Demonstrating compliance with prescribed limits for Airborne bacteria

U	-VE	0	0+	L	M	H

Path 2:

Obtain a valid IAE Certification Scheme (Good Class) certificate issued by EPD (3 credits)

U	-VE	0	0+	L	M	H

Path 3:

Obtain a valid IAE Certification Scheme (Excellent Class) certificate issued by EPD (3 credits + 1 bonus credit)

U	-VE	0	0+	L	M	H

Demonstrating the compliance with the pollutant concentration limits specified in ProPECC PN 2/96 in the car park

U	-VE	0	0+	L	M	H

Developers are required to demonstrate that airborne contaminants in occupied spaces and car parks are below the prescribed levels. Ensuring the IAQ of various spaces will help ensure the health of occupants.

HWB 9: Thermal Comfort

Number of credits attainable: 2 + 1 bonus credit

Initial Cost Premium:

Conduct thermal comfort analysis and demonstrate the thermal comfort requirements can be met in normally occupied spaces (2 credits)

U	-VE	0	0+	L	M	H

Conduct on-site measurements to verify the thermal comfort performance

U	-VE	0	0+	L	M	H

Developers are required to perform thermal comfort analysis and measurement to ensure satisfactory thermal comfort in spaces under normal occupancy. Ensure thermal comfort in buildings can help maintain the productivity of occupants.

HWB 10: Artificial Lighting

Number of credits attainable: 2

Initial Cost Premium:

Artificial lighting performance in normally occupied spaces meets the prescribed criteria in BEAM-Plus

U	-VE	0	0+	L	M	H

Artificial lighting performance in both normally and not normally occupied spaces meets the prescribed criteria in BEAM-Plus

U	-VE	0	0+	L	M	H

Both normally occupied spaces and non-normally occupied spaces are required to meet the prescribed lighting performance levels. The prescribed lighting performance levels are mainly related to the reflectance of various surfaces, illuminance uniformity and glare in buildings. As such, visual comfort in the buildings can be ensured and the productivity of occupants can be maintained.

HWB 11: Daylight

Number of credits attainable: 2 bonus credits

Initial Cost Premium:

U	-VE	0	0+	L	M	H

To obtain these credits, at least 55% of the normally occupied spaces can achieve at least 300 lux of daylight for at least half of the operating hours of the building. Besides, it is necessary to ensure that no more than 10% of the spaces attain more than 1000 lux for more than 250 hours each year. On one hand, daylight access can help to reduce the energy consumption of artificial lighting. On the other hand, access of daylight can help to maintain the well-being and productivity of occupants.

HWB 12: Biological Contamination

Number of credits attainable: 1

Initial Cost Premium:

U	-VE	0	0+	L	M	H

The design and operation of Water Supply Systems, HVAC Systems and other water features have to comply with recommendations in the Code of Practice for Prevention of Legionnaires' Disease 2016 Edition. The conferred benefit is to minimize the chance for occupants to be infected with Legionnaires' Disease.

4.6 Benefit-cost analysis of energy saving measures

Given the importance of the EU category in BEAM-Plus, it is also of interest to separately analyse the benefits and costs of various energy saving measures. Fig. 18 shows the economic benefit-cost ratios of implementing various energy saving measures. It can be seen that the benefit-cost ratios of increasing WWRs were found to be negative. This is because the energy consumption for space cooling

would also increase with WWR. The electricity bills will increase and this results in the negative economic benefit-cost ratios. To this end, increasing WWR is not a preferable option merely from the perspective of economic benefits (in terms of electricity bills) and cost. However, as there may be other considerations when making decisions on adopting a specific WWR (e.g. aesthetics as an intangible benefit), the decisions on WWR may not always follow the suggestions derived from economic benefit-cost ratio alone.

