UNDERSTANDING THE COST OF GREEN BUILDINGS:

EVIDENCE FROM SINGAPORE

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Summary

Sustainability has become a wide-ranging concept that can be applied to almost every aspect of life. A range of new techniques have arisen to help measure and implement sustainability, especially in the field of green buildings which are designed to minimize environmental impact and resource use. However, the response of real estate market has been slow and the often quoted reason is a narrow understanding on the benefits of sustainable buildings. Another reason is due to the perception that building green implies higher construction cost early in the project. The "green cost" issue, which refers to the idea that green building costs significantly more than conventional construction, has recently become one of the most common objections to this type of development.

This systematic study addresses questions on the construction cost of investments in environmental friendly design, and tries to identify whether there exists a cost premium between green and non-green buildings. This study confirms the existence of green cost premium. The average green cost premium for each rating is 2.45% for Platinum, 1.23% for Gold^{plus}, 1.21% for Gold. Green costs make up 1.6% of total construction costs valued at $2.81 million on average and it increases with the *Green Mark rating*.

Moreover, this study evaluates the impact of BCA Green Mark scheme and its ratings on the construction cost and green cost of building projects. A hedonic regression model is provided that considers three groups of attributes including (1) conventional building features; (2) green features; and (3) market

attributes. These factors include number of building storeys, number of units, total area, property type, familiarity of green design and technology, Green Mark rating, estimated energy and water savings, version of Green Mark assessment criteria, and Building Tender Price Index. It was found that among green attributes, Green Mark rating, especially whether the building is awarded Platinum rating or not, is the most consistently significant variable affecting green cost. Green cost percentages increase with Green Mark rating, but negatively relate to total building area (in terms of *GFA)*. Energy efficiency is an integral part of Green Mark Scheme and also the main focus of developers, at the same time the energy performance is positively and significantly related to green cost. Unfortunately, because of the limited sample, the study did not conclusively evaluate the significance of the variables as expected. Besides, the findings reveal a wide potential for buildings to get greener since only a small portion (36%) of green features have been adopted in the building projects.

The purpose of this study is to shed more light on estimations of the potential costs and provide valuable insight to end users, professionals, research institutions, industry and government with empirical evidence. The results do contribute to the growing knowledge on green building developments and help accelerate the response of the real estate market to the concept of sustainability.

1 Introduction

1.1 Background

Sustainability is a broad concept that can be applied to various contexts, from local to a global scale, from human to other living systems. It is recognized as seeking balance between environmental, social and economic demands or - the "three pillars" of sustainability which challenge conventional economic wisdom. Its wider acceptance maybe trace back to the publication of *Our Common Future* (Bruntland, 1987) in which the United Nation's World Commission on Environment and Development proposed that sustainable development is required to meet human needs without increasing environmental problems. Since then, sustainability has become a top priority for both government and industry (Sturge, 2007; Tesh, 1993).

In dealing with sustainability, governments in different countries implement a series of legislative measures, such as planning and establishing judicial and social regulations. Firms seek to orient themselves as responsible and responsive to environment and society, as well as to consider corporate social responsibility (CSR) in their decision making. CSR has become a normative standard in evaluating firms' choices about inputs (e.g., the source of raw materials), internal processes (e.g., the treatment of employees), and outputs (e.g., community relations) (Waddock & Graves, 1997). Business begins to embrace responsibility for the impact of their activities on the environment, consumers, employees, communities, stakeholders and all other members of the public sphere.

In the 21st Century, sustainability is reinforced due to the threat posed by global warming. The Intergovernmental Panel on Climate Change (IPCC) (Metz et al., 2007) reported that most of the observed temperature increase dating from the middle of the 20th century was caused by increasing concentrations of the human-induced greenhouse gases (GHGs). On February 20, 2007, the Global Roundtable on Climate Change launched "The Path to Climate Sustainability: A Joint Statement by the Global Roundtable on Climate Change", which called on governments to set targets for GHGs and carbon dioxide emissions reduction. More recently, the surging public awareness of sustainability has resulted in a more sustainable lifestyle, which refers to the adoption of recycling and renewable energies. To support measuring and implementing sustainability, various new techniques have arisen such as Life Cycle Assessment, the Ecological Footprint Analysis, and sustainable building approaches (Blewitt, 2008).

In general, the building sector has a dominating impact on the environment, which contributes up to 50% of CO_2 emissions, 40% of energy consumption, 16% of water usage, 40% of solid landfill waste, 50% of raw materials and 71% of electricity demand (Newell, 2008). Therefore, green buildings, which are designed to help reduce environmental impact and resource consumption (Kingsley, 2008), have gained considerable attention since its first appearing on the theoretical stage. It is defined as “the practice of 1) increasing the efficiency with which buildings and their sites use energy, water, and materials, and 2) reducing building impacts on human health and the environment, through better sitting, design, construction, operation, maintenance, and removal” (Cassidy, 2003; Kibert, 2003)—the complete building life cycle, and provide occupants with an environment as healthy as possible. In other words, green buildings provide considerable benefits such as less disruption of local ecosystems and habitats, resource conservation, decreased air, water and noise pollution, superior indoor air quality, increased employee productivity and reduced absenteeism (Larson et al.). In a study by Fisk (2000), green buildings were found to add $20 to $160 billion in increased worker productivity per year. Kats(2003) estimates productivity benefits are ten times the energy savings from green efforts. Of course, such claims of higher productivity require further verification to rule out the possibility of just short term phenomenon or the effect of new environments (Miller et al., 2008).

As a result of these benefits, governments in many countries have attached high importance to green buildings, and announced many legislation and subsidies to promote the movement of voluntary environmental certification systems for new buildings and refurbishments (Kingsley, 2008). Up to now, more than 10 countries have adopted different rating systems for green buildings such as U.S., U.K., Canada, Australia, Italy, Japan and Singapore (see Figure 1- 1). Among them, the most widely used rating system is LEED (Leadership in Energy and Environmental Design). Since its inception in 1998, LEED has rated over 14,000 projects in 50 U.S. states and 30 countries covering 98.7 km^2 of development area. In Singapore, through active promotion and intense educational efforts, the Green Mark Scheme has certified 215 buildings (250 projects in total) from 2005 to 2009(see Figure 1-2), including 31 Platinum Awards, 20 Gold^{plus} Awards, 93 Gold Awards and 78 Certified Awards. In 2009, there are three newly launched schemes, namely, Green Mark for Infrastructure, Green Mark for Office Interior, and Green

Mark for Landed Houses.

Figure 1- 1 Worldwide Green building rating systems

Source: Philip Yu, Green Building and LEED, Taiwan Energy Service Seminar (2007-6-14, Pg16)

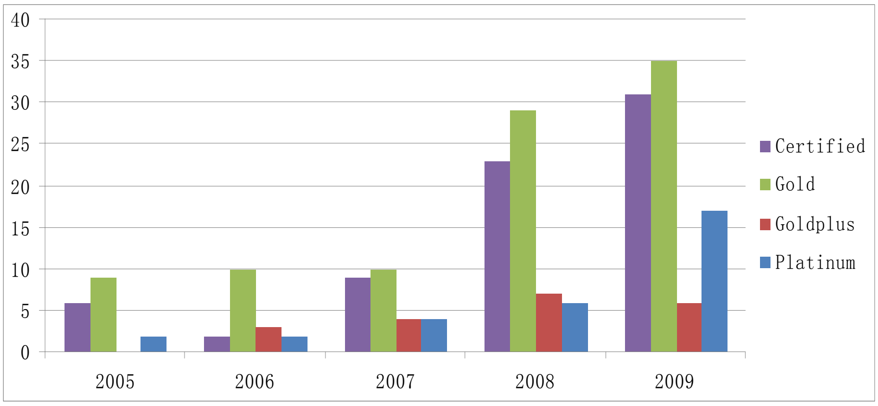


Figure 1- 2 Statistics on BCA Green Mark awards (from 2005 till 2009)

Although many buildings have used BCA Green Mark scheme as a design protocol and measuring standard and then obtained certification, the number of certified buildings began to dramatically increase only since 2008, as shown in Figure 1- 2. In fact, until 2007, only 45 buildings in Singapore have attained the BCA Green Mark award, which only account for a small percentage of the total number of buildings, and merely constitute an insignificant portion of the total built-up area. In New York City, of the nearly 5,000 new construction projects issued in 2007, only 4% registered for LEED certification. Although this study and figures are based in the U.S., a similar situation is mirrored in Singapore. Nevertheless, the response of real estate market is slow. The possible reasons are as follows:

The frequently quoted reason for this phenomenon is a narrow understanding of the benefits of sustainable buildings (Bennett, 2006). Among the benefits mentioned before, the most concerned ones are the perceived higher annual savings, increased rental fee and sales price. These benefits have been confirmed by recent studies, although still call for more empirical verification. Values of green buildings are expected to increase roughly 7.5%, the ROI (rate on investment) by 6.6%, occupancy ratios by 3.3% and the rent ratio by 3% (Green Building Smartmarket report, 2006). Furthermore, a group of studies (Fuerst & McAllister, 2009; Eichholtz et al., 2008; Miller et al., 2008 and a forthcoming paper by Wiley et al., 2008) focused on the effect of environmental certification on sale prices and rents respectively, and they all confirmed that there is sales premium and rental premium when comparing green buildings (LEED and energy star) with similar conventional buildings, although with a wide range from 3% to 35%. The most widely quoted paper among these was conducted by Miller et al.(2008), which provided a general comparison and tentative analysis of these series of papers while all similar studies are still preliminary and some are still in working paper form.

A further reason for this slow reaction is probably due to the lingering perception that building green implies higher construction cost in the early phrase (Wiley et al., 2008), thus leaving less financial profits after compensating the extra expense(Sayce et al., 2009). A study carried out by global construction consultants Davis Langdon and the Urban Green Council found out that this sluggish adoption of sustainable building practices in New York City was stemmed from the perception that building green is expensive. It was found “78 percent of architectural, engineering, and construction respondents to Building Design & Construction 2007 survey believed that going green adds significantly to first costs and in CoreNet Global/Jones Lang LaSalle’s January 2008 survey, 30 percent of respondents believed that new green buildings cost 5 to 10 percent more than conventional buildings, and 22 percent believed that green costs more than 10 percent over the cost of conventional buildings” (Lockwood, 2008, Pg5). In fact, these costs have been overestimated as a result of the general deficiency of published data. Green costs are overestimated by 300% according to a recent survey by the World Business Council for Sustainable Development (2007).

Builders, developers and other industrial sectors have already acknowledged the perceived higher annual savings, increased rental fee and sales price. However, when confronting the slightly higher construction cost, they are still hard to be convinced that green buildings worth the investment. It seems sometimes that their doubts are reasonable. Firstly, the potential annual savings are quite uncertain as they depend a lot on the vacancy rate, daily usage and the facilities performance in the long run. Some researchers have found that the quantities could differ by over than 100%. Therefore, such perceived annual savings are perceived with high risk. Secondly, the annual savings are enjoyed by the occupants and tenants, while builders and developers are generally concerned with the capital cost of constructing green building, and would have little interest in operational cost savings (Intrachooto & Horayangkura, 2007; Larson & Lotspeich). These “split incentives” (Fuerst & McAllister, 2008) hamper the probability of building green. But if the building they are constructing is for their own use, builders and developers will consider the operational cost (Intrachooto & Horayangkura, 2007; Larson & Lotspeich). Even if they concern the operational cost, they will still be worried about whether the increased cost can be compensated by such operation savings, especially how long it will take. This suggests a need to discuss or study more on payback time as it remains a concern of those builders and developers.

1.2 Research Problem

Given energy consumption can cause many environmental problems, and buildings consume most of the energy, there has been a growing interest in green buildings, which are designed to limit resource use as well as environmental impact on the entire life of a building, from resource extraction to disposal, and provide occupants with an environment as healthy as possible. Many countries such as U.S., U.K., Canada, has adopted green building as a design protocol and measuring standard for a building’s environment performance. In academia, large numbers of outstanding papers with regard to green buildings have emerged from different areas like architecture and building, especially since 2006. These papers are concentrated in describing the advantages of green buildings through the comparison with conventional buildings, such as lower depreciation, lower risk, the possible change to capital value and rental price, duration to sell or lease, refurbishment costs and other topics. However, the disadvantages of green buildings are also frequently mentioned by different sectors in industry, especially builders and developers. The “green cost” issue, which refers to the idea that green buildings cost significantly more than conventional ones, has recently become one of the most common objections to the green building development.

The literature review (see Chapter 2) found that:

(1) Previous papers have yet to provide a clear opinion about whether sustainability adds to the construction cost of building projects, and if so, by how much.
(2) Even if the cost premium of green buildings projects has been proven by a few studies carried out in foreign context, more studies still need to be developed in the local market since the cost premium tends to vary in different local markets. However, there is a lack of sufficient published data on the building projects in Singapore.
(3) Among the different approaches for estimating the construction cost, the method that applying descriptive design features instead of quantities, such as size, shape, frame, and location, has been studied in academia for many years, but never been widely applied in construction industry. The method requires little data, and is convenient to use and straightforward to show the individual variable’s effect on cost.
(4) Previous studies compare the construction cost per square meter between green and non-green buildings. However, they fail to consider the impact of other possible factors on construction cost as well, such as the market

condition, despite attempts to exclude the impact of different building features by selecting similar samples to compare with.

Based on these, the research problems are:

(1) There is a need to identify the green cost of building projects in Singapore, and evaluate the impact of BCA Green Mark ratings on construction cost and green cost, and by how much.

(2) There is a need to develop a method that considers both descriptive design features and other possible factors in the model, to apply in both theoretical and empirical analysis.

Therefore, the research problems can be summarized in the following statement:

Is there a cost premium between green and non-green buildings? If yes, how can BCA Green Mark scheme and its ratings affect the construction cost and green cost of building projects in Singapore, and by how much? In what way this impact can be represented in a model for use in theoretical and empirical analysis?

1.3 Research Objectives

The development of green buildings has become a favorite topic in recent years. When designing such buildings, the developers require possessing a comprehensive understanding of assessment criteria and scoring system. To make a more accurate estimation on the potential costs and adjust their design at the early stage, it would thus be of interest to know the factors affecting the construction cost of green building. Therefore, this study addresses questions on the development of green building, examine the green cost and its possible determinants, and essentially focus on the extent of the impact of BCA Green Mark ratings and green performance on construction costs. The objectives of this study are as follows:

(1)To study the Green Mark scheme and Green Mark rating

(2)To identify whether there exists a construction cost premium between green and non-green buildings;

(3)To analyze the impact of Green Mark ratings and green performance on construction costs;

(4)To adjust the conventional cost estimation method to estimate the construction cost of green building.

1.4 Significance of the Study

Due to the growing awareness of sustainability issues, a large number of papers regarding sustainability have emerged in these years, especially after 2006(see Figure 1- 3), which is slower than the demand of developing green buildings.

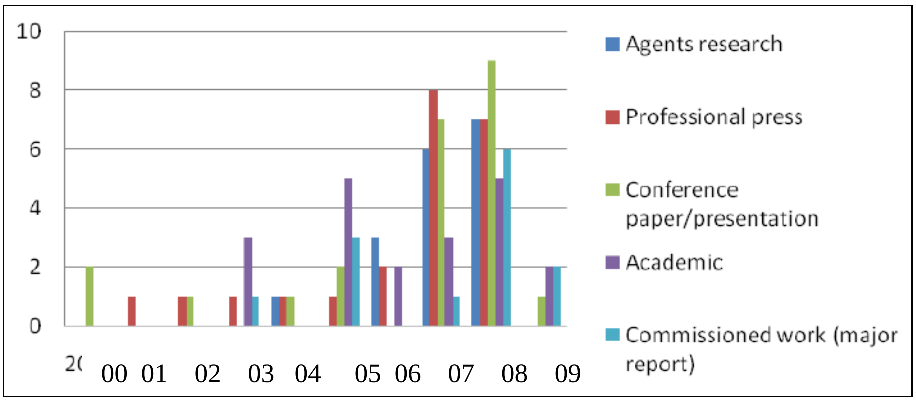


Figure 1- 3 Date and type of the publications (until March 2009)

Source: Sayce et al., 2009, Pg 8

Up to 2009, most publications with respect to green buildings appear in U.S., U.K. and Australia. Of the articles studied by Sayce et al.(2009), only some (18%) did not derive from these countries. Moreover, the rating system discussed in the literature concentrated on LEED, Energy Star and BREEAM (*Building Research Establishment Environmental Assessment Method*) (Figure 1- 4), while for others, "the evidence is not yet there" (Sayce et al., 2009). Therefore, it is not clear whether these research findings can be extended to other countries, or other rating systems, thus suggesting a need to investigate other rating system like BCA Green Mark scheme as it exists in Singapore.

Few papers are written on BCA Green Mark Scheme since it was only introduced in 2005. The only evidence available is some general percentage findings from Building Construction Authority (BCA) to indicate that building green is less expensive than many developers think, although it may still cost more than the conventional buildings (based on several buildings' experience). However, they did not provide the detailed information about the buildings sampled or the methodology used to validate their findings.

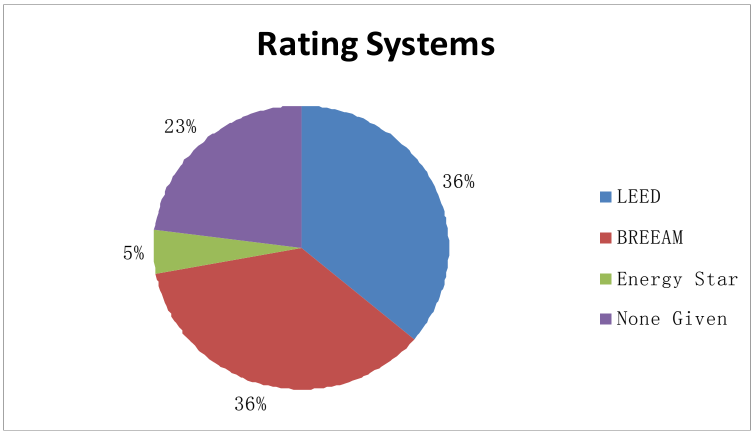


Figure 1- 4 Three main rating systems in literature - BREEAM, LEED, Energy Star
Source: Sayce et al., 2009, Pg 16

Although many studies on construction costs of green buildings have been carried out, the "green cost" issue is unclear or indefinite. The reasons partly lie in that most of these studies are case studies. The conclusions are derived from statistical results with comparing the construction cost per square meter between green buildings and non-green ones, and thus have much local variation that adds to or reduces the marginal costs of going green. They fail to consider the impact of other possible factors on construction cost as well, such as the market condition, despite attempts to exclude the impact of different building features by selecting similar samples to compare with. This study, therefore, goes well beyond case studies and uses a hedonic model to empirically prove the factors affecting the construction cost and the extent of their impacts.

This study aims to provide useful insight to academia, government, and private sector with empirical evidence, help developers and other participants in the property market make more accurate estimations of the potential costs. It is hoped to contribute significantly to the growing knowledge on green building development and help accelerate the response of real estate market to the concept of sustainability.

1.5 Organization of the Study

For the purpose and focus of this study, the research is limited to the building and construction industry in Singapore. This study is organized as follows.

- Chapter 1 contains a brief overview of the research background and research problem, research objectives. It also introduces the significance of this study.
- Chapter 2 presents the literature review conducted on past research works with regard to green cost issues, summarizes the possible determinants of construction cost and green cost.
- Chapter 3 provides complimentary information on the implementation necessary of green building in Singapore.
- Chapter 4 describes various measurements of construction cost and green cost in practice and theory.
- Chapter 5 provides details on the procedure of data collection, definitions of the study variables, sources of the data, and the descriptive statistics for empirical samples.
- Chapter 6 presents empirical findings of the study. The determinants of construction cost, green cost and green cost percentage are tested separately by conducting several linear regressions.
- Chapter 7 further discusses the development of green buildings and BCA Green Mark Scheme in recent years, and the trend of construction cost and

green cost in the near future.

- Chapter 8 concludes the study by summarizing some of the key findings, limitations of the study and future extensions to the current research are also discussed.

2 Literature Review

2.1 Introduction

This part lists previous evidences and conclusions from cost studies with regard to green building. Moreover, it analyzes and concludes the potentially significant factors that determine how much a green building project will cost. Some of them can influence green cost as well.

2.2 Construction Cost of Green Buildings

2.2.1 Definition of Construction Cost and Green Cost

The total cost of a project includes three parts: site acquisition cost, direct construction costs and indirect construction costs (such as consulting fee and certification fee) (Gottfried, 2003).

The term “construction cost” normally refers to direct construction cost, and it excludes the land cost, legal and professional fees, development charges, authority fees, finance costs, loose furniture, fittings and works of art, tenancy work, site infrastructure work, diversion of existing services, resident site staff cost, models and prototypes, future cost escalation, goods and services tax(RLB report).

In the context of this study, “green building” refers to the building which employs the usage of green technologies and features and got certified by relevant departments. Comparably, “non-green building” refers to the conventional and uncertified building. “Green cost” refers to the cost of green, which indicates the cost premium for constructing a green building over than constructing a non-green building.

2.2.2 An Overview of "Green Cost" Issues

The "green cost" issue, which refers to the idea that green buildings cost significantly more than conventional constructions, has recently become one of the most common objections raised to the development of green building (Lockwood, 2008).

The general view of this issue is that the perceived costs of green buildings are higher than conventional buildings', but lower than is often thought. The costs of green buildings were found to be overestimated by 300 %(Johnson, 2007). In the local scene, a thesis recently done by one of my alumni found out that over 50% of the 36 respondents believed that constructing a green building costs 10% more than constructing a conventional building.

Among the research with regard to green cost, one of the earliest empirical and most cited studies was done by Kats(Kats et al., 2003), who filled the gap with the most comprehensive compilation of valuations of green building benefits and costs. With a sample of 33 LEED projects (25 office buildings and 8 school buildings), they found for different LEED ratings, average cost premium of 0.66% for LEED certified, 2.11% for silver, 1.82% for gold, and 6.50% for platinum buildings. Turner Construction (2005) found a similar results with Kats et al.(2003) . They found the number was 0.8%, 3.5%, 4.5%, and 11.5% in sequence. With reviewing a series of green affordable projects, Bradshaw et al. (2005), however, disagreed with previous studies. Their results showed that the Total Development Cost (TDC) Premiums for Greening ranged from -18.33% to 7.25% and the Design and Construction Cost Increases for Greening ranged from -25% to 38.94%.

A recent and authoritative study, came from Davis Langdon (a global construction consultancy), analyzed 83 building projects with a primary goal of LEED certification, and make comparisons with 138 similar building projects without the goal of sustainable design (Matthiesen & Morris, 2006). Surprisingly, they concluded that “many projects are achieving LEED within their budgets and in the same cost range as non-LEED projects” and that “there is no significant difference in average costs for green buildings as compared with non-green buildings”. However, this is consistent with the findings of their earlier studies (Matthiesen & Morris, 2004). A survey done by the World Business Council for Sustainable Development found that green costs, in general, is only 5% higher than the cost of conventional construction (2007). A report done by Davis Langdon (2007) studied the cost of achieving specific levels of green (using the Australian Green Star system) by comparing the budgets of green buildings with similar non-green buildings. The report concluded that there is a 3% to 5% premium for a 5-Star building, with an additional 5% for a 6-Star building. Another cost study assessed the cost of office buildings that are designed to meet a BREEAM Excellent rating and concluded that a 6% premium is due to sustainable design features for the building. With data supplied by USGBC, Miller et al.(2008) proved that there were extra costs to go green (see Figure 2- 1) with wide variation by location (Table 2- 1), but still increased with the LEED rating. Yudelson (2008) estimated the overall cost premium including both design and construction ranges 0% to 2% for LEED certified, 1% to 4% for Silver, 2% to 5% for Gold, 2% to 10% for Platinum.

In the light of Singapore market, the green premiums range from 0.4% to 8%, and are assumed to be paid back within 8 years. These numbers vary with Green Mark Rating, property type and the year of statistics. Table 2- 2 shows the latest prescribed green premium in terms of Singapore dollar per square meter (same thereafter). These numbers are derived from the comparison between each green building with a similar non-green building, and are used for developers to estimate their GM GFA so as to attain additional subsidies from BCA. Since some non-green buildings have green features as well and are also somehow energy efficient, the research need to identify their green features and designs and then set up a benchmark for comparison with green buildings. The mean value and range of green cost and estimated payback (years) for each Green Mark rating are stated separately in Table 2-3 and Table 2- 4. *Payback* describes the number of years for the profits or savings earned by a project to pay back the original outlay, which can be calculated with the following equation, according to Pereira (2004):

$$\frac{\text{Total Investment for Capital Expenditure}}{\text{Annual Savings} + \text{Annual Depreciation}} = \text{Years to Payback} \tag{2.1}$$

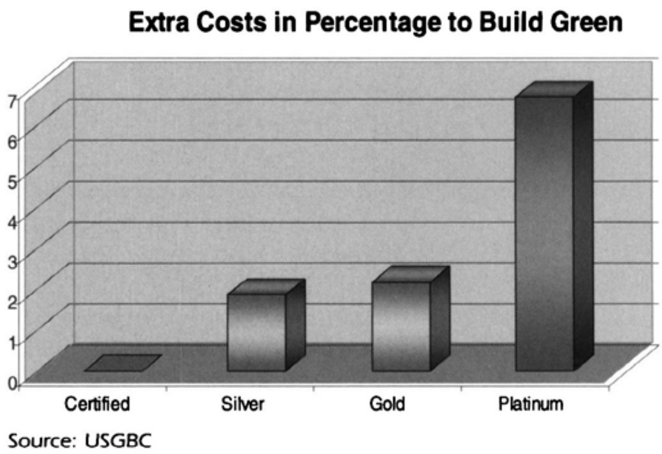


Figure 2- 1 Extra costs to become LEED certified as of 2007 excluding Certification fees

Source: Miller et al., 2008, Pg 391

Table 2- 1 Extra costs to go green vary by region

Source: Miller et al., 2008

Market	Platinum	Gold	Silver
USGBC Ave.	7.8%	2.7%	1.0%
San Francisco	7.8%	2.7%	1.0%
Merced	10.3%	5.3%	3.7%
Denver	7.6%	2.8%	1.2%
Boston	8.8%	4.2%	2.6%
Houston	9.1%	6.3%	1.7%

Table 2- 2 Latest rate of Prescribed Green Premium with effect from 1 September 2009

Source: BCA report, 2008

Classification	Prescribed Green Premium
Residential Platinum	$ 123/sqm
Residential $Gold^{plus}$	$ 92/sqm
Non-Residential Platinum	$ 182/sqm
Non-Residential $Gold^{plus}$	$ 92/sqm

Table 2- 3 Average green cost and payback times for Green Mark developments

Source: BCA report, 2008

Commercial buildings		
BCA Green Mark rating	Average green cost (%)	Average Payback(years)
Platinum	4.0	6.0
Gold^{Plus}	1.8	7.0
Gold	0.7	3.1
Residential buildings		
BCA Green Mark rating	Average green cost (%)	Average Payback(years)
Platinum	3.1	6.1
Gold^{Plus}	1.7	3.1
Gold	1.2	2.2

Note：Sample size is 27.

