

Technical Guidelines on Code of Practice for Energy Efficiency of Building Services Installation



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1 Introduction

1.1 Ordinance (Cap 610) and Code of Practice (BEC clauses 1.1 & 1.2)

Energy consumption in buildings is a key concern in the combat of climate change, and to improve the energy efficiency in buildings, the Buildings Energy Efficiency Ordinance (Cap 610) (hereinafter referred to as the Ordinance) was enacted in Nov 2010 and comes into full operation on 21 Sep 2012. The Ordinance applies to four key types of building services installations namely lighting installations, air-conditioning installations, electrical installations and lift and escalator installations. The Ordinance requires building services installations in prescribed buildings to comply with a code of practice issued by the Electrical and Mechanical Services Department (EMSD). In Feb 2012, EMSD issued the “Code of Practice for Energy Efficiency of Building Services Installation”, hereinafter referred as the “Building Energy Code” or “BEC”, which sets out the technical guidance and details in respect of the minimum energy efficiency requirements governing the building services installations under the Ordinance.

The Ordinance also requires the carrying out of energy audit, for prescribed buildings in respect of their central building services installations, in accordance with the “Code of Practice for Building Energy Audit”, hereinafter referred as the “Energy Audit Code” or “EAC”, which was collectively issued with the BEC by EMSD.

1.2 Technical Guidelines (TG-BEC)

To assist in the understanding of the energy efficiency engineering requirements in the BEC against the legislative background of the Ordinance, EMSD in collaboration with various professional institutions, trade associations, academia and government departments issues this publication - the “**Technical Guidelines on Code of Practice for Energy Efficiency of Building Services Installation**”, in short **TG-BEC**. The TG-BEC provides an overview and certain explanations of the legislative requirements and the BEC’s engineering requirements, with illustrative tables, diagrams and examples, and in particular detail descriptions on the declarations and forms issuance in the demonstration of compliance. For purpose of ready cross reference, the headings of the clauses in the TG-BEC have the relevant BEC clause numbers marked in brackets alongside.

Serving as guidelines to the BEC and being not a legislative document, the TG-BEC should not take precedence over the Ordinance or the BEC in respect of the interpretation of the intent and meaning of the requirements in the Ordinance and the BEC. Being a guidelines document, the TG-BEC also provides, in parallel to the basic understanding of the requirements of the BEC, the good engineering practices for enhanced energy efficiency.

A separate technical guidelines document supplementing the EAC in respect of building energy audit is also issued, which is outside the scope of the TG-BEC.

1.3 EMSD Web-site

To have a holistic view of the requirements of the Ordinance, readers of the TG-BEC are encouraged to study the Ordinance and the BEC, which can be browsed at the web-site of the Ordinance (<http://www.beeo.emsd.gov.hk>). The web-site provides a briefing on the Ordinance, the BEC and the EAC, along with the technical guidelines, and the necessary information updates. Attention is also drawn to the web-site's FAQ web-page that gives answers to frequently asked questions about the Ordinance and the BEC.

1.4 Nomenclature

The TG-BEC is abbreviated as TG in this publication. When referring to a section, clause or table in the BEC, the section, clause or table would be prefixed with the designation BEC.

1.5 Minimum Standard of BEC

The BEC requirements, which are the minimum energy efficiency standards under the Ordinance, are promulgated through the mandate. The BEC requirements should by no means be treated as the ultimate goal of energy efficiency. To enhance the energy efficiency of their buildings in the combat of climate change, building owners and designers are strongly encouraged to exceed these minimum standards in their building designs.

2 Interpretations and Abbreviations

2.1 Interpretations (BEC clause 2.1)

Section 2 of both the Ordinance and the BEC give the interpretations of terminologies adopted in the Ordinance and the BEC. These interpretations are also applicable to the TG. For ready reference, some of these interpretations are extracted (as shown in shaded boxes) below. The sections quoted in the extracts refer to the relevant sections in the Ordinance, unless otherwise stated.

'building services installation' means –

- (a) an air-conditioning installation;
- (b) an electrical installation;
- (c) a lift and escalator installation; or
- (d) a lighting installation;

TG Remarks to 'building services installation'

The interpretations of air-conditioning installation, electrical installation, lift and escalator installation and lighting installation are extracted in relevant Sections 5 to 8 in the TG.

'Certificate of Compliance Registration' means a Certificate of Compliance Registration issued under section 10 and, where applicable, renewed under section 13;

'commercial building' means a building that is –

- (a) used for offices, shops or entertainment facilities; or
- (b) used for the purpose of any trade, business or profession (but not used as an industrial building);

'common area', in relation to a prescribed building –

- (a) means any area of the building other than the parts that have been specified in an instrument registered in the Land Registry as being for the exclusive use, occupation or enjoyment of an owner; and;
- (b) includes, unless so specified, car parks, entrance lobbies, lift lobbies, corridors, staircases, common toilets, common store rooms, plant rooms, switch rooms, pipe ducts, cable ducts, refuse rooms, material recovery chambers, covered podia, covered playgrounds, occupants' clubhouses and building management offices;

'consent to the commencement of building works' means –

- (a) a consent given by the Building Authority under section 14 of the Buildings Ordinance (Cap 123); or

(b) an approval given in respect of a building not governed by that Ordinance which serves, in relation to that building, a purpose similar to that of the consent;

'developer', in relation to a building or a proposed building, means the owner of the land on which the building is built or will be built;

'Form of Compliance' means a Form of Compliance issued under section 17;

'occupation approval' means -
(a) an occupation permit; or
(b) an approval or a consent issued by a relevant authority to occupy a building for which no occupation permit is required under the Buildings Ordinance (Cap 123);

'occupation permit' – means an occupation permit or a temporary occupation permit issued under section 21(2) of the Buildings Ordinance (Cap 123);

'owner', in relation to a prescribed building, has the same meaning as in the Buildings Ordinance (Cap 123);

'registered energy assessor' means a person who is for the time being registered under section 30;

'responsible person', in relation to a building or a unit of a building, means a person who occupies or is in possession or control of the building or unit (whether under a lease or licence or otherwise);

'stage one declaration' means a declaration referred to in section 8(1);

'stage two declaration' means a declaration referred to in section 9(1);

'unit', in relation to a building, means –
(a) a unit or a part of the building; or
(b) 2 or more units or parts of the building that are -
(i) occupied by the same occupier for the purpose of the same undertaking, and
(ii) interconnected by an internal corridor, internal staircase or other internal access;
but does not include a common area of the building;

2.2 Abbreviations (BEC clause 2.2)

The abbreviations in BEC Section 2 are also applicable to the TG. In addition, the following abbreviations are used in the TG –

'AHU' refers to air handling unit

'ASHRAE' refers to American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc

'BEC' refers to Building Energy Code or Code of Practice for Energy Efficiency of Building Services Installation

'BMS' refers to building management system

'CAV' refers to constant air volume

'CBSI' refers to central building services installation

'CIBSE' refers to The Chartered Institution of Building Services Engineers (U.K.)

'COCR' refers to Certificate of Compliance Registration

'COP' refers to coefficient of performance (of chiller, heat pump or central chilled or heated water plant)

'DMC' refers to deed of mutual covenant

'EAC' refers to Energy Audit Code or Code of Practice for Building Energy Audit

'EMSD' refers to Electrical and Mechanical Services Department

'FCU' refers to fan coil unit

'FOC' refers to form of compliance

'IESNA' refers to Illuminating Engineering Society of North America

'OA' refers to occupation approval

'O&M' refers to operation and maintenance

'PAHU' refers to primary air AHU (for pre-treated fresh air)

'REA' refers to registered energy assessor

'TG' or **'TG-BEC'** refers to the Technical Guidelines on Code of Practice for Energy Efficiency of Building Services Installation

'VAV' refers to variable air volume

3 Application

3.1 Scope of Application (BEC clause 3.1)

3.1.1 For a building belonging to one of the categories prescribed in Schedule 1 of the Ordinance, which is referred to as a prescribed building, the BEC is applicable to its building services installations. Schedule 1 covers most of the building categories commonly found in Hong Kong, including commercial buildings (such as office buildings and shopping malls), hotels, guesthouses, residential buildings, industrial buildings, composite buildings, education buildings, government buildings etc. For ready reference, Schedule 1 of the Ordinance is extracted in TG Table 3.1.1 below. The title of Schedule 1 draws reference to "Certificate of Compliance Registration" and "Form of Compliance", which play a prominent role in the compliance mechanism introduced in TG clauses 4.1 to 4.4.