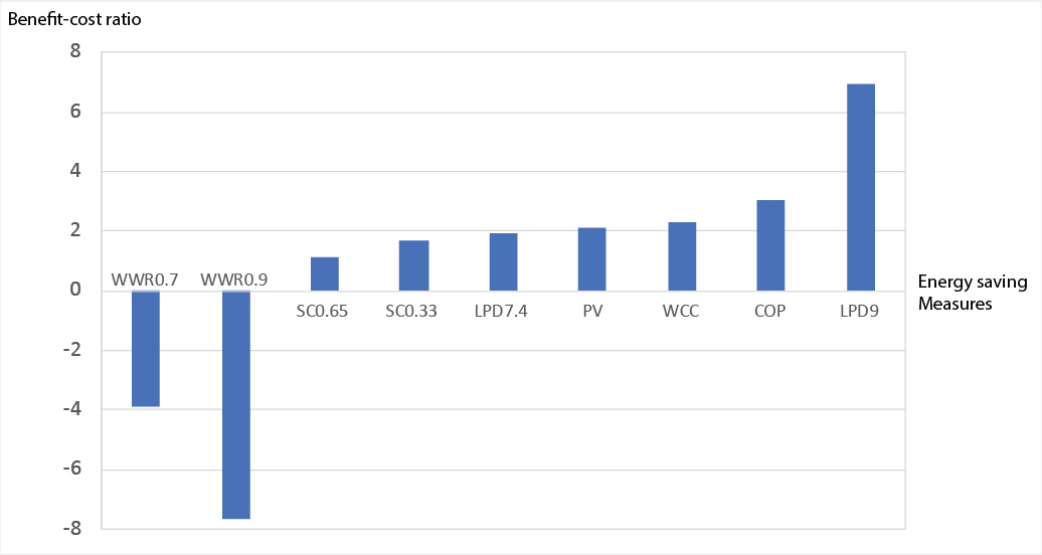

Figure 18 Benefit-cost ratios of implementing various energy saving measures

Apart from WWRs, the benefit-cost ratios of energy saving measures have been found to range from 1.1 to 6.8. Increasing the lighting power intensity to 9 W/m^2 is found to be of the highest benefit-cost ratio (i.e. 6.8), followed by increase the COP of the HVAC system to 3.5 (with benefit-cost ratio of 3.0), and adoption of water-cooled system (i.e. benefit-cost ratio of 2.3). Meanwhile, it was found that the utilisation of glazing with lower shading coefficient values will yield the lowest benefit-cost ratios. Meanwhile, it should also be noted that increasing the set-point temperature to 25.5˚C and rotating the building plan by 22.5˚ can also provide savings in energy consumption and hence electricity bills. However, the value of ΔC in Eqn. (1) would be 0 when considering these two measures. Thus, their benefit-cost ratios will become infinite. Despite so, they are the most preferable options in terms of benefits and costs as ΔC in Eqn. (1) equals 0.

4.7 Focus group meeting

To ensure the results from this study are in line with the practice in the industry, it is essential to solicit opinions from the industry practitioners and developers about the practicality of complying the requirements of individual

BEAM-Plus credits and performance grades. Between 2021 and 2022, three in-depth private meetings had been arranged to solicit opinions from architects and engineers, clients, and BEAM consultants' on (i) whether our measures proposed for complying with individual performance credit requirements were practical and logical, and (ii) whether there were any other potential measures that we had not been taken into considerations. In all three meetings, it was generally agreed that the measures of reusing building elements / materials were hard to implement. Specifically, architects were asked about details of building materials, e.g. shading coefficient values and specifications of window glazing as they have considerable impacts on space cooling loads. Questions on specific credits that they would like to obtain as the first order of priority, and that they tried to avoid as well as their underlying reasons were also discussed with clients and designers during their private meetings. Their replies was that credits that would incur relatively high cost generally would not be targeted. For example, the adoption of BIM would not be recommended for most developers, as it would likely incur high cost. On the other hand, credits within SS Category were also not recommended unless site conditions permitted. Meanwhile, they would recommend clients to go for credits involving computer simulations (e.g. credits related to indoor lighting performance (HWB10)) if they had the confidence that these credits could be obtained after the simulations. To further check the accuracy of our cost estimates, BEAM consultants were also asked about their charges of different types of services provided to clients. The findings from these private meetings had been used as valuable references for deriving realistic cost estimates as well as identifying practical strategies to pursue higher performance grades and earn more credits.