Table 2- 4 Range of green cost and payback periods by Green Mark rating

Source: BCA report, 2008

BCA Green Mark rating	Green Cost (%)	Payback Period (years)
Platinum	2% to 8%	2 yrs to 8 yrs
Gold^{plus}	1% to 3%	2 yrs to 6 yrs
Gold	1% to 2%	2 yrs to 6 yrs
Certified	0.3% to 1%	2 yrs to 5 yrs

2.2.3 Discussion

The general view on "green cost" issue is that the costs of green buildings are perceived to be a little higher than conventional buildings', but lower than is often thought. There are various studies regarding green cost issue after Kats et al.(2003). Despite the growing body of research and increasing availability of data, the green cost is hard to pin down and is presented as a wide range in previous studies. Some research suggested this green cost is as a result of introducing more expensive (and sustainably-sourced) materials, more efficient mechanical systems and other high performance features, and better design, modeling and integration (Circo, 2007; Kats et al., 2003). Other research thought that this cost increment could be caused by longer time spent on the integrated design and commissioning processes since there are usually many adapting orders during the construction than normal projects. Moreover, some wider but relevant points need to be addressed.

Firstly, most studies with regard to green cost are U.S. based; hence, it is not clear whether these research findings can be extended to other markets and other scheme except for LEED, thus suggesting a need to investigate Green Mark Scheme as it exists in Singapore and several places beyond Singapore.

Secondly, the studies did not distinguish between the various levels of rating but only between rated and non-rated buildings. The results from such research are rather general and unclear. The cost premiums vary extensively, thus resulting in being rather inconclusive.

Thirdly, the strongest evidence has emerged from statistical results which compare the construction costs per square meter between green and non-green buildings. However, they fail to rule out the possible factors affecting the construction cost, such as the market condition, experience in the local market and the project or portfolio scale, despite attempts to exclude the impact of different building features by selecting similar samples to compare with. Other possible impacting factors are further discussed in the next section.

Last but not least, the studies did not differentiate the existing buildings from the new buildings, since the construction cost of existing building only refers to the refurbishment fee.

2.3 Cost Considerations of Green Buildings

Cost of construction on a “per square meter (or per square foot)” basis for houses vary dramatically. It largely depends on several attributes like site conditions, local regulations, project scale, and the availability of skilled trader. De Souza et al.(2007) suggested that many other factors could affect construction cost and calculations of green cost, such as the time limit of a project, financing options and capital structure, increasing fee with regard to risk and uncertainty and materials selection.

In the following part, an attempt is made to identify the factors influencing construction cost and green cost, in the following order: (1) conventional building attributes; (2) green attributes; (3) other attributes.

2.3.1 Conventional Building Attributes

In conventional building cost estimation method, the frequently used factors include number of storeys, number of units, frame type, total area (GFA), built year, and building quality. In addition, their transformations are also been used in the equation, such as construction cost per square foot of building and area per storey. In this section, some of the important factors are discussed in depth.

Frame type

The frame types widely used in building are load bearing, steel, wood, or concrete (see code A, B, C, D in Table 2- 5). Others include pre-fabricated or pre-engineered, steel and concrete, load or wall bearing and steel, load or wall bearing and wood and load or wall bearing and concrete(see codes E–K in Table 2- 5).

Table 2- 5 Code Frame Type

Source: Wheaton & Simonton, 2007

0	Alterations, non-building, etc. without framing
A	Load or Wall Bearing (no further description)
B	Steel
C	Wood
D	Concrete
E	Pre-Fabricated or Pre-Engineered
F	Other Described Framing Types
G	Unknown Framing Type (no description)
H	Steel and Concrete
I	Load or Wall Bearing and Steel
J	Load or Wall Bearing and Wood
K	Load or Wall Bearing and Concrete

Number of storeys

Chau(2007) stated that construction cost should increase with height, since constructing more storeys need more materials and labor. Therefore, a positive relationship is expected between number of storeys and total construction cost. There has been an old controversy on how building height affects construction cost. Literature have historically found the relationship between unit construction cost and the number of storeys was linear (Tregenza, 1972), J-shaped with a turning point at 6 storeys(Flanagan & Norman, 1978), reciprocal (Chau, 1999), and U shaped with a turning point at around 35 storeys(Picken & Ilozor, 2003). The non-linear relationship could due to "the cost of some fixed components of a building (e.g., roofs, foundation) fall initially as the number of storeys increased" (Chau et al., 2007). Moreover, Schriver and Bowlby (1985) found unit construction costs increased with the number of storeys, but decreased with total floor area.

Property type

Matthiesen and Morris (2004) found construction cost is affected by property type and varies a lot within the same rating, but there is no significant statistic difference between green and non-green buildings.

Project size

Yudelson (2008) suggested that project size has a negative relationship with cost premium. A smaller project may have a higher cost premium because certain of the costs of LEED have fixed-cost elements independent of project size that will add to the cost per square foot.

2.3.2 Green Attributes

As discussed in last section, conventional features largely decide the overall amount of a building project. At the same time, the costs are also increased by incorporating sustainable design - the “green features”, which is discussed later in this section. This group of factors has a wide range, including the familiarity of the project team with sustainable design, certification level required, building performance and the changes of assessment criteria. “In most cases, these factors have a relatively small but still noticeable impact on the overall cost of sustainability. Cumulatively, however, they can make quite a difference.”(Morris, 2007, Pg 55)

The familiarity of green design and technology

Construction cost may be perceived higher if the contractors are unfamiliar with sustainable design and thus overestimating the risk they may face or if the contractor may be less willing to bid on “difficult” projects since they have so much other work to do (Matthiesen & Morris, 2004). Similarly, Kats et al.(2003) also thought the relative newness of green technology may add uncertainty when estimating the construction cost.

The familiarity of green design and technology can be represented by the year of “green” experience of the developer or the number or project they have completed, and assumed to have a negative relationship with construction cost. Kats et al.(2003) found many states in U.S. had experienced a trend of declining costs associated with increased experience in green building construction. This finding was confirmed by Geof et al. (2003). Based on 50 green building projects’ experience of KEMA Xenergy(a company)’s, Geof et al. (2003) concluded that the cost of a company’s first LEED project was far more than their subsequent projects and the incremental cost of LEED decreased over time. Figure 2- 2 shows the trend in incremental cost for meeting LEED Silver in Seattle over 4 years. As can be seen, the cost premiums for many LEED Silver buildings have declined from 2000 to 2003, no matter what the sizes of the projects are. The reason of this decline has been explained as: the company may spend money on “developing a waste management plan, finding a list of acceptable low-VOC finishes, or establishing appropriate contract documents” (Geof et al., 2003); therefore, the start-up of a company’s green building program and training cost a large fraction of the whole expenditure.

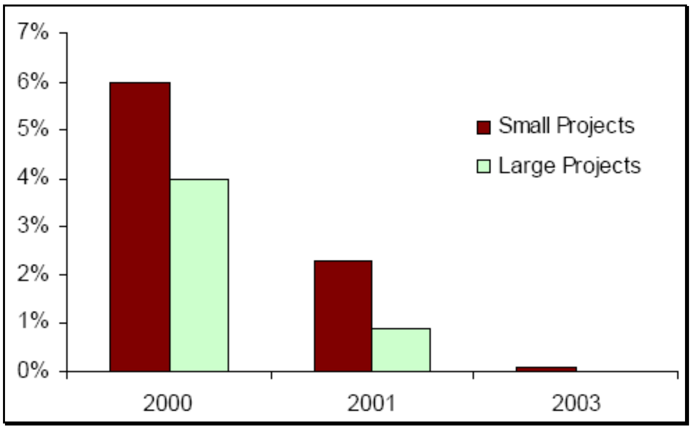


Figure 2- 2 Trend in incremental cost for meeting LEED Silver in Seattle over 4 years (data not available for 2002)

Note: Large projects (over $10 million); Small projects (under $10 million)

Source: Geof et al., 2003

Certification level required

Level of the certification sought is clearly an issue. As approaching to higher levels of certification, even with an integrated design process, the overall cost are likely increased by adding better elements such as green roofs, photovoltaics, and certified wood products. A large number of studies need to be done before the design phase, for example, natural ventilation analyses, computational fluid dynamic studies, more frequent energy modeling and others. In some cases, building in Platinum rating can possibly be accomplished for zero or low cost premium. Based on available data, Kats et al.(2003) found the rising cost levels associated with more rigorous levels of LEED. And they also perceived LEED Gold may be the most cost effective design objective for green buildings. Accordingly, this study examines the construction cost as well as its relationship with Green Mark rating, and at the same time evaluates whether there is an optimal strategy of rating selection.

Estimated energy savings and water savings

Estimated energy savings and water savings reflect the general efficiency of the green design, and they have been listed as two of the key green features for green buildings in BCA Green Mark annual report. Circo (2007) found construction costs increase by 3-5% because of the adoption of energy efficiency facilities. The second Info Data report in a series of Davis Langdon's insights into Sustainability (Davis Langdon, 2007) found that energy improvement and water efficiency are the most important attributes that drive the green strategies and promote the development of energy centric approaches and water centric approaches. Moreover, due to the pressure of reduction on carbon dioxide emission, many regions in different countries implemented a carbon tax, such as Australia, Canada, New Zealand, California and Colorado in the U.S., and some countries in European Union. According to BCA, Energy saving is calculated as:

$$\textit{Energy saving } (\%) = \textit{Reference model's annual energy consumption} - \textit{Design model's annual energy consumption} \quad (2.1)$$

Where the Reference Model must be the same as the Proposed Model in shape, size and orientation.

The updating BCA Green Mark Scheme

BCA Green Mark Scheme has kept updating its assessment criteria since its inception in 2005. Up to now, there are several versions of assessment criteria that have been employed in green building assessment. Based on the analysis in Chapter 7, the updating of BCA Green Mark Scheme caused the differences in building performance and therefore affects the construction cost. To represent the differences among several versions of assessment criteria, a dummy variable "*Greenmarkversion*" is included in our regression model, which equals to 1 means the version of Green Mark assessment criteria is not the newest one. Detailed discussions are presented in Chapter 7.

Different selections of green features

Different selections of green features could affect both the construction cost and green cost. A detailed analysis on this factor is presented as a part of results in Chapter 7.

2.3.3 Other Attributes

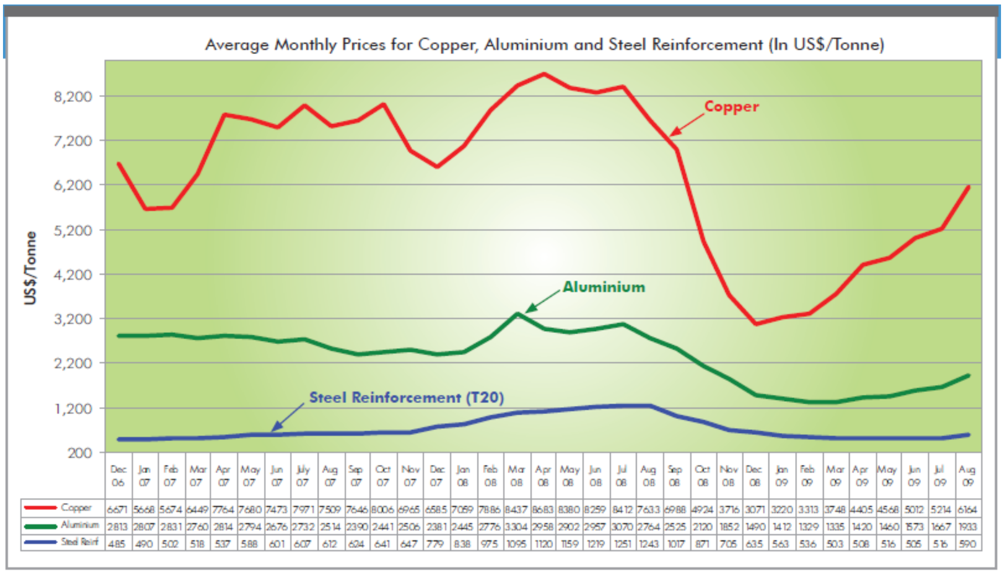
Since Singapore is a city-state, it is unnecessary, like the other countries do, to consider many aspects of differences within the country like local standards or climate. The attributes considered in our analysis are as follows.

Demographic Location

In U.S. and other countries, there is a difference in cost and feasibility between rural and urban area. Due to Singapore's small size, only difference exists between within CBD and out of CBD. Since construction cost excludes land cost, it is unnecessary to consider location in our study. However, construction cost still differs by site condition and project location (Morris, 2007). For instance, the west facing façade will gain more heat, while north or south facing windows can help ventilation. If the building is quite close to the main road, the windows must add the design for avoiding noise. All these differences will eventually increase the cost.

Material prices

Material quantities survey is the fundamental procedure when contractor estimate cost of a proposed building; hence, basic material and commodity prices affect the construction costs. Generally, the materials used in construction mainly contain two parts. One part is the basic construction materials, including Ready-Mixed Concrete, Cement, and Steel Reinforcement Bars (see Table 2- 6 and Table 2- 7). The other part is metal, mainly including Copper, Aluminum, Steel Reinforcement (see Figure 2- 3), wherein the copper price has changed dramatically over the last two years. However, the difficulty of this study is that the data about the exact amount of each basic material consumed by each building is not available, since most of the green building projects are under construction. Therefore, the material price is solely used instead of the entire cost on materials ($\sum$ *Price for Material (i)* ×*Quantity (i)*), as one attribute into the model to estimate the construction cost. Because material prices are time-series data (see Figure 2- 3), while construction costs are panel data, the price change over time cannot be reflected. However, the estimated cost data is predicted by the contractor using the materials price in the award year or the year before award year. Therefore, the price for each material both in the award year and the year before award year is used into our model to see its impact.



Data Source: London Metal Exchange, BCA and RLB

Figure 2- 3 Metal Price Movements

Source: RLB research and development quarterly report, 2009, 9(47)

Table 2- 6 The demand for Basic Construction Materials in 2008 and 2009

Materials	Demand		% Change
	2008p (Net Imports and Production)	2009f (Based on Construction Output)	
Ready-Mixed Concrete	9.9 mil m^3	11.4 mil m^3	15%
Cement	4.4 mil m^3	5.1 mil m^3	16%
Steel Reinforcement Bars	1.3 mil tonnes	1.5 mil tonnes	15%

Table 2- 7 Market price for Basic Construction Materials in 2007 and 2008

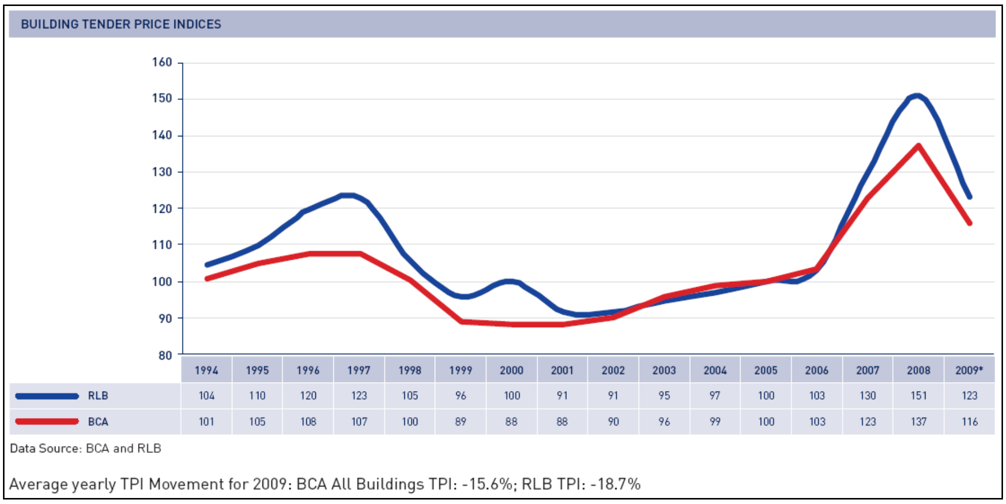
Materials	Market Price		% Change
	Dec 07	Dec 08p	
Ready-Mixed Concrete	\$127 per m^3	\$121 per m^3	-4.7
Cement	\$115 per tonne	\$123 per tonne	7
Steel Reinforcement Bars	\$1,055 per tonne	\$1,050 per tonne	-0.5

Building Tender Price Index (TPI)

Market condition is vital to the construction industry, and therefore influence the construction cost of a project. Because of the global economic slowdown, availability of new construction projects in Singapore has declined noticeably in 2009, particularly for the private sector. In fact, compared to other major cities in Asia, Singapore experienced a sharper decrease in construction cost from 2007 to 2009(RLB research and development quarterly report, 2009, 6(46)).

De Neufville et al. (1977) employed market conditions index to form their "good years" and "bad years" to study the bidders aversion to risk when dealing with small and large projects, and when operating in good years or bad. Here, the market conditions index was derived by dividing the tender price index for any given quarter by the building cost index for that quarter, and it reflected the buoyant of the market. Above the midpoint index was defined as "good year" and below as "bad year". Thereafter, in1999, Gunner and Skitmore (1999) used an essentially same technique in his comparative analysis of pre-bid forecasting of building prices.

In the local scene, the Tender Price Index is more applied than the market condition index in either industry or academia; therefore, it is used in this study as a reflection of market condition. With the data taken from actual tender prices, the Tender Price Index (TPI) reflects the movement of construction cost by years, combining the impact of the price changes of materials, manpower, plants & machinery, and overheads and profits. Both RLB (Rider Levett Bucknall LLP) and BCA publish their TPI every quarterly. Due to the differences in methodology and sample, there is variance between two indexes, as shown in Figure 2- 4; however, both the two indexes show the same trend. As can be seen from the trend, before the financial crisis, the TPI keeps increasing since 2001, especially moved up significantly after 2006. Since the TPI has already considered the material changes in their calculation, it is unnecessary to consider the material price factor again; otherwise multicollinearity problem will be caused. In our regression, the average number of RLB and BCA index are used to describe the market factor, as shown in Table 2- 8.



Notes: Variances between the RLB and the BCA Tender Price Index arise from differences in the index derivation methodology, the basket of items and weightages used for each index and the variety of building projects utilised. The index basket here excludes piling works and Mechanical & Electrical services.

Starting from the publication of 2009 indices, the BCA and RLB Tender Price Index are adjusted with a **new base year of 2005 (i.e. 2005 index = 100)**.

* Average indices as of 4th Quarter 2009.

Figure 2- 4 Building Tender Price Index (Year 2005=100)

Source: RLB research and development quarterly report, 2010, 3 (49)

Table 2- 8 Mean values of Building Tender Price Index by year

	RLB	BCA	Average
2005	100	100	100
2006	103	103	103
2007	130	123	126.5
2008	151	137	144
2009	123	116	119.5

Note: Building Tender Price Index is adjusted with a basic year of 2005(Year 2005=100).

2.4 Summary

This chapter provided a comprehensive review of literature in green building cost studies. It concluded the determinants of construction cost and green cost, including number of storeys, number of units, total area, property type, familiarity of green design and technology, Green Mark rating, estimated energy and water savings, version of Green Mark Scheme, and Building Tender Price Index. The review is helpful in developing a cohesive theoretical and analytical framework for the estimation of construction cost and green cost of new buildings.

3 Green Building: A Solution for Energy Problem

3.1 Introduction

BREEAM (BRE Environmental Assessment Method) was introduced in the U.K. as a voluntary measurement of the sustainability for new non-domestic buildings. LEED (Leadership in Energy and Environmental Design) is a globally recognized Green building assessment system. Since its inception in 1998, this system has been used in over 14,000 projects in the U.S. and 30 countries as a framework to identify and implement green building design, construction and maintenance related solutions. Compared to the markets in the U.S. and U.K., the practice and policy are still relatively underdeveloped in Singapore since BCA Green Mark Scheme was just launched in 2005, which aims to help the movement of environmental friendly buildings in Singapore's construction industry. This chapter provides a general review of the energy problem and regulatory background that pertain to the implementation of green building in Singapore.

3.2 Energy Intensity in Singapore and Related Measures to Achieve Energy Efficiency

Energy intensity is usually used as an indication of the level of energy efficiency in a country and is measured in terms of energy consumption per dollar of gross domestic product (GDP). Low energy intensity means that the country is able to produce each unit of output using less energy. Based upon the results from EIA's International Energy Statistics and IEA's Key World Energy Statistics, the energy intensity for Singapore in 2006 is higher than other developed countries including Finland, Australia, U.S. Japan and U.K., and even the world average, although Singapore's energy intensity has dropped by 15% from 1990 to 2005.

In the light of these statistics, it is observed as a crucial issue to increase the energy efficiency and at the same time reduce the amount of pollution given off (EPA, 2004)). The Inter-Ministerial Committee on Sustainable Development (IMCSD) recently released the second master plan for green construction for the next 20 years. The plan sets a target to reduce energy intensity by 20% from 2005 levels by 2020 and by 35% from 2005 levels by 2030. To help Singapore meet the targets, National Environment Agency (NEA) established a multi-agency committee named the Energy Efficiency Programme Office (E^2PO), whose brand is "fight climate change, conserve energy, and save money". E^2PO aims to promote energy efficiency in various sectors through the Energy Efficient Singapore (E^2 Singapore) policies and measures (shown in Appendix Table 1).

Singapore is an equatorial country with relatively uniform temperature and high humidity. The daily temperatures range from 22 °C to 34 °C and the average daily relative humidity is about 84.3%. "Most of the 2.07 million employees are working in air-conditioned spaces that are cooled and de-humidified so as to achieve higher work productivity."(Lee & Rajagopalan, 2008). In 2005, buildings used 0.9% of the total fuel consumed and 31% of the total end-use electricity consumed (see Figure 3- 1). Given Singapore's hot and humid climate, it is reasonable that the demand of building forms a large part of energy consumption. Once a building is constructed, energy is consumed during the operation of the building. The energy cost directly affects the bottom-line of tenants and building owners (Eichholtz et al., 2009). As Singapore is a city-state with limited natural resources, it is important for buildings to be energy efficient. This is also suggested by a report from National Climate Change Strategy. The government in Singapore has taken the lead in promoting environmental sustainability and friendliness. They have initiated several funding and incentive schemes regarding green building (shown in Appendix Table 2).

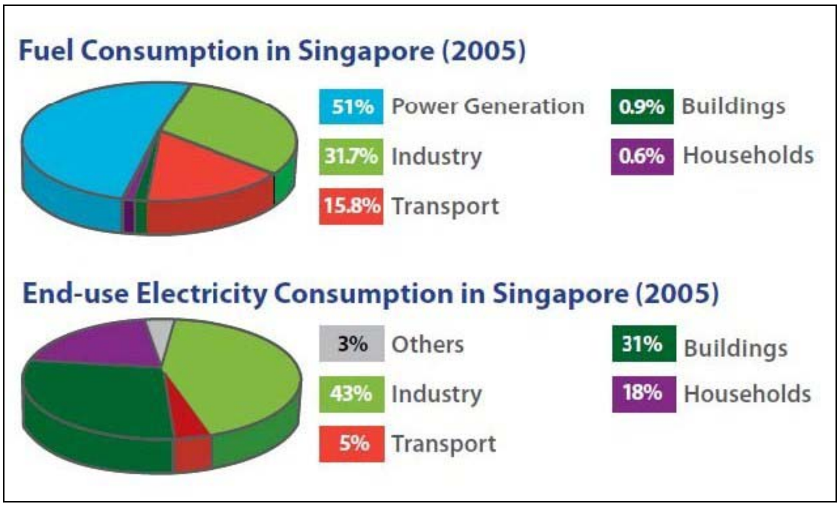


Figure 3- 1 Energy consumption in Singapore (2005)
Source: E^2 Singapore, Pg6

Governments in different countries are taking many legislative measures to achieve energy efficiency in buildings, such as requiring all government buildings to be green, providing information on green buildings to the private sector, and offering subsidies to those who build green. Governments in the U.K., for example, have introduced planning legislation, building regulations and social legislation to implement sustainability (Sayce et al, 2010). Within the U.S., many local governments have adopted LEED incentive programs, including tax credits, tax breaks, density bonuses, reduced fees, priority or expedited permitting, free or reduced-cost technical assistance, grants and low-interest loans (USGBC, 2007, Summary *of Government LEED Incentives*).