<u>Table 3.1.1 : Extract of Schedule 1 of the Ordinance (Cap 610)</u>	
Schedule: 1	BUILDINGS THAT REQUIRE CERTIFICATE OF COMPLIANCE REGISTRATION AND FORM OF COMPLIANCE
	<ol style="list-style-type: none"> 1. Commercial building. 2. A portion of a composite building that is not for residential or industrial use. 3. Hotel and guesthouse. 4. Common area of a residential building. 5. Common area of a portion of a composite building that is for residential or industrial use. 6. Common area of an industrial building. 7. Building that is occupied principally for an education purpose. 8. Building that is occupied principally as a community building including a community hall and social services centre and composite building occupied as 2 or more such places. 9. Building that is occupied principally as a municipal services building including a market, cooked food centre, library, cultural centre and indoor games hall and composite building occupied as 2 or more such places. 10. Building that is occupied principally for medical and health care services including a hospital, clinic and rehabilitation centre. 11. Building that is owned by the Government and used principally for the accommodation of people during the performance of any function of the Government. 12. Passenger terminal building of an airport. 13. Railway station.

- 3.1.2 For residential buildings, industrial buildings, commercial/residential composite buildings' residential portions, and commercial/industrial composite buildings' industrial portions, the BEC applies only to their common areas.
- 3.1.3 To identify if a building is a prescribed building, reference may be made to the usage categorization in its occupation approval issued by the Building Authority or in its instrument or land record maintained with the Land Registry or Lands Department (record in the form of land register, memorial, government lease, conditions of grant/sale/exchange etc.).
- 3.1.4 The scope of coverage of building services installations prescribed in the Ordinance pursuant to their interpretations under Section 2 of the Ordinance is confined to the four key types of installations of lighting, air-conditioning, electrical, and lift and escalator (their interpretations are also extracted in TG Section 2).
- 3.1.5 The applicability of the Ordinance is not dependent (pursuant to BEC clause 3.1) on the form or source of electrical supply to the building, irrespective of from the electricity supplier, from renewable energy, from on-site power generation etc.
- 3.2 Limit of Scope of Application (BEC clause 3.2)
- 3.2.1 The Ordinance has no retrospective effect on existing building services installations, which can remain at their existing levels of performances until they undergo major retrofits that fall within the scope of major retrofitting works.
- 3.2.2 Having prescribed in Schedule 1 the categories of buildings to which the Ordinance applies, it follows that the Ordinance does not apply to buildings not prescribed in Schedule 1, examples being a ventilation shaft building (for ventilating underground railway or cross-harbour tunnel), a power substation etc.
- 3.2.3 In respect of residential buildings, industrial buildings, commercial/residential composite buildings' residential portions, and commercial/industrial composite buildings' industrial portions, the BEC does not apply to areas that are outside the common areas, which are essentially their residential units or industrial units. By the same token, the BEC does not apply to these buildings or portions should they not have common areas (building with common area further described in TG clauses 4.2.4(a)).
- 3.2.4 The Ordinance also prescribes in section 4 that it does not apply to -
- buildings of special types by small electrical supply, by restricted size, by historical nature, or by ceasing to exist;
 - building services installations solely for specific purposes of fire suppression, surgical operation, usage in construction site, industrial manufacturing, research, air traffic safety, or railway traffic safety; or
 - lighting installation solely for purpose of exhibit, decoration, or visual production.

For ready reference, section 4 of the Ordinance (and Schedule 2 of the Ordinance) that prescribes the limit of scope of application is extracted in TG Table 3.2.4 below. Examples of building services installations to which the Ordinance does not apply, by virtue of fulfilling criteria prescribed in Schedule 2, are given in TG clauses 5.1.2 (lighting), 6.1.3 (air-conditioning), 7.1.3 (electrical) and 8.1.3 (lift & escalator).

<u>Table 3.2.4 : Extract of Section 4 and Schedule 2 of the Ordinance (Cap 610)</u>	
<p>Section: 4 Limit of scope of application</p> <p>(1) This Ordinance does not apply to -</p> <ul style="list-style-type: none"> (a) a building of which the main electrical switch governing the electricity supply of the building has an approved loading not exceeding 100A, 1-phase or 3-phase; (b) a building - <ul style="list-style-type: none"> (i) of not more than 3 storeys; (ii) having a roofed-over area of not more than 65.03 m²; and (iii) having a height of not more than 8.23 m; (c) a proposed monument or a proposed historical building declared under section 2A of the Antiquities and Monuments Ordinance (Cap 53); or (d) a monument or a historical building declared under section 3 of the Antiquities and Monuments Ordinance (Cap 53). <p>(2) This Ordinance does not apply to a building if the Director is satisfied on a declaration by the owner of the building that the building will cease to exist within 12 months after the date of the declaration.</p> <p>(3) This Ordinance does not apply to the building services installations specified in Schedule 2.</p>	<p>Schedule: 2 BUILDING SERVICES INSTALLATIONS TO WHICH THIS ORDINANCE DOES NOT APPLY</p> <ul style="list-style-type: none"> 1. An installation that is solely used for - <ul style="list-style-type: none"> (a) fire suppression; (b) fire extinguishing; or (c) fire suppression and extinguishing. 2. An installation that is solely used for - <ul style="list-style-type: none"> (a) surgical operation; (b) clinical treatment; (c) blood processing; (d) providing or maintaining appropriate environment settings for life protection; or

<p>(e) any combination of the purposes specified in paragraphs (a), (b), (c) and (d).</p> <p>3. An installation that is used in a construction site for construction works only.</p> <p>4. An installation that is solely used for industrial manufacturing.</p> <p>5. An installation that is solely used for research in an educational institution.</p> <p>6. A lighting installation that is solely used for -</p> <p style="padding-left: 20px;">(a) illumination of an exhibit or product on display including special lighting for illuminating merchandise or art work;</p> <p style="padding-left: 20px;">(b) decoration including special lighting for architectural feature or festival decoration effect;</p> <p style="padding-left: 20px;">(c) visual production including special lighting for performance, entertainment or television broadcasting; or</p> <p style="padding-left: 20px;">(d) any combination of the purposes specified in paragraphs (a), (b) and (c).</p> <p>7. An installation that is solely used for -</p> <p style="padding-left: 20px;">(a) air traffic regulation;</p> <p style="padding-left: 20px;">(b) air traffic safety;</p> <p style="padding-left: 20px;">(c) air traffic control; or</p> <p style="padding-left: 20px;">(d) any combination of the purposes specified in paragraphs (a), (b) and (c).</p> <p>8. An installation that is solely used for -</p> <p style="padding-left: 20px;">(a) railway traffic regulation;</p> <p style="padding-left: 20px;">(b) railway traffic safety;</p> <p style="padding-left: 20px;">(c) railway traffic control; or</p> <p style="padding-left: 20px;">(d) any combination of the purposes specified in paragraphs (a), (b) and (c).</p>
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3.2.5 The scope of coverage of building services installations prescribed in the Ordinance does not cover installations of fire services, security system, broadcast reception etc. which given them serving a building may sometimes also be regarded in the trade as under the scope of building services installation in a broad sense.

3.3 Examples of Non-applicable Building Services Installations

Certain examples of building services installations to which the Ordinance does not apply are given in TG Table 3.3 below.

<u>Table 3.3 : Examples of Building Services Installations to which the Ordinance Does Not Apply</u>	
<u>Building services installation</u>	<u>Justification</u>
Fire service pump	A fire service installation, and thus not a building services installation under the Ordinance
Electrical circuit solely serving the above pump	Solely for fire suppression and extinguishing (item 1(c), Schedule 2 of Ordinance)

Smoke extract fan such as for basement (fan not for other use except for smoke extract)	Solely for providing a low smoke concentration level for life protection (item 2(d), Schedule 2 of Ordinance)
Electrical circuit solely serving the above fan	
<p>Remark: Further examples are also given in TG sections 5 to 8 according to the different categories of building services installations.</p>	

3.4 Determination of Application Threshold

Attention is drawn to section 5 of the Ordinance, which is extracted in TG Table 3.4 below for ready reference. The rating of an installation, in the determination of application threshold, is the rating at works completion.

<p><u>Table 3.4 : Extract of Section 5 of the Ordinance (Cap 610)</u></p>
<p>Section: 5 Determination of application threshold</p> <p>If the applicability of any provision of this Ordinance is to be determined by reference to any threshold including the approved loading of a main electrical switch, the rating of an installation or the floor area of any place, the calculation or measurement must, unless otherwise prescribed, be made at the time when the relevant works have been completed.</p>

4 Technical Compliance with the Ordinance

This section gives an overview of the process to demonstrate the compliance with the Ordinance. This section focuses on the legislative requirements prescribed in the Ordinance (mainly in Parts 2 and 3, covering sections 7 to 20), whereas the technical energy efficiency requirements of the BEC are explained in TG Sections 5 to 10.