In addition, a focus group meeting was held on 07 December, 2022 with an aim to verify the cost estimates determined in this study and further solicit opinions from the industry about the practicality of earning individual BEAM-Plus credits and performance grades. Six participants, who are in the field of BEAM consultants, architects and developers, attended the focus meeting but most of them did not want to disclose their names. Three main topics discussed in the meeting were (i) strategies of earning credits or performance grades, (ii) ease of implementation of sustainable measures to earn individual BEAM-Plus credits' and (iii) the motivations and willingness-to-pay for developers for BEAM-Plus eco-labels. Prior to the meeting, all participants had received a softcopy of our findings on the cost estimates of individual credits and performance for review.

(i) <u>Strategies of earning credits or pursuing higher performance grades</u>
<u>(Objective V)</u>

As suggested by the participants, BEAM consultants usually pre-assess the design and site conditions to identify credits that can be earned without tremendous additional effort or costs. From this pre-assessment exercise, consultants will have a preliminary idea on the potential performance grade that can be achieved for a specific design. In the next step, they will discuss with their clients to see whether they like to pursue a higher performance grade. If so, consultants will explore opportunities in earning more credits. Quite often, when proposing target credits to

be earned, the first priority will be those credits which bear no or minimal cost and design implications. The second priority will be those credits which induce some design implications but minimal or without cost implications. Credits bearing low cost implications will only be proposed after the first two priority groups have been scrutinized. Consultants will then present to their clients a list of potential securable credits for aiding the clients to make decisions.

Unsurprisingly, developers usually may have concerns on the cost implications of earning credits. This partly explains why consultant will propose to earn credits with minimal cost implications as the first priority.

- *"It was true that private developers have concerns about the cost implications. An example would be the installation of PV panels. It could be expensive. The maintenance cost was also their concerns."*
- *Of different BEAM-Plus credits, participants also mentioned credits requiring simulation as a way to prove the performance of buildings. Usually, consultants would propose to target at those credits that they had high confidence that the performance requirements can be met.*
- *"Usually, we will propose to target credits with lower cost implications. Credits that require simulation was one example."*
- *"Performing simulation did not mean that the credit would be obtained. However, if we feel that the credit could not be obtained after pre-assessment, we might not propose to target the credit and perform simulation."*
- *"When we proposed to perform simulations, we had some confidence that the associated credits could be obtained."*
- *"We will not propose to perform simulations if we felt that the credits could not be obtained. For example, if there were a lot of buildings surrounding the site, we might not propose to perform daylighting simulations as the associated credits might not be obtained."*
- *"From our experience, we usually had some ideas about the credits associated with simulations that could be obtained. In this case, we would perform simulations to target for these credits."*

However, the strategies of choosing credits might be different according to the type of developers, e.g. owner-developers or just developers.

(ii) <u>Ease of implementation of sustainable measures to earn individual BEAM-Plus credits *(Objective I)*</u>

During the focus group meeting, measures that are difficult to implement has been discussed and identified. Most of the participants agreed that there could be some given conditions, especially related to the site, will make some measures very difficult or challenging to implement. Specifically, measures affected by the site or surrounding conditions could be hard to implement. Examples of credits due to the site conditions that were very difficult or challenging to obtain.

- *"The credit related to neighborhood daylighting depended on the surrounding buildings."*

- *"Measures related to the site aspect were hard to implement because it was impossible to change the conditions surrounding the site."*
- *"For example, if the site was surrounded by traffic roads, it was impossible to obtain the credit related to ecology."*

Besides, credits related to building structure can also be difficult to implement. Specifically, the reuse of structure and the adoption of prefabricated elements for building structure are quite challenging in terms of implementation.

- *"I believed the credit for the reuse of structure was difficult to earn. I guessed it was mainly for projects related to revitalization of historical buildings. It was hard to earn this credit for other projects."*
- *"Due to the structural design, it was sometimes very hard to use precast or prefabricated elements."*

Some measures related to site landscaping can also be hard to implement. The participants in the focus group meeting especially brought out the issue of tree planting. There are situations that make tree planting impractical. Landscape architects may not want to plant trees due to other design considerations. The maintenance cost of planting trees is also a concern.

- *"Credits related to tree coverage could be hard to obtain. Landscape architects should have a lot of concern regarding the positions of trees. The maintenance cost afterwards was also a concern."*
- *"For single building projects, the footprint could be so small that it was impossible to have tree planting …. And even for large developments, the landscape architects might not want to plant trees as there could be other design considerations."*
- *"For tree planting, maintenance cost was also an issue to consider."*

Building design will certainly affect the practicality of earning certain credits. Credits related to daylighting design may not be easily obtained due to constraints imposed by interior layout of an office building.

