
# BCA Green Mark Certification - Verification Audit

## Workflow & Compliance Requirement Checklist

History of amendments

| S/N | Brief Description of changes | Revision date |
|---|---|---|
| 1.0 | Updated form EM-2 in Appendix D | 22 Nov 2013 |
| 2.0 | New Section 9, 10, 11 and 12 to explain the workflow for GLS programme projects | 26 May 2014 |
| 3.0 | Section 9, 10, 11 and 12 were revised to include information on the mandatory requirement for projects on land sold under the Government Land Sales Programme in two additional GLS sites –Woodlands Regional Centre and Punggol Eco-Town and added information on verification audit requirement | 29 Aug 2014 |

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## BCA Green Mark Verification Audit For New Buildings

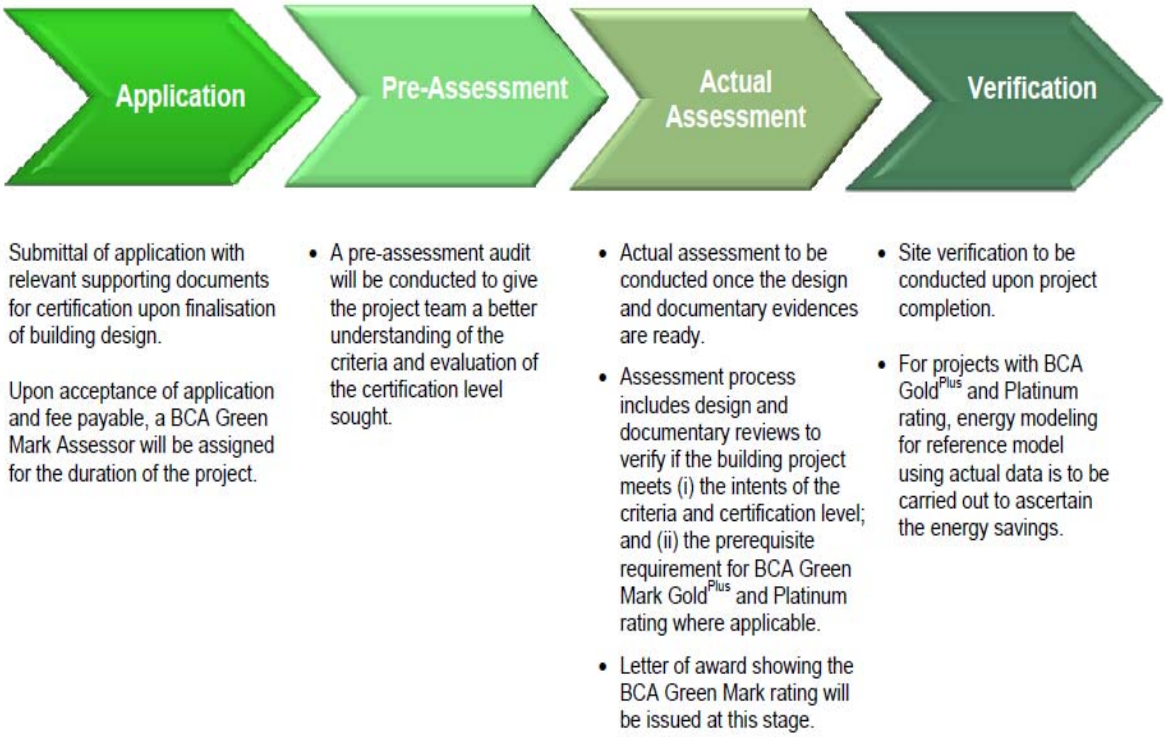
### CONTENTS



**APPENDICES**

# 1. CERTIFICATION PROCESS

The Building and Construction Authority (BCA) Green Mark Certification Process is as follows:




The Verification Audit is the last step of the BCA Green Mark Certification Process which is to be completed within the validity of the certification.

# 2. OBJECTIVE

The intent of this BCA Green Mark Certification Process – Verification Audit Document is to set out the verification audit workflow and requirements of the building owners and developers for BCA to conduct the site verification upon project completion.

The objective of the verification audit is for BCA to validate and for building developers/ owners to demonstrate compliance with the committed design specifications in terms of:

1) Implementation of the green features site installation and/or control strategies; operation functionalities and performance; and

2) Energy savings over the code-compliance buildings

which were committed during the Actual Assessment.

The Workflow and Checklist of Documentation Requirement below outlines the Verification Audit Process.

If you need clarification on any aspect of this Document, please contact BCA, Singapore.

# 3. 2-STAGE VERIFICATION FOR GREEN MARK CERTIFICATION

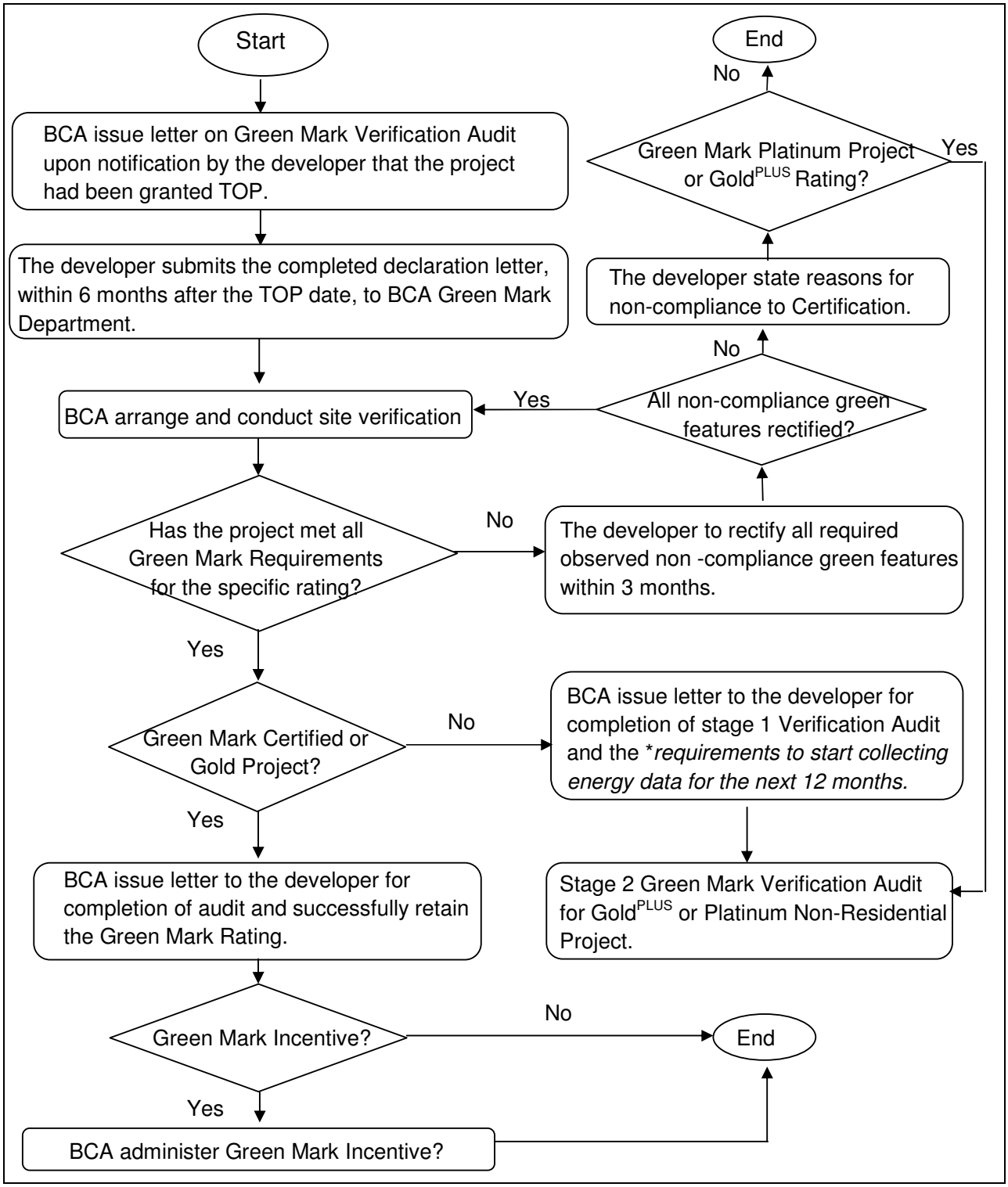
The 2-stage verification audit is as follows:

Stage 1: The building developer/ owner is to determine the functionality and performance of the green features which resulted in the certification and demonstrate compliance with to the committed deign specification through documentary evidences and site verification.

During the course of site verification, key observations of the green features, photos will be taken for record purpose.

Stage 2: Applicable only for BCA Green Mark Gold$^{PLUS}$ and Platinum certified ***Non-Residential*** projects. The developer/ owner is to determine the energy savings for the building over its reference model using 12-month actual operation data and demonstrate compliance to the committed energy savings which resulted in the certification.