4.1 Control Regime (BEC clauses 4.1 & 4.2)

4.1.1 The control regime draws reference on the date of the "consent to the commencement of building works" for superstructure construction. Buildings having the consent given on or before 21 Sep 2012 may be broadly referred to as existing buildings, and those having the consent given after 21 Sep 2012 the newly constructed buildings. In addition, based on the timing of the construction activities in buildings, the control regime also ties in with two distinct timeframes that are distinguished by the occupational approval or OA, the earlier timeframe being from design through building construction to OA issue, and the later timeframe being the post-OA routine building operation stage. For existing buildings, the control is mainly on the post-OA major retrofitting works. For newly constructed buildings, the control applies to both the earlier and later timeframes. The control regime is further described in TG Table 4.1.1 below.

Table 4.1.1 : Control Regime (Parts 2 & 3, Cap 610) Based on the Date of "Consent to the Commencement of Building Works" for Superstructure Construction^{@1}		
	<u>Prescribed buildings with consent given after 21 Sep 2012^{@2}</u> (newly constructed buildings)	<u>Prescribed buildings with consent given on or before 21 Sep 2012^{@2}</u> (existing buildings)
General	The BEC is applicable to all building services installations in these buildings regardless of whether or not they are major retrofitting works ^{@1} .	The BEC is applicable to building services installations that are regarded as major retrofitting works in these buildings.
At design stage through to occupation approval (OA)^{@1}	In respect of the building services installations provided by the developer ^{@3} when a building is newly constructed, the building services installations in the building as at OA have to comply with the BEC requirements. The demonstration of compliance per TG clause 4.2.2 is required.	The BEC is not applicable.

Post-OA, i.e. during routine building operation	When major retrofitting works ^{@1} are involved	In respect of the building services installations regarded as major retrofitting works (completed after OA), the building services installations have to comply with the BEC requirements. The demonstration of compliance per TG clause 4.2.3 is required.	In respect of the building services installations regarded as major retrofitting works completed on or after 21 Sep 2012, the building services installations have to comply with the BEC requirements. The demonstration of compliance per TG clause 4.2.3 is required.
	When non-major retrofitting works are involved	For building services installations not regarded as major retrofitting works (completed after OA), the building services installations still have to comply with the BEC requirements. However, the demonstration of compliance per TG clause 4.2.2/4.2.3 is NOT required.	The BEC is not applicable.
Remarks: @1 Interpretations of terminologies “consent to the commencement of buildings works”, “developer” and “OA” in the Ordinance are extracted in TG Section 2. Interpretation of “major retrofitting works” in the Ordinance is extracted in TG clause 4.2.5. @2 21 Sep 2012 - is the date of the full operation of the Ordinance. @3 It is common that installations provided by the developer include the central building services installation (CBSI), which is further described in TG clause 4.2.4.			

4.1.2 For the majority of private buildings, the “consent to the commencement of building works” is given by the Building Authority; for buildings not of the private sector, a consent carrying a similar effect in respect of permission to commence building works may be issued by the Architectural Services Department or by the Housing Department for buildings constructed by the respective Departments. When the building is ready for occupation, the Building Authority would issue an “occupation approval”, or “OA” in short, for buildings of the private sector; likewise the Architectural Services Department and the Housing Department would issue an OA carrying a similar effect in respect of permission to occupy a building for buildings under their purview.

4.2 Demonstration of Compliance

4.2.1 Overall Process and Parties Involved

Based on the control regime in TG Table 4.1.1, the process in the demonstration of prescribed buildings’ compliance with the requirements of the Ordinance in respect of

the fulfilling of the BEC requirements is described in TG clauses 4.2.2 and 4.2.3 below. The process includes the making of declarations, the issuing and obtaining of form and the obtaining of certificate (pursuant to Parts 2 and 3 (covering sections 7 to 20) of the Ordinance). The compliance process involves the developer, registered energy assessor (REA), owner and responsible person, who have their respective legal responsibilities under the Ordinance; the interpretations of these persons/parties are also given in TG Section 2. The process involves the forms 'stage one declaration', 'stage two declaration', 'Certificate of Compliance Registration (abbreviated as COCR)', and 'Form of Compliance (abbreviated as FOC)'; the interpretations of these terminologies are also extracted in TG Section 2.

4.2.2 Declarations and Certificate of Compliance Registration

4.2.2.1 With reference to the control regime in TG Table 4.1.1, TG Table 4.2.2 below describes the compliance process at design stage through to OA for newly constructed buildings.

<u>Table 4.2.2 : Demonstration of Compliance with Ordinance (Part 2, Cap 610) – Building Services Installations Provided by Developer</u>
<p>Design stage through to OA - newly constructed buildings (consent given after 21 Sep 2012)</p> <p>(a) For developer provided installations, typically including amongst others the building's central building services installation (CBSI) ^{@2} in newly constructed prescribed buildings -</p> <p>i) the developer of the building, at the design stage of the building must :</p> <ul style="list-style-type: none"> - make a stage one declaration ^{@1} (section 8(1) of Ordinance) and submit the declaration to EMSD, to declare that all the building services installations to be provided by the developer in the building (at or before the time when a stage two declaration is made) in respect of the building are designed, and will be installed and completed, in accordance with the BEC requirements; - in making the declaration engage a registered energy assessor (REA) ^{@1 @3} to certify the declaration to the effect that suitable design provisions have been incorporated into the planning and design of the building in accordance with the BEC requirements; and - the stage one declaration must be submitted within 2 months after the day on which the consent to the commencement of building works for the superstructure construction of the building is given; and <p>ii) the developer of the building, at the building's OA stage must :</p> <ul style="list-style-type: none"> - make a stage two declaration ^{@1} and submit the declaration to EMSD, to

<p>declare that all the building services installations provided by the developer in the building at or before the time when the declaration is made have been designed, installed and completed in accordance with the BEC requirements;</p> <ul style="list-style-type: none"> - in making the declaration engage an REA to certify the declaration to the effect that all the building services installations provided by the developer in the building at or before the time when the declaration is made have been designed, installed and completed in accordance with the BEC requirements; and - the stage two declaration must be submitted to EMSD within 4 months after the day on which the OA is issued in respect of the building. <p>(b) The REA certifying the stage two declaration should have in the 30 days before the certification personally inspected the building services installation covered by the certification.</p> <p>(c) The submission of stage one and stage two declarations have to be in the specified forms and be accompanied by the documents specified in the forms, and for stage two declaration the accompanying too by the prescribed fee. The different forms and their usage are further described in TG clause 4.5 below.</p> <p>(d) EMSD would, based on the merit of the stage two declaration, issue the Certificate of Compliance Registration (COCR)^{@1} within 3 months of receipt of the declaration. A COCR is valid for 10 years and has to be renewed. COCR is further explained in TG clauses 4.2.2.2 and 4.2.2.3.</p>
<p>Remarks:</p> <p>@1 Interpretations of terminologies 'stage one declaration', 'stage two declaration', 'REA', and 'COCR' in the Ordinance are extracted in TG Section 2.</p> <p>@2 Meaning of CBSI is further introduced in TG clause 4.2.4.</p> <p>@3 The REA is a role of professional engineers opened up in the Ordinance to assist the developers, owners or responsible persons to comply with the legislative requirements. The duty and registration of the REA is given in the Ordinance and the Buildings Energy Efficiency (Registered Energy Assessors) Regulation (Cap 610B) under the Ordinance. The certification of BEC compliance in declarations cannot be carried out by a person who is not an REA.</p>

4.2.2.2 The COCR is a proof that the building services installations provided by the developer, typically including amongst others the central building services installation (CBSI), comply with the BEC requirements. CBSI is further discussed in TG clause 4.2.4. To obtain the COCR, the developer is to first submit the stage one declaration, which is to be followed by the stage two declaration. The stage one declaration serves simply as the developer's undertaking that he/she would cause the design and installation of the building services installation he/she provides for the building to be in accordance with the BEC requirements. To signify the significance of the planning for BEC compliant design and installation in accordance with the compliant design, the declaration

requires the certification by an REA. When the building is ready to be occupied by its occupiers and users, the authority will issue an OA, and it is time that the stage two declaration comes in, which requires the certification by an REA in respect of the erected building services installations' compliance with the BEC. EMSD would, based on the merit of the stage two declaration, issue the COCR. EMSD keeps a register of buildings issued with a COCR, and the register is available for public inspection.

4.2.2.3 Renewal of COCR

Subsequent to the issue of the COCR, the owner(s) of the building (i.e. the Owners' Corporation or all owners, single owner etc.), every 10 years, is/are required to engage an REA:

- to certify that the design (not the condition of performance then) of all the four key types of CBSIs are maintained to a standard not lower than the BEC version applied in the first COCR of the building, and
- if a FOC has been issued for a certain CBSI, to certify that the design of installation is maintained to a standard not lower than the BEC version applied in the latest FOC issued in respect of the installation; and
- to submit application to EMSD for renewal of the COCR (application fee required).

4.2.2.4 Building Complex

There are building blocks that collectively form a building complex. TG clause 4.2.7 below introduces the building block concept that may be applicable to a building complex. The building block concept affects the numbers of declarations and COCRs in the demonstration of compliance.