- *"For an office building, it was not quite possible to earn credits associated with daylighting if the interior is an open plan office design as daylight might not be able to penetrate into inner zones."*

Apart from the above, there are also measures that are difficult to implement due to the relatively higher maintenance cost.

- *"Measures that might lead to long-term maintenance issues could be a concern."*
- *"Installation of PV panels could be difficult due to the high maintenance costs."*
- *"Sometimes the facility management team might have some concerns on the maintenance cost of some measures to be taken."*

Also, there are measures that developers do not want to implement as they think the measures may substantially affect the design.

- *"Taking landscaping as an example. The developers might not want to implement a measure if it could affect the atmosphere / design they want to achieve."*

Construction waste recycling, to some extent, is also hard to implement. For small scale developments like single building projects, attaining a high recycling rate can be difficult, or even impractical. At the same time, there can be some hidden costs for contractors, which they may be reluctant for them to disclose before earning specific credits. Gathering the information and documents for these credits require a lot of time resources for both consultants and contractors. Usually, consultants will not recommend securing those credits.

- *"The cost of dumping was of course high. Although it seemed that there could be saving in cost if there could be a high waste recycling rate, the reality was that there might not be so much waste for recycling. Attaining a rate of 60% was impractical. There were mainly general wastes towards the end of the projects, especially for single building projects. There might not even be companies which will collect the waste."*
- *"According to our experience, it was hard to obtain the credits related to construction waste recycling. Usually we did not target these credits. I believed most consultants would not suggest their clients to attempt to obtain these credits."*
- *"I agree that not many consultants would suggest these as target credits. First, it is needed to gather a lot of information. Second, the final score that could be obtained from these credits was low. Even if we put substantial efforts in gathering all the information required and attempt to obtain these credits, we might not be able to obtain them at the end."*
- *"My experience is that we did not try to obtain these credits before. There could also be a lot of hidden costs for the contractors."*
- *"To obtain these credits, contractors would have to disclose a lot of sensitive information in terms of costs. They might not want to disclose such information. Both consultants and contractors needed to spend a lot of time to collect the information or documents required. I supposed most consultants would just give up these credits."*

The credits for BIM and digital platform can also be challenging to implement due to higher cost. Private developers may not be keen to secure these credits.

- *"For BIM and digital platforms, developers might not do it if they do not plan to do so in the beginning."*
- *"BIM and digital platforms were usually for government projects. It was rare for private developers to do it."*

Interestingly, there can be measures that may not be difficult to implement itself. However, the requirements on the supporting documentation or demonstrations may make it difficult to implement the measure. However, the participants did not mention any concrete example for this point.

- *"Sometimes, it was hard to implement a measure not because it is difficult do it. It can be that it is difficult to prepare the documents and demonstrate that the measure has been implemented."*

(iii) <u>Developers' Motivations and Willingness to Pay for BEAM-Plus Credits/Grades *(Objective III, IV)*</u>

Different developers may have motivations for pursing higher BEAM-Plus performance grades. For smaller developers, it can be merely for the purpose of earning GFA concession. However, they may also ask their consultants to research on the performance grades achieved by the nearby developments so that they can have some reference baselines for the grades that they may want to target for their developments.

- *"For smaller developers, of course the main motivation would be GFA concession. However, some developers would ask us to research on the surrounding developments and check their BEAM-Plus grades as references."*
- *The motivations for bigger developers might be different from the smaller counter parts. Larger developers usually had their own corporate policy concerning sustainability. The corporate policy would become their motivations for pursuing higher BEAM-Plus grades.*
- *"For big developers, they probably had their own sustainability goal. They might have various projects targeting different BEAM-Plus grade. Usually, a silver grade was the minimum for the developments of these big developers."*
- *"Our experience was that larger developers had their own sustainability policy."*

In addition, some corporations may have sustainable procurement policies requiring them to only rent or buy premises that achieve certain sustainability ratings. Besides, the sustainability ratings of the developments may affect the success of obtaining green funds. Conceivably, they become the motivations for developers to target their developments for specific performance grades.