# 4. VERIFICATION AUDIT WORKFLOW FOR GREEN MARK CERTIFICATION PROJECTS – STAGE 1 VERIFICATION AUDIT WORKFLOW




**Only applicable for **Non-Residential** projects.*

# 5. VERIFICATION AUDIT FOR GREEN MARK CERTIFICATION PROJECTS - STAGE 1 COMPLIANCE REQUIREMENTS FOR NON-RESIDENTIAL BUILDING

**Part 1: Energy Efficiency**

| Criteria | Compliance Requirement |
|---|---|
| NRB 1-1 Building Envelope - ETTV | Documentary Evidences<br>• Purchase orders/ delivery orders, for the brands/models of the installed glazing, stipulating the U-value and SC specifications, to demonstrate compliance with the committed building façade thermal performance i.e. ETTV.<br>• Product catalogue as supplementary documents to PO/DO for making reference of the installed glazing U-value and SC specifications. |
| NRB 1-2 Air- Conditioning System (a)(i) Air-Conditioned Plant | Documentary Evidences<br>• Determine the efficiency of the chilled-water plant using the list of required trend logged operations data stipulated below, and demonstrate compliance with the committed design specifications.<br>• Operating Chiller Plant Efficiency Report (refer to Appendix B for report template).<br>• BMS raw data in Microsoft excel file format for all relevant chiller plant operating performance parameters<br>• Temperature sensors calibration certificates from accredited laboratory and/or factory calibration certificates from manufacturers. |

| Criteria | Compliance Requirement |
|---|---|
| NRB 1-2 Air- Conditioning System<br>(a)(i) Air-Conditioned Plant | <u>Site Requirements</u><br>• Determine the chilled-water plant efficiency using the following operation data/ installations to demonstrate compliance with the design specifications:<br>▪ From Building Management System<br>i. Chilled-water plant kW/RT;<br>ii. Chilled-water supply & return temperatures of the header to be checked for consistency against the temperatures of individual chillers and/or individual branches;<br>iii. Condenser water supply & return temperatures of the header to be checked for consistency against the temperatures of individual chillers and/or individual branches;<br>iv. Chilled-water header flow rate to be checked for consistency against the flow rate(s) of individual branches<br>v. Condenser water header flow rate to be checked for consistency against the flow rate(s) of individual branches<br>vi. The accuracy of the programmed formula for the computation of the kW/RT of the chiller plant.<br>▪ From the operating Chiller panel(s):<br>i. Chilled-water supply & return temperatures to be checked for consistency against the BMS data;<br>ii. Condenser water supply & return temperatures to be checked for consistency against the BMS data;<br>iii. Approach of chilled-water supply – refrigerant evaporating temperature;<br>iv. Approach of chilled-water supply – refrigerant evaporating temperature.<br>▪ Location of the chilled-water flow meter(s) installed to comply with manufacturer's recommendations.<br>▪ Location of the chilled-water temperature sensors installed to comply with manufacturer's recommendations & demonstrate accuracy compliance to the requirements. |

| Criteria | Compliance requirement |
|---|---|
| NRB 1-2 Air- Conditioning System<br>(a)(ii) Unitary Air-conditioners | <u>Documentary Evidences</u><br>• Purchase orders/ delivery orders, for the brands/models of the installed unitary air-conditioners<br>• Product catalogue as supplementary documents to PO/DO for making reference of the installed unitary air-conditioners.<br><br><u>Site Requirements</u><br>• Demonstrate compliance with the committed design specifications. |
| NRB 1-2 Air- Conditioning System<br>(a)(iii) Air Distribution System<br><br>(c) Sensors and automatic control devices for regulating of outdoor air | <u>Site Requirements</u><br>• Determine the sensors installations and the functionality of the control strategies implemented for the air distribution systems using operation data and demonstrate compliance with the design specifications:<br>▪ Location of the $CO_2$ sensors for monitoring of the return air $CO_2$ level;<br>▪ From Building Management System (BMS)<br>i. $CO_2$ level of the return air and the resultant percent opening of the ventilation air dampers to checked for regulation of outdoor air;<br>ii. Supply air off-coil temperature and the resultant percent opening of the modulating valves to checked indoor thermal comfort;<br>iii. Chilled-water supply & return temperatures to be checked for consistency against the chilled-water plant header and/or branches temperatures; |
| NRB 1-3 Building Envelope | <u>Site Requirements</u><br>• Demonstrate compliance with the committed design specifications making reference to the as-built drawings. |

| Criteria | Compliance requirement |
|---|---|
| NRB 1-4 Natural Ventilation (exclude car parks) | Site Requirements<br>• Demonstrate compliance with the committed design specifications making reference to the as-built drawings. |
| NRB 1-5 Daylighting | Site Requirements<br>• Determine the effectiveness of the daylighting design strategies implemented and demonstrate compliance with the committed designed specifications. |
| NRB 1-6 Artificial Lighting | Documentary Evidences<br>• Purchase orders/ delivery orders of the installed lighting fixtures to demonstrate compliance with the committed design specifications. |
| NRB 1-7 Ventilation in Car Parks | Site Requirements<br>• Determine the sensors installations and the functionality of the control strategies implemented for the car park ventilation systems using operation data and demonstrate compliance with the design specifications:<br>(i) CO sensors<br>(ii) Ductless fans<br>(iii) From BMS:<br>CO level and the resultant supply and exhaust fans' frequency to check for modulation of the demand based ventilation system |
| NRB 1-8 Ventilation in Common areas | Site Requirements<br>• Demonstrate compliance with the committed design specifications. |

| Criteria | Compliance requirement |
|---|---|
| NRB 1-9 Lifts and Escalators | <u>Documentary Evidences</u><br><br>• Purchase orders/ delivery orders of the installed lifts and/or escalators to demonstrate compliance with the committed design specifications.<br><br>• Product catalogue as supplementary documents to PO/DO for making reference of the installed lifts and/or escalators.<br><br><u>Site Requirements</u><br><br>• Demonstrate compliance with the committed design specifications. |
| NRB 1-10 Energy Efficient Features | <u>Documentary Evidences</u><br><br>• Determine the functionality, performance and savings of energy efficient systems using trend logged operations data and demonstrate compliance with the committed design specifications.<br><br><u>Site Requirements</u><br><br>• Determine the functionalities of the energy efficient features implemented and demonstrate compliance with the committed designed specifications.<br><br>▪ From Building Management System:<br>• Determine the performance of the energy efficient systems by using measured and/or monitored operation data and demonstrate compliance with the committed design specifications. |

| Criteria | Compliance requirement |
|---|---|
| NRB 1-11 Renewable Energy | <u>Documentary Evidences</u><br><br>• Determine the performance of the renewable energy generation system(s) by using trend logged data of the energy generated and demonstrate compliance to the committed design specifications,<br><br><u>Site Requirements</u><br><br>• Demonstrate the implementation and functionalities of the renewable energy generation systems and determine compliance with the committed designed specifications. |

**Part 2 Water Efficiency**

| Criteria | Compliance requirement |
|---|---|
| NRB 2-1 Water Efficient Fittings | Documentary Evidences<br>• Purchase orders/ delivery orders, for the brands/models of the installed sanitary fittings to demonstrate compliance to the committed design specifications.<br>Site Requirements<br>• Determine the flow rate of the sanitary fittings using e.g. a beaker and stop watch and demonstrate compliance with the committed design specifications. |
| NRB 2-2 Water Usage and Leak Detection | Documentary Evidences<br>• Water consumption monitoring and trend logged data of major water usage to demonstrate compliance to the committed design specifications.<br>Site Requirements<br>• Demonstrate the provision of water sub-meters and determine compliance with the committed design specifications.<br>▪ From Building Management System:<br>• Demonstrate the monitoring of major water usage and determine compliance with the committed design specifications. |
| NRB 2-3 Irrigation System and Landscaping | Documentary Evidences<br>• Purchase orders/ delivery orders, for the species of drought tolerant plants<br>Site Requirements<br>• Demonstrate the use of non portable water for landscape irrigation and determine compliance with the committed design specifications.<br>• Demonstrate the provision of water efficient irrigation system and determine compliance with the committed design specifications. |

| Criteria | Compliance requirement |
|---|---|
| NRB 2-4 Water Consumption of Cooling Tower | Documentary Evidences<br>• Determine the cycles of concentration of the condenser water treatment system achieved, by using water test report and demonstrate compliance to the committed design specifications.<br>Site Requirements<br>• Demonstrate the provision of NEWater supply for the condenser water make-up. |

**Part 3 Environmental Protection**

| Criteria | Compliance requirement |
|---|---|
| NRB 3-1 Sustainable Construction | Documentary Evidences<br>• Purchase orders/ delivery orders, for the brands/models of the environmental friendly products, to demonstrate compliance with the committed design specifications, and/or undertaking from the developer. |
| NRB 3-2 Greenery | Documentary Evidences<br>• Demonstrate compliance with the committed trees planting design making reference to the as-built drawings.<br>• Demonstrate the use of compost recycled from horticulture waste.<br>Site Requirement<br>• Demonstrate the restoration, conservation and/or relocation of trees on site. |
| NRB 3-3 Environmental Management Practice | Documentary Evidences<br>• Demonstrate the monthly graphical plots and bills of energy use, water use and construction waste throughout the course of construction works.<br>• CONQUAS Certification<br>• Demonstrate the provision and circulation of the Building Users' Guide.<br>Site Requirement<br>• Demonstrate the provision of recycling facilities. |

| Criteria | Compliance requirement |
|---|---|
| NRB 3-4 Public Transport Accessibility | Site Requirement<br><br>• Demonstrate the site accessibility to public transportation or provision of private shuttle bus service.<br><br>• Demonstrate the provision of adequate bicycle parking lots.<br><br>• Demonstrate the connection of covered walkway from the development to public transport services |
| NRB 3-5 Refrigerants | Site Requirement<br><br>• Demonstrate the implementation and functionalities of the refrigerant leak detection system. |
| NRB 3-6 Stormwater Management | Site Requirement<br><br>Demonstrate the implementation and functionalities of the stormwater management system and determine compliance with the PUB's ABC Water Design Guidelines. |

**Part 4 Indoor Environmental Quality**

| Criteria | Compliance requirement |
|---|---|
| NRB 4-1 Thermal Comfort | Site Requirements<br>• Determine the thermal comfort of the applicable air-conditioning spaces using measured and/or monitored operation data and demonstrate compliance with the committed design specifications. |
| NRB 4-2 Noise Level | Site Requirements<br>• Determine the noise level of the applicable spaces using measured and/or monitored operation data and demonstrate compliance with the committed design specifications. |
| NRB 4-3 Indoor Air Pollutants | Documentary Evidences<br>• Purchase orders/ delivery orders of low VOC paints and/or adhesive certified under SGLS to demonstrate compliance with the committed design specifications. |
| NRB 4-4 Indoor Air Quality Mangement | Documentary Evidences<br>• Purchase orders/ delivery orders of filtration media to demonstrate compliance with the committed design specifications and SS 554: Clause 4.3.4.5 & Annex E.<br>• IAQ management plan test report to demonstrate compliance with guidelines in SS554: Clause 4.6 & Annex F.<br>Site Requirements<br>• Determine the differential pressure sensor installations and the functionality of the control strategies implemented for the air distribution systems and demonstrate compliance with the design specifications via the BMS. |
| NRB 4-5 High Frequency Ballast | Documentary Evidences<br>• Purchase orders/ delivery orders of high frequency ballast to demonstrate compliance with the committed design specifications. |