In fact, energy efficiency has recently been one of key triggers to adopt Green building, and became the main focus of many building consultants. On one hand, there is a wide potential to save energy, since energy is wasted in many of the buildings because of inefficient design and neglected operation (Geof et al., 2003; Lee & Rajagopalan, 2008). Energy efficiency is the most visible change compared with other features; hence, its improvement can be adopted by clients most easily. On the other hand, energy is the most profitable area, which may come from two sources. One comes from the energy savings. The more energy efficient equipment they adopt, the more money they will save. The other is from the energy trading. Energy savings can be transferred to Carbon credit and sold in European market, thus making money for the building owners.

3.3 BCA Green Mark Scheme

Due to the rapid economic growth and urban population expansion, Asian countries such as Singapore, China, and India are looking forward green buildings to preserve their resources and environments. To solve the energy problem and achieve energy efficiency in buildings, the governments in Singapore introduced BCA Green Mark Scheme in January 2005. Derived from LEED, BCA Green Mark Scheme aims to move Singapore's construction industry towards environmental friendly buildings, and provides a comprehensive framework for assessing building performance and environmental friendliness. Buildings are awarded the BCA Green Mark based on five key criteria (Figure 3- 2):

- Energy Efficiency
- Water Efficiency
- Site/Project Development & Management
- Good Indoor Environmental Quality & Environmental Protection
- Innovation

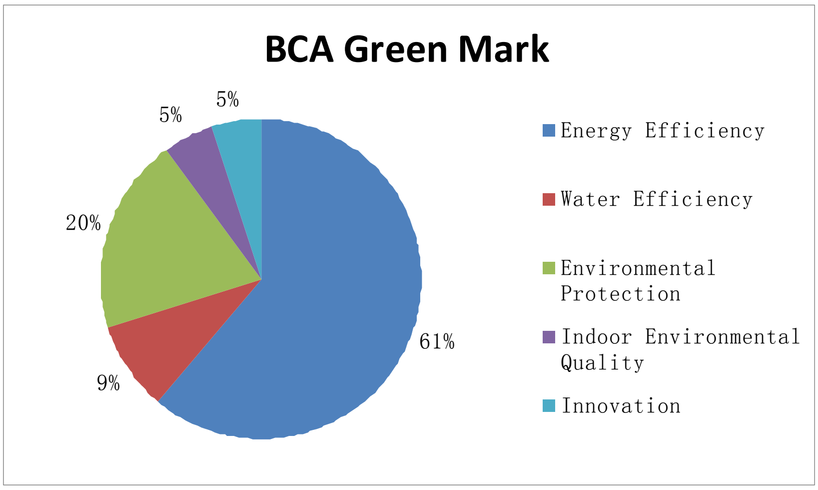


Figure 3- 2 Five key criteria in BCA Green Mark and their percentage in total score

The assessment process consists of an initial assessment leading to Green Mark award. Points are given when the design meets specific targets. Based on the total points obtained, buildings are rated Platinum (90-100), Gold^{Plus}(85-89), Gold(75-84) or Certified(50-74), which provides an indication of the environmental friendliness of the building design. In addition to achieving the minimum points in each rating scale, the project has to meet all prerequisites, and score at least 50% of the points in each category except the Innovation category.

Green Mark for buildings includes four categories: Residential New Buildings, Non-Residential New Buildings, Non-Residential Existing Buildings, and

Landed Houses (newly launched). New buildings are required to have triennial assessment, which is to ensure that the Green Mark building continues to be well-maintained. The scheme for existing building will enable building owners and operators to meet their sustainable operations goals and to reduce negative impacts of their buildings on the environment and occupant health over their entire life cycle. From 2008, all new buildings and existing buildings undergoing major retrofitting works with gross floor area (GFA) above 2000m^2 must meet the Green Mark certified standard. Moreover, in the Sustainable Singapore blueprint the government has set a target for 80% of the existing building stock to achieve at least Green Mark Certified by 2030. As a respond to the new regulation, new buildings account for 86% of 85 awarded green buildings in 2009.

Up to 2009, 215 building projects (250 in total) have been awarded by Green Mark, including 31 Platinum Awards, 20 Gold^{plus} Awards, 93 Gold Awards and 78 Certified Awards. Their regional distribution can be seen in Figure 3- 3. Beyond Singapore, Green Mark building projects have spread many countries in these years, such as India, China, Malaysia and others (see Figure 3- 4).

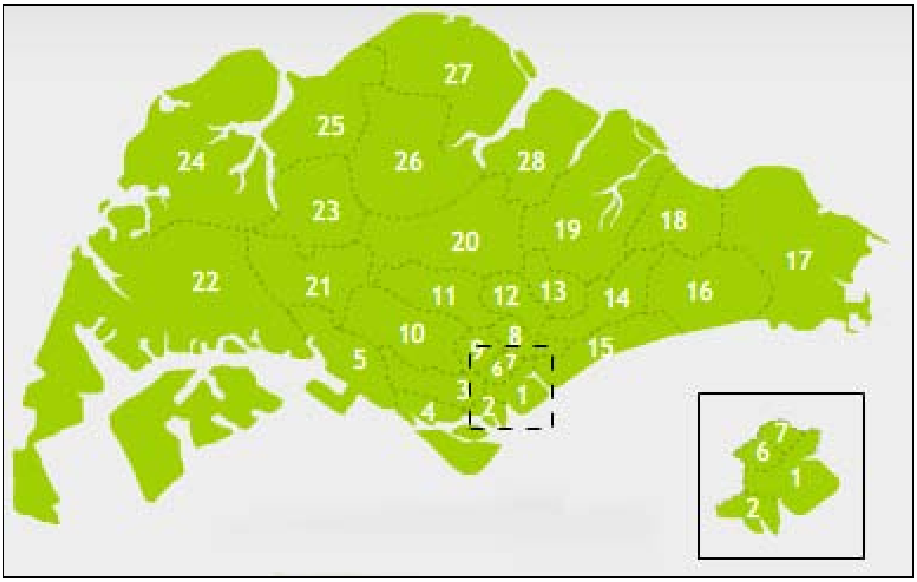


Figure 3- 3 BCA Green Mark - In Singapore

Source: Green Mark website (http://greenmark.sg/index_ci.php/buildings/search)

Figure 3- 4 BCA Green Mark- Beyond Singapore

Source: BCA report

3.4 Summary

This chapter provided complimentary information on the implementation necessary of green building in Singapore. The energy intensity of Singapore is higher than other developed countries and the world average, which means that more energy is consumed for producing each unit of output. A large proportion of energy consumption is actually from the demand of buildings likely due to Singapore's hot and humid climate. Since the way of constructing a building directly affects the bottom value of energy consumed by tenants and building owners, it is vital and necessary to adopt green building in Singapore. Green buildings provide benefits on facilitating reduction in water and energy bills, reducing potential environmental impact, improving indoor environmental quality for healthy and productive workplace, and providing clear direction for continuous improvement. Governments have taken a range of legislative measures to promote the widespread adoption of green building, especially the BCA Green Mark Scheme, which serves as a comprehensive framework for building performance assessment and provides a clear direction for further improvement. Its inception can facilitate the movement of Singapore's construction industry towards environmental friendly buildings. Based on the five key criteria, the buildings are rated to four ratings include Platinum, Gold^{plus}, Gold and certified, or otherwise suggested to resubmit for assessment. Until now, over 300 buildings have been awarded by Green Mark and the footprint of Green Mark Scheme has spread many other countries beyond Singapore.

4 Research Methodology

4.1 Introduction

The construction industry comprises developers, project managers, architects, structural engineers, M&E engineers, main contractors, quantity surveyors and other specialized consultants. It comprises subcontractors, skilled tradesmen and unskilled workers as well in one or a number of fields of activity.

As noted by Hillebrandt(2000), the construction industry has many features that are found individually in other industries, but combine and interact with each other; hence, the industry is made rather difficult to plan for, forecast, manage, and control. These features include: high cost of product, time delays, impact of technology, problems such as slow decision-making, misunderstandings and conflict between the various parties, poor management, illegal and unethical activities. Due to these features, some major projects can take 3 to 5 years (or longer) to complete from the decision to build to handover of the final building. Cost estimation in the early stage plays an integral role in the whole construction process.

There are two kinds of cost estimation methods: one is quantity survey that is widely used in the industry, while the other is regression model used within research field. These two methods seldom interact with each other because of the different application stages and different people they are served for. Section 4.2 reviews and compares these two methods, which serves as background information to provide the practical basis for the theoretical method. Section 4.3 presents two methods used in the measurement of green cost.

4.2 Measurement of Construction Cost

4.2.1 Introduction

“Cost models are technical models used to help in evaluating the monetary consequences of building design decisions.”(Maver, 1979) It can help to judge whether the design or the proposal is within budget and optimize the utility of money. Building cost estimation methods can be classified in many ways. One of the most significant classifications is based on the degree of project definition, which is the percentage of completed architectural and engineering designs (see in Figure 4- 1).

Owner’s conceptual estimation (as shown in Blue Text Box in Figure 4- 1) usually has a wider range than contractor’s detailed estimation (as shown in Orange Text Box in Figure 4- 1). It happens that the contractor’s bidding price is quite far from owner’s initial estimation at the early stage. Therefore, to avoid this situation, there is a need to develop a model that can be used for owner’s conceptual estimation and that can provide more accurate estimation of budget during design stage as well, so that the owner can adjust their design or certification target and know better about the feasibility of their plan in the design stage.

In some cases, bidders purposely submit a price lower than their estimation in the bidding stage to get the project. As the project goes on, the contractor requests the owner to increase their investment since the project is estimated (see *Contractor Progress estimate during construction* in Figure 4-1) to excess the initial budget, which is their bidding price (known as *Contractor detail estimation*). When this occurs, the whole construction will be prolonged and at the same time cost will be incurred. The reason for this situation may be due to the "the lowest tender price wins" system which is usually adopted in the construction industry, no matter whether the price is reasonable. There is a gap between the owner's expectation (*Engineering Estimate-90% Completion*) and contractor's bidding price(*Contractor detail estimation*), which means that the owner's expectation usually has a wider accuracy range, so that it becomes more difficult for them to ascertain whether the lowest bid price is reasonable. This situation suggests a need to develop a model that can help owner make a more accurate estimation about the construction cost of their building and can used to assess the feasibility of contractor's bidding price. With such model, the owner can better supervise and improve the overall economy of the project, and ensure quality in addition to controlled timeline and budget.

A theoretical model used in research can probably fill up the accuracy gap between owner conceptual estimates and contractor detailed estimation by quantity survey. The research models are believed to be less accurate than the engineering methods. However, it requires little data, and is convenient and straightforward to show the individual variable's effect on cost, and therefore can be used for advising in design stage.

This study builds up a regression model with sample of contractor estimated cost data. In the following, first, a closer look is taken at the different estimation methods used by developers and contractors. Then, the regression models used in previous cost studies are concluded in this study, so as to provide the basis for our model developments and empirical analysis in Chapter 6.

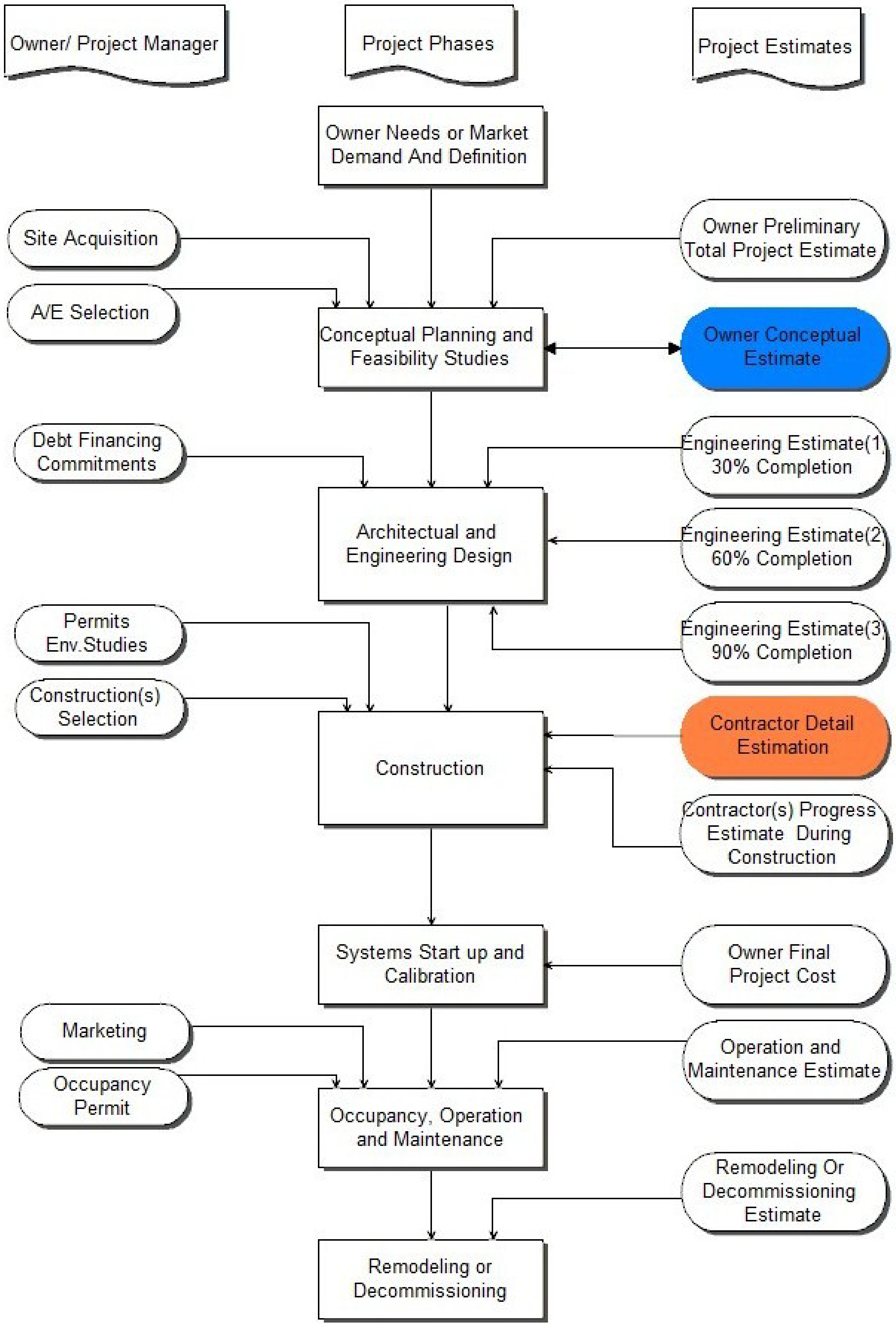


Figure 4- 1 Project Life Cycle Estimates

Source: Popescu et al., 2003, *Estimating Builidng Costs*, Pg 57

4.2.2 Cost Estimation- Practical Method

In the early stage, the developers use relatively simple methods to conduct a conceptual estimation. This method requires that the estimator complete the several steps (Mark et al., 2006; Marston, 1999; Popescu et al., 2003; Smith, 2007), which are:

1. Determine the usable area of the building, number of units or occupant units (e.g., cars in a parking garage, beds in a hospital, students in a high school, etc.).
2. Determine the standard average costs per unit area, which are selected from the most recently published standards for the type of building that most closely matches the project.
3. Adjust regional factors, time factors (usually inflation) considering the midpoint of the construction phase (months from the date of estimate).
4. Adjust cost by unusual characteristics, special requirements for interior and exterior finishes, specialized fixed equipment or systems not accounted for in the "standard".

In other words, the construction cost can be conceptually estimated with the following formula:

Construction cost =Average cost per sqm 【2】 × *Gross area* 【1】 *(or Average cost per unit* 【2】 × *Number of Units* 【1】*)* × *Quality factor* 【4】 × *Location factor* 【3】 × *Time factor* 【3】 × *other adjusting factors* 【4】 (4.1)

Notes:

1. Quality factor represents 3 classes, including low, good, or best;
2. "【】"denotes the step number mentioned above that was used to determine the factor.
3. Time factor is estimated as the following formula:
   Time factor = Index for Year B / Index for Year A
   (Or, cost in Year B= Index for Year B / Index for Year A × cost in Year A)
   Where *Index* represents Building Tender Price Index (TPI).

However, published standard data or average cost per unit area that can be used for simple estimation is unavailable for new green buildings. The possible methods instead are either summarizing new standard data for this bench of buildings-green buildings, or making several necessary adjustments for those special green features. Since the former requires large quantities of data to support, the latter may be more feasible.

Apart from the simple conceptual estimation method, contractors usually rely on the detail cost estimates. This study collects the tender price instead, which refers to the lowest bid price submitted by all the contractors after they complete quantity survey and other detailed estimation. This kind of cost data can be called contractor detail estimated cost, as shown in Red Text Box in Figure 4- 1. For this kind of estimation, traditional models generally take the form:

$$P=p1+p2+\dots pn=q_1r_1+q_2r_2+\dots q_Nr_N \qquad (4.2)$$

Where:

P = total estimated cost;

p = individual cost;

q = quantity; and

r = price of individual resource, e.g. labor, material, plant etc.

These models are reliable and have been widely applied in engineering estimation by quantity surveyors. Compared with the conceptual estimation, this estimation is more accurate and has a stricter expected accuracy range. As seen from Table 4-1, there is an accuracy gap between the owner's expectation and contractor's bidding price.

Table 4- 1 Building cost estimates comparison

Estimate class	Scope	Project definition % A/E complete	Beneficiary	Expected accuracy range (%)	Methodology
Conceptual estimate	Feasibility study	<10	Owner(s), Financier	-25, +50	Historical information
Contractor detail estimation	Bidding contractor(s) construction budget	100	Financier, Const. Mgr. Owner(s), Contractor, Subconstractors	-5, +10	Detail quantity take off Detail unit price estimate

Notes: Estimate accuracy is an indication of the degree to which the future final (true) cost of a building varies from the estimate prepared earlier.

Source: Popescu et al., 2003, *Estimating Builidng Costs,* Pg 56

4.2.3 Cost Estimation- Theoretical Model

The approach used in cost model research for many years is based on the idea of using descriptive features of a design instead of quantities, such as size, shape, frame, and location.

Hedonic regression analysis was used to examine construction costs in the residential market by Somerville (1999). Actually, hedonic regression analysis is a revealed preference method of estimating rent and price, and is commonly used in real estate appraisal, real estate economics and Consumer Price Index (CPI) calculations. After Rosen (1974), hedonic equations have been widely applied to many product differentiated markets (Brown & Rosen, 1982), including single family house prices (Palmquist, 1984), and then to commercial rents and prices (Wheaton & Torto, 1994).

Regression or multiple regression analysis is usually powerful statistical tool that can either analyze or predict the impact or contribution of potential new items to the overall estimation. It can be represented in the form:

$$Y=a+b1X1+b2X2+\ldots+bnXn \quad (4.3)$$

Where:

Y = the predictor;

X1..Xn = measures of some characteristics that help to predict Y.

A few major assumptions are necessary:

1. The values of predictor variables are exact;

2. There is no correlation between the predictor variables;
3. The actual observations Y are independent over time; and
4. The error term is independently, randomly, and normally distributed with a mean of zero.

In terms of building cost estimation, this implies:

(1) The costs data are exact rather than approximate.
(2) The tender prices for one contract are not affected by the tender prices for the previous contract.

Several options can be used to create a hedonic regression model (Cropper et al., 1988), such as linear and semi-log form of *COST* or *COST/SF*. Semi-log models seemed to produce the best results in previous studies. However, there is a debate on whether *COST or COST/SF* as the dependent variable provides the best results. The former produces better fits, while the latter tends to have more normally distributed errors. Wheaton and Simonton (2007) tested each of the different regression models in their analysis and it turns out that the semi-log regression of *COST/SF* produced the best statistical results in terms of parameter significance.

Wheaton and Simonton (2007) used the natural log of cost(in terms of dollars) divided by total area (in terms of total square footage) of the project, ln(*COSTSF*), as a dependent variable, and conducted a semi-log regression model to estimate the relationship between building's construction cost and its construction features. Their results of the hedonic regression for the sample were statistically significant with R square values ranging between 0.64 and

0.86 for the six apartment regressions and between 0.50 and 0.65 for the office markets regressions. The log linear model estimated is hence:

$$\text{Ln}(COSTSF) = \alpha_0 + \alpha_1 STOREY + \alpha_2 UNITS + \alpha_3 AREA + \sum \beta_i FRAME + \sum \beta_i YR_i \quad (4.4)$$

Where:

COSTSF	=	Construction cost per square foot of building;
STOREY	=	Number of storeys;
UNITS	=	Number of units in the project (apartment regression only);
FRAME	=	Dummy variable for type of construction, steel frame, concrete, load bearing, or wood;
AREA	=	Square feet of building in 1000s;
YR_i	=	Dummy variable for each year; and
α,β	=	Estimated statistical parameters.

Another model related to this field is the one developed by Chau et al.(2007). To study the relationship between construction cost and building height, two linear models are used for estimation. The models are as follows:

$$C = \beta_0 + \beta_1 H + \beta_2 H \times FP + \beta_3 FP + \beta_4 PRI + \varepsilon \quad (4.5)$$

Where:

PRI	=	a proxy of building quality, which equals 1 for private sector projects (which tend to be of better quality) and 0 for subsidized public housing;
H	=	building height (or the number of storeys);
FP	=	footprint area (floor area per storey);
βi	=	the i^{th} unknown coefficient to be estimated;
ε	=	the error term; and
H xFP	=	an interaction term so that H and FP can have a joint effect on C.

To allow for a height-varying marginal cost, a more flexible functional form is needed. Box-Cox transformation (Box & Cox, 1964) is applied to each strictly positive variable, X:

$$X^{(\lambda)} = \frac{X^{\lambda} - 1}{\lambda} \tag{4.6}$$

Where λ is a parameter to be estimated.

This method has been widely used in other studies when there is no a priori knowledge on the exact functional form (Chau, 1999).

After the Box-Cox transformation is applied, the model in Equation (4.6) becomes:

$$C^{(\lambda_0)} = \beta_0 + \beta_1 H^{(\lambda_1)} + \beta_2 H^{(\lambda_1)} \times FP^{(\lambda_2)} + \beta_3 FP^{(\lambda_2)} + \beta_4 PRI + \varepsilon \tag{4.7}$$

Since the parameters were no longer linear, they had to be estimated by the maximum likelihood estimation (MLE) technique, assuming that the error term followed a normal distribution. The linear model was transformed to the following model (called the Box-Cox model) for further estimation by the OLS technique:

$$\ln C = \beta_0 + \beta_1 H + \beta_2 H \times \ln FP + \beta_3 \ln FP + \beta_4 PRI + \varepsilon \tag{4.8}$$

4.3 Measurement of Green Cost

Two methods are often used in green cost calculation, either comparing the green features with normal features individually or comparing a green building with a similar building as a whole. The former is to look at the cost of individual green features, and compare itself with the building without the green features or using normal materials and designs (Morris, 2007). The total green cost or called additional cost is the summary of added cost of each green feature, which can be easily obtained from the breakdown cost report. The latter is to compare a green building with one or several conventional buildings similar in shape, project size or else. Their cost difference can be calculated as green cost.

However, the difficulty of both the two methods is how to set up the benchmark of conventional buildings for comparison, since some conventional buildings still have green elements and are also somehow energy efficient. To overcome the difficulty, some studies (e.g., Matthiesen & Morris, 2004) select a population of buildings with similar programs but not called as green buildings to set up the baseline of green features for comparison. This approach eliminates some of the subjectivity but adds in difficulties like how to find an adequate number of comparable buildings and at the same time make sure they are truly comparable. Apart from considering the significant variations between buildings, the comparison also needs to adjust costs for time and location, so as to make the results convincible. Even if there is enough data, the distribution of costs data is still skewed. It is possible that a large number of projects report zero or very low premiums, while a small number report much larger premiums; hence, the cost premium for the average project (median) is smaller than the average (mean) cost premium. Moreover, the number of buildings studied in the sample has great impact on the averages, thus making the results even more sensitive. Due to the shortage of data and the limitation suffered from, this method is not widely used and still need further studies and improvement. However, it can still be tracked in some of the studies undertaken by Davis Langdon. One major research of such studies (Matthiesen & Morris, 2006) found that there is no significant difference in average cost between green buildings and non-green buildings. Given their results, the study suggested that this method may not be a quite good method as expected.

4.4 Summary

This chapter reviewed the different methods used in practical and theoretical analysis of construction cost and two methods often used in green cost calculation. To help the owner make a more accurate estimation to the building tender price and modify their designs in an early stage, a model is set up to predict the tender price of proposed buildings with the limited information the owner could determine at the conceptual planning stage, and shorten the accuracy range as well. The models used in regression analysis are built on the models presented in this chapter but with other adjusting factors. Chapter 6 further discusses our models and the corresponding empirical analysis as well.

5 Sample Selection and Data Description

5.1 Introduction

This chapter provides details on the procedure of data collection, definitions of the studied variables, data sources, and the descriptive statistics for empirical samples. Especially, the uniqueness of our data is highlighted as well.

