



INDEPENDENT REVIEW OF BCA GREEN MARK SCHEMES

For: Building and
Construction Authority
(BCA)

Project Team **Squire Mech**
ma1019@squiremech.com
*Er. Teo Yann
Er. Ng Boew Suan
Mr. Chan Chun Keian*

BSD
gmreview_esd@bsd.com.sg
*Mr. Tan Phay Ping
Mr. Yong Ping Quen
Ms. Rachel Lam*

Arcadis
SGQS6952@arcadis.com
*Mr. Lorimer A. Doig
Ms Cheryl Lum
Ms. Tan Siew Yee Yvanie*

RSP
180119@rsp.sg
*Mr. Ng Meng Hui
Ms. Konnie Kao*

Executive Summary

The study assessed the performance of the BCA Green Mark (GM) Schemes by benchmarking against other international green rating tools and adopting a life-cycle cost approach to analyse the cost and benefits.

The BCA Green Mark criteria and its assessment process were benchmarked against established green building rating tools that are recognised internationally. The key findings from the study shows that the Green Mark scheme is:

- well established in tropics/subtropics with comparable green cost premium¹ to other green building rating tools
- among a few green building rating tools to incorporate face-to-face green building assessments²
- the only green building rating tool, that verifies energy performance during building operations

The study also reviewed the upfront cost of Green Mark projects using a Life Cycle Costing Analysis (LCCA) to provide a holistic picture of the cost of greening a building over its Lifecycle. The study found that, from the life cycle cost perspective:

- A Green Mark building reaps net positive savings (in terms of energy and water savings) throughout its lifecycle, and they outweigh the upfront investment cost
- The Net Present Value of the savings stream commensurate with the BCA Green Mark rating
- There is a strong business case for developers to adopt the highest Green Mark rating

NRB	Green Cost Premium	Simple Pay Back (yrs)	NPV Savings per GFA (median \$/GFA)	RB	Green Cost Premium	Simple Pay Back (yrs)	NPV Savings per GFA (median \$/GFA)
Gold	0.12%-1.80%	0.81-2.45	48	Gold	0.23%-1.71%	NA for residential projects as most of the savings are enjoyed by the household	39
GoldPlus	0.70%-1.87%	1.89-3.56	117	GoldPlus	0.64%-3.76%		54
Platinum	1.00%-4.40%	2.30-5.80	225	Platinum	0.79%-4.15%		140

Table 1: Summary of Cost-Benefit Analysis across various GM NRB and RB Projects

¹ Green Cost Premium – the cost difference between green design features and conventional design feature.

² Face – to – face assessment: the process of evaluating the environmental performance of the building done in person by the certification body.

Contents

Executive Summary.....	1
1. Benchmarking of BCA GM NRB: 2015 & GM RB: 2016 Scheme.....	3
1.1 Objective	3
1.2 Approach and Methodology	3
1.3 Findings and Observations	4
2. Lifecycle Cost Analysis (LCCA) for Green Mark Projects	6
2.1 Approach and Methodology	6
2.2 Findings and Observations	7
3. Overall Conclusion	9
References.....	10

1. Benchmarking of BCA GM NRB: 2015 & GM RB: 2016 Scheme

1.1 Objective

The benchmarking study aims to provide a comprehensive examination on how the BCA Green Mark (GM) schemes perform in relation to other international green rating tools in terms of approach and assessment.

1.2 Approach and Methodology

After considering factors such as years of establishment, climatic condition, countries in which the tools are adopted, the following green building rating tools were shortlisted for the comparative study³:







	BCA Green Mark ⁴	LEED v4 ⁵	BREEAM ⁶	BEAM Plus ⁷	Green Star ⁸	GBI ⁹
Country of Origin & Launch Year	 Singapore (2005)	 United States of America (1998)	 United Kingdom (1990)	 Hong Kong (1996)	 Australia (2003)	 Malaysia (2009)
Adoption	15 countries	> 160 countries	86 countries	1 country	2 countries	1 country
Application	Tropical Climate	Various Climate Conditions	Various Climate Conditions	Various Climate Conditions	Subtropical Climate	Tropical Climate
Developed By	Building and Construction Authority (BCA)	US Green Building Council (USGBC)	Building Research Establishment (BRE)	Hong Kong Green Building Council (HKGBC)	Green Building Council of Australia (GBCA)	Malaysian Institute of Architects (PAM) and Association of Consulting Engineers Malaysia (ACEM)
Certification Checked By	BCA Green Mark Department	Green Business Certification Incorporation (GBCI) – 3rd party	BREEAM Assessor, BRE Global will monitor the assessment quality process of the assessor	BEAM Plus Technical Review Committee (TRC)	Green Star Certified Assessor	GBI Accreditation Panel (GBIAP)
Tier Rating	3 Tiers: Gold, Gold PLUS & Platinum	4 Tiers: Certified, Silver Gold & Platinum	6 Tiers: Unclassified, Pass Good, Very Good Excellent & Outstanding	4 Tiers: Bronze, Silver, Gold & Platinum	6 Tiers: One Star, Two Star, Three Star Four Star Five Star & Six Star	4 Tiers: Certified, Silver, Gold & Platinum
Building Re-Certification	Every 3 Years	One-Time Certification	One-Time Certification	Every 5 Years	Every 5 Years	Every 3 Years
No. of Projects	3,900	> 90,000	18,138	199	> 2,200	484

Table 2: Summary of Details of Green Mark and Other Green Building Rating Tools (correct as at 2019)

³ Benchmarking of the various green rating tools was subjected to the accessibility of the data of the various sources and the information is based on literature review conducted in 2019

⁴ Source: www.bca.gov.sg/Greenmark/Greenmark_criteria

⁵ Source: www.usgbc.org/leed, www.statista.com/green buildings in the US

⁶ Source: www.breem.com, <http://tools.breem.com/projects/explore/map.jsp>

⁷ Source: www.hkgbc.org.hk, www.beamsociety.org.hk/en_beam_assessment_project_4.php

⁸ Source: www.gbca.org.au/project-directory

⁹ Source: www.greenbuildingindex.org/how-gbi-works/gbi-rating-system, www.greenbuildingindex.org/how-gbi-works/gbi-executive-summary

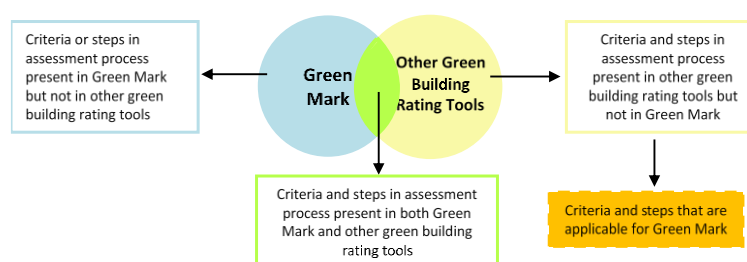


Figure 1: General Methodology Framework on Benchmarking

The general framework for comparing the BCA Green Mark scheme and assessment process with other green building rating tools scheme include:

- Filtering out the common criteria and steps in the assessment processes for all the green building rating tools, as they affirm the necessity of such criteria or steps.
- Identifying criteria and steps in the assessment process present in BCA Green Mark but excluded in other green building rating tools to establish the relevance with respect to the Singapore context and vice versa
- Shortlisting criteria and steps from other green building rating tools that are applicable in the Singapore context and suitable for Green Mark

1.3 Findings and Observations

1.3.1 Benchmarking of GM Scheme

The two latest Green Mark schemes were benchmarked against selected non-residential and residential green building rating tools respectively. It is important to note that the building code and regulation standards vary from country to country which may affect scope and applicability of sustainable indicators. The criteria listed in **Table 3** are covered in BCA Green Mark NRB: 2015 and RB: 2016 but are not fully represented in other green building rating tools. This highlights importance of these criteria and their relevance within the Singapore context.