- *"The developers might have concerns that the green funds might consider the sustainable ratings of their developments. They would target higher ratings so as to make their portfolio better."*
- *"Some corporates would have their own policy when renting a property. They might only rent office spaces in a property with certain sustainable grade… To this end, developers might even try to achieve WELL and LEED grades for their developments."*

Meanwhile, the business decisions on whether or not the buildings are continually owned or operated by developers is also an essential factor affecting the motivation or willingness-to-pay for achieving specific grades.

- *"This was certainly a major concern. It was not only about BEAM-Plus grades. Whether or not the developers would operate the buildings would even affect the building designs. If they had their own requirements in terms ESG, they would certainly attempt to pursue higher BEAM-Plus grades for the developments they operate or lease."*

Concerning willingness-to-pay for the BEAM-Plus performance grades, although it is not certain about the specific amount or percentage that they are willing to pay, participants agreed that developers usually have some rough ideas about the additional costs required for achieving a certain grade from their own project experiences. In addition, the scale of the project will have an important impact on the amount of willingness-to-pay. The amount of willingness-to-pay may be lower for small-scale developments as cost per GFA of achieving BEAM-Plus grades is higher for smaller scale developments, and vice versa. Developers of small-scale developments may be more prepared to invest minimal money cost and attain an 'unclassified' performance rating in order to enjoy the GFA concession given the current major shortfalls in the GFA concession requirements.

- *"Developers should have an idea about the cost premium, although they would not disclose such information. But my understanding was that they had an idea about the cost for pursuing higher BEAM-Plus grades in their cost plan."*
- *"The scale of the projects would play a role. For larger developments, the average cost of pursuing higher BEAM-Plus grades would generally be lower. For small developments, the cost per GFA could become quite significant."*
- *"Cost of performing simulation was the same regardless of the scale of the project."*
- *"Our experience was that for single building developments, it was common that the developers only attempt to get an 'unclassified' rating."*

5 Policy implications and recommendations

Policy recommendations in general

Yeung et al. (2020) suggested that GFA concession should be of the first priority in terms of policies to promote the construction of sustainable buildings. Along this line, the focus group meeting of this study also discussed this issue and revealed that the main purpose of some developers to register for BEAM-Plus assessment was the increase in saleable area of their development. Developers may just register and obtain an "unclassified" grade for the development to fulfil the minimum requirement for obtaining the GFA concessions. Under the current GFA concession policy laid down in PNAP APP-151, developers must disclose the information regarding energy performance / BEAM-Plus assessment for their development project granted with GFA concession. However, this can be disclosed in a very vague manner. For example, "the sales brochure of Twin Regency in the New Territories, some energy performance information was provided without mentioning BEAM Plus by name" (Hu & Yu, 2020). In fact, Hu & Yu (2020) also

suggested that the price premium of buildings for achieving bronze grade or above would be increased by disclosing the information about "unclassified" grade to the public. A more transparent way of disclosure of the BEAM-Plus grade is needed. To improve the effectiveness of current policy, it is recommended to require mandatory disclosure of the performance grade in a more explicit manner, regardless of GFA concession being granted or not. Also, it is proposed that the percentage of GFA concession granted should be directly linked to the BEAM-Plus performance grade achieved. This will further motivate developers to target at more sustainable building developments.

Policy recommendations concerning different stakeholders

As different stakeholders will have different interests and concerns on sustainable buildings, different types of policies can be deployed that can cater for the characteristics of different stakeholders to encourage more sustainable building construction in Hong Kong. In the followings, the policies proposed for developers and tenants / buyers will be discussed separately.

Developers

Although there will be an initial cost premium, energy saving measures can usually lead to savings in life-cycle cost. However, developers may not be able to enjoy the savings in electricity bills as if they are going to sell buildings after construction. This will render energy saving measures not attractive to speculative developers. As a result, additional incentives may be needed for specifically encouraging the implementation of energy saving measures. Provision of low interest green loans or subsidies can be one of the policies to be formulated. Besides, tax rebate linked to the energy performance of buildings can also provide monetary incentives to developers to implement these measures.

On the other hand, owner-developers will be able to benefit from the savings in energy bills after implementing measures for energy or water saving. This may instil stronger motivation for them to implement the energy saving or water measures.