4.2.3 Form of Compliance for Major Retrofitting Works

4.2.3.1 With reference to the control regime in TG Table 4.1.1, TG Table 4.2.3 below describes the compliance process during post-OA routine building operation for both newly constructed buildings and existing buildings. The meaning of major retrofitting works in the table is further discussed in TG clause 4.2.5.

<u>Table 4.2.3 : Demonstration of Compliance with Ordinance (Part 3, Cap 610) – Major Retrofitting Works</u>
Post-OA routine building operation - both newly constructed buildings and existing buildings
(a) For both newly constructed buildings (consent given after 21 Sep 2012) and existing buildings (consent given on or before 21 Sep 2012),

<ul style="list-style-type: none">♦ if major retrofitting works^{@1} are carried out in respect of<ul style="list-style-type: none">- a building services installation that serves a unit^{@1}, the responsible person^{@1} of the unit, or- a building services installation that serves the common area of a building, the owner^{@1} of the common area^{@1}, or- a CBSI^{@2}, the owner^{@1} of the installationis required to<ul style="list-style-type: none">➔ engage an REA^{@1 @3} to personally inspect the major retrofitting works and certify in a FOC^{@1} that the works comply with the BEC requirements; and➔ obtain from the REA the FOC for the works within 2 months after work completion. <p>(b) The FOC has to be in the specified form and be accompanied by the documents specified in the form.</p> <p>(c) The REA must send a copy of the FOC to EMSD and the property management company of the building, and if there is no such company or the company cannot be found or ascertained to the owner of the building.</p> <p>(d) Unlike the COCR, both the accompanying fee (payable to EMSD) and renewal are not required.</p>
<p>Remarks:</p> <p>^{@1} Interpretations of terminologies 'owner', 'responsible person', 'unit', 'common area', 'FOC' and 'major retrofitting works' in the Ordinance are extracted in TG Section 2. Meaning of 'major retrofitting works' is further introduced in TG clause 4.2.5.</p> <p>^{@2} Meaning of CBSI is further introduced in TG clause 4.2.4.</p> <p>^{@3} The REA is described in Remark@3 in TG Table 4.2.2. The certification of BEC compliance in FOC and its issuance cannot be carried out by a person who is not an REA. The interpretation of 'REA' is also given in TG Section 2.</p>

4.2.3.2 The FOC is a proof that the building services installations categorized as major retrofitting works of the owner or responsible person comply with the BEC requirements.

4.2.3.3 Completion of Major Retrofitting Works

Pursuant to section 17(3) of the Ordinance, the major retrofitting works are regarded as completed when all the building services installations involved in the works unless otherwise specified in TG clause 10.1.8(c) are ready to be used for the principal function as designed. For example, if lighting installation, electrical installation and air-conditioning installation are involved in the works and the air-conditioning installation is the last completed, the works are regarded as completed when the air-conditioning installation is also ready to be put into normal operation. In practice, a

certificate of completion issued by the works consultant or contractor, if available, may be regarded as documentary evidence illustrating the completion date of the works.

4.2.4 Central Building Services Installation (CBSI)

Given the building services installations provided by the developer typically cover the CBSI, and that the requirements on major retrofitting works for CBSI are different from those for non-CBSI, the differentiation of CBSI from the other building services installations would be helpful. For ready reference, the interpretation of CBSI in the Ordinance is extracted below.

'central building services installation' means –

- (a) a building services installation in a prescribed building that does not solely serve a unit of that building; or
- (b) a building services installation in a prescribed building that has no common area except an installation that –
 - (i) solely serves a unit of that building; and
 - (ii) is owned by a person who is not the owner of that building;

As prescribed in the Ordinance and with reference to the interpretation of CBSI above, there are buildings with common area and buildings that have no common area.

(a) Buildings with Common Area (with deed of mutual covenant)

A building with common area typically has a deed of mutual covenant (DMC) (interpreted in Building Management Ordinance, Cap 344), and its entrance lobby, common lift lobbies, common corridors, common staircases, common toilets, management offices etc. (that are not for the exclusive use of the respective units' owners) or "common area" are generally commonly used. In such a type of building, there are typically a number of building services installations that are shared by several (or all) units in the building. These installations are also generally "commonly used" – such as lifts and escalators, central air-conditioning, etc.

Examples of CBSI and non-CBSI are given in TG Table 4.2.4 (a) below.

Table 4.2.4 (a) : Examples of CBSI and non-CBSI for a Building with Common Area
<p><u>Commercial building (e.g. with office/shopping & leisure units) with common area</u></p> <p>Consider a commercial building with DMC and having office and/or shopping & leisure units, and some of the units have been specified in instrument(s) registered in the Land Registry as for the exclusive use of the respective owners. The building may have units leased to tenants. Areas such as entrance lobby, common lift lobbies, common corridors, common staircases, common toilets etc. (that are not for the exclusive use of the respective units' owners) in the building are typically referred to as the common area of the building.</p>

	Lighting installation	Air- conditioning installation	Electrical installation	Lift and escalator installation
Examples of CBSI	Luminaires in the common area	Central chilled/heated water plant (for air-conditioning); AHU serving two or more units	Main LV switchboard and rising mains	Lift serving common lift lobbies
Examples of non-CBSI	Luminaires in a unit that is leased or separately owned	AHU solely serving a unit that is leased or separately owned	Circuit on the outgoing side of electricity supplier's electricity meter for a unit	Escalator within and solely serving a department store (a unit)

(b) Buildings without Common Area (without DMC)

A building without common area typically has no DMC.

i) Examples of CBSI and non-CBSI for a building having units leased to tenants are given in TG Table 4.2.4 (b) below.

Table 4.2.4 (b) : Examples of CBSI and non-CBSI for a Building Without Common Area and Having Units Leased to Tenants				
<u>Commercial building (e.g. with office/shopping & leisure units) without common area</u>				
Consider a commercial building without DMC and having office and/or shopping & leisure units; there are units leased to tenants and each of these units has not been specified in an instrument registered in the Land Registry as for the exclusive use of a unit owner. The building is under a single ownership, and may be regarded as one without common area.				
	Lighting installation	Air- conditioning installation	Electrical installation	Lift and escalator installation
Examples of CBSI	Luminaires in main entrance, common lift lobbies, common staircases etc.; Luminaires in a unit that is not leased; Luminaires owned by the building owner in a leased unit	Central chilled/heated water plant (for air-conditioning); AHU serving a unit that is not leased; AHU owned by the building owner and serving a leased unit	Main LV switchboard and rising mains; Circuit with supply on account of the building owner	Lift serving the common lift lobbies
Examples of non-CBSI	Luminaires in a unit leased to a tenant who owns the luminaires	AHU solely serving a unit leased to a tenant who owns the AHU	Circuit on the outgoing side of electricity supplier's electricity meter for a unit that is leased to	Escalator within and solely serving a department store (a unit) that is leased to a tenant who

			a tenant who owns the circuit	owns the escalator
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ii) Consider a commercial building without common area, i.e. without units that have been specified in instrument(s) registered in the Land Registry as for the exclusive use of an owner, and having no areas leased to tenants. All the building services installations (under the Ordinance) in the building are regarded as CBSI.

(c) CBSI in Commercial Portion of Composite Building

Having provided the principles to differentiate between CBSI and non-CBSI in items (a) & (b) above for a commercial building, the same principles apply to the commercial portion of a composite building.

4.2.5 Major Retrofitting Works

Pursuant to Schedule 3 of the Ordinance, works for building services installations are regarded as major retrofitting works either by virtue of having involved a works area of not less than 500 m² or having involved a main component of a CBSI. For ready reference, Schedule 3 of the Ordinance is extracted in TG Table 4.2.5 below.

Table 4.2.5 : Extract of Major Retrofitting Works in the Ordinance
‘major retrofitting works’ means the works specified in Schedule 3 –
<u>Extract of Schedule 3 of the Ordinance (Cap 610)</u>
<p>Schedule: 3 MAJOR RETROFITTING WORKS</p> <ol style="list-style-type: none"> 1. Works involving addition or replacement of a building services installation specified in a code of practice that covers one or more places with a floor area or total floor area of not less than 500 m² under the same series of works within 12 months in a unit or a common area of a prescribed building. 2. Addition or replacement of a main component of a central building services installation, including - <ol style="list-style-type: none"> (a) addition or replacement of a complete electrical circuit at rating of 400A or above; (b) addition or replacement of a unitary air-conditioner or air-conditioning chiller of a cooling or heating rating at or exceeding 350 kW; or (c) addition or replacement of the motor drive and mechanical drive of a lift, an escalator or a passenger conveyor.

