SUPPLEMENTARY MATERIALS
The effect of BEAM Plus certification on property price in Hong Kong
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Chapter 1

SM1.1: The reasons behind the higher construction costs for green buildings are twofold: 1) higher cost in employing skilled labour for the production of innovative and high-performance construction materials; and 2) higher life-cycle energy consumption as a result of higher embodied energy in the production of these materials, which has been found to be positively correlated with a development's eventual construction cost (Langston, Y. L., Langston, C. A. 2008; Jiao *et al.* 2012; Bansal *et al.* 2014; Copiello 2016).

SM1.2: A Comparison of BEAM Plus with BREEAM and LEED

Components shared by BEAM Plus, LEED, and BREEAM

There are number of elements shared among BEAM Plus, LEED, and BREEAM. For instance, under all three schemes, new buildings are being evaluated, grounded on the results obtained from simulations (or calculations). A 'baseline' (or reference/zero-credit) building, which only complies with the minimum regulatory requirements as indicated in the environment-related code and regulations, is compared with the "assessed building" with the proposed designs for the evaluation of a building's environmental performance in various areas (Lee *et al.* 2007). Additionally, despite the disparities in terms of recognized simulation tools for assessment (Haapio, Viitaniemi 2008), the compliance with the ASHRAE Standard 140 Standard Method is a standard feature for all three schemes (see Roderick *et al.* 2009; Lee 2012).

As for the items being evaluated during assessment, it is found by Lee (2013) that these three schemes cover the highest number of key assessment aspects (19). While the elements to be assessed are similar between BEAM Plus, LEED, and BREEAM, how they are measured under these schemes are rather different. For instance, while a building's relative improvement in environmental performance (usually in percentage) is the subject of assessment under BEAM Plus and LEED[1], its "absolute" performance (in overall CO2 emissions) is the subject of assessment under BREEAM (Lee 2012). Yet, it is found by Chen and Lee (2013) that LEED is the most stringent when it comes to measuring carbon emissions of a building at the operational stage, whilst BEAM Plus is the least stringent. By contrast, BREEAM is found to be noticeably more stringent than BEAM Plus and LEED concerning the level of lighting density (Ng *et al.* 2013).

A comparatively simple additive approach is used under BEAM Plus, LEED, and BREEAM (Lee 2013); and supplementary themes are established under all three schemes to compensate exceptional environmental performance (Alyami, Rezgui 2012). Despite such similarities, it is found that LEED is the most stringent of the three in terms of its default parameters and assessment criteria, whereas BEAM Plus allows for the highest level of flexibility with regard to possible trade-offs[2] between different areas[3] (Lee 2012). By contrast, it is also discovered that obtaining credits for a building under BREEAM is more difficult than the other two (Lee, Burnett 2008), and that BEAM Plus is the most stringent in terms of scores needed for certification (Lee 2013)[4].

Components shared by BEAM Plus and LEED

A number of themes are only shared between BEAM Plus and LEED. Firstly, both BEAM Plus and LEED follow a two-phase certification arrangement (i.e. Provisional and Final), in that assessments can be conducted at the pre-design, design, and construction phases, but not at the operations phase. BREEAM, by contrast, has a one-phase certification arrangement, as assessment under this

[1] There is, however, a slight difference between HK-BEAM (and BEAM Plus) and LEED. While BEAM adopts an energy budget approach in which the assessed annual energy use is compared with that of the baseline building, LEED, in what is called the energy cost budget (ECB) approach, incorporates the relative economic values of fuels into consideration by converting energy use into monetary terms (Lee *et al.* 2007; Lee 2012).

[2] Besides, BEAM Plus is also not as stringent as LEED with reference to the default indoor design conditions and condenser pump power, and the allowable trade-offs (Chen, Lee 2013).

[3] In fact, when BEAM is being used as an alternative compliance route to the codes and regulations, the allowable trade-offs under this scheme tend to result in even better energy performances. According to Lee and Yik (2002), the maximum possible energy savings for the implementation of the original HK-BEAM is 31.9% while the building energy codes only result in energy savings of 7.9%.

[4] However, it is easier to obtain lower level credits (i.e. 40%), but not the higher credit levels, under BEAM than it is under LEED (Lee, Burnett 2008).

scheme covers all four phases of development (i.e. pre-design, design, construction, and operations). Certification is based on design specifications, as well as predicted and actual performance (Lee 2013)[5].

In addition, both BEAM Plus and LEED have separate versions for new and existing buildings, while BREEAM only has one version since it has a one-phase certification arrangement to make certain that the predicted environmental performance of the assessed building is actually fulfilled (Lee 2013). Also, LEED and BEAM Plus, unlike BREEAM, take indoor ozone contamination and indoor particle pollution[6] under consideration in their assessments (Wei *et al.* 2015). Moreover, BEAM Plus and LEED proffer detailed information with regard to the strategies used in indoor sampling (Wei *et al.* 2015), and have similar regulations concerning roof thermal properties, vegetation, and reflectance (Chen *et al.* 2015).