5.2 Data Collection

In Chapter 2, the research determined the factors that influence the construction cost, and at the same time confirmed the information and details of each building project needed for this research, which comprise five categories of data sets including “Identification”, “Location”, “Building attributes”, “Green Attributes” and “Market attributes”, as shown in Table 5-1. “Building attributes” and “Green Attributes” are the most important data sets used in further analysis. In addition, construction cost data needed for this research includes construction cost, breakdown cost and green cost.

Table 5- 1 Data description

Category	Details
Identification	Development Name Property type Developer
Location	Address Postal Code Planning Region Planning Area
Building attributes	Number of blocks Number of storeys (above ground) Number of basements Number of Units Frame type (load bearing, steel, wood, or concrete or others) GFA* (including Net Lettable Area, Attributable Net Lettable Area, GFA) TOP* date (Estimated) Construction cost (including construction cost, breakdown cost for each feature) Green cost
Green attributes	Green Mark award Award Year EETV value, EEI value (For commercial building) RETV value (For residential building) Estimated Water savings(m^3/yr) Estimated Energy savings(kWh/yr) Air-conditioning plant system efficiency(kW/ton) Use of green features
Market attributes	Building Tender Price Index(TPI) for each year

**Notes:*

1. GFA– refers to Gross Floor Area. It includes all covered floor areas of a building, except otherwise exempted and uncovered areas for commercial uses are deemed the gross floor area of the building for purposes of plot ratio control and development charge. The gross floor area is the total area of the covered floor space measured between the centre line of party walls, including the thickness of external walls but excluding voids. Accessibility and usability are not criteria for exclusion from GFA.(defined by Urban Redevelopment Authority as of January 2010)
2. TOP date – refers to Temporary Occupation Permit (TOP). When the building works are completed, the applicant and the Qualified Person shall apply to the Commissioner of Building Control for a certificate of Statutory Completion (CSC) or a Temporary Occupation Permit (TOP). The building can only be occupied when a CSC or TOP is granted.

According to the literature review in section 4.3, two different approaches can be used in green cost calculation. One is the summary of added cost of each green feature. The other is to compare the cost of a green building with the average cost of a series of similar buildings without green features, or to compare the cost difference between the green building and a most comparable normal building. Both of the two methods require a large number of data and the detailed design documents of conventional buildings to set up the benchmark of green features and their costs for comparison; therefore, it is unlikely to calculate the green cost by ourselves since the normal or existing building's design information and corresponding costs are unavailable.

Fortunately, many developer companies are capable of calculating green cost themselves by comparing with other projects they completed or some projects they may know; and it is permissible for us to acquire this green cost information directly from these developers. However, these green costs may vary greatly among developers due to the difference in their calculation methods and benchmarks for calculation. To avoid adding more noise to the analysis, only a few main developers are chosen as target of the data source. The data source is also limited to those with relative more green buildings under construction, so as to keep the conformity in estimation and calculation. Our target developers are finally set as the "leading" companies within the real estate industry in Singapore, especially who has developed more than three green buildings and been awarded as "leading firms" by BCA Green Mark.

The data needed for our research involves much confidential information, so getting data is the hardest and the most important part of this research.

Construction cost data is usually quite confidential and will only be published after the buildings have been completed for many years. In addition, few companies would like to release their construction data, especially for new buildings which are still under construction. Based on these, we contacted a few developers, consultancies, and governments via email or phone. In the end, the research obtained the kind support and guidance from BCA, UGL Premas and Surbana International Consultants Pte Ltd. The data used in our research are provided by two companies: 1) City Development Limited, which is the only company that won Green Mark Champion Award, and 2) Keppel Land, which is one of the six companies with 2 or more projects rated Green Mark Gold^{plus} or Platinum. BCA Green Mark Champion Award was launched in 2008, who recognizes developers not only have "strong commitment towards corporate social responsibility and outstanding achievements in environmental sustainability" (Leading Firms in Green Mark Awards, BCA website, available from http://www.bca.gov.sg/GreenMark/Leading_Firms_in_GM_Awards.html), but also achieve over 10 projects rated Green Mark Gold and above. Now CDL is the only company that won Green Mark Champion Award. Overall, the building projects developed by these two companies represent the highest level of green buildings in Singapore.

Green Mark has set up different schemes for new buildings, existing buildings, and beyond buildings (see in Figure 5- 1). Because for existing buildings, the construction cost mainly refers to the retrofitting cost, only new buildings are included in our sample. We collect the estimated construction cost for buildings under construction, while we use the actual expenditure as construction cost for newly completed buildings. Known from some developers, the projects are usually completed within their budget. In this sense, the estimated construction cost and the actual expenditure make no differences to the developers; hence they can compare with each other.

Figure 5- 1 Green Mark Structure
Source: BCA website (http://www.bca.gov.sg/GreenMark/green_mark_projects.html)

As mentioned in Chapter 2, because Green Mark Scheme keeps updating in these years and only new buildings that awarded after 2008 are assessed under the same version of assessment criteria, top priority is given to the most recent building projects in sample selection.

The sample projects are limited to new buildings developed by one of the "leading" companies and awarded by BCA Green Mark at best after 2008. Based upon these requirements, the total number of green buildings collected in our sample is 20. Although the sample size is restricted, the number is already impressive due to the following reasons. On one hand, the total number of the building projects that meet our requirements is not large and the information required for this study, including cost data and design documents, is quite confidential since the sample projects are just awarded by Green Mark after 2006 and most of the projects are still under construction. On the other hand, the collection of such confidential data is really difficult for many reasons, like incentives of releasing such data, different persons in charge of different projects. In this sense, the obtaining of these datasets makes our research and its results so unique from others. The theoretical results may not be significant due to the limitation of sample size, however still provide insight to the real estate industry and other research in this field.

5.3 Definition of Variables

Table 5-2 presents the dependent and independent variables used in our empirical model and their definitions. In our sample, all commercial buildings have a same frame type - reinforced concrete type, while all residential buildings, which refer to condominium buildings, also have a same frame type- concrete type. Therefore, property type (variable *Proptype*) is solely included in our regression instead of including both frame type and property type.

Table 5- 2 Variables and definitions

Variable name	Definition
Dependent variables	
Cost	Construction cost of the project(Unit, S$million)
LnCost	The semi-log form of *Cost*(Unit, S$)
CostperGFA	Cost per GFA(same with RLB report) (Unit, S$/sqm)
LnCostperGFA	The semi-log form of *CostperGFA*
GreenCost	Incremental cost for green features and other additional provision, (Unit, S$million)
LnGreenCost	The semi-log form of *GreenCost* (Unit, S$)
GreenCostpercentage	The percentage of green cost in construction cost, (Unit, %)
Independent variables	
Basic variables	
GFA	Gross Floor Area is the area of building enclosed covered spaces excluding car park and driveway areas calculated for purposes of planning submission.(Unit, 1000sqm)
StoreyNO	The number of storeys
UnitsNO	The number of units
AREAPS	Area per storey, (Unit, Sqm/storey)
LnAREAPS	The semi log form of *AREAPS*
StoreyNOLnAREAPS	*StoreyNO*× *LnAREAPS*
TPI	Building Tender Price Index (Year 2005=100)
EnergySavings	Estimated Energy Savings (Unit, kWh/yr)
Ln EnergySavings	The semi-log form of *EnergySavings*
WaterSavings	Estimated Water Savings (Unit, m^3/yr)
Ln WaterSavings	The semi-log form of *WaterSavings*
Dummy Variables	
Proptype	A dummy variable with 1 denoting the property type is residential, otherwise zero.
Greenmarkversion	A dummy variable with 1 denoting the award year of a green building is 2006 and 2007, otherwise zero. *Greenmarkversion* equals to 1 means the version of Green mark assessment criteria is not the newest one and affect the rating assessment.
Familiarity	A dummy variable with 0 denoting the project is the first or second project to each developer, otherwise 1. *Familiarity* equals to 1 means the green design and technology is well known to the developer, otherwise zero.
Platinum	A dummy to indicate the Green Mark Platinum rating
Goldplus	A dummy to indicate the Green Mark Gold^{plus} rating

5.4 Descriptive Statistics

Cost data of 20 new green projects in Singapore are used for the empirical analysis. The sampled projects are started from 2006 to 2009. Only several projects have been completed, while most of them are still in the planning stage. As stated in Chapter 2.1.2, the new buildings awarded in 2008 or 2009 are most comparable, since they use the same Green Mark assessment criteria. Therefore, 80 percent of the buildings in our sample are awarded in these two years, as can be seen in Table 5-3.

Table 5- 3 Award Year of sample projects

N	2006	2007	2008	2009	2010
20	1	1	9	7	2

The descriptive statistics are displayed in Table 5-4. The projects in our sample vary a lot, which can be seen from the differences between the minimum and maximum number of each item. Generally, green costs make up of 1.6% of total construction costs valued at $2.81 million on average. Construction cost on a “per square meter” basis (Cost per GFA) is around $3962 for a green building with a gross floor area at around 54688 m^2 on average. With respect to green performance, a green building can save energy by 0.026 to 24.9 million kWh (a percentage of 33% on average) and 273 to 82076 m^3 water (a percentage of 16.3% on average) per year. According to the requirements stated in the assessment criteria, full score can be given if the ETTV value is under 43 W/m^2. All these 3 projects, therefore, get full score in that criterion. In the following, a general analysis of our sample is provided based on the statistical results.

Table 5- 4 Descriptive statistics of overall sample

	N	Minimum	Maximum	Mean
Building attributes				
GFA (m^2)	20	2900	193400	54688.28
No.of Units	15	15	1129	269.73
Attributable Net Lettable Area (sf)	9	30000	1831000	447000.00
Construction cost (S$ million)	19	20	960	229.01
CostperGFA	19	2000.00	6896.55	3961.81
Green attributes				
Green Cost (S$ million)	20	0.15	17	2.81
Green cost percentage (%)	19	0.06	4	1.61
EEI (kWh/m^2/yr)	10	27	174	93.583
ETTV(W/m^2)	3	41	42.76	41.75
Estimated Energy Savings(kWh/yr)	17	262000	24950000	4951478.09
Energy Savings Percentage (%)	4	30	35	33.00
Estimated Water Savings(m^3/yr)	17	272.83	82076	25458.26
Water Savings Percentage (%)	3	3	37	16.33

Note: There is one project that has not appointed the contractor at the time we collected the data. But the developer has calculated the possible green cost according to the design of the project. Therefore, the N value of green cost is one more than the N value of Construction cost and Green cost.

5.4.1 Dependent Variables

Cost per GFA

Cost per GFA in our sample range from $2000/sqm to $ 6897/sqm and it increased with *Green Mark rating*. Specifically, the cost of commercial building is higher than the cost of residential building.

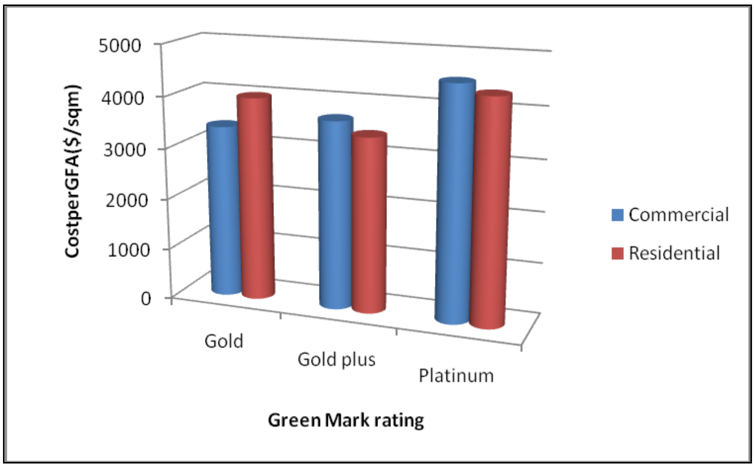


Figure 5- 2 Construction prices (per square meter) by Green Mark rating

Green cost percentage

Generally, the green cost percentages of our sampled buildings range from 0.06% to 4%. As shown in Figure 5- 3, green cost percentages of the buildings have no clear distribution characteristic between different property types, which indicates property type is insignificantly related to green cost percentage. This point needs further confirmation by regression analysis in Chapter 6.

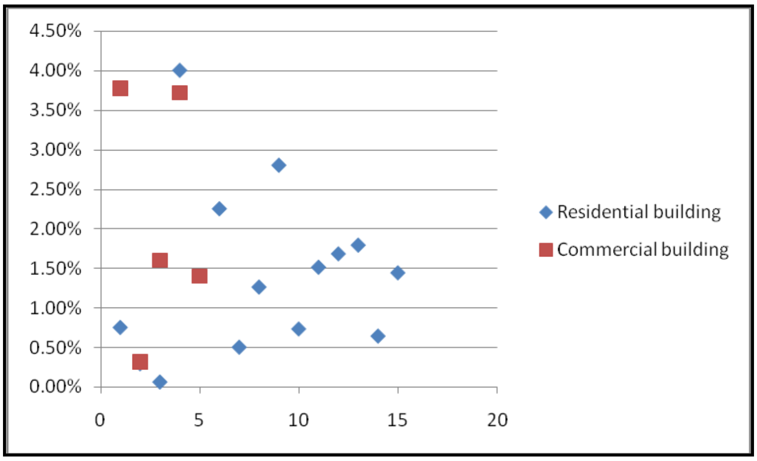


Figure 5- 3 Green cost percentage by property type

Table 5-5 shows the statistical results of green cost percentages by different Green Mark ratings. As can be seen, green cost percentage, although has a wide range, tends to increase with the Green Mark rating. For different Green Mark ratings, the average green cost premium is 2.45% for Platinum, 1.23% for Gold^{plus}, 1.21% for Gold. Green cost percentage in Gold rating has the widest range compared to the other two ratings, which ranges from 0.06% to 4.00%. To get a full picture about our sample, these results are compared with the one from previous studies in Table 5-6. As can be seen, in general, the average green cost percentage of our sample is lower than the results derived from the U.S. papers and BCA reports. Specifically, our statistical results on commercial buildings have more similarity with BCA report than the residential group (see in Table 5- 7).

However, our results are quite sensitive to sample size. When sorting our sample to two groups by property type, as can be seen from Table 5-7, our conclusion that green cost percentage increased with Green Mark rating suffers an exception, which is for residential buildings, the green cost percentage for Gold (1.34%) is higher than the one for Gold^{plus} (1.05%). This exception may be a result of the project difference like project size or green performance. Therefore, besides univariate analysis, multivariable regression analysis is also needed in this study to exactly see the impact of Green Mark rating with including other possible factors in the model.

Table 5- 5 Statistical results of green cost percentage by Green Mark rating

	N	Min	Max	Average
Gold	8	0.06%	4.00%	1.21%
Gold plus	5	0.64%	1.79%	1.23%
Platinum	6	1.26%	3.78%	2.45%

Table 5- 6 Comparison results on average green cost percentages between previous literature and our results

Source	Certified	Silver(or Equivalent)	Gold(or Equivalent)	Platinum(or Equivalent)
Kats et al., (2003)	0.66%	2.11%	1.82%	6.50%
Turner Construction(2005)	0.8%	3.5%	4.5%	11.5%
Miller et al., (2008)		1.0%-3.7%	2.7%-6.3%	7.6%-10.3%
Our sample		1.21%	1.23%	2.45%

Table 5- 7 Comparison results on green cost percentages between BCA report and ours

Green Cost	Our result(A)	BCA report(B)	Difference((A-B)/B)
Commercial buildings			
▪ Platinum	3.75%	4.0%	-6.25%
▪ Gold^{plus}	1.50%	1.8%	-16.67%
▪ Gold	0.31%	0.7%	-55.71%
Residential buildings			
▪ Platinum	1.80%	3.1%	-41.94%
▪ Gold^{plus}	1.05%	1.7%	-38.24%
▪ Gold	1.34%	1.2%	11.67%

5.4.2 Building Attributes

Property type

On average, 80% of Singaporeans live in flats which are built and managed by the Housing and Development Board (HDB) while the rest live in private apartments, condominiums and landed properties. Condominiums are usually packaged with more facilities than private apartments. According to some websites about Singapore real estate, private apartments can also be classified to Condominium, Duplex, Hi-rise Apartment, Low-rise apartment, Apartment, townhouse, Walk up apartment and penthouse. As for landed properties, they are classified as terraced houses, semi-detached houses, detached houses, exclusive bungalows and shop houses. Since the residential buildings in our sample are all condominium, buildings can be just separated to either commercial or residential properties. The residential properties account for 75% (15/20) of the overall properties.

Project size

Yudelson (2008) concluded that fixed cost has a positive relationship with Cost per square feet. The relationship can be represented by the following equation:

$$\textit{Cost per GFA} = \alpha\ \textit{Fixed cost}$$

where α is positive.

The above equation can transformed to:

$$\textit{Cost}/\ (\textit{GFA} \times \textit{Green Cost}) = \alpha\ \textit{Fixed cost/Green cost}$$

$$1/\textit{GFA} = \alpha\ \textit{Fixed cost proportion} \times \textit{Green cost percentage}$$

Therefore, GFA is negatively related to Green cost percentage. However, its relationship with Green cost is indefinite since GFA is positive related to Construction cost.

5.4.3 Green Attributes

Certification level required

Figure 5-4 shows the number of buildings in each Green Mark rating with regard to three different types. As can be seen, most of the residential buildings are rated Certified, while most of non-residential buildings are targeted at Gold. This difference may be due to the different incentives of building green. For residential buildings, the incentive of building green may be to take the ride of “green” label; therefore, their priority is to get certification. In addition, since there is no strong evidence that the sales price difference among different ratings is high enough to compensate the cost difference; hence Certified, as the optimal strategy, gain more responses. On the other hand, non-residential buildings are used for leasing. Buildings with higher ratings can achieve better indoor environment quality for the occupants and lower operation cost; therefore they can attract more tenants or even possibly increase the rental fees. Moreover, non-residential buildings can apply for the Green Mark Incentive program to get cash rebates so as to compensate higher cost; hence, they need to be rated at least Gold to qualify for the application of Green Mark Incentive program.

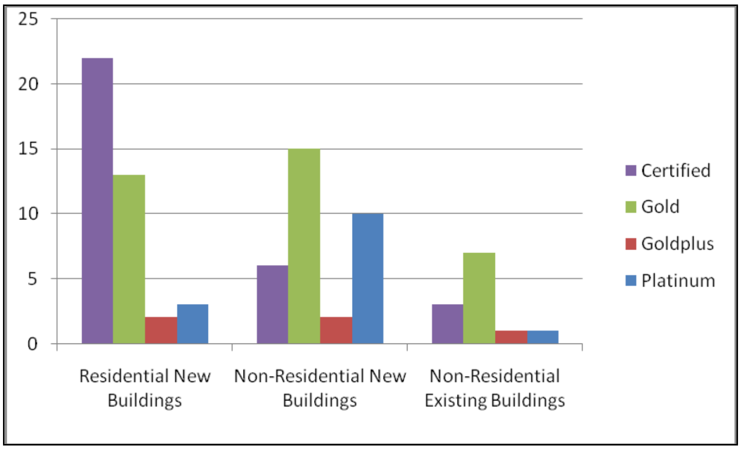


Figure 5- 4 Statistics on Green Buildings awards in 2009 (by category)

In addition, it can be seen that Platinum level is more pursued than Gold^{plus} level by all the three types of buildings. On one hand, some developers suggest that this is because there is almost no difference in performance or rating score between the Gold^{plus} level and Platinum level since the difference between Gold^{plus} rating and Platinum is only 7.5 points as revealed by Table 5-8. On the other hand, Gold^{plus} rating has the narrowest range compared to other ratings, which is from 85 to 89, thus resulting in the lowest number of buildings in this level.

Table 5- 8 Required Score for each Green Mark rating in version 3

Rating	Score Range	Average Score	Difference
Platinum	90-100(10)	95	7.5
Gold^{plus}	85-89(5)	87.5	8
Gold	75-84(10)	79.5	17.5
Certified	50-74(25)	62	

To sum up, based on the overall sample of green buildings in Singapore, our findings that most of the residential buildings are rated Certified, while most of non-residential buildings are targeted at Gold suggest there is a popular rating for different property type. However, this preference is found in our sampled projects. Our sample confirms that the finding revealed by the overall sample, which is Platinum level is more pursued than Gold^{plus} level by all types of buildings (see in Figure 5- 5).

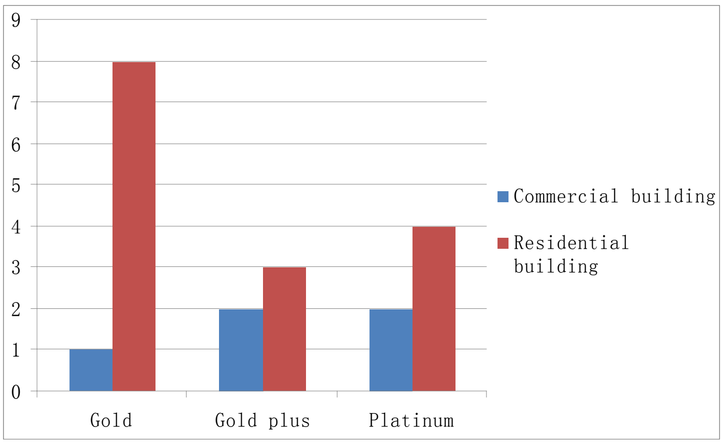


Figure 5- 5 Number of buildings by Green Mark rating

Green Performance

Projects from the same developer are used for this analysis. In general, the green performances of commercial buildings are better than residential buildings', which can be seen from the statistics in Table 5- 9.

Table 5- 9 Descriptive Statistics- Green Performance by type

	Residential			Commercial		
	EEI (kWh/ m^2/yr)	Estimated Energy Savings (kWh/yr)	Estimated Water Savings (m^3/yr)	EEI (kWh/m^2/yr)	Estimated Energy Savings (kWh/yr)	Estimated Water Savings (m^3/yr)
Minimum	27	262000	540	132	9080000	7000
Maximum	144.83	16073856	62000	174	24950000	42000
Mean	67.55	3530143	31516.17	154.33	15040000	19526.67

Different selections of green features

From the case studies conducted in Section 7.2, the study finds the selection of green features differ a lot in projects. In our cases, the number of incorporated green features in Project 1 is two times lower than the average for the rest of the projects, while other 3 projects are similar in green features selection in five categories. However, the detailed design documents for the sampled projects are unavailable and thus the impact of different selection of green features cannot be empirically analyzed in our regression model. Further studies on the impact of different selections of green features need to be carried out.

5.5 Summary

This chapter described the process of data collection. Five aspects of data sets were collected for the sample projects: “Identification”, “Location”, “Technical data”, “Green Attributes” and “Market attributes”. The number of green building projects that meet our requirements is small in Singapore and the information required for this study, including cost data and design documents, is quite confidential. The collection of such confidential data is really difficult for many reasons. A total number of 20 new green building projects are collected in our sample, wherein residential buildings make up 75% of the overall buildings and 80% of the buildings are awarded in 2008 or 2009. Generally, green costs make up 1.6% of total construction costs valued at $2.81 million on average, wherein the average green cost percentages for each Green Mark rating are 2.45% for Platinum, 1.23% for Gold^{plus}, 1.21% for Gold. These results are similar but lower than the results derived from U.S papers. Cost per GFA in our sample range from $2000/sqm to $ 6897/sqm.

Moreover, the descriptive statistics on building attributes and green attributes are also provided in this chapter, and based on these statistics their relationships with dependent variables are assumed as well.

Descriptive statistics (univariate analysis) are important in this study since multivariate regressions are subject to small sample bias. Univariate tests in this chapter provided preliminary evidence to support our research hypothesis.

6 Empirical Findings

6.1 Introduction

The literature review in Chapter 2 provided a comprehensive analysis of the determinants of construction cost and green cost. These determinants include: number of storeys, number of units, total area, property type, familiarity of green design and technology, Green Mark rating, estimated energy and water savings, version of Green Mark Scheme, and Building Tender Price Index. Based on the descriptive results in Chapter 5, their relationships with dependent variables are expected to be as shown in Table 6-1.

Table 6- 1 Estimated relationships between dependent and independent variables

	Estimated Relationship with Dependent variables			
Independent variables	*CostperGFA*	*Cost*	*Green Cost*	*Green cost percentage*
Basic variables				
GFA	-	+	?	-
StoreyNO	+	+	?	
UnitsNO	+	+	+	
Proptype	-	-	-	
AREAPS	+			
Other Variables				
Greenmarkversion	-	-	-	-
Familiarity	-	-	-	-
TPI	+	+		
Platinum	+	+	+	+
Goldplus	+	+	+	+
EnergySavings	+	+	+	+
WaterSavings	+	+	+	+

Notes: + denotes positive relationship, - denotes negative relationship, ? denotes indefinite relationship.

Three negative relationships need to be clarified. Firstly, the cost of commercial building is estimated to be higher than that of residential building, so *Proptype* is expected to have a negative relationship with dependent variables. Secondly, due to the update of Green Mark assessment criteria, the latest green building must perform better than the previous green building to keep the same Green mark rating. Therefore, according to our value setting, the variable *Greenmarkversion* is assumed to be negatively related to the cost related variables. And lastly, the more familiar the developer is, the less they will spend on green building construction; hence, *Familiarity* is negatively related to the dependent variables.