Green Mark NRB: 2015	LEED	BREEAM	BEAM Plus	Green Star	GBI	Description
Building Information Modelling (BIM)*	-	-	-	-	-	BIM was created and used by the project team comprising various consultants and contractors
Full Ventilation Simulation*	Partial ¹⁰	Partial	Partial	-	-	GM credits passive design (supported by CFD) for natural ventilation.
Solar Energy Feasibility Study*	-	-	-	-	-	Solar feasibility study for the potential of solar PV on the project.
Solar Ready Roof*	-	-	-	-	-	
Water Usage Portal & Dashboard	Partial	-	-	-	-	Raise occupants' awareness by monitoring water consumption.
Resource Efficient Building Design through CUI*	-	-	-	-	-	Calculation of CUI encourages developers to optimise the use of concrete.
Low Carbon Concrete*	Partial	-	-	-	-	This refers to the use of green concrete.
Permanent Instrumentation for Mechanical and Ventilation (M&V) Chilled Water System	Partial	-	-	-	-	Promote awareness of energy consumption and minimising energy wastage of the chiller plant.

¹⁰ LEED, BREEAM, and BEAM Plus do not have specific requirements for ventilation simulation. However, CFD simulation could be used to demonstrate thermal comfort compliance for regularly occupied spaces when outdoor weather conditions are favourable, such as hybrid ventilation strategies, passive cooling etc.

Green Mark NRB: 2015	LEED	BREEAM	BEAM Plus	Green Star	GBI	Description
Indoor Air Quality Trending	-	-	-	-	-	Raise occupants' awareness of temperature, relative humidity (RH), and indoor pollutants.
Dedicated Outdoor Air System	Partial	-	-	-	-	Green Mark encourages treatment of outdoor air by cooling and dehumidification.
Integration and Analytics	-	-	-	-	-	Use of smart building operations such as adaptive controls to detect deviation from normal operation settings for energy savings

Table 3: Green Mark NRB: 2015 & GM RB: 2016 Criteria not present in Other Green Building Rating Tools

* Items in blue are present in both NRB & RB scheme

Similarly, criteria included in other green building rating tools but not found in BCA Green Mark NRB: 2015 and RB: 2016 have also been analysed. For this purpose, criteria (e.g. Light Pollution, Tobacco Smoke Control,) that are not contextually applicable to Singapore or currently covered under other existing Singapore legislations were excluded from further analysis.

1.3.2 Benchmarking of BCA Green Mark Assessment Process

The assessment process for various rating tools according to project schedule, role of assessors and documentation process are indicated below.

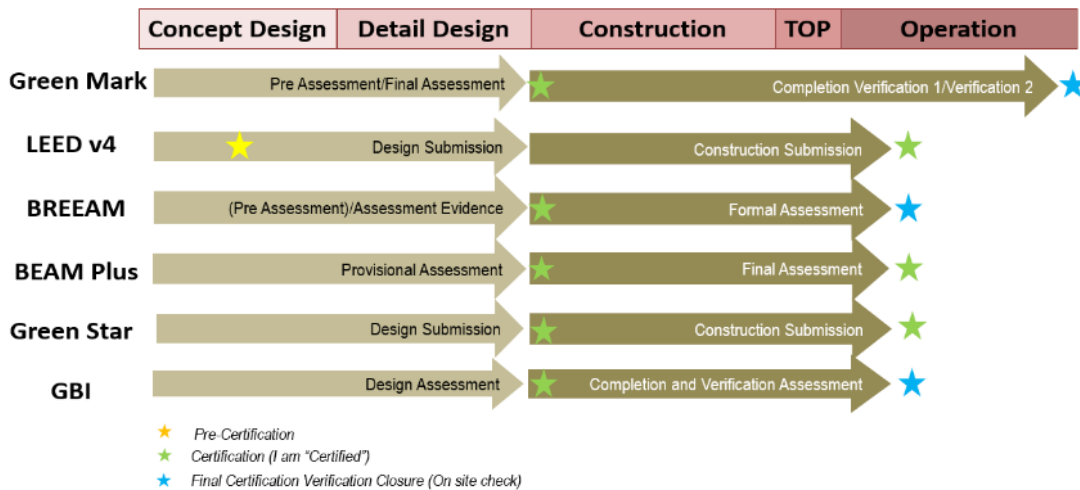


Figure 2: Chronological View of Assessment Process of Different Green Building Rating Tool Schemes