Components shared by BEAM Plus and BREEAM

On the other hand, several common elements shared by BEAM Plus and BREEAM have been identified as well. For instance, while there are individual versions for the assessment of buildings in different development stages under LEED, only one version is used for such assessments under BEAM Plus and BREEAM (Lee 2013). Likewise, both BEAM Plus and BREEAM do not take the latent heat island effect into consideration, while LEED does (Lee 2013). In contrast, according to Chen *et al.* (2015), passive building designs are encouraged under BREEAM and especially under BEAM Plus, but not under LEED as the credits available become lower. Additionally, the importance of building safety and security is highlighted under BEAM Plus and BREEAM, but not under LEED (Kamaruzzaman *et al.* 2016). Lastly, even though the relationship between the scoring scale and the rating scale differs between BEAM Plus and BREEAM, their respective benchmark systems in the measurement of carbon emissions are both non-linear, whereas the one used under LEED is linear (Ng *et al.* 2013).

Elements exclusive to BEAM Plus

There are also multiple elements only covered under BEAM Plus. For example, BEAM Plus is the only scheme of the three which incorporates the evaluations of peak electricity demand[7] (Lee 2013), life-cycle energy consumption[8], life-cycle emission[9], and odour (Kamaruzzaman *et al.* 2016). Since embodied energy and embodied emissions are taken into account in assessments under BEAM Plus, the Hong Kong-based green building scheme also covers the majority of the sub-themes with respect to the selection of building materials and emphasizes the sources of pollution (Kamaruzzaman *et al.* 2016). Other differences that separate BEAM Plus from BREEAM/LEED include the inclusion of envelope thermal properties as an assessment criteria (Chen *et al.* 2015) and the lack of maximum requirement with regard to fenestration (Chen, Lee 2013). The final major difference between BEAM Plus and BREEAM/LEED is that BEAM Plus is one of the few green building certifications (along with Japan's CASBEE) that incorporates social impacts, which concern the well-being and welfare of people, in the assessment of buildings, whereas BREEAM and LEED only focus on a building's environmental impacts (Kamaruzzaman *et al.* 2016).

In addition to these similarities and differences, a number of issues from a variety of aspects have been raised. First and foremost, despite the sheer amount of criteria on which assessments are based, the focus has usually been centred on specific areas[10], and no information regarding how the assessment body determines the respective weightings for different aspects of environmental performance is provided. Also, the prescriptive nature as to how improvements in certain aspect of environmental performance are decided (usually in terms of how many credits to be granted for a certain percentage in improvement), though easy

[5] Besides, the relationship between the rating level and the scoring level is non-linear and concave in BEAM Plus and of LEED, but generally linear in BREEAM (Lee 2013).

[6] The focus of BEAM Plus (i.e. outdoor particle source control) in this regard, however, differs from that of LEED (i.e. Measurements of concentration of indoor PM10).

[7] According to the authors, the peak electricity demand is highlighted under BEAM Plus due to the monopolistic powers two companies (i.e. Hong Kong Electric and CLP) have in the supply of electricity in Hong Kong. As a result of the arrangement with the HKSAR government, known as the "Annual Permitted Return (at 9.99%)", it is to the benefits of these two companies should there be a higher level of electricity consumptions by consumers.

[8] Though embodied energy use (see Lee 2013).

[9] Through embodied GHG emissions (see Chen, Ng 2016).

[10] For instance, the provisions of natural ventilation and daylight figure in BEAM Plus's indoor environmental assessments.

to follow, appears highly inflexible[11]. By contrast, some of the criteria, though not as prescriptive as others, are rather obscure and are sometimes subject to the assessor's subjective judgment rather than objective measurements[12]. Further, for criteria that require calculations, the way in which improvement in the performance of a particular aspect is determined differs among green building certifications, and some calculations are more simplistic than others. All these disparities have been found to result in noticeable differences in the assessed environmental performance (and hence, the rating or credit obtained) even for the same building (see Roderick *et al.* 2009).

Still, does this mean that the assessment results under BEAM Plus, which has fewer assessment criteria and is not as stringent than BREEAM and LEED in different aspects, are not compatible with those under BREEAM and LEED? It is found that, the environmental performance outcomes under BEAM, BREEAM, and LEED, from a variety of aspects, are comparable (Lee 2012; Lee, Burnett 2008)[13]. For instance, according to Lee and Burnett (2008), the market positions of certified buildings, regardless of which assessment scheme is being referred to, are within the first quartile. Also, the assessment results remain the same even if the assessment methods, baseline buildings, simulation tools, and performance criteria change. Lastly, the authors find that buildings with excellent energy performance under either scheme are regarded as the top 5% in the market in this regard. Such compatibility is not limited to assessed performance through simulations. In accordance with Lee (2012), even the actual performances in energy consumption for certified buildings under the three schemes are comparable as well. It is found that the energy performance of BEAM Plus-certified buildings is 32% more efficient than that of non-certified buildings in the U.S.; that the energy efficiency of LEED-certified buildings is 28% more efficient than that of non-certified buildings in the U.S.; and that BREEAM-certified buildings are 25% more efficient in energy performance than non-certified buildings.