<p>Notes</p> <p>(1) For the purposes of item 1 of this Schedule -</p> <ul style="list-style-type: none">(a) an occupants' clubhouse or a car park is to be regarded as a separate common area within the building; and(b) all other common areas are to be regarded together as a separate common area. <p>(2) If works are carried out for more than one place in a unit or a common area of a prescribed building and, having regard to all relevant factors of the case, the works should reasonably be regarded as being under the same series of works, the reference to floor area in item 1 of this Schedule is a reference to the aggregate of the floor area of all those places.</p> <p>(3) In Note (2), "relevant factors" means -</p> <ul style="list-style-type: none">(a) whether the works are carried out by a single contractor;(b) whether the works are carried out under a single agreement;(c) whether the works are carried out pursuant to a single works order;(d) the time at which and the period during which the works are carried out;(e) the manner in which the contractor is paid; and(f) whether the works are treated as a single project in the plans and works programme.
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4.2.5.1 500 m² Works Area Criterion

The 500 m² in item 1 of Schedule 3 refers to the internal floor area of the works area; according to the interpretation in BEC Section 2 internal floor area means the floor area of all enclosed spaces measured to the internal faces of enclosing external and/or party walls. Noteworthy the works area may not be the area served by the concerned building services installations. In practice, such works area may be identified on the relevant layout plans and/or by the actual separation (using hoarding, canvassing, fencing or signage etc.) of the works area on site from the surrounding non-works area.

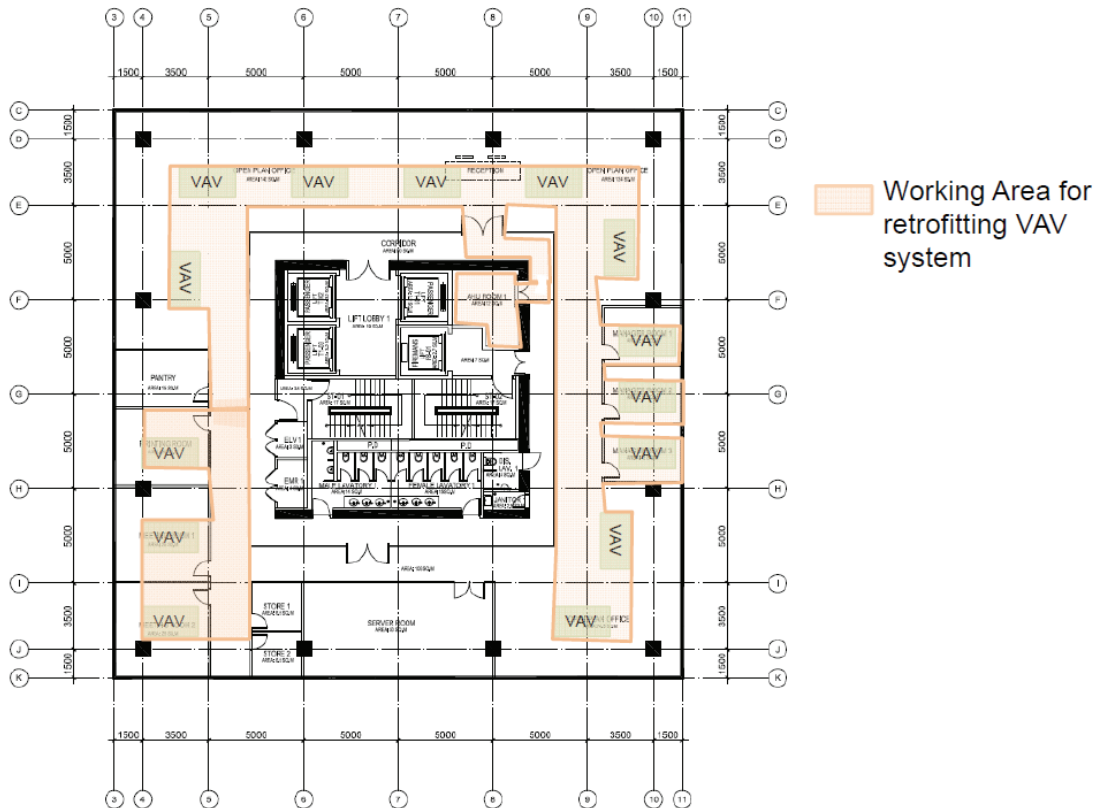
As an indication of what constitute the works area, take for example the retrofitting of a VAV system shown in TG Figure 4.2.5.1 below, which includes -

- AHU plant room area
- Supply and return air ductwork routing area
- VAV box replacement areas, and
- Other electrical work areas (cabling etc.)

If the works area is 500 m² or more, the works would be regarded as major retrofitting

works.

Figure 4.2.5.1: Works area for retrofitting VAV system



4.2.5.2 CBSI Main Component Criterion

Other than the 500 m² criterion, works may also be regarded as major retrofitting works by virtue of the works being an addition or replacement of a main component of a CBSI. In determining the rating of an installation or the floor area of any place leading to the composition of the relevant CBSI, the calculation or measurement, as so described in TG clause 3.4, should be made at the time when the relevant works have been completed.

4.2.5.3 BEC Section 10

BEC Section 10 provides the guidelines on major retrofitting works, which are further elaborated in TG Section 10.

4.2.6 Non-major Retrofitting Works

For works not regarded as major retrofitting works, the above demonstration of compliance is not required. In newly constructed buildings, the building services installations of such non-major retrofitting works are however required to comply with the BEC (also refer TG clause 4.4.3), and as a good engineering practice proper records may be maintained to indicate the compliance. In existing buildings, non-major

retrofitting works are not governed by the BEC, the compliance of which is nevertheless strongly encouraged.

4.2.7 Building Complex

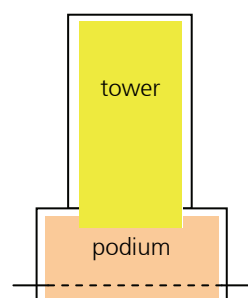
A building complex may contain several physical blocks, and each block may be issued a separate OA based on the different phased completions of the blocks in the complex, or based on their different ownership or management. The following gives the guidelines on the composition of an entity for the making of an individual declaration and obtaining of a COCR.

The terms podium and tower hereinafter mentioned refer to common configuration of large commercial buildings in Hong Kong, where the podium and the tower serve different major usages. It is common that the podium is comprised of the lower floors near ground level, and covers areas for shopping & leisure usage, such as a shopping mall having retail units, restaurants, cinemas, health centres etc., with or without car park, atrium or basement, together with CBSI major plant rooms and utility plant rooms, and it is common that the vertical transportation in the podium relies more on escalators than lifts. On the other hand, the tower is comprised of the floors above the podium, has vertical transportation usually relying more on lifts, and typically has floors each with smaller area than a podium floor; while office work is a common major usage of the tower there are also towers for residential units, hotel, shopping & leisure etc.

4.2.7.1 COCR Per Podium Tower Pair

For a building complex consisting of a podium block and a single tower block, as shown in TG Figure 4.2.7.1, the complex is normally regarded as a single building block requiring a single COCR and thus single stage one and stage two declarations.

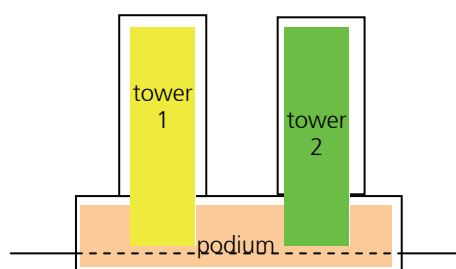
Figure 4.2.7.1 : Building complex with a podium and a tower counted as a single block



4.2.7.2 COCR Per Building Block

For a building complex consisting of three blocks, namely tower 1, tower 2 and podium, as shown in TG Figure 4.2.7.2, a COCR should be obtained for each building block, namely for podium block, tower 1 block and tower 2 block, that is a total of 3 nos.

Figure 4.2.7.2 : Two towers with common podium counted as 3 nos. building blocks

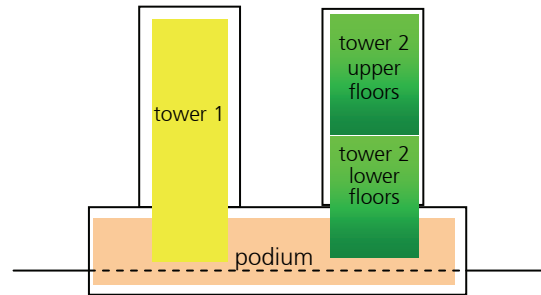


COCRs, with separate stage one declarations and stage two declarations.

Likewise for a building complex with a podium and three towers a total of 4 nos. COCRs should be obtained, a podium and four towers a total of 5 nos. COCRs, and so on.