**Part 5 Other Green Features**

| Criteria | Compliance requirement |
|---|---|
| NRB 5-1 Green Features and Innovations | Site Requirement<br><br>• Demonstrate the implementation and functionalities of the green features and determine compliance with the committed design specifications. |

# 6. VERIFICATION AUDIT FOR GREEN MARK CERTIFICATION PROJECTS - STAGE 1 COMPLIANCE REQUIREMENTS FOR RESIDENTIAL BUILDING

**Part 1: Energy Efficiency**

| Criteria | Compliance Requirement |
|---|---|
| RB 1-1 Building Envelope - RETV | Documentary Evidences<br>• Purchase orders/ delivery orders for the brands/ models of the installed glazing, stipulating the U-value and SC specifications, to demonstrate compliance with the committed building façade thermal performance i.e. RETV.<br>• Product catalogue as supplementary documents to PO/DO for making reference of the installed glazing U-value and SC specifications. |
| RB 1-2(a) Dwelling Unit Indoor Comfort | Documentary Evidences<br>• Purchase orders/ delivery orders for the brands/ models of the installed air-conditioners to demonstrate compliance with the committed design specifications.<br>• Product catalogue as supplementary documents to PO/DO for making reference of the installed air-conditioners Singapore Energy Labelling Scheme rating.<br>Site Requirements<br>• Demonstrate compliance with the committed design specifications making reference to the as-built drawings. |
| RB 1-2(b) Natural Ventilation in Common Areas | Site Requirements<br>• Demonstrate compliance with the committed design specifications making reference to the as-built drawings. |

| Criteria | Compliance Requirement |
|---|---|
| RB 1-3 Daylighting | <u>Site Requirements</u><br><br>• Determine the effectiveness of the daylighting design strategies implemented and demonstrate compliance with the committed designed specifications. |
| RB 1-4 Artificial Lightings | <u>Documentary Evidences</u><br><br>• Purchase orders/ delivery orders of the installed lighting fixtures to demonstrate compliance with the committed design specifications.<br><br>• Product catalogue as supplementary documents to PO/DO for making reference of the installed lighting fixtures specifications.<br><br><u>Site Requirements</u><br><br>• Demonstrate compliance with the committed design specifications making reference to the as-built drawings. |
| RB 1-5 Ventilation in Car Parks | <u>Site Requirements</u><br><br>• Determine the sensors installations and the functionality of the control strategies implemented for the car park ventilation systems and demonstrate compliance with the design specifications:<br><br>(iv) CO sensors<br>Ductless fans |
| RB 1-6 Lifts | <u>Documentary Evidences</u><br><br>• Purchase orders/ delivery orders of the installed lifts to demonstrate compliance with the committed design specifications.<br><br>• Product catalogue as supplementary documents to PO/DO for making reference of the installed lifts specifications. |

| Criteria | Compliance Requirement |
|---|---|
| RB 1-7 Energy Efficient Features | Documentary Evidences<br><br>• Determine the performance of the energy efficient systems by using measured and/or monitored operation data and demonstrate compliance with the committed design specifications.<br><br>Site Requirements<br><br>• Determine the functionalities of the energy efficient features implemented and demonstrate compliance with the committed designed specifications. |
| RB 1-8 Renewable Energy | Documentary Evidences<br><br>• Determine the performance of the renewable energy generation system(s) by using trend logged data of the energy generated and demonstrate compliance to the committed design specifications,<br><br>Site Requirements<br><br>• Demonstrate the implementation and functionalities of the renewable energy generation systems and determine compliance with the committed designed specifications. |

**Part 2 Water Efficiency**

| Criteria | Compliance requirement |
|---|---|
| RB 2-1 Water Efficient Fittings | Documentary Evidences<br>• Purchase orders/ delivery orders, for the brands/models of the installed sanitary fittings to demonstrate compliance to the committed design specifications.<br>• Product catalogue as supplementary documents to PO/DO for making reference of the installed sanitary fittings specifications.<br><br>Site Requirements<br>• Determine the flow rate of the sanitary fittings using e.g. a beaker and stop watch and demonstrate compliance with the committed design specifications. |
| RB 2-2 Water Usage Monitoring | Site Requirements<br>• Demonstrate the provision of water sub-meters and determine compliance with the committed design specifications. |
| RB 2-3 Irrigation System and Landscaping | Documentary Evidences<br>• Purchase orders/ delivery orders, for the species of drought tolerant plants<br><br>Site Requirements<br>• Demonstrate the use of non portable water for landscape irrigation and determine compliance with the committed design specifications.<br>• Demonstrate the provision of water efficient irrigation system and determine compliance with the committed design specifications. |

**Part 3 Environmental Protection**

| Criteria | Compliance requirement |
|---|---|
| RB 3-1 Sustainable Construction | Documentary Evidences<br>• Purchase orders/ delivery orders, for the brands/models of the environmental friendly products, to demonstrate compliance with the committed design specifications.<br>• Product catalogue as supplementary documents to PO/DO for making reference of the environmental friendly products specifications. |
| RB 3-2 Greenery Provision | Documentary Evidences<br>• Demonstrate compliance with the committed trees planting design making reference to the as-built drawings.<br>• Demonstrate the use of compost recycled from horticulture waste.<br>Site Requirement<br>• Demonstrate the restoration, conservation and/or relocation of trees on site. |
| RB 3-3 Environmental Management Practice | Documentary Evidences<br>• Demonstrate the monthly graphical plots and bills of energy use, water use and construction waste throughout the course of construction works.<br>• CONQUAS and/or Quality Mark Scheme certification.<br>• Demonstrate the provision and circulation of the Building Users' Guide.<br>Site Requirement<br>• Demonstrate the provision of recycling facilities. |

| Criteria | Compliance requirement |
|---|---|
| RB 3-4 Public Transport Accessibility | Site Requirement<br><br>• Demonstrate the site accessibility to public transportation.<br><br>• Demonstrate the provision of adequate bicycle parking lots.<br><br>• Demonstrate the connection of covered walkway from the development to public transport services. |
| NRB 3-6 Stormwater Management | Site Requirement<br><br>Demonstrate the implementation and functionalities of the stormwater management system and determine compliance with the PUB's ABC Water Design Guidelines. |

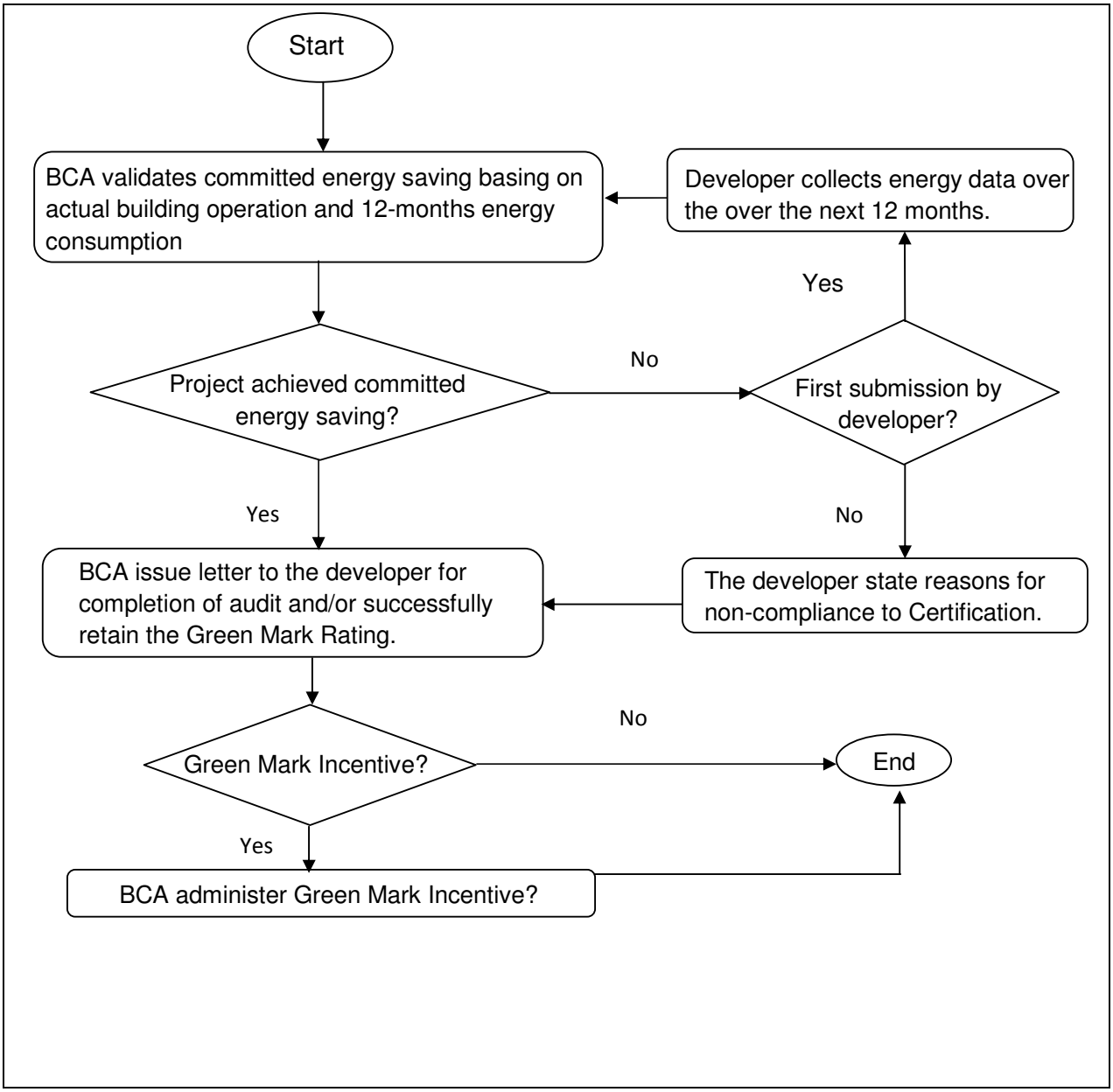
**Part 4 Indoor Environmental Quality**

| Criteria | Compliance requirement |
|---|---|
| RB 4-1 Noise Level | Site Requirements<br>• Determine the noise level of the applicable spaces using measured and/or monitored operation data and demonstrate compliance with the committed design specifications. |
| RB 4-2 Indoor Air Pollutants | Documentary Evidences<br>• Purchase orders/ delivery orders of low VOC paints and/or adhesive certified under SGLS to demonstrate compliance with the committed design specifications.<br>• Product catalogue as supplementary documents to PO/DO for making reference of the SGLS products specifications. |
| RB 4-3 Waste Disposal | Site Requirements<br>• Demonstrate compliance with the committed design specifications making reference to the as-built drawings. |