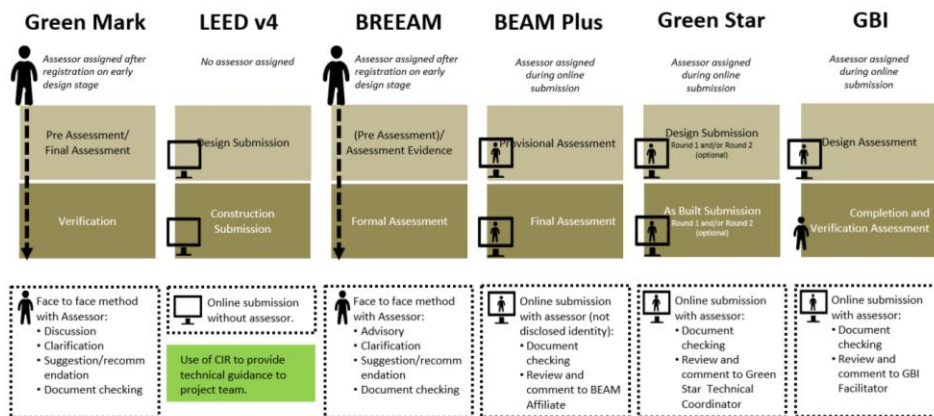


Figure 3: Summary of Assessor Involvement and Document Submission during the Assessment Process for Different Green Building Rating Tool

Having examined the assessment process of GM and other green rating tools, the study observed the following:

- The current face-to-face assessment method between Green Mark Assessor and Project Team is beneficial as it helps to clarify matters between the Assessor and the Project Team within a shorter timeframe. Clarifications between the Assessor the project teams for the other rating tools, such as LEED, BEAM Plus, Green Star, and GBI, are done through online submission and the entire process usually take more time
- The BCA Green Mark is the only rating tool that verifies energy performance during operational stage.

2. Lifecycle Cost Analysis (LCCA) for Green Mark Projects

2.1 Approach and Methodology

A list of GM Non-Residential Buildings (NRB) and Residential Buildings (RB) projects was shortlisted for data collection and analysis based on:

- Wide distribution of BCA GM Gold, Gold^{PLUS} and Platinum rated projects across various building typologies from both public and private sectors
- NRB – GM Building projects certified under GM NRB: 2015 or version 4.1
- RB – GM Building projects certified under GM RB: 2016 or version 4.1
- Previous working experience where at least a member of the consultant Team had worked in the projects to increase the accessibility of information for research and investigative work

The final list of the 40 projects selected for Cost Study is summarised in the Table.

	GM Rating			Total
	Gold	Gold ^{PLUS}	Platinum	
Private Sector	1	4	3	8
Public Sector	2	3	2	7
Total for RB	3	7	5	15
Private Sector	2	4	7	13
Public Sector	3	2	7	12
Total for NRB	5	6	14	25

Table 4: Breakdown of GM Projects for Cost Study

2.1.1. Lifecycle Cost Analysis (LCCA) Approach

This section assessed green cost premiums against cost savings across the building lifecycle. The LCCA is a more comprehensive long-term investment approach compared to calculating the Simple Payback for a building development. A comparison was done between Green Mark-certified buildings versus non-Green Mark buildings by comparing the green cost premium against the cost savings across the buildings' lifecycle. The lifecycle was assumed to be 30 years as it was a reasonable estimate of the economic and functional life of a building. The LCCA provides a holistic approach including:

- Initial Capital Expenditure (Capex)** – cost of investment declared by respective building's project team in the 'Info and Cost Template' for both GM and Baseline Models.
- Operating Expenditure - Utilities (Opex)** – utility consumption declared by the respective building's project team in the 'Info and Cost Template' for both GM and Baseline Models. NRB projects factored in the High Tension (HT) tariff of 22¢/kWh compared to the application of the Low Tension (LT) tariff of 24¢/kWh in RB projects to calculate the utility costs.
- Maintenance Cost** – estimated based on standard equipment life span commonly adopted in the industry and comprehensive maintenance rate from the Team's in-house database. Assumptions include maintenance cost accrued on the year after the Defects Liability Period and re-lamping of lighting luminaires as "Maintenance Cost" and not "Replacement Cost"; with re-lamping schedule as follows:
 - Fluorescent luminaires – 10,000 burning hours;
 - LED luminaires – 50,000 burning hours;

- d. **Replacement Cost** during the lifecycle of the building such as the estimated cost of dismantling, removal from site, supply and installation of new equipment at the end of its life span. The year of replacement varies according to the equipment and their economic life spans. Based on BCA GM templates, the operating hours and replacement schedule for typical Energy Efficiency (EE) items are as tabulated:

System	Replacement
Water-cooled chilled water system	20 yrs
Air-cooled chilled water system	15 yrs
Unitary AC system	10 yrs
Lifts and escalators	20 yrs
Mechanical Ventilation System	15 yrs
Pumps	20 yrs
Solar PV system	15 yrs

Table 5: Estimated Time to Replace Various Building Systems

- e. **End-of-Life (Salvage) Value** – As data on salvage value of green features at the end of its life span is limited, the salvage value is assumed to be zero at the end of 30 years.
- f. **Escalation Rate** of 1.5% p.a. is applied to account for the anticipated annual change in percentage for price levels of the goods/materials and services.
- g. **Net Present Value (NPV)** - method to determine the current value of all future cash flow generated by the project over the 30-years period. The Study adopted a Discount rate of 5% to account future cash flows for time value of money.

2.2 Findings and Observations

Based on the information declared in the 'Info and Cost Template' submitted by the respective building project team, the Green Cost Premium and Simple Payback for the various building typologies and GM ratings were analysed. A 'Box and Whiskers' chart was used to illustrate the results below:

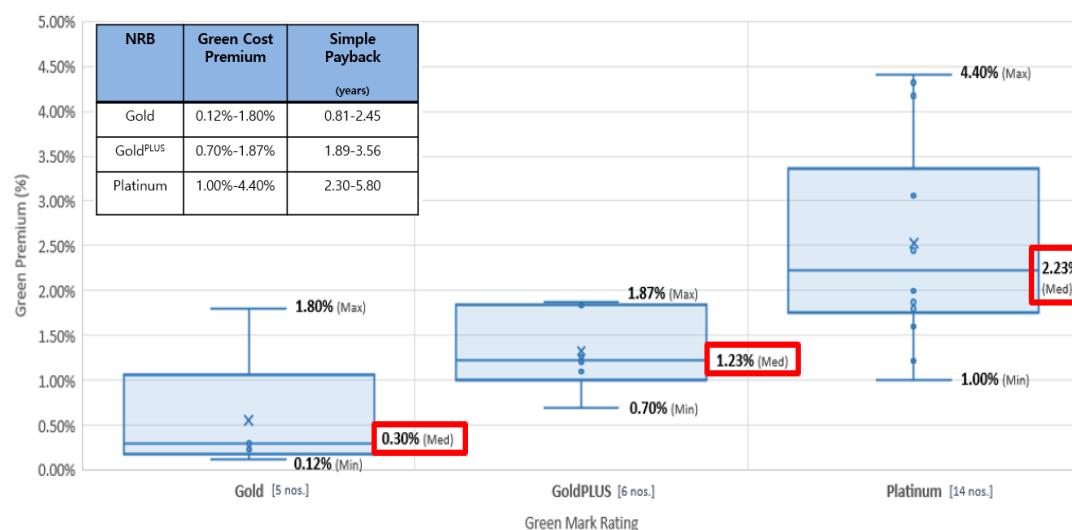


Figure 4: Green Cost Premiums and Simple Payback of NRB Projects

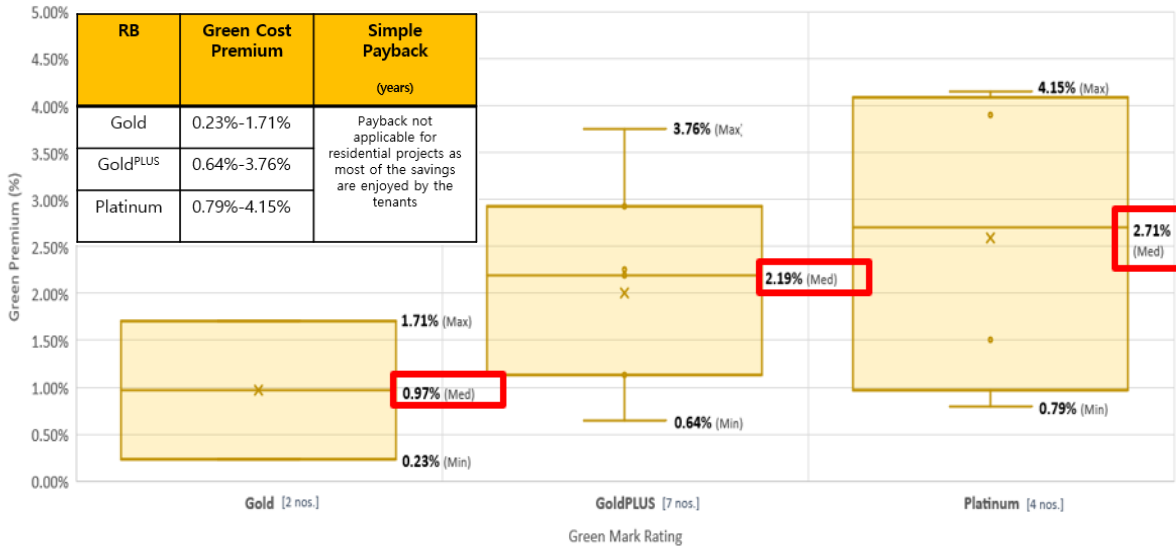


Figure 5: Green Cost Premiums and Simple Payback of RB Projects

The general trend of the median in 'Box and Whiskers' charts in **Figures 4 and 5** showed that the Green Cost Premium for both NRB and RB Projects increased with the GM ratings.

From the LCCA, the NPV LCC savings were further analysed. NPV LCC savings refer to the total lifecycle cost of a Green Mark certified building less the total lifecycle cost of a non-Green Mark building. As the NPV LCC savings varied from project to project depending on the size, complexity, etc. of the projects, the NPV LCC savings were normalised by the Gross Floor Area (GFA) of the respective projects.

The 'Box and Whiskers' charts were used to illustrate the NPV Savings per GFA of the 40 GM projects.

