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Sustainable Building Envelopes (Ecobuildings, Retrofit, Performance Gap)

Sustainability assessment of a laboratory building: case study of highest rated laboratory building in Singapore using Green Mark rating system

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Abstract

Laboratory intensive buildings pose a distinctive challenge in sustainable building design, since they represent energy guzzling spaces due to unique operation and energy demanding activities. Academic Block North (ABN), a laboratory intensive building in Singapore begs to differ from this norm by demonstrating 42% energy savings compared to a building constructed based on code standards. This paper highlights the process of sustainability assessment of ABN to achieve 126 points to go beyond Green Mark Platinum standards for a non-residential building. Such an approach and framework can be applied to other buildings to achieve higher energy efficiency and sustainability benchmarks.

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Keywords: Building performance evaluation, Laboratory Building, Energy Efficiency, Indoor Environment Quality, Sustainable building design, Green Mark, Green Infrastructure

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1. Introduction

In order to address climate change and reducing CO_2 emissions, Singapore has committed to reducing its emission index by 36% from 2005 levels by 2030 [1]. As non-residential commercial buildings consume about 37% of the total electricity [2], the building sector has a critical role in reducing the national energy consumption and carbon emissions. Moreover, laboratory buildings are highly energy intensive due to their unique operation and energy requirements and on an average end up using 5 to 10 times more energy per square foot than office buildings [3]. The main reason for the high-energy consumption in laboratory facilities, is the requirement to provide high ventilation rates and the associated air conditioning loads.

Being a leading advocate for green buildings, Singapore has set up an ambitious target of having 80% green buildings by 2030 [4]. Spearheading this movement is the Green Mark (GM) green building rating scheme, launched in 2005 to provide a platform to asses and improve the overall environmental credentials of buildings. Although the GM scheme was launched more than two decades ago, little has been publicized in literature, especially with regards to the building performance results while compared to more popular green building rating scheme like LEED which have been studied in detail [5] [6] [7] [8] [9]. There has been sporadic mention of GM in studies that compare the assessment criteria between different green building rating schemes [10] [11] and an assessment of the awareness of GM rating scheme by the occupants of the GM building as well as general public [12]. In this study, the results of using GM as a sustainability assessment criterion for a real building located in Singapore is highlighted.

2. Case Study

The case study building is located at the Nanyang Technological University (NTU) campus in Singapore, and is surrounded by four existing buildings as shown in Figure 1. The building is a seven-story academic building with a Gross Floor Area (GFA) of 29,578 m^2. More details of this building can be found in Table 1. This building is a multi-tenanted, laboratory intensive building. It is estimated to allocate 70% of the occupied space as laboratory spaces and the rest as office spaces.

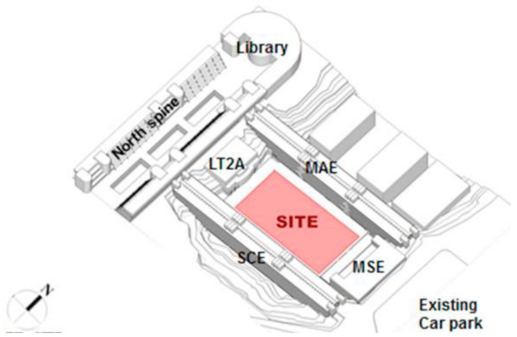

Figure 1: Building Site Plan

Table 1: Project brief

Site Area	5,742 m^2
Location	61 Nanyang Drive, Singapore 637335
GFA	29,578 m^2
Building Footprint	4,942 m^2
No. of Floors	7
Building Height	30.95 m
Building Orientation	North

The project team conducted design charrettes with the major stakeholders of the building to establish key project performance indicators based on the GM assessment criteria. Based on these performance indicators, technology recommendations were made to achieve these targets. For a more realistic understanding of the amalgamation of the technologies and performance, building modelling and energy simulations were performed. Finally, the design was developed via an iterative process to review the existing technology recommendations and results of the simulations. These changes led to achieving the requirements of the GM assessment criteria.