This chapter builds on the methodologies as outlined in Chapter 4 to conduct an empirical analysis, taking all the cost determinants discussed previously into consideration. Several regression models are tested in our analysis. Our empirical modeling strategy consists of a two-stage hedonic pricing equation. In the first stage, each dependent variable is simply related to the basic building attributes for regression. Then in the second stage, the regression considers the green attributes and market attributes measured at the building level. Specifically, all continuous numeric variables were transformed to log values to (1) reduce non-normality found in initial examinations of the dataset, (2) to reduce heteroskedasticity and (3) to be able to interpret the results as elasticities(Fuerst and McAllister, 2009). The empirical results are presented after each model development. Results from both the first stage and second stage are compared in order to see whether green attributes and market attributes are significant determinants of construction cost and green cost of building projects.

In the following sections, the study first investigates the determinants of construction cost by comparing the different empirical results from the nested models. Then the impact of green attributes on green cost and green cost percentage are also examined by conducting several linear regressions.

6.2 Determinants of Construction Cost

The descriptive statistics of our sample are shown in Table 6- **2**. Cost per GFA refers to the construction cost per square meter. With project size ranging from 2900 m^2 to 150,000 m^2, the cost per GFA lies between $2000/$m^2$ to $6897/$m^2$. All developments in our sample are multi-storey buildings of low-rise (six storeys) to super-tall (66 storeys) structures. The analysis is on a building basis while our sample is on project basis, so data transformation is made for each project to run the regression.

Table 6- 2 Summary statistics on selected variables

	N	Minimum	Maximum	Mean	Std. Deviation
CostperGFA	19	2000	6896.552	3961.805	1200.348
lnCostperGFA	19	7.601	8.839	8.239	0.314
CostS$million	19	10	750	132.40	187.872
StoreyNo	20	3	66	25.350	19.682
UnitsNo	15	15	428	121.850	109.235
GFAin1000s	20	2.90	150.00	32.415	38.886
AREAPS	20	171	4400	1507.16	1327.183
TPI	20	103	144	130.05	13.567
Familiarity	20	0	1	0.80	0.41
Proptype	20	0	1	0.75	0.444
GreenMarkversion	20	0	1	0.1	0.308
Platinum	20	0	1	0.30	0.47
Goldplus	20	0	1	0.25	0.44
LnEnergySavings	17	7.87	16.34	13.527	1.903
LnWaterSavings	17	5.61	11.19	8.471	1.727

Notes:

1. *StoreyNo* represents the average number of storeys of the buildings in each project.
2. The numeric values of *GFA*, *Number of Units* and *Construction cost* reported in Table 5-4 are divided by the number of blocks in each building projects, and the results are presented as Variable *GFAin1000s*, *UnitsNo* and *CostS$million*.

Due to the limitation of sample size, all the three models underperform. However, when comparing all the results, the model that produced the best statistical results in terms of parameter significance was a linear regression of construction cost (*CostS$million*).Therefore, only the regression results of model 2 are presented in this section, while the results of Model 1 and Model 3 can be seen in the appendix.

Model 2 use the construction cost as dependent variable. The basic estimation model can be presented as the following equation:

$$\boldsymbol{COST} = c + \alpha 1\ \boldsymbol{STOREY} + \alpha 2\ \boldsymbol{AREA} + \alpha 3 \boldsymbol{AREAPS} + \delta\ \boldsymbol{Proptype} + \sum \beta i\ \boldsymbol{Yi} + \sum \gamma \boldsymbol{TPI} + \varepsilon \quad (6.1)$$

Where:

COST	=	Construction cost;
c	=	constant(intercept);
STOREY	=	Number of storeys;
AREA	=	Gross floor area (GFA) in 1000s; ***AREA*= *AREAPS* × *STOREY***
AREAPS	=	Area per storey;
Proptype	=	1 for residential buildings, and 0 for commercial buildings. Residential building is chosen as defaults for *Propertytype*;
Yi	=	Dummy variables for green attributes of building i;
TPI	=	Building Tender Price Index at year basis. The default year is set as Year of 2005.
αi, β, γ, δ	=	Estimated statistical parameters; and
ε	=	An error term.

First, the dependent variable is simply related to the basic building attributes for regression. *AREAPS* and *STOREY* enter the equation separately (rather than jointly as total floor area), so as to give a clearer understanding on what other factors have been held constant in marginal analysis. Then, an interaction term *AREA* is added to determine the joint effect of *AREAPS* and

STOREY on construction cost. The results can be seen in column (1) and (2) in Table 6-3.

Second, the regression considers both the green attributes and market attributes measured at building level. Column (3) adds TPI in the regression and column (4)~(7) add green attributes. Column (8) and (9) add both green attributes and market attribute.

Seen from Table 6-3, by comparing column (1) and (2), (4) and (5), (6) and (7), (8) and (9), we can see the joint effect of *AREAPS* and *STOREY*. It can be seen that the adding of *AREA* (variable *GFAin1000s*) helps to explain more information with a much higher adjusted R square. *Proptype* and *UnitsNo* can be viewed as the same variable when they enter the equation together. When *UnitsNo* is considered in our model (column (3)(6) (7) (8)(9)), *Proptype* and *GreenMarkversion* are auto-omitted, and some main variables like *APEAPS* and *StoreyNO* turn to negatively related to dependent variable, which is opposite with our expectation. Additionally, by comparing column (6) and (8), (7) and (9), it can be seen that the variables become less statistically significant when the variable *TPI* is included in our regression; therefore, only some sets of regression results with variable *TPI* are reported.

Among the 9 regressions, only the results in column (1) and (4) are consistent with our hypothesis. However, the green attributes are not consistently significant and adjusted R square in column (4) of Model 2 is low, which indicates that this regression does not keep enough explanation information. To sum up, column (1) which only considers building attributes in the regression performs the best results for our sample with an adjusted R square equals to 0.653, while the coefficients of the green attributes are insignificant and cannot be determined in the regression.

Table 6- 1 OLS regression estimation of Construction cost

(Dependent variable: *CostS$million*)

	Dependent Variable: *CostS$million*								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
(Constant)	71.582	16.049	8.459	-143.714	38.655	387.239*	158.232*	389.134	151.553
	(126.272)	(43.181)	(53.941)	(372.076)	(36.171)	(124.435)	(47.689)	(157.413)	(64.622)
AREAPS	0.029	-0.014	-0.003	0.029	-0.021**	-0.133**	-0.078**	-0.133*	-0.078
	(0.029)	(0.011)	(0.008)	(-0.059)	(-0.006)	(0.030)	(-0.011)	(0.036)	(0.015)
StoreyNo	6.159***	-1.707*	0.027	9.069*	-1.175*	-13.941**	-6.855**	-13.917*	-6.846
	(1.657)	(0.922)	(0.825)	(-4.22)	(-0.567)	(3.643)	(-1.44)	(4.488)	(1.887)
GFAin1000s		5.390***	6.817***		5.509***		4.485**		4.528
		(0.500)	(1.911)		(0.215)		(0.687)		(0.907)
UnitsNo			-0.467*			3.440**	1.392*	3.432*	1.390
			(0.238)			(0.761)	(-0.371)	(0.945)	(0.486)
Proptype	-172.513*	8.879		-132.521	-27.866				
	(86.372)	(33.813)		(-173.3)	(-17.015)				
GreenMarkversion				-161.511	84.272**				
				(-271.628)	(-27.611)				
Familiarity				-16.349	-166.323***	-544.025**	-304.794**	-542.938*	-305.115
				(-222.004)	(-21.955)	(121.181)	(-48.3)	(150.074)	(63.297)
Green Mark									
Platinum				93.962	-5.69	-90.947**	-33.338*	-91.205	-32.179
				(-137.511)	(-13.672)	(28.142)	(-11.457)	(34.869)	(15.283)

Goldplus				122.381	-16.622	-132.832**	-60.091**	-133.063*	-58.851
				(-128.56)	(-13.402)	(31.360)	(-13.802)	(38.692)	(18.342)
LnEnergySavings				-12.41	0.817	6.099	-1.276	6.235	-1.668
				(-37.62)	(-3.623)	(4.244)	(-1.578)	(5.920)	(2.282)
LnWaterSavings				27.844	1.147	-33.437*	-5.173	-33.415	-4.957
				(-39.244)	(-3.883)	(13.321)	(-5.542)	(16.312)	(7.281)
TPI			-0.013					-0.027	0.064
			(0.428)					(0.563)	(0.157)
R square	0.710	0.969	0.930	0.750	0.998	0.983	0.999	0.983	0.999
Adj R square	0.653	0.960	0.887	0.375	0.994	0.939	0.996	0.908	0.993

Notes:

1. * denotes 10% significance level; ** denotes 5% significance level; *** denotes 1% significance level. The value in parentheses is the standard error.
2. *Units No.* is only applicable for residential buildings, but not for commercial buildings. Therefore, when including *Units No* in the regression, the variable *Proptype* are excluded for its high collinearity with *Units No*.

6.3 Determinants of Green Cost

With the same data used in cost related regressions, hedonic regressions with *Greencost* as the dependent variable are analyzed in this part. Both the logarithm form and the linear form of *Greencost* are tested. However, the model using the Logarithm form of *Greencost* does not produce reasonable results in terms of parameter significance. Therefore, only the model results using linear form of *Greencost* are reported in this section. The results are shown in column (1) ~ (4) in Table 6-4. The entry method is chosen as Backward, which allows the model automatically remove the less significant variables until all the variables in the model are significant.

All the regressions have relatively high adjusted R square value, ranging from 0.523 to 0.635. Except for *LnEnergysavings*, all coefficients had the expected signs. However, only the coefficients of *Platinum and GFAin1000s* are statistically significant. Specifically, the regression reveals GFA is positively related to Green cost. *LnEnergysavings* is negatively related to *GreenCostS$million*, which is opposite to our expectation. In fact, in all the regressions run previously, the coefficient of *LnEnergySavings* is always negative. This is probably due to missing variables and size limitation, or the difference in reference building for energy savings calculation.

Table 6- 4 OLS regression estimation of Green cost

(Dependent variable: Green Cost S$million)

	Dependent Variable: GreenCostS$million			
	(1)	(2)	(3)	(4)
(Constant)	-1.543	-1.523	2.385	2.056
	(1.153)	(1.180)	(9.526)	(10.276)
GFAin1000s	0.084***	0.076***	0.080**	0.082**
	(0.017)	(0.021)	(0.026)	(0.031)
Proptype				0.388
				(2.645)
GreenMarkversion	-2.580	-3.907	-4.716	-4.949
	(2.913)	(3.597)	(3.957)	(4.459)
Familiarity		-1.772	-2.603	-2.762
		(2.691)	(3.067)	(3.406)
Green Mark				
Platinum	4.207**	4.099**	4.065**	4.164*
	(1.582)	(1.626)	(1.745)	(1.958)
Goldplus	1.724	2.037	2.628	2.714
	(1.586)	(1.690)	(1.955)	(2.140)
LnEnergySavings			-0.528	-0.523
			(0.788)	(0.830)
LnWatersavings			0.364	0.346
			(0.531)	(0.572)
R Square	0.721	0.731	0.747	0.747
Adjusted R Square	0.635	0.619	0.569	0.523

Notes:

1. * denotes 10% significance level; ** denotes 5% significance level; *** denotes 1% significance level. The value in parentheses is the standard error.
2. Units No. is only applicable for residential buildings, but not for commercial buildings. Therefore, the variable *UnitsNo* are excluded for its high collinearity with *Proptype*.

6.4 Determinants of Green Cost Percentage

Green cost percentage related variables are determined in factor analysis and their impact can be seen from Table 6- 5. Constant is insignificant in our model and therefore excluded in our regression. GFA has a negative relationship with green cost percentage, suggesting the existence of scale effect as discussed previously. The bigger the project is, the less the green cost percentage will be. However, the coefficients of Green Mark ratings do not have expected signs. In column (1)~(6), the coefficients of *LnGFA and TPI* are significant. Column (2) and (3) provides the best fit with our sample with an adjusted R square around 0.85. In column (7) ~ (13), the coefficients of *LnEnergySavings* are positive and especially consistently significant, which indicates the adoption of energy efficient facilities has a strong and positive relationship with the increase in construction cost, suggesting incorporating energy efficient fittings and facilities will significantly increase the expenditure in green building projects. Further analysis is need for this part.

Table 6- 1 OLS regression estimation of Green Cost percentage

	Dependent Variable: Greencostpercentage												
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
CostS$million	-0.002*	-0.002*	-0.002*	-0.002*	-0.002*	-0.002*				0.004	0.004	0.003	0.002
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)				(0.002)	(0.002)	(0.002)	(0.003)
GreenCostS$million	0.208***	0.204***	0.219***	0.255***	0.238***	0.238**	0.418	0.505*	0.561**	0.601**	0.595**	0.632**	0.612*
	(0.049)	(0.047)	(0.048)	(0.058)	(0.064)	(0.069)	(0.229)	(0.217)	(0.205)	(0.186)	(0.181)	(0.18)	(0.215)
LnGFA	-0.287	-0.844*	-0.841*	-0.797*	-0.693	-0.696		-0.757	-0.866*	-0.701	-0.581	-0.583	-0.576
	(0.181)	(0.420)	(0.411)	(0.427)	(0.459)	(0.510)		(0.465)	(0.437)	(0.406)	(0.409)	(0.400)	(0.455)
Proptype					-0.430	-0.432							
					(0.572)	(0.623)							
UnitsNO							-0.002**	-0.002*	-0.002**	-0.005**	-0.005**	-0.004*	-0.004
							(0.001)	(0.001)	(0.001)	(0.002)	(0.002)	(0.002)	(0.003)
TPI	0.033**	0.025*	0.025*	0.017	0.017	0.017							
	(0.013)	(0.014)	(0.014)	(0.015)	(0.015)	(0.016)							
Familiarity			-0.640	-1.044	-1.229*	-1.228							-0.279
			(0.525)	(0.598)	(0.661)	(0.710)							(0.920)
Green Mark													
Platinum				-0.497	-0.562	-0.563			-0.792	-1.091*	-1.087*	-1.207*	-1.216
				(0.569)	(0.590)	(0.634)			(0.523)	(0.506)	(0.492)	(0.493)	(0.562)
Goldplus				-0.785	-0.930	-0.926						-0.541	-0.617
				(0.559)	(0.605)	(0.688)						(0.488)	(0.608)

LnEnergySavings		0.475	0.480	0.545	0.510	0.509	0.103**	0.625*	0.721**	0.621*	0.655*	0.682*	0.677
		(0.326)	(0.319)	(0.331)	(0.343)	(0.368)	(0.034)	(0.322)	(0.306)	(0.282)	(0.276)	(0.271)	(0.309)
LnWatersavings						0.003					-0.187	-0.219	-0.214
						(0.179)					(0.162)	(0.161)	(0.184)
R square	0.874	0.893	0.906	0.923	0.928	0.928	0.82	0.865	0.898	0.929	0.944	0.957	0.958
Adj R square	0.836	0.849	0.855	0.854	0.847	0.825	0.76	0.797	0.825	0.858	0.866	0.872	0.834

*Notes:** denotes 10% significance level; ** denotes 5% significance level; *** denotes 1% significance level. The value in parentheses is the standard error. The sample size is 20.

6.5 Summary

Three different hedonic models are determined from the literature to study on the relationship between construction cost and building attributes. Green attributes and market attributes are also be added on to see their impact on construction cost. Both the linear form and logarithm form of construction cost are considered in the model. By comparing the value of Adj R square and the parameters' significance level, only Model 2 produced the relatively reasonable results. The model can be described in the following equation:

$$COST = c + \alpha\, STOREY + \beta\, AREAPS + \gamma\, Proptype + \varepsilon$$

Where:

COST	=	Construction cost on one building basis;
c	=	constant (intercept);
STOREY	=	Number of storeys;
AREAPS	=	Area per storey
Proptype	=	1 for residential buildings, and 0 for commercial buildings. Residential building is chosen as defaults for *Proptype*;
α, β, γ	=	Estimated statistical parameters; and
ε	=	An error term.

However, due to limitation of sample size, the model does not produce consistently significant results as expected when adding variables related to green attributes.

Among green attributes, *Platinum* is the most consistently significant variables that affect *Green cost*, which suggests that rather than Green Mark rating, *Platinum* rating is more vital to *Green cost*. *GFA* has a negative relationship with *Green Cost percentage*, which confirms the existence of scale effect as discussed previously. The bigger the project is, the less the green cost percentage will be. In addition, the coefficients of *LnEnergySavings* are positive and significant when green cost percentage as dependent variable, which indicates incorporating energy efficient fittings and facilities will significantly increase the expenditure in green building projects.

7 Trend, Development and Implications

7.1 Introduction

Chapter 7 reviews the development of BCA Green Mark Scheme and green buildings in recent years, and further discusses the trend of construction cost and green cost in the near future. A comparison among different versions of the assessment criteria is being carried out taking into account the changes in minimum score eligible for each rating. The impact of the updating of Green Mark Schemes is further analyzed with respect to the expenditure for the certification level sought. The study then takes a closer look at the green features incorporated in the samples to examine cost effectiveness of these features and whether enough options have been provided to designers for them to choose for their building design.

7.2 Development of Green Mark Scheme

Green Mark kept updated its assessment criteria since its inception in 2005. Several versions of assessment criteria have been carried out up to now. Table 7- 1 shows the details.

Table 7- 1 Different versions of assessment criteria and their effective date

BCA Green Mark	Effective Date
Launched	Jan-05
Assessment criteria for New Building	
Version 1	17-Oct-06
Version 2	6-Nov-07
Version 3	31-Jan-08
Assessment criteria for Existing Building	
Version 2.0	29-Apr-09
Version 2.1	1-Dec-09

According to the BCA, "Certified Green Mark buildings are required to be re-assessed every three years to maintain the Green Mark status." In other words, buildings may perform differently from their original designs or underperform compared to the other buildings in the same rating because of updating assessment criteria. The reassessment procedure is therefore so important as to keep the previous certified building competent.

The first BCA Green Mark assessment is established on the building design. A Green Mark award will be given to the building according to the criteria for new buildings. The second assessment will base on the actual performance including site verification and the submitted consumption information. A new Green Mark award will be given to the building according to the assessment criteria for existing buildings. Normally, it takes 2 to 5 years to construct a building. Sometimes it may take a longer time if the projects are suspended due to some reasons like the financial crisis. BCA requires building projects to reapply for Green Mark award after 3 years operation. Therefore, only several "fast built" projects have reapplied for Green Mark award under existing buildings scheme, the name list of which can be found in year 2009's report, while others are still under construction. Based on these, we can summarized that only the existing buildings which were reassessed in 2009 and the new buildings which are firstly assessed after 2008 are comparable since they are under the same version of assessment criteria, which are shown in *italic* in Table 7-2. Considering the differences among versions of assessment criteria, we need to include a dummy variable in our regression model. A dummy variable "*Greenmarkversion*" is set in our model, which equals to 0 if the award year of a building project is after the year of 2008.

Table 7- 2 Award Year and Award criterion

BCA Green Mark Award				
Award Year	Assessing Time	Award criterion (Estimated)	Re-assessing Time	Award criterion (Estimated)
2005	May to June 2004	Version 0	***2009***	***Version 2.1***
2006	March to April 2006	Version 0		
2007		Version 1		
2008		***Version 3***		
2009		***Version 3***		

The following sections compare the differences among several versions of Green Mark assessment Criteria from different perspectives, and further analyze the impact of changes on Green Mark Scheme bring to the sought of Green Mark certification as well.

7.2.1 Category Changes

Basically, in both version 1 and version 2, the assessment criteria have 5 parts, including Energy Efficiency, Water Efficiency, Site and Project Management, Indoor Environmental Quality and Environmental Protection, and Innovation. However, in version 3, Site and Project Management is included in Environmental Protection, and Indoor Environmental Quality and Environmental Protection are divided into two parts - Environmental Protection and Indoor Environmental Quality.

7.2.2 Changes of Points Allocation

The classifications of buildings are different among different versions. The buildings are classified in two categories in version 1: new or existing building. Version 2 classifies buildings based on their cooling system- whether it is air-conditioned building or not. In version 3, the classification is more scientific and specific. Buildings are first classified by when it was built - whether it is new or not, and then subdivided based on their usage. The point allocations differences in three versions are summarized in Table 7-3. The criteria selected for comparison include New Building Criteria (Version 1), Residential building Criteria (Version 2.0, or Version 2 instead), and Residential new building Criteria (Version RB/3.0, or Version 3 instead), since they are closer and more comparable. The point allocations of version 3 are adjusted for better visual comparison with other versions, where the total score equals to 100 (as shown in Table 7- 3).

Table 7- 1 Point allocations changes from Version 1 to Version 3

	Version 1		Version 2		Version 3		
	New buildings	Existing Buildings	Residential buildings	Air conditioned buildings	Residential new buildings	Non-residential new buildings	Existing buildings
Part 1: Energy Efficiency	30	25	35	35	65+20	79+20	63
Part 2: Water Efficiency	20	15	15	15	13	14	18
Part 3: Site & Project Management	20	25	25	20	-	-	19 (Sustainable operation and management)
Part 4: Indoor Environmental Quality and Environmental Protection	15	15	15	15	29 (Environmental Protection) 6 (Indoor Environmental Quality)	32 (Environmental Protection) 8 (Indoor Environmental Quality)	18 (Indoor Environmental Quality)
Part 5: Innovation	15	20	10	15	7	7	10
Total	100	100	100	100	120+20	140+20	128

Table 7- 4 Point allocations in Version 3

	For Residential buildings		For non-residential buildings	
	Original	Adjusted(Total score as 100)	Original	Adjusted(Total score as 100)
Part 1: Energy Efficiency	65+20	46.4+14.3(60.7)	79+20	49.4+12.5(61.9)
Part 2: Water Efficiency	13	9.3	14	8.8
Part 3: Environmental Protection	29	20.7	32	20.0
Part 4: Indoor Environmental Quality	6	4.3	8	5.0
Part 5: Innovation	7	5.0	7	4.4
Total	120+20	85.7+14.3(100)	140+20	87.5+12.5(100)

Due to the category changes, part 3 and part 4 are put together in our comparison. Other parts remain unchanged. Point allocations differences among three versions are compared in Figure 7- 1, where the total scores are 100. As can be seen, energy usage remains the focus of interest in BCA Green Mark Scheme. A large portion of total points have been allocated to Part 1-Energy Efficiency, especially in the most recent version (version 3) where the total points increase more than two times in comparison with version 1.

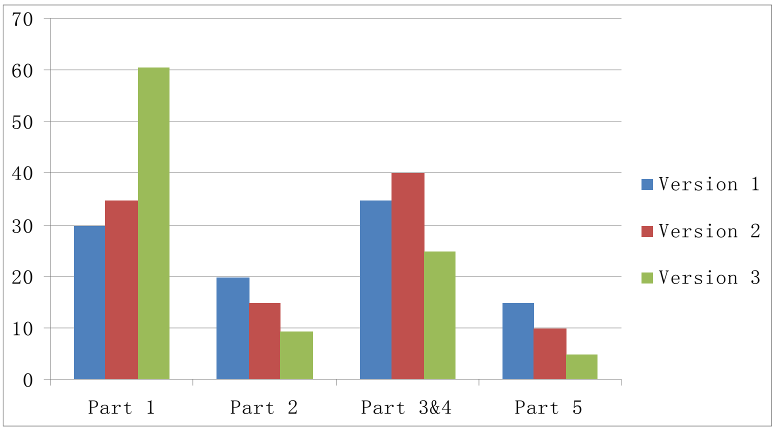


Figure 7- 1 Point allocations by Green Mark version

Regarding the energy performance, several important indexes are widely adopted in building performance estimation, which are also listed in Green

Mark assessment criteria. These indexes include:

ETTV - A large portion of a building's cooling need is caused by heat gain from the environment by the walls, windows and roof of a building. Therefore, ETTV (the envelope thermal transfer value) need to be under 50w/m^2, in air-conditioned commercial buildings. Points will be awarded to buildings based on their ETTV.

RETV- RETV (Residential Envelope thermal Transmittance Value) was researched and developed based on the usage pattern of a typical residential household. It takes into account the choice of materials of building envelopes, the use of shading devices, building orientation among other things. According to the "Code on Envelope Thermal Performance for buildings", RETV shall not exceed 25 W/m^2. This required thermal resistance can help to optimize comfort, minimize heat gain through building envelope and save more energy for each unit. RETV and ETTV, although have a similar concept, differ in the design parameters and requirement. In fact, the requirement of RETV is less stringent than that of ETTV for air-conditioned buildings.

However, the above indexes may only be used to do the general comparison, rather than added to the theoretical model, since they are only applicable for the air conditioned environments, and account for a small proportion of total score (15 points/160 points) for Green Mark.

EEI - The designer is encouraged to use the energy efficiency index (EEI) to compute the energy consumption in buildings based on design load. EEI can be used to assess the energy performance of a building without regarding its size, height or age, according to a study conducted by the Centre for Total

Building Performance (CTBP). Only the top 10% of the office building can achieve EEI of 150KWh/m^2/yr and below, according to a study conducted on Energy Efficiency of Office Buildings in Singapore.

The total points for Water efficiency and Innovation have come down. Specifically, compared with total points allocated in version 1, points in Water efficiency have decreased by 53.5% while points in Innovation become only one third of the original. The decrease in innovation part may be caused by three reasons: (1) Improvement of green technology - Since 5 years have passed, some technologies are no longer new to this field, and some are easier to be applied than the past; (2) the stricter requirements - For instance, if the designers choose to incorporate heat recovery devices or cool paints in the building project, if version 1 is effective, they can get up to 20 points for their innovation, but if version 3 is effective, up to 7 points (5 points after adjustment) can be added to Category 1-7 Energy Efficient Features instead of the innovation part; (3) An important assessment criterion-Renewable energy are moved from Part 5-Innovation to category 1-8, but as BONUS points involved in the assessment. If Bonus points in Innovation parts are included in our measurement, the total innovation points will be much higher (27 points or 19.3 after adjustment).