[11] BEAM Plus has similar issues in this regard. Yet, it does provide alternative routes and bonus categories which offer a higher degree of flexibilities compared to BREEAM and LEED.

[12] An example provided by BEAM Plus is as follows: SA13 Water Pollution During Construction – 1 credit for undertaking adequate measures to reduce water pollution during construction.

[13] A recent study comparing LEED and BEAM Plus has reached similar conclusions (Chen, Lee 2013).

SM1.3: If a development 1) includes both residential and non-residential buildings or 2) is a composite building, GFA concessions for features serving the residential part or the non-residential part of the development will be calculated separately such that GFA concessions for each part will be capped at 10%, based on the total GFA of the respective part of the development (Buildings Department 2011).

SM1.4: Besides the two documents, the development project is required to comply with 1) the sustainable building design (SBD) Guidelines on building separation, building set back and site coverage of greenery (PNAP APP-152); 2) requirements on Design and Construction Requirements for Energy Efficiency of Residential Buildings (PNAP APP-156); 3) the overall cap on GFA concessions described in PNAP APP-152; and 4) the relevant criteria for the acceptance of individual green and amenity features.

SM1.5: This arrangement differs remarkably from a similar scheme launched by the Building and Construction Authority (BCA) and the Urban Redevelopment Authority (URA) in Singapore. Known as the BCA Green Mark Gross Floor Area (GM GFA) Incentive Scheme, developments which have obtained a Gold Plus (Platinum) rating under Singapore's own Green Mark (GM) certification will be granted additional GFA of up to 1% (2%) over the Master Plan Gross Plot Ratio (GPR) control. Besides, the GFA concessions under the BCA GM GFA Scheme is noticeably smaller than Hong Kong's GFA Concession Scheme with BEAM Plus. (http://www.bca.gov.sg/greenmark/gmgfa.html)

SM1.6: BEAM Plus Version 1.1 was launched in August 2010.

Chapter 2

SM2.1: A major difference between HK-BEAM Version 4/04 and BEAM Plus, with respect to climate change and global warming, lies in the latter's emphasis on the reduction in CO2 emissions. Under HK-BEAM Version 4/04, up to 10 credits are obtainable if the assessed residential building is able to reduce its annual energy consumption by 3–22%. Under BEAM Plus, by contrast, a maximum of 15 credits are obtainable, should the assessed building be able to reduce either its CO2 emissions or annual energy consumption by 3–20%.

Meanwhile, a major difference between Version 1.1 and the original BEAM Plus is the changes in credit allocations.

And in BEAM Plus Version 1.2, a holistic component of Passive Design is introduced as an alternative assessment method (residential developments only).

SM2.2: An additional 15 bonus credits are available for registered building projects, 5 of which in the IA category.

SM2.3: The number of criteria under BEAM Plus is less than BREEAM (114) and LEED (107), but more than Japan's CASBEE (50) and China's ESGB (80) (Lee 2013). In Lee's study, however, his count of BEAM Plus's criteria, is 88.

SM2.4: One possible reason behind the fewer criteria BEAM Plus has, compared to BREEAM/LEED, is due to Hong Kong's humid sub-tropical climate, which could render some of the criteria included in assessments designed for buildings in western nations (such as BREEAM/LEED) not suitable for (or not relevant to) Hong Kong.

SM2.5: "Unclassified" refers to a project which has met all the pre-requisites in the BEAM Plus rating tool but has not reached the threshold scores required for certification (i.e. at least a Bronze rating).

Chapter 3

SM3.1: The authors have raised two possible reasons behind the price discount for eco-labelled condominiums, namely 1) the capitalization of future maintenance costs and 2) the fluctuations in the supply of green buildings.

SM3.2: The report also identifies a price premium of 3–5% is identified for every 100-point change in CPEB (Certificat de Performance Energétique des Bâtiments) in Belgium

SM3.3: One of the subjects in Jayantha and Man (2013) is the original HK-BEAM (rather than BEAM Plus). Nonetheless, as the authors use one dummy variable (GREEN) to include residential flats in buildings certified with either HK-BEAM or the Green Building Award, their respective impacts on property prices thus become obscure.

Chapter 4

SM4.1: The sixteen developments are: The Met Delight, High One, High One Grand, High Point, High Park, Maison Rose, Vista, Gardenia, Milan Place, The Prominence, Hey Home, Court Regence, One New York, Beacon Lodge, Sorentino, and One Madison.

SM4.2: The property price index is derived from housing transaction data used to compile average property prices for stamp duty purposes. The difference between the property price index and the average property prices is that the former is designed to assess property price changes in Hong Kong, with quality kept at a constant.

SM4.3: Heteroskedasticity occurs when the variance of the error term (in a Linear Regression Model/Hedonic Pricing Model) is not constant. This violates the fundamental assumption of the Original Least Squares (OLS). Even though the parameter estimates may not be biased in the presence of heteroskedasticity, the standard errors are biased, thus resulting in bias in test statistics and confidence intervals.

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