In the assessment of ABN, the BCA GM for New Non-Residential Buildings (Version NRB/4.1) is considered. To achieve a GM Award, the prerequisite requirements in different GM Rating sections must be fully obtained according to the new non-residential building criteria [13]. ABN in its aspiration to strive for higher energy savings qualified for the GM Incentive Scheme – Design prototype (GMIS-DP) for which the building targeted to achieve beyond GM Platinum; and demonstrate energy savings of at least 40% better than current base code or equivalent [14]. This scheme ensures that the energy efficiency goals of the target building are established quite early in the design stage and hence better performing buildings can then be designed via iterative simulations by the Environmentally Sustainable Designers (ESD) consultants. The team from Energy Research Institute @ NTU (ERI@N) were the designated ESD consultants for this project driving the sustainability design of the project.

3. Results and discussion

The building scored an impressive 126 points out of the total 190 points as summarized in Table 2 and successfully surpassed the requirements of the various benchmarks in GM assessment criteria as shown in Figure 2. The following sections discuss these results in detail.

Table 2: Points summary for ABN

Section Number	Criteria	Available Points	Minimum Points	Scored Points
1	Energy Efficiency	116	30	83
2	Water Efficiency	17	20	10
3	Environmental Protection	42		24
4	Indoor Environmental Quality	8		5
5	Other Green Features	7		4.5
	TOTAL	190	50	126

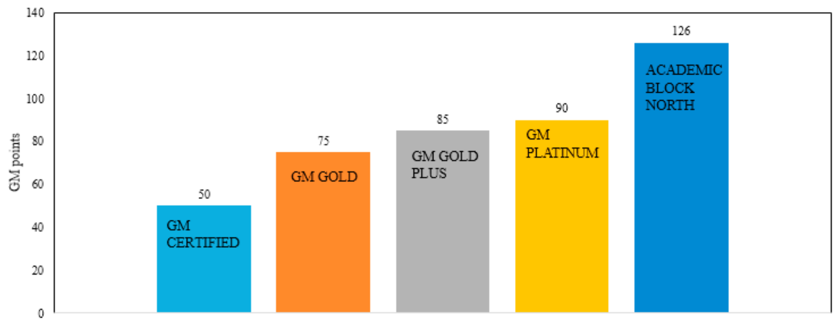

Figure 2: ABN GM score comparison with GM rating requirement

3.1. Energy Efficiency

3.1.1. Thermal performance of building envelope

This section assesses the thermal performance of the building envelope based on the Envelope Thermal Transfer Value (ETTV) [15] based on the guidelines provided by the BCA. Based on passive design features of the building which include, but are not limited to using a low-e double glazed unit (U value : 1.6 Wm^{2}K; SC : 0.30; VLT : 0.40) , employing shading devices, use of cool paints (U Value : 0.73 Wm^{2}K) and low window to wall ratio (0.198), some of which are highlighted in Figure 3(a) the building achieves an ETTV of 18.3 W/m^2 [16] compared to a baseline of 50 W/m^2 (**12 points).**

3.1.2. Air conditioning system

The building utilizes innovative cooling strategies like passive displacement cooling in offices in which the air movement relies on natural convection instead of the fan power, high efficient HVAC equipment as well as control strategies, use of heat pipe to dehumidify the air without the use of additional energy finally leading to a design system efficiency of 0.57 kW/RT compared to baseline of 0.70 kW/RT.

Figure 3: (a) Contributing factors to low ETTV (b) Building Integrated Photo-Voltaics (BIPV) canopy

Apart from this, permanent measuring instruments to monitor chilled water efficiency, provision of variable speed controls for chilled water pumps and cooling tower fans for better part-load plant efficiency, as well as, sensors to regulate outdoor air flow rate to acceptable limits of indoor CO_2 concentration, are provided at ABN for continuous monitoring by the facilities team (**42 points**). A summary of simulated energy performance results is shown in Table 3.

Table 3: Simulated energy performance and savings of ABN [17]

Description	**Reference Model (a) kWh**	**Proposed Model (b) kWh**	**Savings (c) = (a)-(b) kWh**	**Improvement (c)/(a)**
Lighting (AC)	946,665	428,940	517,725	54.7%
Lighting (NON AC)	401,525	110,698	290,827	72.4%
Air-Conditioned Plant	2,358,983	1,364,855	994,128	42.1%
Air System Fans	576,991	305,236	271,755	47.1%
Heat Pump	865,129	-	-	-
MV Fans	84,884	62,716	22,168	26.1%
Lifts	57,065	46,223	10,842	19.0%
Receptacle Equipment	1,767,075	1,767,075	0	0.0%
Domestic Water Systems	9,984	9,984	0	0.0%
Total	7,068,300	4,095,725	2,972,575	42.1%
Power Generation (PV)		145,728.00	-	
Overall Savings (%)		3,949,997		44.1%
Energy Efficiency Index EEI (kWh/m2/year)	286.64	184.15		

3.1.3. Daylighting and artificial lighting

At least 80% of the building common areas (corridors) are daylit (**0.5 points**). Extensive use of energy efficient LED lights, decoupled task and ambient lighting, as well as, motion sensors lead to energy savings of 56.6% over code compliant baseline building (**12 points**).