Tenants and buyers

In the focus group meeting of this study, it has been suggested that developers may not be keen to promote buildings that has attained a certain BEAM-Plus performance grade. This is especially observed for residential developments. One of the reasons may be that the general public is not fully aware of the existence of BEAM-Plus as an eco-label. Yeung et al. (2020) suggested that the lack of public awareness could be a challenge of BEAM-Plus implementation. Raising the awareness of sustainable buildings in public is vital for promoting sustainable buildings construction (Mesthrige et al., 2018). For office building developments, one of the possible motivations for developers to obtain BEAM-Plus grade was due to demands for renting office spaces achieving certain sustainable performance

from tenants, in particular large corporate tenants. Conceivably, the motivations of developers to construct sustainable buildings can be further enhanced when the general public is fully aware of existence and benefits of BEAM-Plus as this may indirectly boost the saleability of the buildings. Thus, policies should also be geared towards the education on the public about sustainable buildings and BEAM-Plus.

According to Mesthrige et al. (2018), incentives for tenants or buyers could be an alternative way to promote sustainable building construction. Monetary incentives such as tax reduction can be granted to tenants or buyers who rent / buy properties with above specific BEAM-Plus grades. The percentages of tax reduction can even be fixed according to the performance grades attained by a building.

Policy recommendations for individual sustainable measures

Some policy recommendations for encouraging the implementation of individual sustainable building measures are discussed in the followings:

According to our cost estimation, recycling of construction and demolition (C&D) wastes could provide some monetary savings in the initial cost. However, there may be practical considerations hindering the decisions to send C&D wastes to recycling. Lack of a mature recycling market may be one of the important factors. As suggested in the focus group meeting, there might not be companies that were willing to collect the wastes even if developers would like to recycle the wastes instead of dumping. Also, information flow is an important element for developing a mature recycling market (Lu et al., 2017). An online system for information exchange between developers / contractors and recycling companies for C&D wastes should be developed in Hong Kong for enhancing the information flow. Support (e.g. in terms of provision of spaces for storing the C&D wastes) can also be provided to recycling companies. Besides, mandatory use of recycled materials in construction may also help to develop a more mature recycling market. In South Korea, it is mandatory to use recycled aggregates for construction projects such as roads and industrial complexes. In addition, higher landfill dumping charges may be a catalyst to force developers / contractors to consider the option of recycling instead of dumping (Wu et al., 2020).

PV panels should also be a measure worth more discussions. Based on our analysis, their payback period was estimated to be longer than 10 years after considering both the savings in electricity bills and feed-in-tariff. Similar to other energy saving measures, developers who not sell the buildings after construction will not be benefited from any saving in electricity bills and feed-in-tariff. Even for owner-developers, the long payback period may become a strong barrier for PV installations. Indeed, on-site electricity generation is an important strategy to reduce carbon emission. Considering the electricity generation potential was found to be 14% of total electricity consumption in Hong Kong (Peng and Lu, 2013), policies should also be formulated to encourage the implementation of PV panels from the perspective of carbon reduction. Promoting the concept of energy services

companies (ESCOs), which will install the PV panel without upfront charge but collect the share of savings after installation, may help to encourage developers, especially for those who will not continue to operate the building after completion, to install PV panels (Lo et al., 2013).

Higher window-to-wall (WWR) ratios will lead to higher energy consumption levels and construction costs. Despite so, most developers will still adopt higher WWRs so as increase the areas of views from the building to outside, which may further enhance the saleability of buildings. Policies can also be formulated to deal with such issues so as to enhance the energy performance of building. Adoption of lower WWRs (e.g. 0.5) should be advocated as a best practice for building design. In fact, one of participants in the focus group meeting also observed that some developers agreed to make the windows a little bit smaller for higher energy savings. On the other hand, more education campaigns should also be organized to educate the public about the advantages of adopting lower WWRs. This will have an indirect impact on decisions of developers.

Apart from reducing the cooling load of the buildings, green roofs and green facades can help reduce the temperature of the surroundings outdoor spaces (Smith & Roebber, 2011; Wong et al., 2010). This will in turn help to improve the walkability of the neighbourhood, which is a social benefit rendered from the adoption of green roof or façade. To this end, the government can provide code of practice or even incentives to developers for the implementations of green roof or façade to the buildings so as to reduce cooling energy consumption and carbon emissions, as well as enhancing walkability of the neighbourhood.