4.2.7.3 Consider a building complex in TG Figure 4.2.7.3, which is similar to TG Figure 4.2.7.2, but this time tower 2 has different OAs respectively for its upper floors and lower floors. Now there are 4 nos. blocks, namely podium block, tower 1 block, tower 2 lower floors block and tower 2 upper floors block, and it is required to obtain for each of

Figure 4.2.7.3 : Building complex with different blocks and phased completion

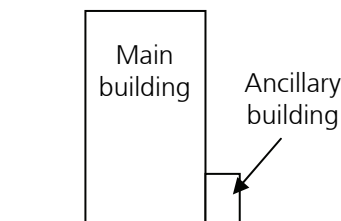


these 4 blocks a separate COCR, that is a total of 4 nos. COCRs for the complex, with separate stage one declarations and stage two declarations. Attention is drawn that the interpretation of OA covers also a temporary occupation permit.

4.2.7.4 Ancillary Building

An annexed ancillary building shown in TG Figure 4.2.7.4 may be considered as a portion of the main building, subject to both being occupied at the same time and issued the same single OA.

Figure 4.2.7.4 : Main building and annexed ancillary building



4.2.7.5 Renewal of COCR for Grouping of Building Blocks under a Single COCR

For purpose of management convenience, the owner of a building complex consisting of different blocks with different COCRs may wish to group them under a single COCR. The grouping may be made through a REA-certified renewal that is prescribed in section 13 of the Ordinance. The owner may renew the block COCRs at the same time and request EMSD to issue a single COCR covering all the developer provided building services installations under the different stage two declarations. Needless to say the maintaining of design standard as described in TG clause 4.4 is to be certified by the REA in the renewal.

Section 13 of the Ordinance offers the provision for COCR renewal, both for purpose of the above COCR grouping, as well as for the renewal upon COCR expiry described in TG clause 4.2.2.3.

4.3 Energy Efficiency Requirements at Design Conditions (BEC clause 4.3)

The energy efficiency requirements in the BEC refer to the performance standards at the corresponding design conditions, and not at the operating conditions which may deviate from time to time from the design conditions. An example is a chiller’s COP is governed by BEC Table 6.12b at the standard rating condition in the table which represents the design condition, and the chiller would likely not operate at the rated COP under actual operating conditions that deviate from the standard rating condition.

4.4 Requirements on Maintaining of Design Standard (BEC clause 4.4)

4.4.1 Duties of Owners and Responsible Persons

The duties of owners and responsible persons given in sections 12(3), 12(4) and 18(2) of the Ordinance to maintain their building services installations to the relevant design standard are extracted in TG Table 4.4.1 below.

<u>Table 4.4.1 : Extracts of sections 12(3), 12(4) and 18(2) of the Ordinance on Maintaining of Design Standard (Cap 610)</u>
<p>12. Duties of owners and responsible persons of building with Certificate of Compliance Registration</p> <p>.....</p> <p>(3) The owner of a building must ensure that -</p> <p style="padding-left: 40px;">(a) the central building services installations in the building are maintained to a standard not lower than that applied in the first Certificate of Compliance Registration issued in respect of the building; and</p> <p style="padding-left: 40px;">(b) if a Form of Compliance has been issued in respect of any central building services installation in the building, the installation is maintained to a standard not lower than that applied in the latest Form of Compliance issued in respect of the installation.</p> <p>(4) The responsible person of a unit of a building must ensure that –</p> <p style="padding-left: 40px;">(a) the building services installations serving the unit that are not the central building services installations in the building meet, and are maintained to, a standard not lower than that applied in the first Certificate of Compliance Registration issued in respect of the building; and</p> <p style="padding-left: 40px;">(b) if a Form of Compliance has been issued in respect of any building services installation serving the unit, the installation is maintained to a standard not lower than that applied in the latest Form of Compliance issued in respect of the installation.</p> <p>.....</p>

18. Requirements applicable to Form of Compliance

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- (2) If a Form of Compliance is issued in respect of any building services installation, the responsible person of the relevant unit or the owner of the relevant common area of the building or, in the case of a central building services installation, the owner of the installation must maintain the installation to a standard not lower than that applied in that Form of Compliance.

The maintaining of standard refers to the maintaining of the design standard of the applicable BEC version. The maintaining of standard does not refer to the maintaining of operating conditions such as optimizing room temperature, chilled water temperature, and lighting level, and cleaning of equipment such as coil surface and filter etc., which are good engineering practices but not the legislative requirements under the Ordinance.

4.4.2 Applicable BEC Version

The standard applied in the COCR refers to the design standard of the applicable BEC version, and the standard applied in the FOC refers likewise to the design standard of the applicable BEC version.

4.4.3 Illustrative Example on Applicable BEC Version

Consider a building that was firstly issued in 2013 with a COCR during which BEC 2012 was the applicable BEC version, and a new version of BEC, say BEC 2012 (Rev. 1) was issued in Feb 2014, which remains at early 2015 as the then updated BEC version.

- (a) Consider in Dec 2014, certain building services installation of the building's CBSI or in a unit in the building undergoes certain retrofitting not of the scope of major retrofitting works. Based on section 12(3)(a) of the Ordinance for CBSI and likewise section 12(4)(a) for units, the retrofitting should be maintained and thus designed to a standard not lower than that applied in the first COCR that had BEC 2012 as the applicable BEC version.
- (b) Nevertheless should the retrofitting in (a) be of the scope of major retrofitting works and involves the issuance say in Dec 2014 of a FOC, the retrofitting, according to section 18(2) of the Ordinance, should be maintained and thus designed to a standard not lower than the BEC standard applied in the FOC, which in this case is BEC 2012 (Rev. 1).

- (c) Take on scenario (b) above and consider that in early 2015, a portion of the above FOC covered installation undergoes further retrofitting not of the scale of major retrofitting works. The design standard of the portion of FOC covered installation should be BEC 2012 (Rev. 1).

4.4.4 Repairs and Retrofits

Further to TG clause 4.4.1, should a repair or retrofit (not of the scope of major retrofitting works) be carried out to a building services installation in a building with COCR or to an installation covered by a FOC, the maintaining of design standard at the standard of the applicable BEC version should apply to the repair and retrofit, illustrative examples given in Table 4.4.4 below.

<u>Table 4.4.4 : Maintaining of Design Standard for Repairs or Retrofits (not of the scope of major retrofitting works) in Buildings with COCR or in Works Covered by FOC</u>	
Replacement of a motor	Replacing motor to comply with minimum motor efficiency levels in the BEC (for BEC 2012 the efficiency levels specified in BEC Table 7.5.1)
Replacement of the compressor of a chiller	Replacing compressor should have an efficiency such that the chiller complies with the minimum COP levels in the BEC (for BEC 2012 the efficiency levels specified in BEC Table 6.12b)
Lighting retrofit	LPD of retrofitted lighting installation to comply with maximum allowable LPD values in the BEC (for BEC 2012 the LPD values specified in BEC Table 5.4)
Change in size of ductwork section of an air distribution system for a conditioned space	The change should not incur the non-compliance with the system fan motor power requirements (for BEC 2012 the requirements in BEC clauses 6.7.1 to 6.7.5)

The maintaining of design standard accepts normal wear and tear, which affects the energy performance of the concerned installations or equipment. Examples of normal wear and tear are a condenser coil having lower heat transfer as a result of minor fins corrosion, a motor having lower efficiency as a result of minor wearing of its bearings, an evaporator of a chiller requiring the plugging of a tube given the tube being beyond repair. Having accepted the wear and tear, it is recommended as good engineering practice that repairs should be carried out to the concerned installations or equipment, to bring close to their respective levels of performance as at the issue of the COCR or

the applicable FOC.

4.4.5 Change of Use

Further to TG clause 4.4.1, in respect of a change of use of a building services installation to which the Ordinance or BEC did not apply before the change but applies after the change, the maintaining of design standard at the standard of the applicable BEC version should apply to the concerned building services installation, which if not at the standard should be brought up to the standard. An illustrative example is the change of an office space to a store room, where there is a reduction of the allowable LPD level which is now presumably lower than the installed LPD (previously for office); the lighting installation in the store room should be brought to the allowable LPD level for store room by means of replacement with lower wattage lamps or removal of luminaires.

4.5 Demonstration of Compliance Using Specified Forms and Technical Forms (BEC clause 4.5)

The declarations and the FOC in TG clause 4.2 above are to be submitted/issued in the corresponding forms, and be accompanied with the prescribed fees and the documents specified in the forms. There are two types of forms, namely specified forms and technical forms, the former on administrative items, and the latter on technical engineering items in the BEC. TG Table 4.5 (a) and Table 4.5 (b) below show respectively the lists of specified forms and technical forms. The decorations are to be made on specified forms EE1 and EE2 respectively, with supplementary information to be provided in form EE-SU and technical engineering information of the building services installations provided in forms EE-LG, EE-AC, EE-EL, EE-LE, EE-PB as appropriate in respect of the compliance with the relevant clauses in the BEC. (These forms can be downloaded at the web-site of the Ordinance.)