7.2.3 Sub-category Changes

Table 7-5 shows that compared with version 1, 36 %(=1-16/25) of the criteria in version 2 are new, which accounts 22 points in total. Moreover, version 3 makes a big change from version 2. Only 45% of the sub-categories in Residential building criteria version 3 (Version RB/3.0) are unchanged from version 2, while 50% of the sub-categories in Non-residential building criteria version 3(Version NRB/3.0) remain the same with its corresponding version 2. And with respect to points, if a building gets full score under version 2, it can only obtain around 45 %(39% for residential buildings, 49% for non-residential buildings) of the total score in version 3. These findings suggest that although performing well under version 2, the building may still face a big challenge to maintain the same rating under version 3, unless it is renovated.

Table 7- 5 Sub-category Changes from Version 1 to Version 2

	Version 1	Version 2	NO. of Unchanged sub-categories
Part 1: Energy Efficiency	6	6	4
Part 2: Water Efficiency	4	3	2
Part 3: Site & Project Management	6	7	6
Part 4: Indoor Environmental Quality and Environmental Protection	7	8	3
Part 5: Innovation	1	1	1
Total No.	24	25	16
Total Score	100	100	78

Table 7- 6 Sub-category Changes from Version 2 to Version 3 for residential buildings

	Version 2	Version RB/3.0	NO. of Unchanged sub-categories	List of Unchanged sub-categories
Part 1: Energy Efficiency	6	8	2	Building Envelope-RETV Energy Efficient Features
Part 2: Water Efficiency	3	3	2	Water Efficient Fittings Water Usage
Part 3	7	4	2	Environmental Management Practice(system) Public Transport Accessibility
Part 4	8	4	2	Noise Level Indoor Air Pollutants
Part 5: Innovation	1	1	1	
Total No.	25	20	9	
Total Score	100	140	55	

Table 7- 7 Sub-category Changes from Version 2 to Version 3 for non-residential buildings

	Version 2	Version NRB/3.0	NO. of Unchanged sub-categories	List of Unchanged sub-categories
Part 1: Energy Efficiency	6	10	2	Building Envelope-RETV Energy Efficient Features
Part 2: Water Efficiency	4	4	2	Water Efficient Fittings Water Usage and leak detection
Part 3 and 4	14	9	7	Environmental Management Practice(system);Public Transport Accessibility; Refrigerants; Thermal Comfort; Noise Level; Indoor Air Pollutants; High frequency Ballasts
Part 5: Innovation	1	1	1	
Total No.	25	24	12	
Total Score	100	160	78	

7.2.4 Green Mark Score-Rating Changes

In the assessment, points can be obtained for compliance with individual criterion. Then the cap of these points will be viewed as the ground for rating buildings. The rating is categorized into four levels - Platinum, Gold^{Plus}, Gold and Certified. The minimum score eligible for each level is set differently in different versions of Green Mark Scheme. The score-rating changes over the three versions are compared in Table 7- 8, where the total score for each version are adjusted to 100. The score ranges in version 3 are adjusted based on the total score for comparison reasons. It can be observed that although the minimum score for each rating in version 3 is higher than previous versions, the relative score eligible for each level has become lower. Building with only about 60% (64.3% for residential building and 56.3% for non-residential building) of the total score can obtain the highest level of Green Mark rating.

Table 7- 8 Point-Scoring Rating Criteria

Score Range for each Green Mark certification level				
Green Mark Rating	Version 1 and 2	Version 3	Version RB/3.0(Adjusted)	Version NRB/3.0(Adjusted)
Platinum	>85	>=90	>=64.3	>=56.3
Gold^{plus}	80-84	85-89	60.7-63.6	53.1-55.6
Gold	70-79	75-84	53.6-60.0	46.9-52.5
Certified	50-69	50-74	35.7-52.9	31.3-46.3

Notes: The original total score of Version RB/3.0=140
The original total score of Version NRB/3.0=160

7.2.5 Discussion

The modification of Green Mark Scheme normally needs a large amount of investigation, feedback, verification, and even re-verification. On one hand, the BCA staffs take advices from experts, professionals in engineering, architecture, building and other fields. They also receive feedback from the developers, contractors and project managers. If they find that some points are too hard to get, or too easy to attain, they will adjust or amend some criteria to make the scheme more balanced. On the other hand, some of the requirements are amended based on the newly policies of other government departments, so as to increase public awareness of some important issues.

Our comparison results confirm that the change of Green Mark Scheme caused the difference in green performance among green buildings; therefore, a dummy variable representing the version of Green Mark is needed in our regression model. Moreover, our findings reveal that more points have been allocated to energy efficiency part in each progressive version. Several possible reasons could cause the changes, they are:

Firstly, energy cost accounts for a large proportion of the future operation cost, and directly affects the benefit of tenants and building owners, especially under Singapore's tropical climate. This is confirmed by Mattson-Teig. In her 2008 Green Building Survey, Mattson-Teig stated that the energy cost is the most important factor that drives the initiatives towards building green (see Figure 7- 2). 83 percent of commercial real estate developers were motivated by energy costs to invest in green designs. In brief, the more energy efficient equipment they incorporate, the more money they will save.

Secondly, energy savings can be transferred to Carbon credit and sold in European market; hence building owners can make money in this way.

Thirdly, energy efficiency has become the main focus of many building consultants. Known from building consultants, like UGL Premas, the increase in energy efficiency can be easily observed in the design of building refurbishment.

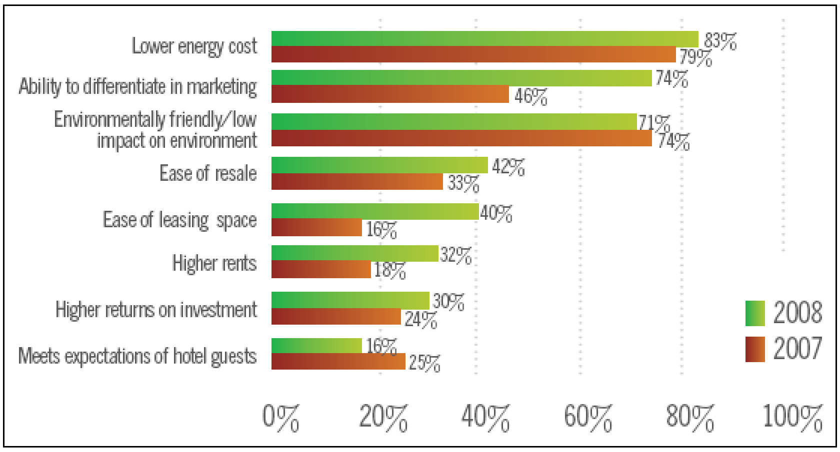


Figure 7- 2 Motivations for energy efficiency investments in 2007 and 2008
Source: Mattson-Teig, Nov 2008

Last but not least, it is required by "carbon emission reduction" in master plan and other energy efficiency related policies in Singapore. Quite a few policies regarding energy efficiency have been put forward in Singapore recently (as discussed in Chapter 3.2).

In conclusion, the energy part has been the most important part in Green Mark assessment criteria. The unchanged criteria only account for around 45% of the total score by points in version 3. Although scoring criteria have become more stringent and difficult to meet, but overall requirements for attaining Green Mark rating have been reduced which still allow old buildings to attain proper rating.

Furthermore, the changes show that the Green Mark assessment has been one of the main drivers towards an “Energy Efficient Singapore”. However, some studies in Singapore have suggested that there might be a problem if overemphasizing the importance of energy efficiency, since such focus could result in the neglect of other aspects. Take the Green Mark scheme version 3 as an example. Observed from Figure 7-1, the percentage given to energy usage (61%) is almost two times higher than the total percentage distributed to other four categories. However, based on the results of her own dissertation, Ho (2008-2009) suggests that “more points should be allocated to material category especially since material conversation serves part of sustainable development.” She also concludes although value the energy usage, LEED, Green Globes U.S. and Australia Green star have a more distributed point allocations and prioritize IEQ as the second issue of concern, which is different from BCA Green Mark(Ho, 2008-2009).

7.3 Selection of Green Features

7.3.1 Number of Features Considered by Developers

This study tracked the BCA Green Mark assessment criteria for residential building, and Green building design guide for air conditioned building. Referring to the case study reports on the several projects, the available green features that can be used and counted as points are summarized as Checklist. The details on how green features correspond to the criteria in checklist are provided in Appendix Table 11. Although this summary is not a detailed list of green features, it can serve as a guide. Specifically, the first three categories are allocated most of the points and hence become the main focus of this part. To fully understand green features considered by COMPANY X, their given list is compared with the checklist we summarized. Seen from Table 7-9, among the 52 kinds of green features listed in the checklist, about 60% of features have been accounted into COMPANY X consideration.

Table 7- 9 Comparison between COMPANY X given list and Checklist

	Checklist of green features	**COMPANY X given list**
1 Energy efficiency		
Building Envelope	Sun-shading	√
	Façade materials	√
Day lighting	Day lighting	√
Natural ventilation	Natural ventilation in common areas	√
	Use of ventilation simulation software	√
	Natural ventilation in car parks	√
	CO sensors for car park MV	√
Air-conditioning system	District cooling	
	Chiller efficiency	√
	VSD on chilled water pumps	
	Use VAV system with VSDs on fans	
	Variable speed cooling tower	
	Motion Sensors	√
	Chiller plant system control	
Lighting	Energy efficient lamps	√
	High Frequency Electronic ballast	
	Occupancy sensors	√
	Scheduling(Automatic scheduling controls)	
	Use of Dimmers	
Lifts and escalators	Efficient lifts	√
	Sleep mode for lift	
	Intelligent lift control	
	Lift car decoration(light weight material)	
	Energy efficient lighting	√
Electrical sub-metering	Electrical sub-metering	√
Greenery	Rooftop and sky gardens	
	Green roof	√
Renewable energy	Solar or other energy	√
Energy efficient features	Heat recovery devices	
	Cool paints	√
	Heat elevators	
	Gas Heaters	√
	Sun pipes	√
2 Water Efficiency		
Water efficient fittings	Water efficient flushing system	
	Water efficient fixtures	

Water efficient landscaping	Water efficient plants	
	Irrigation(Use recycled water, Newater or rainwater for irrigation)	√
	Water efficient irrigation system	√
Metering and accounting	Main and sub-meters, BMS	√
Cooling tower water consumption	Use Newater	
	Better cycles of concentration	
	Efficient drift eliminators	
3 Site and Project management		
Conservation & restoration	Conserve &restore trees	√
	Use recycled compost	√
CONQUAS	CONQUAS	√
Public transport accessibility	Adequate bicycles parking lots	√
	Provision of shuttle bus	√
Environmental management practice	Environmental management program	
	Project team comprises one certified Green Mark manager and/or one Certified Green Mark Professional.	√
	Building maintenance and operation guidelines	√
	Provision of facilities or recycling bins	√
Environment-friendly material	Environment-friendly material	

Notes:

1. "√" denotes the green feature is considered in COMPANY X list.
2. Innovative green features in category 4 and 5 of COMPANY X given list are also been considered in their corresponding criteria in the above checklist, for example "Provision of green roof" and "Engage acoustic consultant".
3. The green features are not limited to the above checklist.

7.3.2 Number of Features Incorporated in Projects

The characteristics of 4 sample projects are presented in Table 7- 10 and the features they incorporate are analyzed in Appendix Table 12. "Y" is marked in the corresponding grid if listed features were incorporated in that project. Both "List of Green Features" and "Base building requirements" are provided by COMPANY X.

Table 7- 10 Project information

Project	Award	No.of Units	GFA (sqm)	Estimated Energy Savings (kWh/yr)	Estimated Water Savings (m3/yr)	Construction cost (S$million)	Green cost Percentage (%)
1	Platinum	85	16676	550914	1686.52	70	1.44
2	Platinum	228	37221	2,822,095	82,076	200	1.68
3	Gold^{plus}	336	46778	2,034,093	4,500	163	1.79
4	Gold^{plus}	-	-	5,845,446	19,800	163	0.24

Compared to conventional buildings, green features incorporated in green buildings can be divided into two kinds: one is the feature using better materials and better design, the other is a new requirement or feature that conventional buildings do not have. The total number of green features that each project incorporates are calculated and presented in Table 7- 11. The categories listed in the table are similar to the assessment criteria in BCA Green Mark. There are five categories, including Design for Energy efficiency, Design for Water efficiency, Site and Project management, Indoor Environmental Quality and Environmental protection, and Other Green Features.

Table 7- 11 Statistics on green features incorporated

Category	Total number of Green Features	Project 1	Project 2	Project 3	Project 4
1. Design for Energy Efficiency	20	6	13	12	10
2. Design for Water efficiency	3	2	2	2	3
3. Site and Project management	12	5	6	7	10
4. Indoor Environmental Quality and Environmental protection	3	0	2	3	1
5. Other Green Features	13	2	5	8	6
Total for 1. 2. 3. 4 and 5.	51	15	28	32	30

It can be observed that there is an obvious difference in the number of green features incorporated between Project 1 and the rest of the projects. The number of incorporated green features in Project 1 is two times lower than the average for the rest of the projects. The discrepancy may be caused by the difference in project size, or point selection strategy. On one hand, the size (in terms of GFA) of Project 1 is less than a half of the sizes of other projects, which possibly need not to incorporate so many kinds of green features. In other words, the building may not provide enough space to facilitate as many green features as others. On the other hand, the difference in total number of incorporated green features could also be a result of different Green Mark point strategies. Assessment criteria contain many one-point items therefore in order to have higher score larger number of these needs to be used. When dealing with green feature selection, it is unnecessary to include every green feature to get every point in each criterion, so that the building may not need to compliant with those one-point items for obtaining points. Instead, it may be much wiser and cost-effective to get the highest score of each applicable criterion for every green feature applied. Even incorporating a same kind of green feature, different selections can result in a quite a big difference in the score obtained in the corresponding criterion. For instance, in Part 1 - Energy Efficiency, use of air-conditions labeled with four ticks can get 10 points more than use of air-conditions labeled with two ticks, and so on. However, it is also probable that the building have insufficient points to attain a certain level, if not trying to get some one-point criterions. In this case, the total number of incorporated green features serves as insurance.

Seen from Table 7-12, green features selection and their distribution among five categories was very similar in 3 projects except for project 1. 58.8% of the 51 available green features are incorporated in these three projects and the adoption rates for the green features in each category are over than the average amount except for category “Other Green Features”. Only incorporating several green features available in category “Other Green Features” can already get the needed points since only a small proportion of the total points are allocated in this part, and moreover, there are more available innovative green features can be chose in this category than others. These insufficient incentive and more choices could be a reason for the relatively lower adoption rate in this category.

Among the 52 green features listed in the Checklist, less than 60% of features have been accounted into COMPANY X consideration. Known from the above results, among 30 kinds of features considered by COMPANY X, around 60% of features are being incorporated in their project. These numbers show that only a small portion (60%×60%=36%) of green features have been incorporated in current building projects. Future buildings can be made more "green" with increment of the amount of green features applied.

Table 7- 12 Statistics on adoption rates of green features

Category	Total No. of Green Features	Project 2	Project 3	Project 4	Average No. of Green Features	Adoption rate
1. Design for Energy Efficiency	20	13	12	10	11.7	58.3%
2. Design for Water efficiency	3	2	2	3	2.3	77.8%
3. Site and Project management	12	6	7	10	7.7	63.9%
4. Indoor Environmental Quality and Environmental protection	3	2	3	1	2.0	66.7%
5. Other Green Features	13	5	8	6	6.3	48.7%
Total for 1. 2. 3. 4 and 5.	51	28	32	30	30.0	58.8%

7.3.3 Green Features with High Adoption Rate

Table 7-13 summarizes the green features with an adoption rate over or equivalent to 75% (including 75% and 100%). From the words in RED, it can be found that almost every feature with high adoption rate are included or counted in COMPANY X standard provision. But on the contrary, not all the green features listed in COMPANY X standard provision have a high adoption rate. This may suggest the COMPANY X standard provision only serves as a recommendation but not a regulation.

The formation of standard provision probably depends on: (1) their strengths and experiences, which refers to the methods well implemented in the past whose repeated application cost less time; and (2) the fact that these features are low cost, which means the listed features cost less, either by saving operational cost or construction cost, or by getting certain points with less money.

Table 7- 13 Summary of Green features with a high adoption rate

List of Green Features	Base Building Requirement	Adoption rate
Provision of better glass (such as low-e, double glazing, tinted glass, laminated glass or glass thicker than 6mm)	6mm thk clear glass	100%
Computer simulation conducted to improve on the building design such as natural ventilation simulation, sun path analysis, etc	No computer simulation	75%
Provision of 4-ticks/3-ticks/2-ticks A/C (COMPANY X Standard Provision)	1-tick A/C	75%
Provision of T5/T8 lighting (COMPANY X Standard Provision)	Normal fluorescent lighting	75%
Provision of motion sensors for lift lobbies/ changing room/ toilets/ staircases, etc. (COMPANY X Standard Provision)	No provision	75%
Provision of ductless / jet fan for car park MV	Ducted MV	75%
Provision of CO sensor or car park MV (COMPANY X Standard Provision)	No provision	100%
Provision of electrical sub-meters (COMPANY X Standard Provision)	No provision	75%
Provision of water sub-meters (COMPANY X Standard Provision)	No provision	75%
Provision of rainwater collection system	No provision	100%
Restoration / transplant of trees (COMPANY X Standard Provision)	No restoration / transplant of trees	75%
Use of recycled drywall partitions (COMPANY X Standard Provision)	Brick walls	75%
Use of road kerb, wheel stopper, drain channel with recycled aggregates	Road kerb, wheel stopper, drain channel with natural aggregates	75%
Use of landscape decking using recycled element	Landscape decking made of new materials	75%
Preparing Green Building User guide(COMPANY X Standard Provision)	No provision	75%
Provision of recycling bins (COMPANY X Standard Provision)	No provision	75%
Provision of bicycle lots (COMPANY X Standard Provision)	No provision	75%
Provision of precast toilets (COMPANY X Standard Provision)	Provision of conventional toilet inclusive of fittings and accessories	75%
Provision of dual refuse chute (COMPANY X Standard Provision)	Normal single refuse chute	75%
Provision of pneumatic waste collection system (COMPANY X Standard Provision)	No provision	75%

7.4 Cost-Benefit Analysis of Green Features

7.4.1 Cost Analysis of Green Features

For our 4 sample projects, *Proportion* is used to calculate the cost increase of each green feature. The formula is:

$$\begin{aligned} Proportion &= \frac{Cost\ of\ each\ green\ feature}{Cost\ of\ basic\ building\ requirement} - 1 \\ &= \frac{Cost\ of\ a\ green\ product\ \times Number(Applicable\ area)}{Cost\ of\ a\ normal\ product\ \times Number\ (Applicable\ area)} \\ &= \frac{Cost\ of\ a\ green\ product\ - Cost\ of\ a\ normal\ product}{Cost\ of\ a\ normal\ product} \end{aligned}$$

According to the above equation, *Proportion* represents how much percentage the cost of a green product is higher than the cost of a normal product and it is independent with project size or applicable area. The total cost of each green feature and its corresponding normal cost can be used to calculate *Proportion*. The results are shown in Table 7-14. It can be observed that *Proportion* has large variation across projects (especially the numbers shown in Blue) and features probably due to the differences in types and other product specifications. On average, the cost of a green features is 61% higher than the normal product (abnormal proportions are excluded from this statistic). Each cell is displayed like this:

Green feature Basic building requirement(shown in blank if not applicable) *Proportion*(shown in blank if not applicable)

Table 7- 14 Costs comparison between green features and basic building requirements

List of Features	Project 1	Project 2	Project 3	Project 4
Provision of better glass (such as low-e, double glazing, tinted glass, laminated glass or glass thicker than 6mm) 6mm thk clear glass	680000 200000 240%	2448007 354840 590%	7104523 5584155 27%	1170000 1080000 8%
Computer simulation conducted to improve on the building design such as natural ventilation simulation, sun path analysis, etc	26,000	36,000	25,000	-
Provision of 4-ticks/3-ticks/2-ticks A/C 1-tick A/C	-	2248758 1800000 25%	2404908 1947975 23%	2990311 1735912 72%
Provision of T5/T8 lighting Normal fluorescent lighting	-	114,958 72,364 59%	287,410 229,928 25%	104,110 80,512 29%
Provision of motion sensors for lift lobbies/ changing room/ toilets/ staircases, etc.	-	74560	26650	60900
Provision of ductless / jet fan for car park MV Ducted MV	-	554990 494200 12%	-	2709216 2257680 17%
Provision of CO sensor or car park MV	9,600.00	32,720	12,800	18,700
Provision of electrical sub-meters	-	3,000	2,350	2,350
Provision of water sub-meters	-	2,700	1,900.00	7,000
Provision of rainwater collection system	50,000	83,200	105,440.00	250,000
Restoration / transplant of trees	5,000	8,000	-	15,000
Use of recycled drywall partitions Brick walls	-	2,553,600 2,520,000 1%	905,700 485,514 87%	905,700 485,514 87%
Use of road kerb, wheel stopper, drain channel with recycled aggregates Road kerb, wheel stopper, drain channel with natural aggregates	-	36,884 33,615 10%	37,000 25,000 48%	-

Use of landscape decking using recycled element Landscape decking made of new materials	97,000 78,000 24%	-	710,000 600,000 18%	250,000 150,000 67%
Preparing Green Building User guide	10,000	5,500	-	10,000
Provision of recycling bins	-	1,500	2,250.00	85.00
Provision of bicycle lots	-	13,500	7,000.00	19,500
Provision of precast toilets Provision of conventional toilet inclusive of fittings and accessories	-	2902400 1533600 89%	9961306.5 8 9802906.5 8 2%	8500000 5700000 49%
Provision of dual refuse chute Normal single refuse chute	-	938545 240000 291%	177152 88576 100%	370000 185000 100%
Provision of pneumatic waste collection system	-	1609650	1037400	2000000

Table 7-15 shows that the green cost distributions among categories differ in projects. On average, 42.45% of green cost is spent on energy efficient equipment and features, which is more than the expenditure on other aspects. This finding reveals that compared with other parts, energy efficiency part is the main focus of interest by developers, no matter from which point of view like the selection of green features, the numbers or the adoption rate of green features, or the cost proportion.

Table 7- 15 Green Cost distributions by category

	Project 1	Project 2	Project 3	Project 4	Average
1. Design for Energy Efficiency	56.8%	47.6%	42.5%	22.9%	42.45%
2. Design for Water Efficiency	24.4%	1.1%	1.9%	5.0%	8.10%
3. Site & Project Management	15.5%	2.9%	14.3%	19.4%	13.03%
4. Indoor Environmental Quality & Environmental Protection	0.0%	1.7%	14.2%	0.2%	4.03%
5. Other Green Features	3.3%	46.7%	27.1%	52.5%	32.40%
Total	100%	100%	100%	100%	

To provide a better and more comprehensive analysis on the cost of green features, besides the cost analysis with our 4 samples, information from other sources were obtained in this study. Information about the registered Suppliers, Contractors and other related sector were retrieved from website such as BCA directory. Unfortunately, the companies either do not have their own website, or provide no exact product information on the website. Moreover, the product information released on EBAY and Alibaba are either not having corresponding item or having a wide range of price with different providers and different types. Therefore the results are indefinite and inappropriate for research purpose.

In conclusion, the costs of green features and green products vary a lot in regions, providers, types and other product specifications. Unfortunately, the local basis data for the products used in our sample buildings are unavailable. More detailed data need to be collected for further analysis.

7.4.2 Benefits Analysis of Green Features

Some green features and their potential savings are summarized in the following (source: Green building design guide for air-conditioned buildings).

Design in Energy Efficiency

VSDs on chilled water pumps	Potential saving
	VSDs save energy for electric motors driving pumps when capacity is reduced. It must be noted that the power consumption of motor varies approximately with the cube of the motor speed. This means that a reduction of speed by 20% will result in reduction of power consumption by a half i.e. 50% saving. Since most air-conditioning system seldom runs at full load, significant energy saving can be made with these VSDs. An Energy Conservation Project at NTU [5] shows that by implementing VSD control on chilled water pumps, an average saving of 18% on chiller plant power was recorded.

VAV system with VSD on Fan	Potential saving
	The fan and motor are initially designed and installed to meet the maximum cooling load of the room. During normal operation, the fan may operate at levels below its maximum rating. Varying the fan speed to satisfy the actual operating requirement will significantly reduce the energy consumed by the fan and motor. This savings can be as much as 15%.

"T5" fluorescent lamp	Potential saving
	The use of T5 lamps combined with electronic high frequency ballast can save energy by up to 40% compare with equivalent standard TL-D systems.

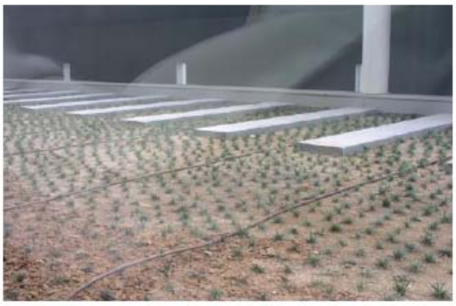
High frequency electronic ballast	Potential saving
	The efficacy of the lamp can be improved by about 10% when fluorescent lamps are operated at higher frequencies.