**Part 5 Other Green Features**

| Criteria | Compliance requirement |
|---|---|
| RB 5-1 Green Features and Innovations | Site Requirement<br>• Demonstrate the implementation and functionalities of the green features and determine compliance with the committed design specifications. |

# 7. VERIFICATION AUDIT WORKFLOW FOR GREEN MARK CERTIFICATION PROJECTS – STAGE 2 VERIFICATION AUDIT WORKFLOW



# 8. VERIFICATION AUDIT FOR GREEN MARK CERTIFICATION PROJECTS – STAGE 2 VERIFICATION AUDIT COMPLIANCE REQUIREMENT

A) Validation of Committed Energy Savings

- When the building starts to operate in a steady state, the developer shall within 2 years after TOP, commence to gather data on actual site operation for the next 12 months period. Using the data on actual site operation, a revised energy modelling shall be performed to compare the annual energy consumption of the Reference Model with the actual consumption of the building.

B) Documentary evidences

- The developer should submit Green Mark Certification – Stage 2 Verification Audit Report of content in accordance to Appendix C.

# 9. VERIFICATION AUDIT REQUIREMENT FOR PROJECTS THAT ARE SUBJECT TO MANDATORY HIGHER GREEN MARK STANDARDS UNDER GOVERNMENT LAND SALES (GLS) PROGRAMME IN SELECTED STRATEGIC AREAS

Building projects that are developed on land sold under the Government Land Sales (GLS) Programme sites in selected strategic areas and are subject to higher Green Mark Standards under the Building Control (Environmental Sustainability) Regulations 2008 are required to be designed and certified to meet the prescribed Green Mark rating as shown in the table below :

| **Selected Strategic Areas**<br>**Exact Location to refer to the Building Control (Environmental Sustainability ) Regulations 2008** | **Requirements for building wholly or partly within area that is on land sold under the Government Land Sales Programme** |
|---|---|
| Marina Bay | Green Mark Platinum Rating |
| Downtown Core – including areas within the CBD located next to Marina Bay | Green Mark Gold$^{Plus}$ Rating |
| Jurong Lake District | Green Mark Gold$^{Plus}$ Rating |
| Kallang Riverside | Green Mark Gold$^{Plus}$ Rating |
| Paya Lebar Central | Green Mark Gold$^{Plus}$ Rating |
| Woodlands Regional Centre | Green Mark Gold$^{Plus}$ Rating |
| Punggol Eco-Town | Green Mark Gold$^{Plus}$ Rating |

Upon completion of building works and commissioning of building system, the Applicant or the Qualified Person (QP) must notify the BCA Green Mark Department / Lead Assessor of the project to initiate the commencement of the verification audit before Temporary Occupation Permit (TOP) or Certificate of Statutory Completion (CSC) application whichever earlier. As the prescribed Green Mark Certification for the projects must be validated through site verification audit before clearance, it is important to give at least three (3) months notice so as to facilitate the TOP and CSC clearance at later stage. The declaration letter in Appendix A must be submitted to the BCA Green Mark Department along with the notice.

In the case of project requiring TOP in phases, the details of the phasing must be spelled out and submitted to the assessor for consideration first so that the necessary verification can be scheduled and completed for the critical and relevant works for clearance.

**Verification Audit for Residential Building Developments**

The verification audit will cover the following :

- Site inspection of green features
- Review of documentary evidences and records
- Site measurements

The details of documentary evidences and site requirements can be found in Section 6 of this document for compliance.

**Verification Audit for Non-Residential Building Developments**

The verification audit will comprise two stages.

Stage 1 – Site Audit and Verification

The site audit and verification will cover the following :

- Site inspection of green features
- Review of documentary evidences and records
- Site measurements which include verification of permanent measuring instruments installed and building cooling system efficiency.

The details of documentary evidences and site requirements can be found in Section 5 of this document for compliance.

Stage 2 – Verification of Building System Performance and Energy Savings

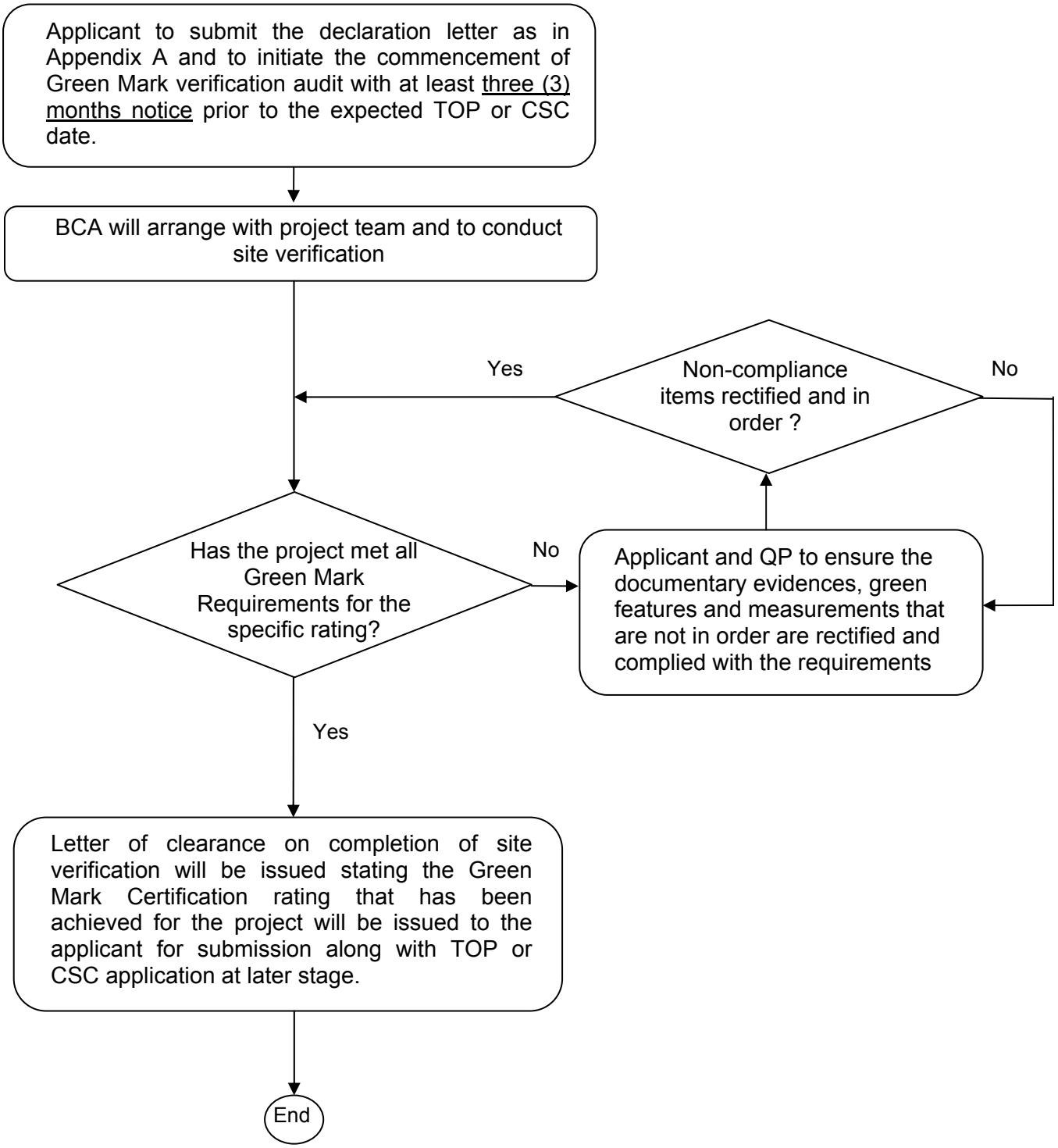
Once the building operation is in a steady state, the data on actual building operation must be collated for a period of 12 months. These data are to be used in the revised energy modelling simulation to demonstrate compliance with the energy savings committed over its reference model using the energy modelling framework as per design.

The details of documentary evidences and site requirements can be found in Appendix C and Appendix D of this document for compliance.