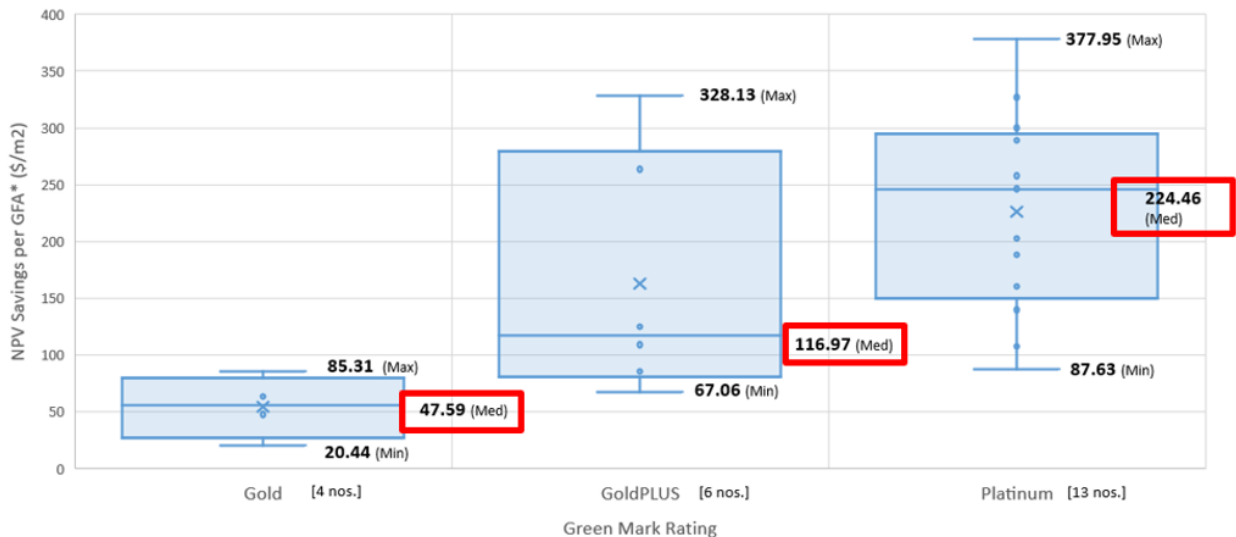


Figure 6: Net Present Value per m² of the GM NRB Projects

As observed from **Figure 6**, NRB projects showed the median NPV savings per GFA for GM buildings increases in tandem with GM ratings.

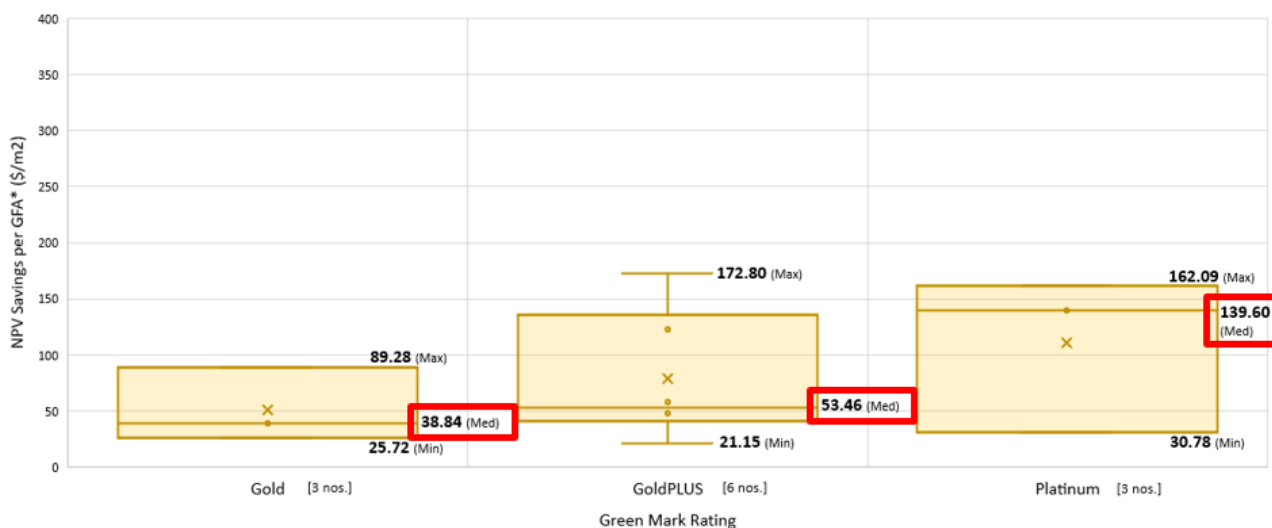


Figure 7: Net Present Value per m² of the GM RB Projects

Similarly, as observed from **Figure 7**, the RB results showed the median NPV savings per GFA for GM buildings increases in tandem with GM ratings.