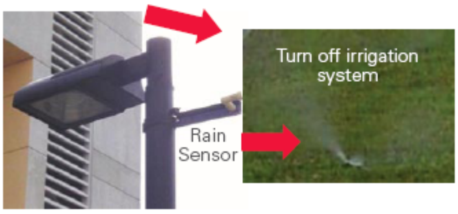
Energy efficient features	Potential saving
• Lift with AC VVVF motor drive 	Compared with conventional variable voltage (VV) drive, VVVF drive could save energy by about 10%.

• Lift with synchronous motor with permanent magnets 	Compared with asynchronous motors, the permanent magnet synchronous motors could save energy by about 30-50% as a result of high power factor (~0.9) and the elimination of excitation current [8].
• Lift with motor drive system - either gearless type or planetary gear type 	The elimination of gear improves the energy efficiency as gearless drive has no gear transmission loss. Planetary gears can also be used to replace the low efficiency worm gears. By utilizing planetary gears, an overall annual savings of about 34% could be achieved when compared with worm gear system [8].

Escalators with slow down feature	Potential saving
	Adjusting the speed of the escalator to slow down when not in use can save energy of up to 30%.

Design in Water Efficiency

Water Efficient Irrigation System	Potential saving
Drip irrigation system 	• Drip irrigation uses 30% to 50% less water than sprinkler irrigation

Rain sensor to shut the irrigation system 	• This project uses drip irrigation that was activated based on time schedule regardless of the weather. By simply incorporating rain sensor to shut the irrigation system off during raining days, savings of 35% of water a year were achieved.

Based on the green feature examples summarized above, the incorporation of such designs in energy efficiency and water efficiency will save energy by over than 10% and around 30% of water per year. Our descriptive results in section 5.4 confirmed this savings estimation, which finds the sampled buildings can achieve annual savings of 33% energy and 16.3% water on average.

7.4.3 Discussion

Based on the four sample projects and Green building design guide released by BCA, this section finds the cost of a green features is 61% higher than the normal product and the incorporation of such designs in energy efficiency and water efficiency will achieve savings of at least 10% per year. The findings are comparable with the descriptive results of the overall sample(see in Chapter 5), which summarizes green buildings cost 1.61% higher than non-green buildings but can achieve an average savings of 33% energy and 16.3% water per year. From the comparison, we can conclude that the cost increase on standalone green feature basis are higher than the overall cost increase on a building basis, but the energy and water savings estimated by the performance of a green feature is lower than the savings estimated by the overall green performance of a building. These differences attribute to the following reasons:

1. The benefits of some green features could be synergistic. The visible benefits could be less if singling out a feature. And sometimes the impact brought by one feature is double-sided, such as the example used in section 4.3. Good orientation and better space planning will improve the day lighting but raise the radiation heat gain as well. In this case, the benefits are difficult to measure.

2. The benefits do not just mean energy savings, water savings and other less operational fee. They also include other kinds of advantages which may not be visible, like the increasing occupants comfort, productivity and health. In addition, the added cost may be compensated by the higher sales price and rental fee.

Therefore, the cost and benefits analysis on each standalone green feature may not be as useful as the cost and benefits analysis on the overall building, but it still can help explain the higher cost and savings observed from the green building projects.

7.5 Trend of Construction Cost and Green Cost

The construction costs are a little higher than the cost of conventional building; however, they can still be reduced if overcoming the barriers. Studies have concluded the probable barriers for reducing cost as follows.

Lack of experience with green building

The design team, construction team, or client may not well understand the principles of sustainable construction and the requirement of rating systems, and therefore need to spend more time on research. They may "waste time researching inappropriate technologies" or "accept a bid that is twice the reasonable amount for commissioning services". Additionally, the risk they may face could also be overestimated due to the relative newness of green technologies, systems and designs (Geof et al., 2003; Kats et al., 2003; Matthiesen & Morris, 2004).

Selection of materials and technologies

The materials and technologies may not be well selected because (1) there are inadequate supplies of manufactured building components which meet LEED standards; and (2) the new and interesting materials and technologies continue to enter the market, thus leaving insufficient time to fully study (Geof et al., 2003).

Attempts to incorporate green after construction starts

Incorporating integrated design at the beginning stage can reduced the total cost substantially, otherwise the redesign work and associated change orders will cause a large amount of inevitably cost which account for more than 6% of the total cost, according to analysis by KEMA Xenergy (Geof et al., 2003).

High indirect fees

Last reason for the higher cost may be due to the higher soft costs, like the certification fee, which may add 1 to 2 percent of the overall budget to the construction cost. Miller et al. (2008) pointed out that other costs are much higher than the certification fee, such as dealing with inflexible, uninformed, and uncooperative local building code regulars or the lack of local experts and resources. Moreover, to make sure that the projects can obtain a certain level, developers need to spent more money on design analysis, computer modeling and simulation, commissioning, product research, and lifecycle cost analysis for alternative materials or building systems.

If the above barriers are eliminated, the overall construction cost can be down, however, in the long run, in the pursuit of more green buildings, the construction cost are surely to keep increasing, concluded by a recent study(2007). Of course, at the same time occupancy rates and capital value will arise as well, while more and more carbon emissions will be reduced (See in Figure 7- 3).

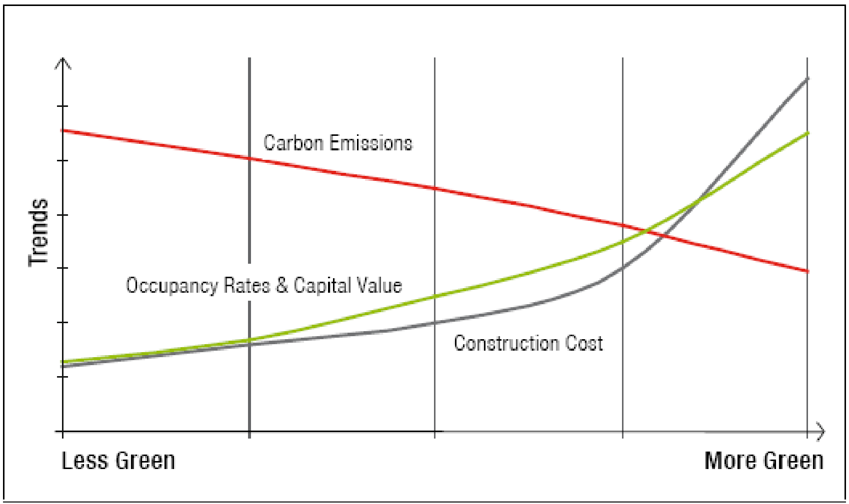


Figure 7- 3 The impact when we go less green to more

Source: Davis Langdon, 2007, *The cost and benefits of achieving green buildings,*Pg3

However, the additional green cost is indefinite to increase with the total construction cost, but more likely will drop in the near future. On one hand, the LEED-compliant materials, systems, and processes will become more common suggested by a report from U.S. It is known that product has its highest price when it first comes to the market, but when it becomes more common, the price will be reduced. On the other hand, the requirement for conventional buildings will be higher - a building with a green design will be viewed as “the norm”, which means “business as usual” cost will rise (2007). In the U.S., some experts in industry claim that the market is moving toward 5 Star Green Star as the base standard for a marketable building. As such, the “extra” costs for going green will diminish, and will sure push the expansion of boundaries of innovation and technology, and more cutting-edge design solutions are expected to see in future.

7.6 Summary

The results summarized in this chapter may be beneficial to the developers and other sectors within green building field in the following aspects:

1. Focus on Energy Efficiency – The changes of Green Mark Scheme show the policies changes towards an Energy Efficient Singapore. The energy efficiency part has become an integral part in Green Mark assessment criteria since it is allocated a large portion of total points. In addition, it is also the main focus of developers comparing with other parts, no matter from which point of view like the selection of green features, the numbers or the adoption rate of green features, or the cost proportion.
2. Difficulty in maintaining the Green Mark status - Since the unchanged criteria only account for around 45% of the total score by points in the newest version (version 3), green buildings may face a big challenge to maintain the same rating. However, it may not be as hard as perceived from the unchanged scores, because the building project are required a relatively lower score to attain a certain rating.
3. A wide potential to incorporate more green features in green buildings - Only a small portion (36%) of green features have been incorporated in the building projects which reveals a wide potential for buildings to get greener. Therefore, more green features and more technologies can be applied in the buildings for better environmental performance.

Last, the study further discussed the trend of construction cost and green cost. It suggests that the construction cost can be reduced in the short term if gathering more experience, better selection of materials and technologies, incorporating integrated design and reducing other fees. However, in the long run, in the pursuit of more green buildings, the construction cost is surely to keep increasing. Green cost will decrease in the future.

8 Conclusion

8.1 Main Findings

This study addresses questions on the construction cost of green building, and tries to identify whether there exists a construction cost premium between green and non-green buildings. The number of green building projects that meet our requirements is small in Singapore and the information required for this study, including cost data and design documents, is quite confidential. The collection of such confidential data is really difficult for many reasons. A total number of 20 new green building projects are collected in our sample, wherein residential buildings make up 75% of the overall buildings and 80% of the buildings awarded Green Mark in 2008 or 2009.

The study confirms that construction costs of green buildings are slightly higher than the cost of non-green buildings. Generally, green costs make up 1.6% of total construction costs valued at $2.81 million on average, wherein the average green cost premium for different Green Mark ratings are 2.45% for Platinum, 1.23% for Gold^{plus}, 1.21% for Gold, which are consistent with but lower than the findings of earlier studies (Kats et al., 2003; Turner Construction, 2005; Miller et al., 2008) and BCA reports. The study also finds that cost per GFA in our sample range from $2000/sqm to $ 6897/sqm. These results fill in the research gap (1) and (2) as stated in Chapter 1.

Going beyond descriptive studies widely used in previous research on the costs of green buildings, this is the first study that tries to empirically prove the impact of green rating and other green performance indicators on the construction cost and green cost, and especially the extent of their impacts. A theoretical model is set to examine this relationship, and as well as help the owner make a more accurate estimation to the building tender price with the limited information they have at the conceptual planning stage. The basic idea is to use conventional hedonic method to estimate the cost, and put other green features together in the model to determine the cost increase. Case studies, descriptive results and regression analyses have found that the costs for green buildings and the costs for incorporating sustainable design elements depend greatly on a wide range of factors, including number of building storeys, number of units, total area, property type, the familiarity of green design, Green Mark rating, estimated energy and water savings, version of Green Mark assessment criteria, and Building Tender Price Index. In most cases, these factors have a relatively small but still noticeable impact on the overall cost of sustainability. Unfortunately, because of our limited sample, the study did not consistently prove the significance of the variables as expected.

Notwithstanding its limitations, this study does suggest that Model 2 produced the relatively reasonable results by comparing the value of Adj R square and the parameters' significance level. The model can be described in the following equation:

$$COST = c + \alpha\, STOREY + \beta\, AREAPS + \gamma\, Proptype + \varepsilon$$

Where:

COST	=	Construction cost on one building basis;
c	=	constant (intercept);
STOREY	=	Number of storeys;
AREAPS	=	Area per storey
Proptype	=	1 for residential buildings, and 0 for commercial buildings.

Residential building is chosen as defaults for *Proptype*;
α, β, γ = Estimated statistical parameters; and
ε = An error term.

Among green attributes, *Platinum* is the most consistently significant variable that affect *Green cost*, which suggests that rather than Green Mark rating, *Platinum* rating is more vital to *Green cost*. *GFA* has a negative relationship with *Green Cost percentage*. This may confirm the existence of scale effect discussed previously. The bigger the project, the less the green cost percentage will be. In addition, the coefficients of *LnEnergySavings* are positive and significant. This indicates that the investment on energy efficiency equipment will sure increase the overall cost of green building.

By comparing three versions of Green Mark assessment criteria, our study finds that energy efficiency is an integral part of Green Mark Scheme and also the main focus of developers. The updates of Green Mark Scheme also influence the rating of a green building project. The unchanged criteria only account for around 45% of the total score by points in the newest version, but at the same time the building projects require a relatively lower score to attain a certain rating.

Moreover, this study attempts to provide a concrete case study by employing four green residential buildings developed by a company and analyzing the green features these projects incorporate. The study reveals that current green building design adopts 36% of available green features, indicating that future buildings can be made more "green" with increment of the amount of green features applied.

The descriptive results find that green buildings cost 1.61% higher than non-green buildings but can achieve an average savings of 33% energy and 16.3% water per year. Case studies with four projects also reveal the cost of a green features is 61% higher than the normal product and the incorporation of such designs in energy efficiency and water efficiency will achieve savings of at least 10% per year. Seen from the differences, the study concludes that the cost and benefits analysis on each standalone green feature may not be as useful as the cost and benefits analysis on the overall building, but it still can help to understand the higher cost and savings observed from the green building projects.

8.2 Limitations of the Study

There are some limitations in this study. First, the information and cost data for non-green buildings is unavailable. We are not able to calculate Green cost by ourselves. The green cost calculations may differ among developers due to the difference in their calculation methods and benchmarks for calculation.

Second, multivariate regressions are subject to small sample bias, thus resulting in the insignificant results. The data sample is restricted by the availability of green cost data. If overcoming the green cost calculation problem, more sample buildings can be collected and the results can be more convincible. Since our regression results are not ideal, the study did no robust test or endogeneity test for our model.

Third, the results of this study are sensitive to the sample selection. The same comparisons done with a completely different sampling of buildings may yield completely different or even conflicting results.

8.3 Recommendations for Future Work

Given the limitations of this thesis, there are some extensions to this work that would help expand and strengthen the results. Such extensions for future studies may include considerations of:

- More certified buildings included in their sample to get a more robust and significant results since the number of green buildings in Singapore is consistently and dramatically increasing in recent years
- More in-depth studies on the impact of different selections of green features on construction cost and green cost premium
- More in-depth studies on cost-benefit analysis on standalone green feature if the local cost information for the products becomes available

Moreover, attempts to compare the cost of a specific green building with other buildings of similar size and function in a different location may not provide as much help in understanding the cost of green design as perceived. Future studies could try to understand the construction cost of existing buildings before and after renovation, make a comparison between conventional and green designs for the same building, so as to make a more meaningful assessment of the construction cost.

More research needs to be carried out, not just focuses on the initial cost increments, but also steps into the life cycle cost assessment. Several researchers and scholars have already analyzed this task but there is still a long way to go. And more importantly, green should no longer be viewed as something that is added on to a building, but something that is part of the design, construction and operations process from the very beginning. This change of our perception may be much easier and important.

In the future, more attention should be given to the collaborative effort between both the industry and government, such as (1) increase the number of a trained and expert group of individuals who are able to provide effective advice and guidance for the rest of the industry;(2) publish more information on green technologies and green features would help to increase in the GMS, the industry is seeking a source of cost information for green construction to assist them in their building decisions. Furthermore, it would be much helpful to set up a separate TPI (Tender Price Index) for green buildings if more cost data became available.

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Appendices

Appendix Table 1 Summary of Policies and Measures in E^2 Singapore

	Power Generation	Industry	Buildings	Transport	Households
Promote adoption of energy efficient technology and measures	clean Development Mechanism				
	$10 million EASe Scheme Accelerated depreciation allowance Investment allowance				
	Promote cogeneration and trigeneration via industrial land planning and facility siting	Design for Efficiency scheme Grant for Energy Efficient Technologies	Building regulations Government take the lead Energy Smart Mandating Green Mark Certified $20 million Green Mark Incentive Scheme Grant to upgrade building Envelopes Residential building standards	Manage vehicle usage and traffic congestion Improving and promoting the use of public transport Fuel economy labeling Green Vehicle Rebate Promoting Fuel-Efficient Driving Habits	Mandatory labeling Minimum energy performance standards Electricity Vending System Electricity consumption tracking device
Research &development, and Capability building	Innovation for Environmental Sustainability fund				
			Green Buildings R&D fund		
	Energy service company accreditation scheme Singapore Certified Energy Manager Programme and Training Grant				
Raise awareness	Energy efficiency seminars and workshops Energy efficiency website Public awareness programme				

Appendix Table 2 Summary of Green building Schemes

Green buildings schemes	**Sponsor**	**Aim**	**Details**
Green Mark Incentive Scheme for Existing Buildings (GMIS-EB)	BCA	In the Sustainable Singapore blueprint the government has set a target for 80% of the existing building stock to achieve at least Green Mark Certified rating by 2030. A $100 million Green Mark Incentive Scheme for Existing Buildings (GMIS-EB) was set up by BCA to encourage private building owners of existing buildings to undertake improvements in energy efficiency.	Co-funds is provided up to 35% of the costs for energy efficiency improvements and capped at $1.5 million.
Green Mark Incentive Scheme for New Buildings (GMIS-NB)	BCA	To accelerate the adoption of green building technologies and design practices. The enhanced scheme provides cash incentives to developers, building owners, project architects and M&E engineers, who achieve at least a BCA Green Mark Gold rating in the design and construction of new buildings.	$20 million
Green Mark Gross Floor Area Incentive Scheme (GM-GFA)	BCA and URA	To encourage the private sector to develop buildings that attain the higher Green Mark ratings.	URA will grant additional floor area over and above the Master Plan Gross Plot Ratio (GPR) control, up to 1% for Green Mark Gold^{plus} developments and up to 2% for Green Mark Platinum developments, and subject to a cap of 2,500 sqm for Gold^{plus} and 5,000 sqm for Platinum.
MND Research Fund for the Built Environment	Initiative by MND and managed by BCA.	To encourage and support applied R&D that will raise the quality of life and make Singapore a distinctive global city. Under the MND (the Ministry of National Development) Research Fund, some key focus areas include sustainable development projects such as integrating solar technologies into building facades.	$50 million The fund covers 30% to 75% of the qualifying cost of the project, subject to a cap of $2 million.
Pilot Incentive Scheme for	NParks	Start in September 2009 to encourage existing building	Funding is provided up to 50% of the cost of

Green Roofs		owners to green their rooftops. The scheme will pilot in the Downtown and Orchard Planning areas, and target low to mid-rise buildings that are highly visible and buildings with low level of street-level greenery.	installation of the green roofs.
Gross Floor Area Incentives for Outdoor Refreshment Area on Rooftops	URA	Grant existing buildings within the Orchard and Downtown Core planning areas additional gross floor area (GFA), beyond the Master Plan permissible Gross Plot Ratio (GPR), to be used for an outdoor refreshment area (ORA) on the rooftop if development owners introduce rooftop landscaping.	The incentive scheme provides bonus GFA of up to 200 sqm or 50% of the roof space for ORA use.

Appendix Table 3 Green Mark for Existing Buildings (Version 1)

GREEN MARK FOR EXISTING BUILDINGS
Point allocations of Green Mark Criteria

	Points allocated
Part 1: Energy Efficiency	
1. Energy Efficiency Index	7
2. Continual Improvement for Energy Efficiency	7
3. Electrical Sub-metering	2
4. Energy Efficient Systems & Features	6
5. Roof Top Gardens & Landscaping	3
Sub-total	**25**
Part 2: Water Efficiency	
1. Continual Improvement for Water Efficiency	6
2. Water Efficient Fittings	6
3. Water Efficient Irrigation and Landscaping	3
Sub-total	**15**
Part 3: Building Management & Operation	
1. Building Maintenance	3
2. Environmental Management System	8
3. Building Maintenance and Operation Guidelines	4
4. Preservation & Enhancement of Landscaping	3
5. Public Transport Accessibility	1
6. Recycling	4
7. Occupant Health	2
Sub-total	**25**
Part 4: Indoor Environmental Quality and Environmental Protection	
1. Effective Ventilation	2
2. High Frequency Ballasts	2
3. Luminance Level	2
4. Thermal Comfort	2
5. Noise Level	2
6. Indoor Air Quality Audit	2
7. Refrigerants	3
Sub-total	**15**
Part 5: Innovation	
1. Innovation	20
Sub-total	**20**
Total	**100**

Effective Date: 17 Oct 2006

Appendix Table 4 Green Mark for New Buildings (Version 1)

GREEN MARK FOR NEW BUILDINGS
Point allocations of Green Mark Criteria

	Points allocated
Part 1: Energy Efficiency	
1. Building Envelope Design	6
2. Energy Efficiency Index	4
3. Electrical Sub-metering	2
4. Energy Efficient Systems & Features	12
5. Lighting Zoning	1
6. Roof Top Gardens & Landscaping	5
Sub-total	**30**
Part 2: Water Efficiency	
1. Water Efficient Fittings	6
2. Water Usage and Leak Detection	4
3. Water Efficient Irrigation and Landscaping	4
4. Water Consumption by Cooling Tower	6
Sub-total	**20**
Part 3: Site & Project Management	
1. Conservation & Restoration of Site Ecology	3
2. CONQUAS	2
3. Public Transport Accessibility	1
4. Environmental Management System	6
5. Environment Friendly Materials	5
6. Building Maintenance and Operation Guidelines	3
Sub-total	**20**
Part 4: Indoor Environmental Quality and Environmental Protection	
1. Effective Ventilation	2
2. High Frequency Ballasts	2
3. Luminance Level	2
4. Thermal Comfort	2
5. Noise Level	2
6. Indoor Air Pollutants	2
7. Refrigerants	3
Sub-total	**15**
Part 5: Innovation	
1. Innovation	15
Sub-total	**15**
Total	**100**

Appendix Table 5 Green Mark for Air-Conditioned Buildings (Version 2.0)

GREEN MARK FOR AIR-CONDITIONED BUILDINGS (VERSION 2.0)

Points allocation of Green Mark Criteria

	Pre-requisite points allocated	Additional Points allocated	Total
Part 1: Energy Efficiency			
1. Building Envelope Design	4	6	
2. Energy Efficiency Index	2	3	
3. Electrical Sub-metering	2	-	
4. Energy Efficient Features	4	8	
5. Efficient Lighting Control	2	-	
6. Greenery Provision	-	4	
Sub-total	**14**	**21**	**35**
Part 2: Water Efficiency			
1. Water Efficient Fittings	2	4	
2. Water Usage and Leak Detection	2	1	
3. Water Efficient Irrigation and Landscaping	-	4	
4. Water Consumption of Cooling Tower	2	-	
Sub-total	**6**	**9**	**15**
Part 3: Site & Project Management			
1. Conservation & Restoration	-	3	
2. CONQUAS	-	2	
3. Public Transport Accessibility	-	1	
4. Environmental Management System	3	2	
5. Environment Friendly Materials	1	4	
6. Buildable Design	-	1	
7. Building Maintenance and Operation Guidelines	1	2	
Sub-total	**5**	**15**	**20**
Part 4: Indoor Environmental Quality and Environmental Protection			
1. CO and CO_2 Monitoring	1	1	
2. High Frequency Ballasts	-	2	
3. Luminance Level	2	-	
4. Thermal Comfort	2	-	
5. Noise Level	-	2	
6. Indoor Air Pollutants	-	2	
7. Refrigerants	-	3	
Sub-total	**5**	**10**	**15**
Part 5: Innovation			
1. Innovation		15	
Sub-total		**15**	**15**
Total	**30**	**70**	**100**

Effective Date: 6 Nov 2007

Appendix Table 6 Green Mark for Residential Buildings (Version 2)

GREEN MARK FOR RESIDENTIAL BUILDINGS

Points allocation of Green Mark Criteria

	Pre-requisite points allocated	Additional Points allocated	Total
Part 1: Energy Efficiency			
1. Building Envelope Design	4	3	
2. Energy Efficiency Index	2	-	
3. Electrical Sub-metering	2	-	
4. Energy Efficient Features	4	11	
5. Natural Ventilation	-	5	
6. Greenery Provision	2	2	
Sub-total	**14**	**21**	**35**
Part 2: Water Efficiency			
1. Water Efficient Fittings	3	6	
2. Water Usage	2	-	
3. Water Efficient Irrigation and Landscaping	-	4	
Sub-total	**5**	**10**	**15**
Part 3: Site & Project Management			
1. Conservation & Restoration	-	3	
2. CONQUAS	-	2	
3. Public Transport Accessibility	-	4	
4. Environmental Management System	3	2	
5. Environment Friendly Materials	1	6	
6. Buildable Design	-	1	
7. Building Maintenance and Operation Guidelines	2	1	
Sub-total	**6**	**19**	**25**
Part 4: Indoor Environmental Quality and Environmental Protection			
1. CO Monitoring	1	-	
2. Luminance Level	1	-	
3. Noise Level	-	1	
4. Indoor Air Pollutants	-	3	
5. Refuse Chute	-	1	
6. Pollution Control	3	1	
7. Effective Ventilation	-	3	
8. Daylighting	-	1	
Sub-total	**5**	**10**	**15**
Part 5: Innovation			
1. Innovation		10	
Sub-total		**10**	**10**
Total	**30**	**70**	**100**

Effective Date: 6 Nov 2007

Appendix Table 7 Green Mark for Non-Residential building (Version 2)

BCA Green Mark Version NREB/2.0 Non-Residential Existing Building Criteria (Version 2)