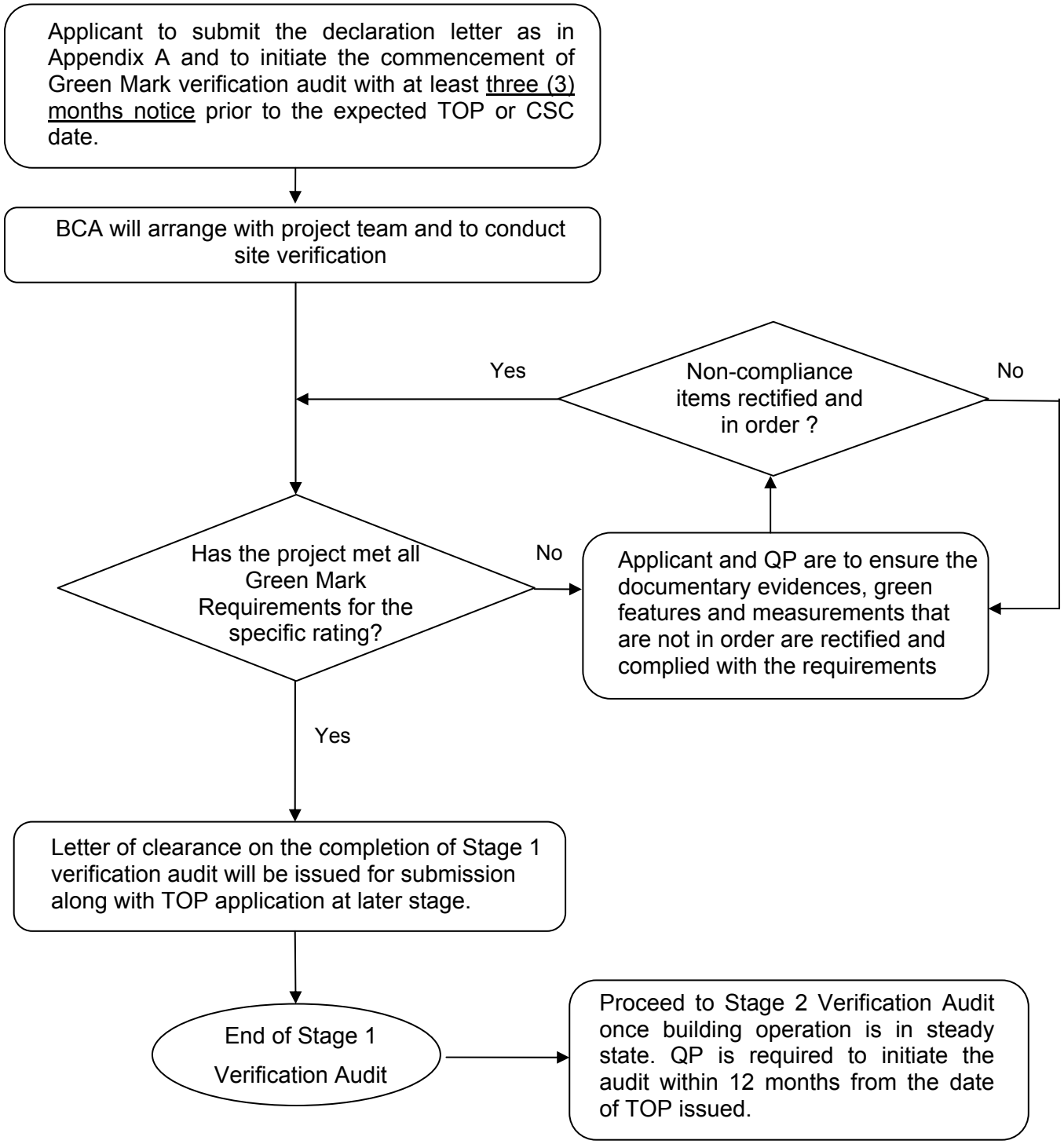
**Verification Audit Work Flow**

The flowcharts of the verification audit processes can be found in the following Section 10, 11 and 12 of this document for clarity.

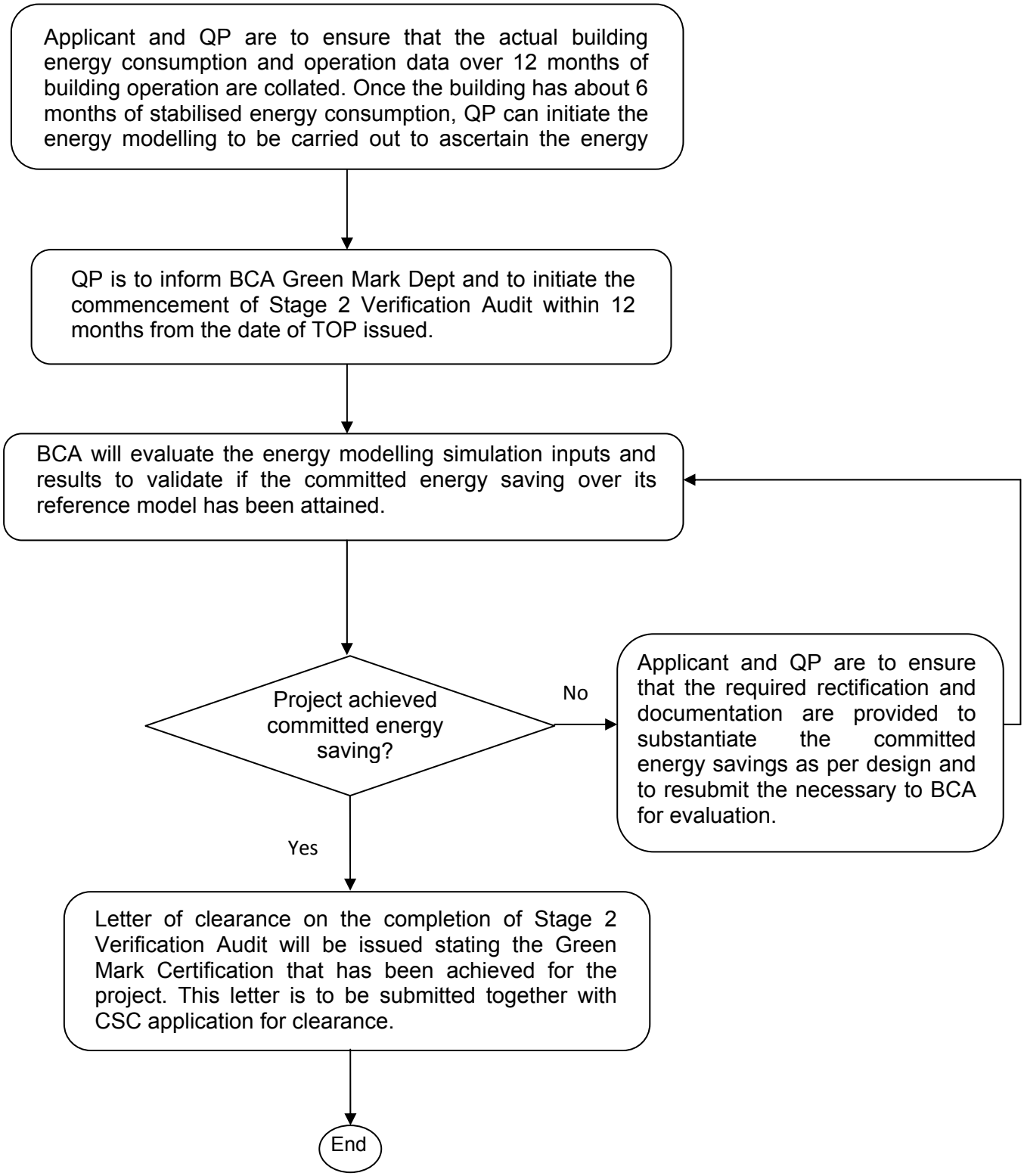
## 10. VERIFICATION AUDIT WORKFLOW – RESIDENTIAL BUILDING DEVELOPMENTS UNDER GLS PROGRAMME IN SELECTED STRATEGIC AREAS



# 11. STAGE 1 VERIFICATION AUDIT WORKFLOW – NON-RESIDENTIAL BUILDING DEVELOPMENTS UNDER GLS PROGRAMME IN SELECTED STRATEGIC AREAS



## 12. STAGE 2 VERIFICATION AUDIT WORKFLOW – NON-RESIDENTIAL BUILDING DEVELOPMENTS UNDER GLS PROGRAMME IN SELECTED STRATEGIC AREAS



**APPENDIX A**

# GREEN MARK FOR BUILDINGS

## SITE VERIFICATION - DECLARATION LETTER

(Date)

Director
Green Mark Department (New Development)
Building and Construction Authority
5 Maxwell Road
#17-00 Tower Block MND Complex
Singapore 069110

Dear Sir/ Madam,

**DECLARATION ON GREEN MARK FEATURES IMPLEMENTED IN (project name)**

We hereby declare the list of variations in project design and green features incorporated in the above-mentioned development, tabulated in Table 1: Variation List of Features. This is made in comparison with those features committed during the Green Mark actual assessment, held on (actual assessment dates).

Moreover, additional green feature(s) incorporated in the development which are not highlighted during the actual assessment, are listed in Table 2: List of Additional Features.

Besides the above-mentioned listed green features, we declare that there is no other variation in the project design and green features incorporated in the development as per commitment made during the actual assessment. Should there be any queries, please do not hesitate to contact us.

Thank you.