LCC Analysis Affirms That GM Building Reaps More Benefits than Non-GM Building throughout Its Lifecycle

NRB	Green Cost Premium	Simple Pay Back (yrs)	NPV Savings per GFA (median \$/GFA)	RB	Green Cost Premium	Simple Pay Back (yrs)	NPV Savings per GFA (median \$/GFA)
Gold	0.12%-1.80%	0.81-2.45	48	Gold	0.23%-1.71%	NA for residential projects as most of the savings are enjoyed by the household	39
GoldPlus	0.70%-1.87%	1.89-3.56	117	GoldPlus	0.64%-3.76%		54
Platinum	1.00%-4.40%	2.30-5.80	225	Platinum	0.79%-4.15%		140

Table 1: Summary of Cost-Benefit Analysis across various GM NRB and RB Projects

3. Overall Conclusion

Benchmarking of BCA GM Scheme concluded the following:

- GM scheme is well established in tropics/subtropics with comparable Green Cost Premium to other green building rating tools
- It is among a few green building rating tools to incorporate face-to-face green building assessments
- It is the only green building rating tool, which verifies energy performance during building operations

Lifecycle Cost Analysis (LCCA) for Green Mark Projects

- A Green Mark building reaps net positive savings (in terms of energy and water savings) throughout its lifecycle, and they outweigh the upfront investment cost
- The Net Present Value of the savings stream commensurate with the BCA Green Mark rating
- There is a strong business case for developers to adopt the highest Green Mark rating

References

- BCA. (2016). *Green Mark for Non Residential Buildings NRB: 2015*. Singapore: Building and Construction Authority.
- BCA. (2017, September 22). *BCA Green Mark Assessment Criteria, Online Application and Verification Requirements*. Retrieved from Building and Construction Authority:
https://www.bca.gov.sg/GreenMark/others/GM_RB_2016_criteria_final.pdf
- BCA. (2018, August 1). *Green Mark for Non-Residential Buildings NRB: 2015*. Retrieved from BCA Green Mark Assessment Criteria, Online Application and Verification Requirements:
https://www.bca.gov.sg/GreenMark/others/Green_Mark_NRB_2015_Criteria.pdf
- BRE. (2017). *BREEAM International New Construction 2016 Technical Manual*. Watford: BRE Global Ltd.
- Chen, T. L. (2018). *Green Buildings and GBI Certification. Green Building Index. Penang.(GBI reference)***
- Dat, T. D., Ghaffarianhoseini, A., Naismith, N., Zhang, T., Ghaffarianhoseini, A., & Tookey, J. (2017). *Building and Environment 123. A critical comparison of green building rating systems*.
- GBCA. (2015). *Green Star Design & As Built version 1.1 Submission Guidelines*. Green Building Council of Australia.
- GSB. (2010). *Green Building Index Non Residential New Construction Design Reference Guide & Submission Format*. Kuala Lumpur: Greenbuildingindex Sdn Bhd.
- HKGBC. (2012). *BEAM Plus New Building version 1.2*. Hong Kong: BEAM Society Limited.
- Hong Kong Construction Industry Institute, & Hong Kong Polytechnic University. (2005). *Cost and Financial Benefits of Undertaking Green Building Assessment. (BEAMPlus Reference)***
- Langdon, D. (2004). *Costing Green: A Comprehensive Cost Database and Budgeting Methodology. (LEED Reference)***
- Langdon, D. (2007). *The Cost and Benefit of Achieving Green Buildings. Davis Langdon Management Consulting.(Green Star Reference)***
- Soulti, E., & Leonard, D. (2016). *The value of BREEAM: A review of latest thinking in the commercial building sector. Watford: BRE Global Ltd.(BREEAM Reference)***
- USGBC. (2013). *LEED Reference Guide for Building Design and Construction version 4*. Washington, D.C.: U.S. Green Building Council.

Glossary

- **NRB** – Non-Residential Building
- **RB** – Residential Building
- **BIM** – Building information Modelling
- **CUI** – Concrete Usage Index, is an indicator of the amount of concrete used to construct the superstructure (including structural & non-structural elements).
- **CFD modelling** – Computation Fluid Dynamics modelling, determines thermal comfort of naturally ventilated space.
- **ETTV** – Envelope Thermal Transmittance Value, ETTV gives an evaluation of the thermal performance of a building envelope.
- **AC system** – Air-conditioning System
- **Permanent Instrumentation for the M&V of Chiller water System** – Measurement and Verification
- **LCCA** – Study of all the costs associated with processes, materials and goods from acquisition to ownership and maintenance, through to and including disposal.