Table 4.5 (a) : List of Specified Forms (BEC Compliance), Cap 610	
<u>Form No.</u>	<u>Type of Form</u>
EE1	Stage One Declaration
EE2	Stage Two Declaration
EE3	Application for Renewal of COCR
EE4	FOC
EE-SU	Supplementary Information for Forms EE1, EE2, EE3 or EE4
EE-EX	Application Form for Exemption from Specified Standards and Requirements for COCR, FOC or Energy Audit

Table 4.5 (b) : List of Technical Forms (BEC Compliance)	
<u>Form No.</u>	<u>Type of Form</u>
EE-LG	Technical Data of Lighting Installation for BEC 2012
EE-AC	Technical Data of Air-conditioning Installation for BEC 2012
EE-EL	Technical Data of Electrical Installation for BEC 2012
EE-LE	Technical Data of Lift & Escalator Installation for BEC 2012
EE-PB	Technical Data of Performance-based Approach for BEC 2012

4.6 Responsible Person, Unit, Clubhouse & Carpark, and Residential Unit & Industrial Unit

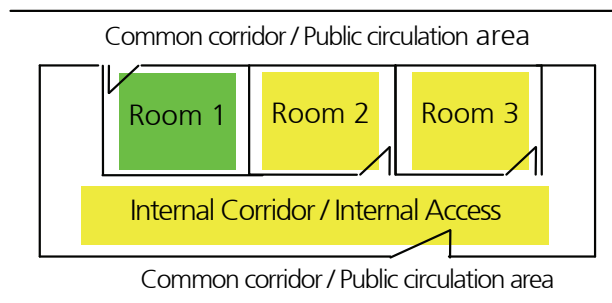
4.6.1 Responsible Person

TG clauses 4.2.2 and 4.2.3 introduce the responsibilities of the owner and the responsible person, in respect of building services installations in the common area and in units. Based on the interpretation of responsible person (TG Section 2), if the building services installation in a unit is owned and controlled by the owner of the building and not the unit’s leasing tenant, the responsible person may be the owner of the building.

4.6.2 Unit

In general, a unit that is interpreted in TG Section 2 usually has full-height partition wall or vertical physical segregation and direct access to common corridor, common lobby, or public circulation area. A “unit” may consist of more than one room, as shown in Figure 4.6.2 below.

Figure 4.6.2 : Unit with single room and unit with multiple-room
 Room 1 counted as 1 no. unit, and
 Room 2, Room 3 and Internal Corridor / Internal Access counted as 1 no. Unit



4.6.3 Clubhouse and Carpark

4.6.3.1 An occupants’ clubhouse or a car park, unless otherwise stated in the DMC or OA, can be regarded as a separate common area within the building according to Note (1)(a) to

Schedule 3 of the Ordinance (extracted in TG Table 4.2.5). With them being separate common areas, the aggregate of works areas in the clubhouse is thus independent from that of the car park, and likewise independent from the remaining common area such as common lobbies, corridors, staircases etc. Take for example a retrofit involving say 300 m² of the clubhouse, 300 m² of the car park and 300 m² of the common lobbies, corridors and staircases. The 500 m² criterion of major retrofitting works (TG clause 4.2.5.1) is not applicable in this case, as the works area in each of these three common areas when measuring separately and independently from each other is only 300 m², and as such the involvement of a FOC is not required.

4.6.3.2 TG Table 4.6.3.2 below shows the applicability of BEC requirements to an occupant’s clubhouse or a car park, for the so listed prescribed building categories. The applicability is subject to the conditions stated in TG clauses 4.6.3.3 & 4.6.3.4 that follow.

Table 4.6.3.2 : Applicability of the BEC Requirements to an Occupant’s Clubhouse or a Car Park		
<u>Category of Building (in which the clubhouse or car park is located)</u>	<u>Building with Common Area</u>	<u>Building with No Common Area</u>
Residential building	Yes	No
Commercial building	Yes	
Composite (commercial / residential) building	Yes, if the clubhouse or car park has a commercial portion and the applicability is to this commercial portion	

4.6.3.3 In the case of car park, its areas that are regarded as common area should however not include the parking spaces that have been specified in instruments registered in the Land Registry as being for the exclusive use of the respective owners of the parking spaces, implying that the applicability of the BEC requirements are limited to areas such as common driveway, loading/unloading spots, walkways etc. outside these parking spaces.

4.6.3.4 The applicability in TG Table 4.6.3.2 is the applicability in respect of a relevant portion of the building, and not in respect of a building services installation, which is yet to be checked for the applicability of the Ordinance by nature and type of the installation such as CBSI, non-CBSI, owned by owner of building, exclusion by virtue of Schedule 2 of the Ordinance etc.

4.6.4 Residential Unit and Industrial Unit

Attention is drawn to the BEC’s non-applicability to residential units and industrial units, as described in TG clause 3.2.3.

4.7 Summary of Requirements

The developer, owner and responsible person of building(s), unit(s) in building(s) and CBSI should check for his/her building if the Ordinance is applicable to his/her building(s), unit(s) and building services installations –

- (a) identify if the building is a prescribed building under Schedule 1 of the Ordinance (also refer TG Table 3.1.1);
- (b) check if the building is excluded from the requirements of the Ordinance by virtue of fulfilling the conditions prescribed in sub-sections 4(1) or 4(2) of the Ordinance (refer also TG Table 3.2.4 re sub-sections 4(1) and 4(2) of the Ordinance); and
- (c) for a building to which the Ordinance is applicable,
 - i) for newly constructed building
 - make REA-certified declarations and obtain the COCR (pursuant to Part 2 of the Ordinance, refer also TG Table 4.2.2),
 - ensure his/her building services installations comply with the BEC, and
 - renew the COCR upon expiry after 10 years,
 - ii) for each lot of major retrofitting works
 - ensure his/her building services installations comply with the BEC, and
 - obtain from an REA the FOC (pursuant to Part 3 of the Ordinance, refer also TG Table 4.2.3),taking into consideration the applicable exclusions in Schedule 2 of the Ordinance (refer also TG Table 3.2.4 re Schedule 2 of the Ordinance), and
 - iii) maintain the building services installations to the standard of the applicable BEC version (refer TG clause 4.4).

4.8 Other Legislative Provisions

Other than described above, the Ordinance has set out for purpose of its enforcement the mechanism for -

- application to the Director for exemption from specified standards and requirements, and for extension of the period for making declaration and obtaining FOC,
- issue of improvement notice by the Director to the party contravening a requirement under the Ordinance,
- empowering an authorized officer (of EMSD) to enter a building and conduct inspection and to require the responsible person to produce relevant documents,
- appeal, and
- penalties for offences, majority in the form of monetary fines, whereas penalties for

the provision of false or misleading information or for the obstruction of authorized officer in the exercise of power would involve imprisonment.

5 Energy Efficiency Requirements for Lighting Installation

5.1 Scope of Application (BEC clause 5.1)

5.1.1 Comprehensive View on Applicability (BEC clause 5.1.1)

BEC Section 5 provides the guidelines for lighting installations. To gain a comprehensive view in relation to the Ordinance, BEC clause 5.1 should be read in conjunction with –

- BEC Sections 3 & 4 that briefly describe the scope and limits of the application of the Ordinance based on its prescribed requirements in Parts 2 & 3; and
- TG Sections 3 & 4 that elaborate on the scope and limits of application and the necessary steps to demonstrate the compliance with the Ordinance and the BEC.

For reference, the interpretation of ‘lighting installation’ under the Ordinance and the BEC is extracted below -


‘Lighting installation’, in relation to a building, means a fixed electrical lighting system in the building including -



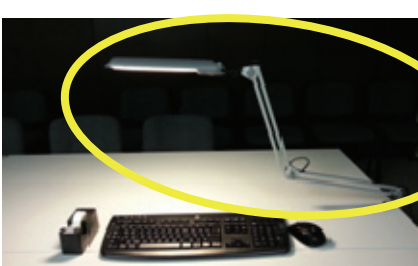


- (a) general lighting that provides a substantially uniform level of illumination throughout an area; or
- (b) maintained type emergency lighting,


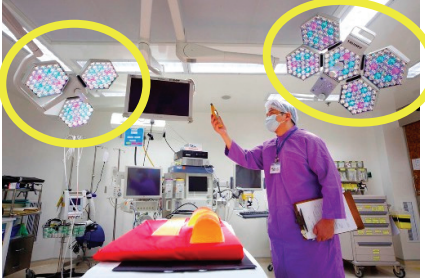



but does not include non-maintained type emergency lighting;




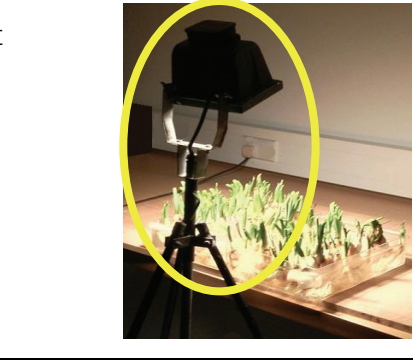


5.1.2 Examples of BEC Non-applicable Installations (BEC clause 5.1.2)


BEC clause 5.1.2 lists certain lighting installations to which the Ordinance does not apply, and further examples of these installations are given in TG Table 5.1.2 below.