Yours faithfully,

(Person-in-charge)

(Company Name, Designation)

(Contact No., email address)

**APPENDIX A**

Table 1: Variation List of Features

| Item No. | Item Description | Description of Variation(s) | Rectification to Variation(s) (to be filled in by Assessors) |
|---|---|---|---|
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**APPENDIX A**

Table 2: List of Additional Features

| Item No. | Item Description | Remark(s) | Evaluation of Feature(s) (to be filled in by Assessors) |
|---|---|---|---|
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**APPENDIX A**

PROJECT INFORMATION:

| Names of Contact Person for Site Verification | DID/ HP | Email Address |
|---|---|---|
| | | |
| | | |

**APPENDIX B**

Date: DD/MM/YEAR

# OPERATING SYSTEM EFFICIENCY REPORT

# FOR

# ENTER BUILDING NAME

## Contents

# 1.0 Building Information

Enter a brief description of the building here.

| | | |
|---|---|---|
| Building Name | : | |
| Building Address | : | |
| Postal Code | : | |
| Building Type | : | |
| Gross floor area (GFA), $m^2$ | : | |
| Air conditioned area, $m^2$ | : | |

# 2.0 Operating System Efficiency Information

| | | |
|---|---|---|
| Location | : | **Enter location of chilled water plant** |
| Date of submission in notice | : | **Enter submission deadline stipulated in BCA notice** |
| Data Logging Interval | : | 1 minute sampling |
| Trend Logged Parameters* | : | Chilled Water Supply main header temperature |
| | | Chilled Water Return main header temperature |
| | | Chilled Water flow rate at chilled water return main header |
| | | Condenser Water Supply main header temperature |
| | | Condenser Water Return main header temperature |
| | | Condenser water flow rate at chilled water return main header |
| | | Power input to Chiller(s) |
| | | Power input to Chilled water pump(s) |
| | | Power input to Condenser water pump(s) |
| | | Power input to Cooling tower(s) |

**** Trend logged parameters are not limited to the above and may vary depending on the piping and electrical circuit design.***

# 3.0 Chilled Water Plant information*

**Table 1: Chiller Information (Example)**

**APPENDIX B**

| ID | Description | Type | Name plate motor (kW) | Cooling Capacity (RT) | Chilled water LWT | Chilled water ΔT | Rated Efficiency kW/RT | Year Installed |
|---|---|---|---|---|---|---|---|---|
| CH01 | Chiller 1 | Centrifugal | 150 | 1000 | 6.7 °C | 5.5°C | 0.55 | 2012 |
| CH02 | Chiller 2 | VSD Screw | 90 | 500 | 6.7 °C | 5.5°C | 0.52 | 2012 |

| ID | Description | Name plate motor (kW) | Pump Head (m) | Flow rate (L/S) | Rated Pump/ Fan efficiency | Rated Motor Efficiency |
|---|---|---|---|---|---|---|
| CHWP01 | Chilled water pump 1 | 55 | 30 | 151.2 | 85% | 95% |
| CHWP02 | Chilled water pump 2 | 30 | 30 | 75.6 | 85% | 95% |
| CWP01 | Condenser water pump 1 | 45 | 20 | 189 | 85% | 95% |
| CWP02 | Condenser water pump 2 | 22 | 20 | 94.5 | 85% | 95% |
| CT01 | Cooling tower 1 | 45 | - | 130 | 75% | 92% |
| CT02 | Cooling tower 2 | 45 | - | 130 | 75% | 92% |

**Table 2: Ancillary equipment Information (Example)**

***Based on equipment design specifications and name plate ratings.***

## *3.1 Chilled Water Plant Normal Operating Hours*

Monday to Friday : 0730 – 1900 Hrs

Saturday : 0730 – 1300 Hrs

Sunday : No operations

Note: The operating hours should follow the table in clause 6.1.4

# 4.0 Instrumentations

Accurate measuring instruments complying with the Green Mark Version 4.1 *(or state relevant version)* criteria for non-residential buildings were used during the audit to gather information on the power consumption, temperatures and flow rate.

The points of measurements are listed in the following table:

| ID | Description | Sensor Type | Installation Location | Measurement/ Calibration range | End to End Measurement Uncertainty (°C or %) | Last Calibration Date |
|---|---|---|---|---|---|---|
| TT01 | CHWS Temperature | 10K Ω Thermistor | CHWS Header | 0°C - 40°C | ±0.03 °C | 15/10/2012 |
| TT02 | CHWR Temperature | 10K Ω Thermistor | CHWR Header | 0°C - 40°C | ±0.03 °C | 15/10/2012 |
| TT03 | CWS Temperature | 10K Ω Thermistor | CWS Header | 0°C - 40°C | ±0.03 °C | 15/10/2012 |
| TT04 | CWR Temperature | 10K Ω Thermistor | CWR Header | 0°C - 40°C | ±0.03 °C | 15/10/2012 |
| FM01 | CHW Flow | Magnetic Full Bore | CHWR Header | 30 l/s- 200 l/s | 0.5% | 20/10/2012 |
| FM02 | CW Flow | Magnetic Full Bore | CWR Header | 30 l/s- 200 l/s | 0.5% | 20/10/2012 |
| kW01 | Chiller 1 Power | True RMS, 3 phase | ACMSB1 | 60 – 600 kW | 0.5% | 30/10/2012 |
| kW02 | Chiller 2 Power | True RMS, 3 phase | ACMSB2 | 60 – 600 kW | 0.5% | 30/10/2012 |
| kW03 | CHW Pump 1 & 2 Power | True RMS, 3 phase | | 20 – 200 kW | 0.5% | 30/10/2012 |
| kW04 | CW Pump 1 & 2 Power | True RMS, 3 phase | CHW SB | 20 – 200 kW | 0.5% | 30/10/2012 |
| kW05 | CT 1 & 2 Power | True RMS, 3 phase | CT Panel | 15 – 150 kW | 0.5% | 30/10/2012 |