POINT ALLOCATION

ASSESSMENT CRITERIA			POINTS AVAILABLE	PREQUISITIES
ENERGY EFFICIENCY (To achieve minimum 30 points)				
Maximum Cap of 50 points can be scored	Minimum 30 points to be scored	**Part 1 – Energy Efficiency**		
		1-1 Energy Efficiency	22	15
		1-2 Systems Energy Efficiency	23	11
		1-3 Energy Monitoring	4	-
		1-4 Energy Policy & Management	4	4
		1-5 Renewable Energy / Energy Efficient Features [BONUS]	10	-
		SubTotal (Part 1)	**63**	**30**
OTHER GREEN REQUIREMENTS (To achieve minimum 20 points)				
Maximum Cap of 50 points can be scored	Minimum 20 points to be scored	**Part 2 - Water Efficiency**		
		2-1 Water Monitoring	4	-
		2-2 Water Efficient Fittings	10	6
		2-3 Alternative Water Sources	2	-
		2-4 Water Efficiency Improvement Plans	1	-
		2-5 Cooling Towers	1	
		SubTotal (Part 2)	**18**	**6**
		Part 3 - Sustainable Operation & Management		
		3-1 Building Operation & Maintenance	4	-
		3-2 Post Occupancy Evaluation	2	2
		3-3 Waste Management	8	6
		3-4 Greenery	3	-
		3-5 Public Transport Accessibility	2	-
		SubTotal (Part 3)	**19**	**8**
		Part 4 - Indoor Environmental Quality		
		4-1 Indoor Air Quality Performance	6	4
		4-2 Environmental Protection	5	-
		4-3 Lighting Quality	4	1
		4-4 Thermal Comfort	2	1
		4-5 Internal Noise Level	1	-
		SubTotal (Part 4)	**18**	**6**
		Part 5 – Other Green Features [BONUS]		
		SubTotal (Part 5)	**10**	-
GRAND TOTAL			**128**	**50**

Effective Date: 29 April 2009

Appendix Table 8 Green Mark for Non-Residential Existing Building (Version 2.1)

BCA Green Mark Version NREB/2.1 Non-Residential Existing Building Criteria (Version 2.1)

POINT ALLOCATION

ASSESSMENT CRITERIA			POINTS AVAILABLE	PREQUISITIES
ENERGY EFFICIENCY (To achieve minimum 30 points)				
Maximum Cap of 50 points can be scored	Minimum 30 points to be scored	**Part 1 – Energy Efficiency**		
		1-1 Energy Efficiency	22	15
		1-2 Systems Energy Efficiency	23	11
		1-3 Energy Monitoring	4	-
		1-4 Energy Policy & Management	4	4
		1-5 Renewable Energy / Energy Efficient Features [BONUS]	10	-
		SubTotal (Part 1)	**63**	**30**
OTHER GREEN REQUIREMENTS (To achieve minimum 20 points)				
Maximum Cap of 50 points can be scored	Minimum 20 points to be scored	**Part 2 - Water Efficiency**		
		2-1 Water Monitoring	2	-
		2-2 Water Efficient Fittings	12	6
		2-3 Alternative Water Sources	2	-
		2-4 Water Efficiency Improvement Plans	1	-
		2-5 Cooling Towers	1	
		SubTotal (Part 2)	**18**	**6**
		Part 3 - Sustainable Operation & Management		
		3-1 Building Operation & Maintenance	4	-
		3-2 Post Occupancy Evaluation	2	2
		3-3 Waste Management	8	6
		3-4 Greenery	3	-
		3-5 Public Transport Accessibility	2	-
		SubTotal (Part 3)	**19**	**8**
		Part 4 - Indoor Environmental Quality		
		4-1 Indoor Air Quality Performance	6	4
		4-2 Environmental Protection	5	-
		4-3 Lighting Quality	4	1
		4-4 Thermal Comfort	2	1
		4-5 Internal Noise Level	1	-
		SubTotal (Part 4)	**18**	**6**
		Part 5 – Other Green Features [BONUS]		
		SubTotal (Part 5)	**10**	-
GRAND TOTAL			**128**	**50**

Effective Date: 1 December 2009

Appendix Table 9 Green Mark for Residential Buildings (Version RB/3.0)

Point Allocations - BCA Green Mark for Residential Buildings (Version RB/3.0)

		Category	Point Allocations
(I)		**Energy Related Requirements**	
Maximum Cap of 50 points	**Minimum 30 points**	**Part 1 : Energy Efficiency**	
		1-1 Building Envelope – RETV	15
		1-2 Dwelling Unit Indoor Comfort	16
		1-3 Natural Ventilation in Common Areas	2
		1-4 Lighting	15
		1-5 Ventilation in Carparks	8
		1-6 Lifts	2
		1-7 Energy Efficient Features	7
		Category Score for Part 1 – Energy Efficiency (Exclude Bonus Points)	**65**
Bonus 20 points		1-8 Renewable Energy *(Bonus Points)*	20
(II)		**Other Green Requirements**	
Maximum Cap of 50 points	**Minimum 20 points**	**Part 2 : Water Efficiency**	
		2-1 Water Efficient Fittings	10
		2-2 Water Usage	1
		2-3 Irrigation System	2
		Category Score for Part 2 – Water Efficiency	**13**
		Part 3 : Environmental Protection	
		3-1 Sustainable Construction	12
		3-2 Greenery	6
		3-3 Environmental Management Practice	9
		3-4 Public Transport Accessibility	2
		Category Score for Part 3 – Environmental Protection	**29**
		Part 4 : Indoor Environmental Quality	
		4-1 Noise Level	1
		4-2 Indoor Air Pollutants	3
		4-3 Waste Disposal	1
		4-4 Indoor Air Quality in Wet Areas	1
		Category Score for Part 4 – Indoor Environmental Quality	**6**
		Part 5 : Other Green Features	
		5-1 Green Features & Innovations	7
		Category Score for Part 5 – Other Green Features	**7**
		Total Points Allocated :	**120**
		Total Point Allocated (Include BONUS points):	**140**
		Green Mark Score (Max) :	**100 + Bonus 20 points**

Appendix Table 10 Green Mark for Non-Residential Buildings (Version NRB/3.0)

Point Allocations - BCA Green Mark for Non-Residential Buildings (Version NRB/3.0)

		Category		Point Allocations
(I) Energy Related Requirements				
Maximum Cap of 50 points	Minimum 30 points	**Part 1 : Energy Efficiency**		
		1-1 Building Envelope – ETTV	Section (A) Applicable to air-con areas	15
		1-2 Air-Conditioning System		27
		Sub-Total (A) - Item 1-1 to 1-2		42
		1-3 Building Envelope - Design/Thermal Parameters	Section (B) Applicable to non air-con areas	29
		1-4 Natural Ventilation (exclude carparks)		13
		Sub-Total (B) - Item 1-3 to 1-4		42
		1-5 Artificial Lighting	Section (C) Generally applicable to all areas	12
		1-6 Ventilation in Carparks		5
		1-7 Ventilation in Common Areas		5
		1-8 Lifts and Escalators		3
		1-9 Energy Efficient Practices & Features		12
		Sub-Total (C) - Item 1-5 to 1-9		37
		Category Score for Part 1 – Energy Efficiency (Exclude Bonus Points) **Prorate Subtotal (A) + Prorate Subtotal (B) + Subtotal (C)**		**79**
Bonus 20 points		1-10 Renewable Energy *(Bonus Points)*		20
(II) Other Green Requirements				
Maximum Cap of 50 points	Minimum 20 points	**Part 2 : Water Efficiency**		
		2-1 Water Efficient Fittings		8
		2-2 Water Usage and Leak Detection		2
		2-3 Irrigation System		2
		2-4 Water Consumption of Cooling Tower		2
		Category Score for Part 2 – Water Efficiency		**14**
		Part 3 : Environmental Protection		
		3-1 Sustainable Construction		14
		3-2 Greenery		6
		3-3 Environmental Management Practice		8
		3-4 Public Transport Accessibility		2
		3-5 Refrigerants		2
		Category Score for Part 3 – Environmental Protection		**32**
		Part 4 : Indoor Environmental Quality		
		4-1 Thermal Comfort		2
		4-2 Noise Level		2
		4-3 Indoor Air Pollutants		2
		4-4 High Frequency Ballasts		2
		Category Score for Part 4 – Indoor Environmental Quality		**8**
		Part 5 : Other Green Features		
		5-1 Green Features & Innovations		7
		Category Score for Part 5 – Other Green Features		**7**
			Total Points Allocated :	**140**
			Total Point Allocated (Include BONUS points):	**160**
			Green Mark Score (Max) :	**100 + Bonus 20 points**

Effective Date : 31 Jan 2008

Appendix Table 11 Checklist of green features and description

Category	Checklist of green Features	Description	List of Green Features
1. Design for Energy Efficiency			**Energy Efficient Building Envelope**
	Façade materials	Using better glass allows high transmission of light without excessive heat absorption.	Provision of better glass (such as low-e, double glazing, tinted glass, laminated glass or glass thicker than 6mm)
			Provision of external walls with better properties to enhance ETTV
			Provision of insulation/ cool paint for external façade
			Energy Efficient Building Envelope (Cont'd)
	Sun-shading	It shades the buidling from direct sunlight to minimize solar heat gain, and also retains its aesthetic value while allowing enough daylight to the rooms	Provision of additional sun-shading (both vertical and horizontal) which is not in the original design but include to improve RETV
	Use of ventilation simulation software	To identify the most effective building design and layout to achieve good natural ventilation	Computer simulation conducted to improve on the building design such as natural ventilation simulation, sun path analysis, etc
			Energy Efficient Lift
	Energy Efficient Lift		Provision of motor-roomless lift/ re-generative lift
			Energy Efficient Fridges
	Air c-conditioning system	Enhance dwelling unit indoor comfort	Provision of 4-ticks/3-ticks/2-ticks fridges
			Energy Efficient Air-Conditioners
			Provision of 4-ticks/3-ticks/2-ticks A/C
			Energy Efficient Light for Common Areas, External Areas and Car Park
	Energy efficient lamps		Provision of T5/T8 lighting
			Provision of LED lamps
	Occupancy sensors	Detecting occupant motion and light the space only when it is	Provision of motion sensors for lift lobbies/ changing room/ toilets/

		occupied.	staircases, etc.
	Day lighting		**Energy Efficient Light for Common Areas, External Areas and Car Park (Cont'd)** Provision of sun pipes to maximize day lightings
	Ventilation in carparks	(1) carparks designed with natural ventilation (2) CO sensors are used to regulate the demand for mechanical ventilation(MV)	**Basement Car Park Mechanical Ventilation (MV)** Provision of ductless / jet fan for car park MV Provision of CO sensor or car park MV
			Other Energy Efficient Features
	Electrical sub-metering		Provision of electrical sub-meters
	Renewable energy		Provision of Solar panel Provision of solar hot water Provision of heat exchange pump to supply hot water to club house changing room
2. Design for Water Efficiency	**Metering and accounting**	The main and sub-meters should be linked to a building management system(BMS) for recording water usage trend.	Provision of water sub-meters
	Water efficient irrigation system	Drip irrigation system with rain sensor to shut the irrigation system	Provision of water efficient irrigation system
	Use recycled water, NEWater or rainwater for irrigation		Provision of rainwater collection system
3. Site & Project Management	**CONQUAS**	Green Mark certified buildings should meet industry average CONQUAS(construction quality assessment system) score to achieve acceptable quality standards.	Premium cost for CONQUAS and Quality Mark
	Project team comprises one certified Green Mark manager and/or one		Engage Green Mark consultant

	Certified Green Mark Professional.		
	Conserve &restore trees		Restoration / transplant of trees
	Use recycled compost		Use of recycled drywall partitions Use of road kerb, wheel stopper, drain channel with recycled aggregates Use of recycled drainage cells Use of landscape decking using recycled element
	Building maintenance and operation guidelines		Preparing Green Building User guide
	Provision of facilities or recycling bins		Provision of recycling bins
	Adequate bicycles parking lots		Provision of bicycle lots
	Environment-friendly materials		Others environmental friendly materials:

Note: For energy efficient lamps, their detailed information and luminous efficacy are listed below.

Luminous efficacy of 3 types of lamps

Lamp types	Lumens per Watt	Average life(operating hours)
Fluorescent tube"T8"	90	12,000
Fluorescent tube"T5"	105	17,000
LED	70	40,000

Appendix Table 12 Summary of green features by category

Category	List of Green Features	Base Building Requirement (For comparison)	Project 1	Project 2	Project 3	Project 4	Adoption rate
1. Design for Energy Efficiency	**Energy Efficient Building Envelope**						
	Provision of better glass (such as low-e, double glazing, tinted glass, laminated glass or glass thicker than 6mm)	6mm thk clear glass	Y	Y	Y	Y	100 %
	Provision of external walls with better properties to enhance ETTV	120mm thk concrete wall	Y	-	-	-	25%
	Provision of insulation/ cool paint for external façade	Normal external paints	Y	Y	-	-	50%
	Energy Efficient Building Envelope (Cont'd)						
	Provision of additional sun-shading (both vertical and horizontal) which is not in the original design but include to improve RETV (COMPANY X Standard Provision)	No provision	-	-	-	-	
	Computer simulation conducted to improve on the building design such as natural ventilation simulation, sun path analysis, etc	No computer simulation	Y	Y	Y	-	75%
	Energy Efficient Lift						
	Provision of motor-roomless lift/ re-generative lift	Lift with AC VVVF motor drive	-	Y	-	-	25%
	Energy Efficient Fridges						
	Provision of 4-ticks/3-ticks/2-ticks fridges (COMPANY X Standard Provision)	1-tick fridges	-	-	Y	Y	50%
	Energy Efficient Air-Conditioners						
	Provision of 4-ticks/3-ticks/2-ticks A/C (COMPANY X Standard Provision)	1-tick A/C	-	Y	Y	Y	75%
	Energy Efficient Light for Common Areas, External Areas and Car Park						

	Provision of T5/T8 lighting (COMPANY X Standard Provision)	Normal fluorescent lighting	-	Y	Y	Y	75%
	Provision of LED lamps	Normal PLC/bollard lighting	-	Y	Y	-	50%
	Provision of motion sensors for lift lobbies/ changing room/ toilets/ staircases, etc. (COMPANY X Standard Provision)	No provision	-	Y	Y	Y	75%
	Energy Efficient Light for Common Areas, External Areas and Car Park (Cont'd)						
	Provision of sun pipes to maximize day lightings	No provision	Y	-	Y	-	50%
	Basement Car Park Mechanical Ventilation (MV)						
	Provision of ductless / jet fan for car park MV	Ducted MV	-	Y	Y	Y	75%
	Provision of CO sensor or car park MV (COMPANY X Standard Provision)	No provision	Y	Y	Y	Y	100 %
	Other Energy Efficient Features						
	Provision of Solar panel	No provision	-	Y	-	-	25%
	Provision of electrical sub-meters (COMPANY X Standard Provision)	No provision	-	Y	Y	Y	75%
	Provision of gas operated water heater for all apartment units (COMPANY X Standard Provision)	Usage of electrical hot water	-	-	-	Y	25%
	Provision of gas operated water heater to supply hot water to club house changing room (COMPANY X Standard Provision)	Usage of electrical hot water	-	-	-	Y	25%
	Provision of solar hot water (COMPANY X Standard Provision)	Usage of electrical hot water	-	-	-	-	
	Provision of heat exchange pump to supply hot water to club house changing room (COMPANY X Standard Provision)	Usage of electrical hot water	-	Y	Y	-	50%
	Sub-Total for Design for Energy Efficiency (1)	20	6	13	12	10	
2. Design for	Provision of water sub-meters (COMPANY X Standard Provision)	No provision	-	Y	Y	Y	75%

Water Efficiency	Provision of water efficient irrigation system	No provision	Y	-	-	Y	50%
	Provision of rainwater collection system	No provision	Y	Y	Y	Y	100 %
	Sub-Total for Design for Water Efficiency (2)	3	2	2	2	3	
3. Site & Project Management	Premium cost for CONQUAS and Quality Mark (COMPANY X Standard Provision)	No CONQUAS and Quality Mark	-	-	Y	Y	50%
	Engage Green Mark consultant	No Green Mark consultant	-	-	Y	Y	50%
	Restoration / transplant of trees (COMPANY X Standard Provision)	No restoration / transplant of trees	Y	Y	-	Y	75%
	Use of recycled drywall partitions (COMPANY X Standard Provision)	Brick walls	-	Y	Y	Y	75%
	Use of road kerb, wheel stopper, drain channel with recycled aggregates	Road kerb, wheel stopper, drain channel with natural aggregates	-	Y	Y	Y	75%
	Use of recycled drainage cells	Drainage cells made of new materials	Y	-	-	Y	50%
	Use of landscape decking using recycled element	Landscape decking made of new materials	Y	-	Y	Y	75%
	Preparing Green Building User guide(COMPANY X Standard Provision)	No provision	Y	Y	-	Y	75%
	Provision of recycling bins (COMPANY X Standard Provision)	No provision	-	Y	Y	Y	75%
	Provision of bicycle lots (COMPANY X Standard Provision)	No provision	-	Y	Y	Y	75%
	Provision of shuttle bus	No provision	-	-	-	-	
	Others environmental friendly materials:	No provision	Y	-	-	-	25%
	Sub-Total for Site & Project Management (3)	12	5	6	7	10	
4.	Engage acoustic consultant	No acoustic	-	Y	Y	-	50%

Indoor Environmental Quality & Environmental protection		consultant					
	Provision of low-VOC paint (COMPANY X Standard Provision)	Normal paint	-	Y	Y	-	50%
	Provision of adhesive with low formaldehyde for wardrobe / kitchen cabinet	Normal adhesive	-	-	Y	Y	50%
	Sub-Total for Indoor Environmental Quality & Environmental Protection (4)	3	0	2	3	1	
5. Other Green Features	Provision of precast toilets (COMPANY X Standard Provision)	Provision of conventional toilet inclusive of fittings and accessories	-	Y	Y	Y	75%
	Provision of A/C condensate water collection	No collection of A/C condensate	-	Y	-	-	25%
	Provision of dual refuse chute (COMPANY X Standard Provision)	Normal single refuse chute	-	Y	Y	Y	75%
	Provision of pneumatic waste collection system (COMPANY X Standard Provision)	No provision	-	Y	Y	Y	75%
	Provision of compost bins	No provision	-	Y	Y	-	50%
	Provision of self-cleaning/ TiO2 paints for external façade	Normal external paints	-	-	Y	-	25%
	Provision of photo-catalytic paint for wet areas such as kitchen	Normal paints	-	-	Y	-	25%
	Provision of eco-ponds	No provision	-	-	Y	Y	50%
	Provision of infiltration trenches	No provision	-	-	-	Y	25%
	Provision of green walls	No provision	Y	-	-	Y	50%
	Provision of green roofs	No provision	Y	-	-	-	25%
	Provision of gas detectors	No provision	-	-	-	-	
	Provision of Etrack to	No	-	-	Y	-	25%

	dwelling units	provision					
	Sub-Total for Other Green Features (5)	13	2	5	8	6	
Total for (1), (2), (3), (4) and (5)		51	15	28	32	30	

Regression Analysis with Model 1 and Model 3

Model 1

In first stage, we simply relate the logarithm of construction cost per square foot to number of storeys, number of units, gross floor area and property type. Based on the Wheaton and Simonton (2007)'s model, our basic estimation model is hence:

$$\ln \mathbf{COSTSF} = c + \alpha\, \mathbf{STOREY} + \beta\, \mathbf{UNITS} + \gamma\, \mathbf{AREA} + \delta\, \mathbf{Proptype} + \varepsilon \quad (1)$$

Where:

COSTSF	=	Construction cost per square meter;
c	=	constant(intercept);
STOREY	=	Number of storeys;
UNITS	=	Number of units in a building;
AREA	=	Gross floor area (GFA) in 1000s;
Proptype	=	1 for residential buildings, and 0 for commercial buildings. Residential building is chosen as defaults for *Propertytype*;
$\alpha, \beta, \gamma, \delta$	=	Estimated statistical parameters; and
ε	=	an error term.

The results are presented in column (5) in Table a. Then in second stage, the regression considers the green attributes and market attributes measured at building level. The relationship can be described as the following equation:

$$\ln \mathbf{COSTSF} = c + \alpha\, \mathbf{Xi} + \sum \beta i\, \mathbf{Yi} + \sum \gamma\, \mathbf{Tenderprice} + \varepsilon \quad (2)$$

Where:

Xi	=	a vector of hedonic characteristics of building i;
Yi	=	Dummy variables for green attributes of building i;
Tenderprice	=	Building Tender Price Index at year basis. The default year is set as Year of 2005.
$\alpha, \beta, \gamma, \delta$	=	Estimated statistical parameters; and
ε	=	an error term.

Table a presents the results of estimating the hedonic model (column 6) using the 20 building projects data between 2006 and 2010. Column (1) to (4) add control variables. In Column (1), the coefficients of *StoreyNo*, *Platinum* and *LnWaterSavings* are positive and significant at the 10%, 5% and 5% level, respectively. They provide additional information for practitioners to estimate the total construction cost of a building based not only on building attributes but also green attributes. However, the coefficient of *UnitsNo* and *LnEnergySavings* have an opposite sign despite they are significant.

Comparing with the results in column (5) and (6), it can be seen that the adding of green attributes helps to explain more information with a much higher adjusted R square. Column (4) produces a good fit, with adjusted R^2 equal to 67.3%. However, *UnitsNo, GFAin1000s* and *LnEnergysavings* have an opposite relationship with the dependent variable, which reject our hypothesis. It may suggest that this model is not suit so well.

The coefficient for *GFAin1000s* is expected to be negative and significant, because there is an economy of scale in all construction, and cost per square foot typically declines as the overall size of the project increases. That is to say, larger projects typically have increased productivity due to the increased efficiency of repetitive work.

Model 3

According to Chau et al.(2007)'s findings, the Box-Cox model can be best simplified as:

$$\ln \textbf{COST} = c + \hat{a}1\textbf{\textit{STOREY}} + \hat{a}2\textbf{\textit{STOREY}} \times \ln\textbf{\textit{AREAPS}} + \hat{a}3 \ln \textbf{\textit{AREAPS}} + \delta \textbf{\textit{Proptype}} + \sum \beta i \textbf{\textit{Yi}} + \sum \gamma \textbf{\textit{Tenderprice}} + \varepsilon \quad (6)$$

We use this Box-Cox model to the hedonic regression. The results displayed in Table b were quite significant statistically with R^2 values ranging between 0.594 and 0.874. Seen from column (17), even we only include building attributes for regression, *StoreyNo* still negatively relate to *LnCost*. The coefficient of *StoreyNo*, *Gold*^{plus} *and LnEnergySavings are,* however, negative and contradicts our expectation.

In summary, our estimation results (column (1) to (3)) are still not good by running Model 3.

Table a OLS regression estimation of Construction cost on Building Attributes (Dependent variable: Logarithm of Construction cost per square meter)

	Dependent Variable: *lnCostperGFA*					
	(1)	(2)	(3)	(4)	(5)	(6)
(Constant)	7.815***	7.342***	7.466***	6.651***	7.307**	8.142***
	(0.777)	(0.895)	(0.879)	(0.803)	(0.813)	(1.014)
StoreyNo	0.030**	0.035**	0.032**	0.048**	0.052**	0.008
	(0.011)	(0.012)	(0.012)	(0.012)	(0.011)	(0.010)
UnitsNo	-0.005**	-0.007**	-0.010*	-0.016**	-0.017**	-0.006
	(0.002)	(0.003)	(0.004)	(0.004)	(0.004)	(0.004)
GFAin1000s			0.029	0.051	0.048	0.033
			(0.026)	(0.023)	(0.020)	(0.035)
Familiarity		-0.540	-0.618	-0.849	-1.029	
		(0.518)	(0.510)	(0.413)	(0.371)	
Green Mark						
Platinum	0.377*	0.361	0.345	0.670*	0.565	
	(0.186)	(0.185)	(0.181)	(0.220)	(0.200)	
Goldplus				0.423	0.315	
				(0.221)	(0.201)	
LnEnergySavings	-0.117*	-0.103	-0.119	-0.207*	-0.163	
	(0.055)	(0.056)	(0.056)	(0.063)	(0.061)	
LnWaterSavings	0.221*	0.273*	0.280*	0.482*	0.471*	
	(0.105)	(0.116)	(0.113)	(0.137)	(0.116)	
BuildingTenderPrice					-0.008	0.001
					(0.005)	(0.008)
R square	0.683	0.739	0.802	0.911	0957	0.320
Adj R square	0.418	0.427	0.455	0.673	0.765	0.017

Notes:

1. :* denotes 10% significance level; ** denotes 5% significance level; *** denotes 1% significance level. The value in parentheses is the standard error.
2. Units No. is only applicable for residential buildings, but not for commercial buildings. Therefore, the variable Proptype are excluded for its high collinearity with Units No.

Table b OLS regression estimation of Construction cost

(Dependent variable: Logarithm of Cost)

	Dependent Variable: *lnCost*		
	(1)	(2)	(3)
(Constant)	14.137***	13.383	13.714***
	(1.644)	(7.861)	(1.648)
StoreyNo	-0.046	-0.166	-0.019
	(0.070)	(0.311)	(0.070)
STOREY lnAREAPS	0.015	0.038	0.010
	(0.010)	(0.045)	(0.010)
lnAREAPS	0.313	0.400	0.468**
	(0.256)	(1.127)	(0.213)
GreenMarkversion	-0.611		
	(0.768)		
Familiarity	-0.446	-0.853	
	(0.631)	(3.092)	
Platinum	0.261	0.414	
	(0.366)	(0.695)	
Goldplus	-0.223	-0.072	
	(0.380)	(0.673)	
Proptype	-0.255		-0.197
	(0.416)		(0.397)
LnEnergySavings	-0.032	-0.151	
	(0.116)	(0.232)	
LnWaterSavings	0.138	0.310	
	(0.111)	(0.423)	
UnitsNo		-0.006	
		(0.017)	
Adj R-square	0.874	0.594	0.840

Notes:

1. * denotes 10% significance level; ** denotes 5% significance level; *** denotes 1% significance level. The value in parentheses is the standard error.
2. Units No. is only applicable for residential buildings, but not for commercial buildings. Therefore, the variable Proptype are excluded for its high collinearity with Units No.