Better IAQ is essential in order to ensure the health of the occupants. Although there is currently a voluntary IAQ Certification Scheme (HKSAR Government Indoor Quality Management Group, 2019a), The Hong Kong government "does not have, or plan to introduce, legislation specifically addressing the issues of IAQ" (HKSAR Government Indoor Quality Management Group, 2019b). However, checklists on preventive maintenance of the HVAC system (OSHA, 2011) can be provided so that they can act as a guide on the actions plans of facility managers can take in order to ensure the IAQ of buildings.

6 Public dissemination of Results

The findings arising from this project have been disseminated to academics, professionals in the construction and BEAM related industries, students studying in fields related to building construction as well the general public. For academics and professionals, the results were shared in Hong Kong Joint Symposium 2022 "City for Future – Journey to Carbon Neutral Building" (22nd November, 2022), whose attendance were drawn from a wide range of academics and professionals of different disciplines in the construction industry. Figure 17 shows the photo in the symposium after the presentation. During the focus group meeting of this study, results of this study were also shown to the participants, who are building professionals such as BEAM consultants and architects. The discussions during the

meeting indeed were a two-way communication in which the findings were disseminated to these professionals while the research team could gain more inputs and insights from the findings of the study. Apart from the above, the results of the study will be delivered as a content in the course of Sustainability of the Built Environment, i.e. compulsory course of Master of Science program in Sustainable Urban Development and an elective core course in Master of Science High Performance Building" offered by the Department of Building Environment and Energy Engineering, The Hong Kong Polytechnic University. The normal quota of these Sustainability course is around 100 students each year. In order to communicate the results to the general public, a pamphlet has been published online (see Appendix A). The contents of the pamphlet outlines the objectives, research activities carried and results of this study. It can be downloaded from

https://issuu.com/jerry-leung/docs/beam_cost_benefit_flyer.

Figure 17 Photo taken in Hong Kong Joint Symposium 2022 "City for Future – Journey to Carbon Neutral Building" after the presentation (first one on left: presenter of this study)

7 Conclusion

In this study, the costs and benefits of earning individual credits and achieving various performance grades within BEAM-Plus has been revealed *(Objectives I, II)*. Developers' motivations and willingness to pay for achieving BEAM-Plus grades have also been investigated *(Objective IV)*. Policy recommendations have also been formulated based on the findings of this study. Basically, reuse of building structure can lead to the largest savings in initial cost. However, this may not always be feasible for many building construction projects. On the other hand, focusing on the credits within Energy Use (EU) category will help to gain higher percentage scores *(Objective V)*. In fact, this is what the BEAM consultation industry is currently practicing. Meanwhile, recycling of materials is

considered hard to implement although it is theoretically able to acquire monetary savings in initial cost *(Objective I)*.

In regard to the motivation behind and willingness-to-pay by developers to pursue higher performance grades, the main driver is probably GFA concession. However, there are also developers who are eager to pursue higher BEAM-Plus grades for their building projects so as to comply with their own company sustainable policies. Some high sustainable awareness tenants will only rent office spaces in buildings that have achieved higher sustainable performance grades. In this regard, some developers may be interested to cater for these needs and pursue higher BEAM-Plus grades *(Objective III)*.

Finally, some policies concerning building sustainability have also been recommended based on the findings from this study. Policies should be formulated separately according to whether developers who will, or will not operate the building after completion, or tenants and buyers. Bearing the considerations of interests of all these three stakeholders will help to formulate more comprehensive policies to pursue the idea of sustainable built environment.

Meanwhile, the findings of these study have also been disseminated via a number of channels to facilitate communication of the findings to academics, professionals and general public. It is believed that the dissemination of the findings of this study to these three parties may help promote a more sustainable built environment and transform Hong Kong into a more sustainable with no or even zero carbon city.