**Table 3: Instrumentation Table (Example)**

# 5.0 Chiller Plant Performance Analysis

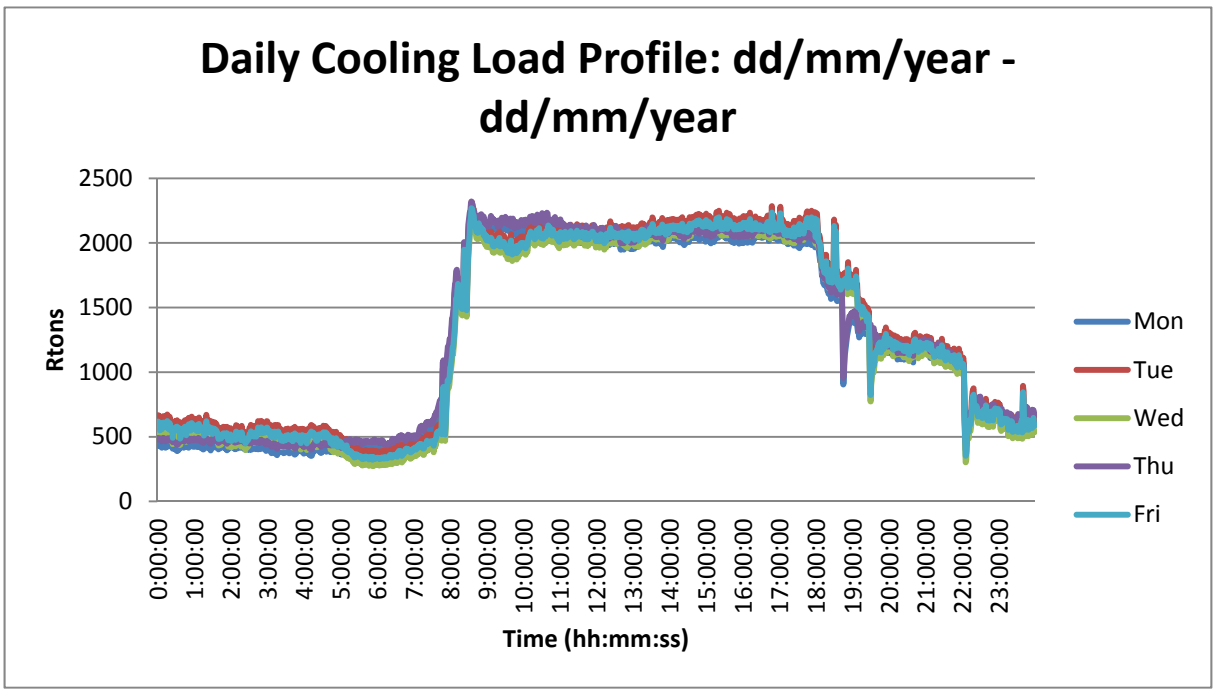


**Figure 1: Super-imposed plot of daily Cooling Load Profile (Example)**

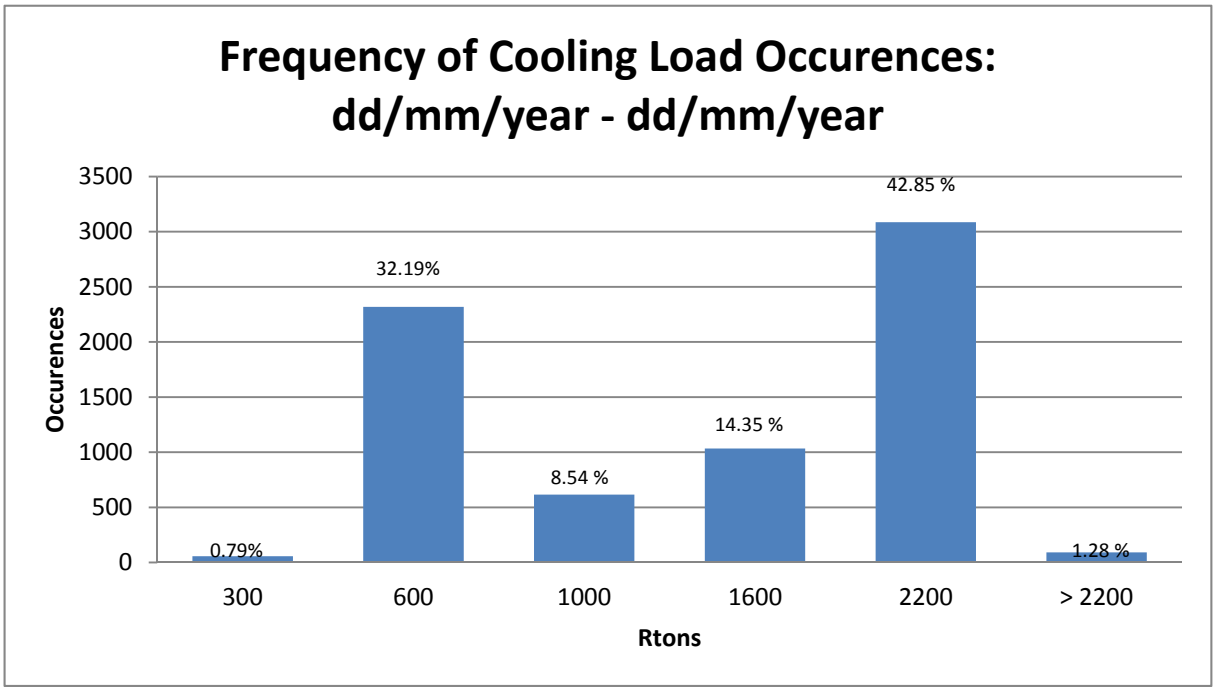


**Figure 2: Histogram of Cooling Load Occurrences (Example)**

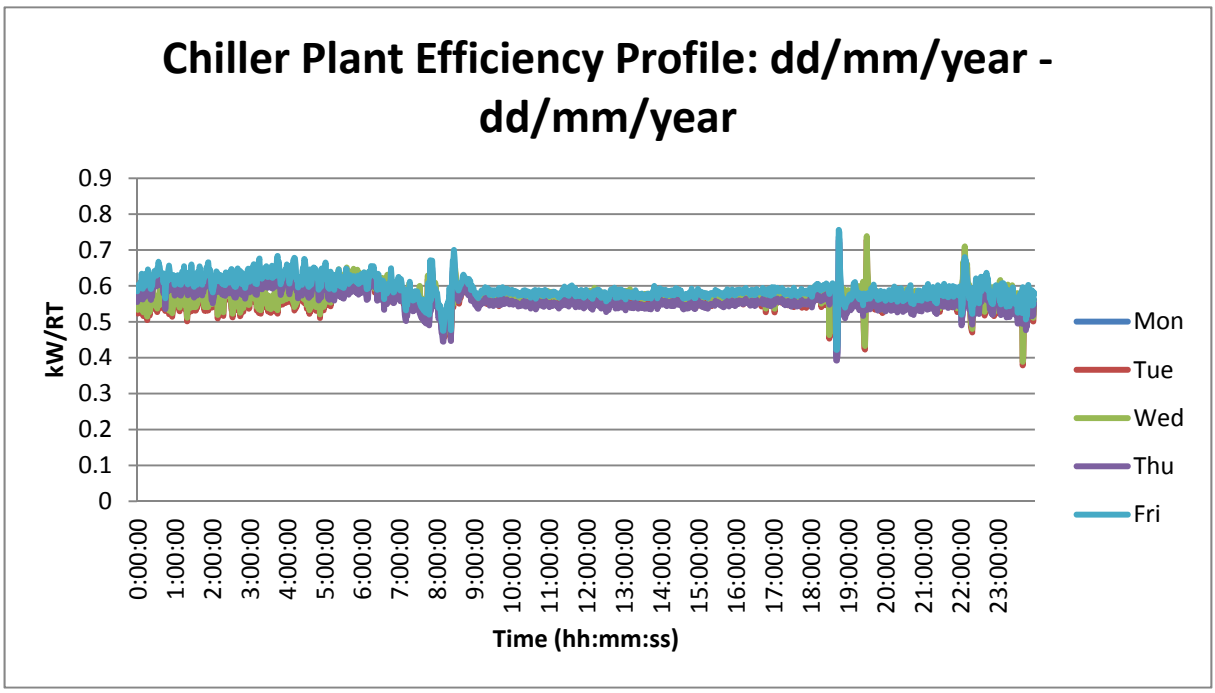


**Figure 3:Super-imposed plot of daily chiller plant efficiency**

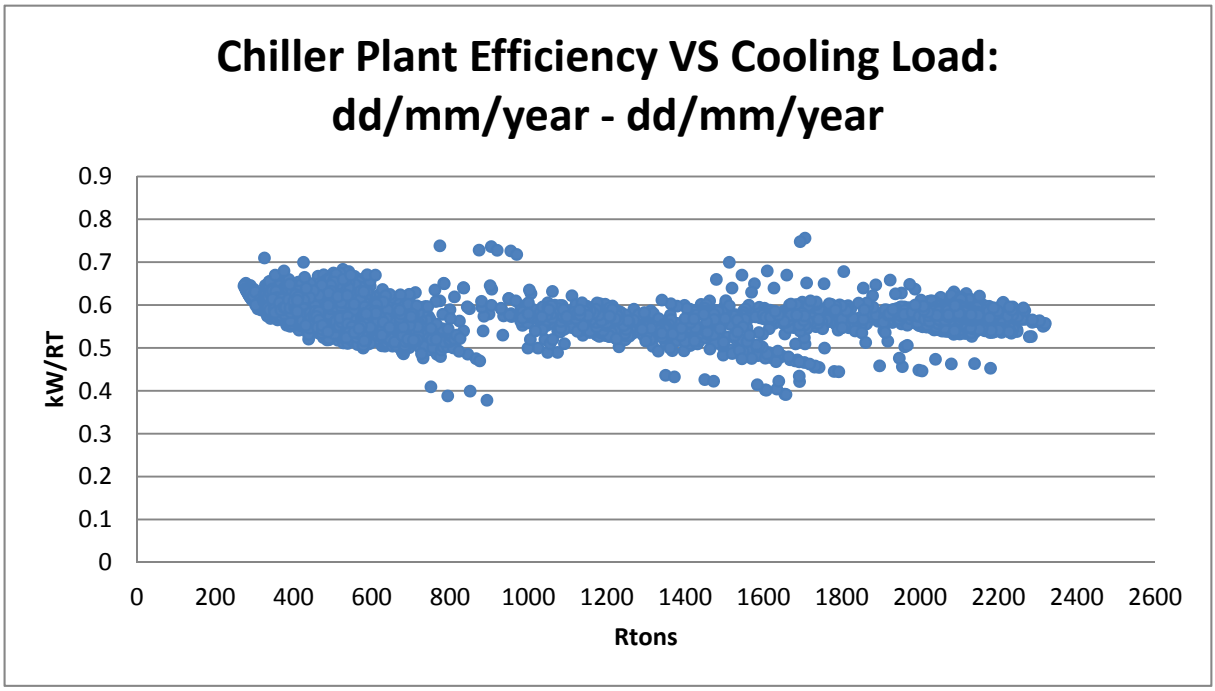


**Figure 4: Scatter plot of chiller plant efficiency over cooling load**

## 12.1 5.1 Summary of Chilled Water Plant Performance

| | Unit | Unit |
|---|---|---|
| **Chiller(s) efficiency** | | kW/RT |

| | | |
|---|---|---|
| **Chilled water pump(s) efficiency** | | kW/RT |
| **Condenser water pump(s)*** | | kW/RT |
| **Cooling tower (s)Efficiency*** | | kW/RT |
| **Overall chiller plant efficiency** | | kW/RT |

*Not applicable to air-cooled chilled water plant

## 6.0 Summary of Heat Balance

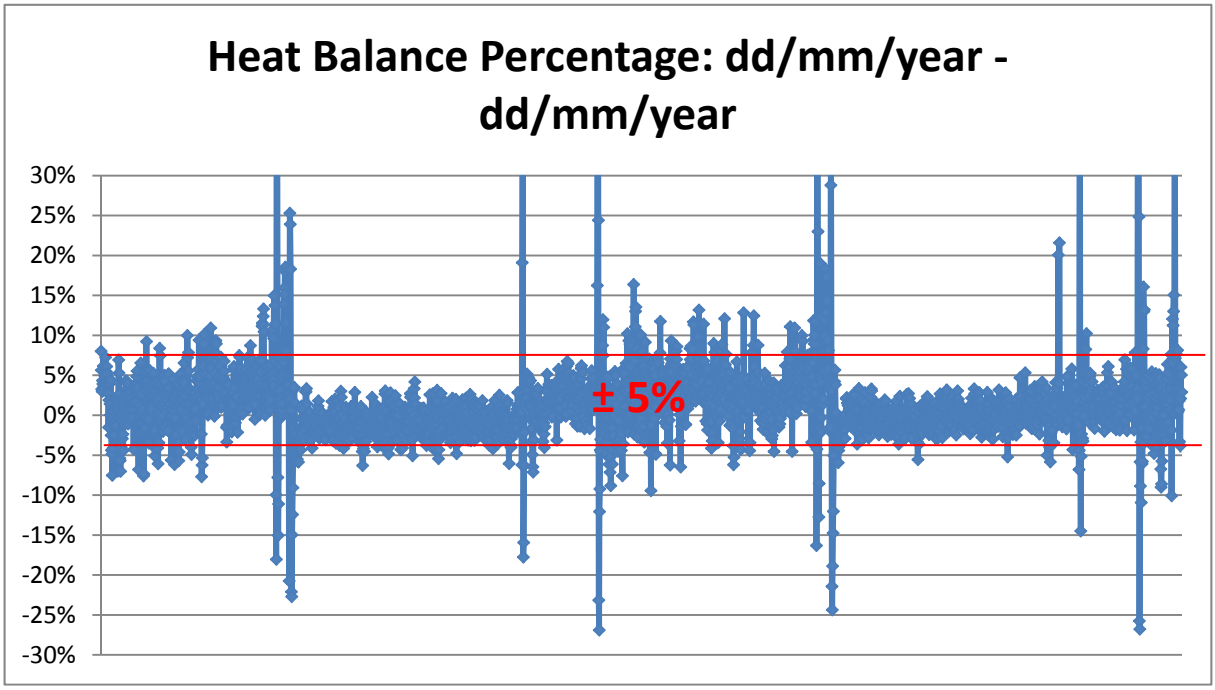


**Figure 5: System Level Heat Balance Plot**

| | Quantity | Unit | Formula |
|---|---|---|---|
| **Sum of total electrical energy used** | | kWh | (A) |
| **Sum of total cooling produced** | | RTh | (B) |
| **Sum of total heat rejected** | | RTh | (C) |
| **Chiller Plant Efficiency** | | kW/RT | (A) / (B) |
| **Total Heat Balance Data Count** | | - | (D) |
| **Data Count > + 5% error** | | - | (E) |
| **Data Count < - 5% error** | | - | (F) |
| **Data Count within ±5% error** | | - | (G) = (D) – (E) – (F) |
| **% Heat Balance within ±5% error** | | % | 100 x (G) / (D) |