3.1.4. Common areas ventilation, lifts and energy efficient practices and features

The design team utilized computational fluid dynamics simulations to design naturally ventilated staircases and lift lobbies and mechanical ventilation in toilets and corridors [16]. The lifts are Variable Voltage and Variable Frequency Drive (VVVFD) lifts with sleep mode to conserve energy during periods of non-usage. Energy efficient features like use of heat pipes, sun pipes in toilets contribute as energy efficient practices (**15 points**).

3.1.5. Renewable energy

The building BIPV on the canopy shown in Figure 3 (b) and it is estimated that 2.73% of energy consumption of the building may be replaced by the renewable solar energy generated (**13.6 points**).

3.2. Water efficiency

Water efficiency of the building is ensured by using Water Efficiency Labelling Scheme (WELS) certified fittings. The building also has provision for water meters to monitor major water usage and all these meters are linked to the BMS for leak detection. In order to reduce the use of potable water for cooling purpose, the cooling water treatment system achieves minimum 7 cycles of concentration at acceptable water quality (**9.5 points**).

3.3. Environment protection

This section encourages projects to adopt building design, construction practices and materials that are sustainable. ABN uses recycled concrete aggregate and has a low concrete usage index of 0.45 (**5 points)**. The building also uses environmentally friendly products like modular green roof tray, drainage mats, water proofing membrane, carpet flooring, autoclaved aerated concrete blocks, pre-cast lightweight concrete panels, acoustic and green labelled ceiling boards, composite timber flooring, vinyl flooring, green labelled external paint system, partition wall system and rockwool insulation. All of these products are certified by approved local certification body and are applicable for non-structural building components and construction garnering **4.75 points** in this section. The building uses extensive greenery to achieve a Green Plot Ratio [18] of 3.82 (**5 points)**. The project team has good environmental credentials and follows good environmental management practices like providing a building user guide and provision for facilities and recycle bins for storage of segregated recycled waste (**5.25 points**). Apart from this, the building is easily accessible to bus stops and has provision for covered walkway to facilitate connectivity and use of public transport (**2 points**). ABN commits to use refrigerants with 0 ozone depletion potential and a refrigerant leak detection system at critical areas of plant rooms containing chillers and other equipment (**2 points**).

3.4. Indoor environmental quality

The occupied spaces of the building are designed with good ambient sound levels as recommended in SS553 (**1 point**). The building is designed to reduce indoor air pollutants by opting for low VOC paints and environmentally friendly adhesives (**2 points**). High frequency ballasts are used in luminaires (**1 point**).

3.5. Other green features

ABN adopts a demolition protocol to ensure at least 35% of crushed concrete waste was sent to approved recyclers with proper facilities (**2 points**). ABN also caters for a siphonic rain water discharge system at roof (**1 point**). Apart from these features, a live building performance dashboard for tenants and visitors was installed so as to educate the users and visitors of the building to its energy saving and sustainability features, especially since the majority of the users would be students (**0.5 point**). An automated fumehood control has been adopted in the laboratories which uses a motion sensor to automatically close the sash when not in use. This helps in conserving energy from the fumehoods when not in use (**0.5 point**).

4. Conclusion

The case study of ABN highlights the methodologies and innovations within the sustainability assessment framework of GM to help deliver a high performance and sustainable green building. This sustainability assessment framework is a key driver for improving energy efficiency, water efficiency, environmental protection, indoor environmental quality and other green features in a building. Moreover, achieving a high rating in sustainability assessment schemes can also contribute to transparency in energy use in buildings and educate the users of their contribution to reduced energy consumption and CO_2 emissions. Further study may be done in understanding the actual performance during the measurement and verification stage of the building to understand the gaps of the current assessment. An assessment scheme for laboratory buildings could be developed in the future based on these learnings.

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