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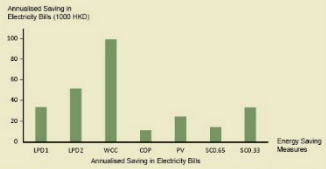
Appendix A

Online pamphlet to disseminate the findings of this study

Benefits of BEAM Plus Credits

Tangible Benefits



The tangible benefits of sustainable buildings certified under BEAM-Plus are mainly derived from savings in energy, which can be reflected in the savings in electricity bills.

Intangible Benefits

There are also a number of intangible benefits associated with BEAM-Plus certified sustainable buildings. For example, the obtaining of daylighting credits can help boost the productivity of building occupants.

Policy Insights

Policy Implications

Some policy implications can be drawn from this study findings:

- More incentives should be provided to developers who do not operate the buildings for the implementation of sustainable measures.
- More education campaigns are needed to promote BEAM-Plus among general public.
- A more mature market of construction and waste recycling should be developed.
- Recommend the design strategy to adopt lower window-to-wall ratio.

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Costs and Benefits of Undertaking BEAM (Building Environment Assessment Method) Plus New Building Assessments in Hong Kong

Dr. C.K. Chau
Prof. Edwin H.W. Chan
Dr. T.M. Leung

A project (Project Number: 2021.A6.169.21A) funded by the Public Policy Research Funding Scheme of The Government of the Hong Kong Special Administrative Region.

Background

Buildings are responsible for 60 per cent of the carbon footprint in Hong Kong. Building energy constitutes 90% of the city's total primary energy consumption, which generates a large amount of greenhouse gas (GHG) emissions. In recognition of this staggering statistics, creating a sustainable built environment is an indispensable element of the current and future policies for energy saving and GHG emission reduction. This project attemps to reveal the costs and benefits of BEAM-Plus certified sustainable buildings in Hong Kong.

About BEAM Plus

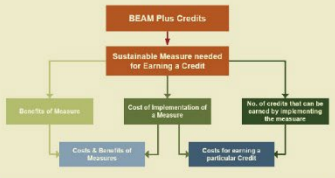
BEAM-Plus (formerly HKBEAM) was firstly launched by Hong Kong Green Building Council (HKGBC) in December 1996. It is a voluntary assessment scheme and all-inclusive environmental assessment tool for built environment impact of a building. The voluntary recognition scheme encourages developers to include requirements that are advantageous to building occupants and built environment in the building design. Up to date, over 2000 new and existing buildings out of 50,000 building stock in Hong Kong have been assessed under BEAM-Plus Scheme. Under the current structure of BEAM-Plus V2.0, a credit and scoring system is adopted. Basically, there are five different performance grades, namely, Unclassified, Bronze (40% Score), Silver (55% Score), Gold (65% Score), and Platinum (75% Score), with Platinum as the highest grade.

Project AIMs

This project embraces five main objectives:

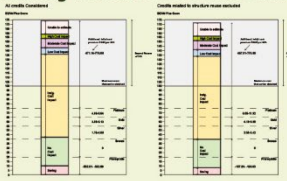
- To identify the economic and environmental benefits and non-economic obstacles of achieving BEAM-Plus V2.0 grades;
- To estimate the costs and benefits of obtain creditss under BEAM-Plus with due regards to initial costs, lifecycle costs and operational cost associated with a new sustainable building development;
- To investigate the extent to which various grades under BEAM-Plus can provide economic incentives for developers in terms of energy efficiency, building performance, and other social and environmental aspects of sustainability;
- To explore whether developers' motivations and willingness-to-pay (WTP) for achieving different performance grades;
- To develop effective sustainable design strategies for developers and designers to obtain different BEAM-Plus performance grades for a new building development or a major work of addition or alteration.

Methodology



A Flow Chart Showing the Adopted Methodology Protocol

Initial Cost Premium for Attaining Various Performance Grades



Life Cycle Cost for Attaining Various Performance Grades

The cost implications of BEAM-Plus credits can be divided in to 6 categories. Even when targeting at a Platinum grade, all credits to be earned fall into either Negative (with monetary saving), 0 (no additional cost), or 0+ (insignificant cost impact) categories. In fact, reuse of building structure can provide huge monetary savings in initial cost despite it may not be feasible for every building development project. On the other hand, implementation of energy saving measures, e.g. LED, may yield saving in life cycle cost. Reducing the window-to-wall ratio can provide both savings in initial and life cycle cost.