**Table 4: Heat Balance Summary**

**APPENDIX C**

## Green Mark Certification – Stage 2 Verification Audit Submission Report Content

The project developer or building owner should submit Stage 2 Verification Audit Report of at least, but not be limited to, the following content:

1) EM Form 2: Submission Form for Energy Modeling for Green mark Scheme (Validation After Project Completion) - Appendix D
2) Electricity bills (landlord and/or tenant bills if applicable)
3) Operating System Efficiency Report – Appendix B
4) As-built Electrical Single-line Schematics drawings
5) Description of deviations of the building operations to the Proposed Energy Model which was submitted for Green Mark Certification e.g. monthly building occupancy rate, receptacle loads, data centre addition etc.
6) BMS data log for the individual energy end use as in FORM EM – 2.2: Summary of Actual Consumption of Energy Use; kWh raw data in softcopy Microsoft Excel file format and categorized according to the meters as-built schematics design.
7) Temporary logging of energy end use as in FORM EM – 2.2: Summary of Actual Consumption of Energy Use; kWh raw data in softcopy Microsoft Excel file format.
8) Data Centre **Monthly** Energy Consumption - kWh raw data in softcopy (if applicable).
9) BMS **Hourly** and **Monthly** data log for renewable energy generation
10) For **Actual** Building Operations, state:
    (i) operation hours for the spaces using the cooling load profiles
    (ii) operation of chiller plant
        - Operating hours
        - Installed capacity
        - Duty and standby
        - Latest 1- week building cooling load
        - latest 1-week chiller plant efficiency profile
    (iii) operation hours of other air-con systems e.g. unitary system for after office hours cooling demand
        - Spaces with after office hours demand
    (iv) human load schedules
    (v) lighting schedules
11) EEI Calculation

12) For **Reference Energy Model, state**:

(i) operation hours for the spaces (Must be similar to actual operation)

(ii) operation of chiller plant

- capacity and configuration in simulation
- simulated 1- week building cooling load
- simulated 1-week chiller plant efficiency profile

(iii) Operation hours of other air-con systems e.g. unitary system for after office hours cooling demand (Must be similar to actual operation)

- Spaces with after office hours demand

(iv) Human load schedules (Must be similar to actual operation)

(v) Simulation file in softcopy

13) For GMIS projects, Form GMIS-1: Submission Form for energy Modeling for Green Mark Incentive Scheme (Finalisation of Building Design)

## Form EM-2: Submission Form for Energy Modeling For Green Mark Scheme (Verification After Project Completion)

| | |
|---|---|
| Green Mark Department (New Development)<br>Building & Construction Authority<br>5 Maxwell Road #16-00<br>Tower Block, MND Complex<br>Singapore 069110 | INSTRUCTIONS:<br>(1) Please refer to the Explanatory Notes attached before completing the form.<br>(2) Use a separate set of forms for each building.<br>(3) *Delete accordingly |

Project Ref. No.: _____

Description of Building / Building Works: _____

_____

_____

_____

*Lot / Plot _____ *TS / MK _____

Address / Road : _____

_____

(1) As the Qualified Persons responsible for the design of M&E services for the above mentioned project, we declare that:

a. the energy modeling conducted for the project is in accordance with the requirements of BCA's Framework for Energy Modeling for Green Mark Scheme and
b. based on the results of the energy modeling, the building's actual energy consumption is ____% lower than that of the revised Reference Model.

(2) We attach the following documentations to support the above declaration:

a. Summary of Space and ETTV of the Building Envelope (*required if there is change*) (Form EM-2.1)
b. Summary of Actual Consumption of Energy by End Use including Efficiency Indicators (Form EM-2.2)
c. Summary printout from energy modeling software for the revised Reference Model (required if there is change in space use, scheduling or occupancy).

| | |
|---|---|
| Name, Address, Email and Tel of M&E Consultancy Firm for the project | (1) Name & Signature of Qualified Person (Mechanical PE) |
| | (2) Name & Signature of Qualified Person (Electrical PE) |

## FORM EM-2.1: Summary of Space and ETTV of the Building Envelope

(*required if there is a change*)

| **(A) Space Summary** | | | |
|---|---|---|---|
| Building Use | Air-Conditioned Area (m2) | Non Air-Conditioned Area (m2) | Total Area (m2) |
| 1. Office | | | |
| 2. Toilets | | | |
| 3. Storage | | | |
| 4. Corridor | | | |
| 5. Atrium | | | |
| 6. Foodcourt | | | |
| 7. Mechanical / Electrical | | | |
| 8. Staircase | | | |
| 9. Conference | | | |
| 10.Retail Outlets | | | |
| 11.Carpark | | | |
| 12. Others | | | |
| | | | |
| ***Total*** | | | |
| **Note: The building use floor areas for both the Reference and Actual Building must be the same.** | | | |

| **(B) Building Envelope Summary - ETTV** | | | |
|---|---|---|---|
| Orientation of Façade | Gross Area of External Walls ($m^2$) | Reference Model ETTV ($W/m^2$) | Actual Building ETTV ($W/m^2$) |
| North | | | |
| North-East | | | |
| East | | | |
| South-East | | | |
| South | | | |
| South-West | | | |
| West | | | |
| North-West | | | |
| **Average ETTV of the Building Envelope ($W/m^2$)** | | 50 $W/m^2$ | |

## FORM EM-2.2: Summary of Actual Consumption of Energy by End Use including Efficiency Indicators

| End Use | Reference Model Energy Consumption (kWh) | Actual Building Energy Consumption (kWh) | Tolerance (%) |
|---|---|---|---|
| Lighting – (Air-Conditioned Space) | | | |
| Lighting- (Non Air-Conditioned Space) | | | |
| Receptacle Equipment | | | |
| [1]Air-Conditioned Plant | | | |
| [2]Air System Fans | | | |
| Mechanical Ventilation Fans | | | |
| Lifts | | | |
| Escalators | | | |
| Domestic Water Systems | | | |
| Others | | | |
| | | | |
| **Total Building Energy Consumption** | | | |

**Renewable Energy Sources**

| End Use | Energy Produced (kWh) | Reference Model Energy Consumption (kWh) | Actual Building Energy Consumption (kWh) | Tolerance (%) |
|---|---|---|---|---|
| Photovoltaics | | | | |
| Others | | | | |
| **Total Building Energy Consumption including Renewable Energy Sources** | | | | |

[1] Chilled Water System (chillers, water pumps and cooling towers)
[2] Chilled water Air Handling and Fan Coil units

**APPENDIX D**

**Building Energy Performance/ Operation Indicators**

| Efficiency Indicators | Reference Model | Actual Building |
|---|---|---|
| **Total Energy Efficiency Index, EEI (kWh/$m^2$/yr)** | | |
| **Normalised Energy Efficiency Index, EEI (kWh/$m^2$/yr) *** | | |
| **System Efficiency of Air-Conditioned Plant (kW/RT)** | | |
| **Air System Fans (kW/RT)** | | |
| **Cooling Load Density (W/$m^2$)** | | |
| **Lighting and Receptacle Equipment System Efficiency (W/$m^2$)** | | |
| **Office** | | |
| **Hotel** | | |
| **Retail Mall – Retail Space** | | |
| **Retail Mall – F&B Space** | | |
| **Hospital** | | |

***Normalised EEI Formula**

Normalised EEI = [(TBEC-DCEC)/ (GFA-DCA)] x (NF/OH)

Where:

(a) TBEC : Total building energy consumption (kWh/year)
(b) DCEC : Data centre energy consumption (kWh/year)
(c) GFA : Gross floor area ($m^2$)
(d) DCA : Data centre area ($m^2$)
(e) NF : Normalising factor based on a typical weekly **55** operating hours (hrs/week)
(f) OH : Weighted weekly operating hours (hrs/week)

Note:

(1) All major energy consumption of equipments are to be included

(2) EEI is to be normalized to 100% occupancy rate

**APPENDIX D**

**EXPLANATORY NOTES FOR APPENDIX B – SUBMISSION FORM FOR ENERGY MODELING FOR GREEN MARK SCHEME (Validation After Project Completion)**

To facilitate verification of the declared energy consumption, the submission forms shall be accompanied by the following:-

(a) The detailed computation of the ETTV values for the Actual Building and revised Reference Model using APPENDICES 1 to 4 of "ETTV CALCULATON FORMAT IN RESPECT OF AN AIRCONDITIONED BUILDING" (*required if there is a change*).

(b) Certification of the simulation program is tested in accordance to the ASHRAE Standard 140.

(c) The input data of the simulation program for the revised Reference Model shall include:

1. Space input data for all zones comprising detail information on construction materials and their properties designed for each individual zone. For example, room area, walls, windows, doors, floors, partitions, sensible and latent loads (lightings, occupancy rates, receptacles loads, Outdoor ventilation rates, misc loads etc).

2. Schedules for each individual operating zone (eg. lighting, occupants, mechanical fans, AHUs, other mechanical and electrical equipment, etc.)

**Note:**

1. The developer shall furnish a softcopy of the executable input data file(s) used in the generation of the energy estimates for the Proposed and Reference models.

2. The developer shall produce detailed shop drawings and other necessary information which is necessary for the comprehensive evaluation of the energy modeling before awarding the Green Mark Scheme, as and when requested by BCA.

(d) The output data of the simulation program for the revised Reference Model shall include:

1. Monthly energy consumption by Mechanical and Electrical system components (eg. Air-Conditioned Systems, Lighting Systems, Receptacle Equipment, Lifts, Escalators, etc).

(e) The FORM EM- 2 shall be signed by the Qualified Persons (both Mechanical and Electrical Professional Engineers) for the project.