Table 5.1.2 : Examples of BEC Non-applicable Lighting Installations	
<u>Examples</u>	<u>Justifications</u>
<p>(a) Outdoor lighting illuminating building facade</p> <div style="display: flex; justify-content: space-around;">  </div>	<p>BEC clause 5.1.2 (a)</p>

	
<p>(b) Lighting on outdoor lamp-pole</p>	 <p>BEC clause 5.1.2 (a)</p>
<p>(c) Desk lamp with flexible cable & plug</p>	 <p>BEC clause 5.1.2(b)</p>
<p>(d) Film viewer to view X-ray film (commonly found in medical clinics)</p>	
<p>(e) Lighting integral to a fume cupboard</p>	 <p>BEC clause 5.1.2(c)</p>
<p>(f) Lighting integral to food-warming equipment (e.g. in restaurants)</p>	
<p>(g) Lighting integral to exit sign or directional sign</p>	 <p>BEC clause 5.1.2(d)</p>

<p>(h) Lighting integral to signage for promoting a specific brand, product or service</p>		
<p>(i) Lighting in an operating theatre in a hospital, lighting solely used for surgical operation</p>		<p>BEC clause 5.1.2(e) (fulfilling item 2(a), Schedule 2 of the Ordinance)</p>
<p>(j) Lighting solely for illuminating art work or exhibit</p>		<p>BEC clause 5.1.2(e) (fulfilling item 6(a), Schedule 2 of the Ordinance)</p>
<p>(k) Lighting solely for illuminating merchandise on display (commonly found in retail shops)</p>		
<p>(l) Lighting solely for outlining the ceiling and circular column interface</p>		<p>BEC clause 5.1.2(e) (fulfilling item 6(b), Schedule 2 of the Ordinance)</p>

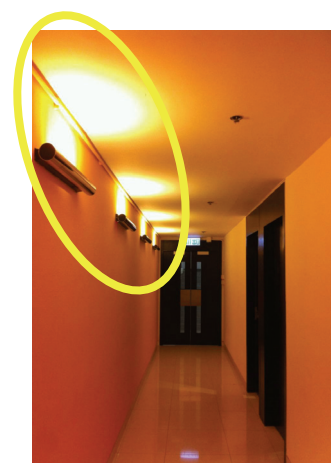
<p>(m) Lighting solely to outstand architectural profile</p>		
<p>(n) lighting solely for providing festival decoration effect</p>		
<p>(o) Lighting solely for conducting of performance (commonly found in and around performance stages)</p>		<p>BEC clause 5.1.2(e) (fulfilling item 6(c), Schedule 2 of the Ordinance)</p>
<p>(p) Lighting solely for plant growth</p>		<p>Outside the scope of lighting installation interpreted in the Ordinance, which only covers general lighting that provides a substantially uniform level of illumination throughout an area</p>
<p>(q) Luminaires for sale and not for illuminating a space</p>		
<p>(r) Non-maintained type emergency lighting (with battery-pack) operating only during failure of normal power</p>		<p>Outside the scope of lighting installation interpreted in the Ordinance, which does not cover non-maintained type emergency lighting</p>

<p>(s) Lighting in a monument or historical building</p>		<p>The Ordinance is not applicable, as prescribed in sub-sections 4(1)(c) and 4(1)(d) of the Ordinance</p>
<p>Remark : The justification above is subject to the fulfilling of the separate control circuitry requirement as described in TG clause 5.5.4.</p>		

5.1.3 Lighting Serving Both as General Lighting and for Purpose Prescribed in Item 6 of Schedule 2 of the Ordinance

In the justifications for certain examples in TG Table 5.1.2 above (items (j) to (o) in particular), the non-applicability of the Ordinance or BEC is by virtue of the lighting installation fulfilling item 6 of Schedule 2 of the Ordinance (also refer TG Table 3.2.4). Attention is drawn that should the lighting installation serves also as general lighting that provides a substantially uniform level of illumination, there would be no exemption. For example in a corridor in a hotel, as shown in TG Figure 5.1.3, should the illumination be provided only by a series of uplights, which serve both purposes namely general illumination and decoration, the uplights are governed by the BEC, and the LPD of the corridor has to comply with the corresponding maximum allowable value in BEC Table 5.4.

Figure 5.1.3 : Lighting serving as general lighting and decoration



5.2 General Approach (BEC clause 5.2)

The energy efficiency requirements in BEC clauses 5.4 to 5.5 are based on the general approach to energy efficiency given in BEC clause 5.2.

5.3 Definitions (BEC clause 5.3)

BEC Section 2 provides the interpretations and abbreviations related to the BEC and the Ordinance, including those for lighting installation.

5.4 Lighting Power Density (LPD) (BEC clause 5.4)

5.4.1 Maximum Allowable LPD (BEC clause 5.4.1)

(a) Classifying of Space as Type of Space in BEC Table 5.4

Maximum allowable LPD values are specified in BEC Table 5.4. The REA/designer should classify an applicable space in a design as one of the types of space in BEC Table 5.4. There may be spaces in the design that are not identically named as those in BEC Table 5.4, and under the circumstance the REA/designer should exercise his/her professional judgment on the function of the space to make the classification. If the REA/designer is in doubt, he/she should seek EMSD's advice. Certain examples of the classification are given below.

Reference to surrounding space

Take for example a space under design being dedicated as "reception area" for an office set-up. Since "reception area" is not included in BEC Table 5.4, the REA/designer can reasonably classify the space as "office" in Table 5.4. Similarly should the "reception area" be used for a gymnasium set-up, the space may be classified as "gymnasium" in Table 5.4. Another example is a "data centre" within an office set-up may be classified as "office".

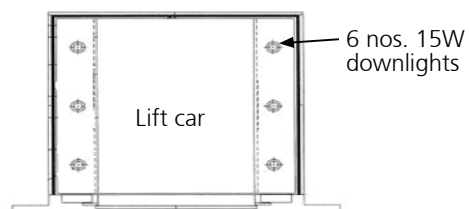
Demarcation based on function and nature

Consider another example of a passage under design being dedicated as mainly for circulation of in-house staff, the passage may be regarded as "corridor", whereas a similar passage mainly for the public may be regarded as "public circulation area". A place serving food and has a restaurant license (issued by Food and Environmental Hygiene Department) may be regarded as "restaurant", whereas one with a canteen license may be regarded as "canteen".

(b) Space with Less than 100W Lighting Installation

According to BEC clause 5.4.1, a space having total electrical power of fixed lighting installations not exceeding 100 W is not governed by the LPD requirement in BEC Table 5.4. This is to avoid the imposing of unnecessary inflexibility in the choice of luminaires for a small area space of which the LPD based on Table 5.4 can easily be exceeded even with a minimum no. of luminaires. Examples of a small area space are a store room and a lift car. The lift car example is illustrated in TG Figure 5.4.1(b), which shows a lighting installation less than 100W.

Figure 5.4.1 (b) : BEC LPD requirement not applicable to lift car with < 100 W lighting



(c) Internal Floor Area

In calculating the LPD of a space, the internal floor area measuring from the internal surfaces of the enclosing walls should be used. The area should include the thickness of columns and party walls, if any, within the space.

(d) Original LPD standards (Initial version) and revised LPD standards (Rev. 1)

For the different effective dates of the revised LPD standards (Rev. 1) in Table 5.4 of the Addendum no. BEC01 and the BEC 2012 (Rev. 1) in respect of the issue of stage one declaration (signed by the developer) and FOC (signed by the REA) under the Ordinance, please refer to the Technical Circular No. 1/2014 which is available at the web-site of the Ordinance. The revised LPD standards (Rev. 1) apply to the lighting installation covered in a stage one declaration or FOC issued on or after the corresponding effective date given in the Technical Circular. Both the original LPD standards (Initial version) and the revised LPD standards (Rev. 1) are acceptable in the stage one declaration and FOC issued before the corresponding effective date.

Both the original LPD standards (Initial version) and the revised LPD standards (Rev. 1) are acceptable in the stage one declaration and FOC issued before the corresponding effective date.

The edition of the BEC in a relevant standard form (Form EE1, EE2, EE3 and EE4 etc.) under the Ordinance for issuance on or after the corresponding effective date must be inputted as "2012 (Rev. 1)". For issuance before the aforesaid corresponding effective date, the edition of the BEC should be inputted as –

- (i) "2012 (Rev. 1)" if the revised LPD standards (Rev. 1) are adopted, or
- (ii) "2012" simply if the original LPD standards (Initial version) are adopted.

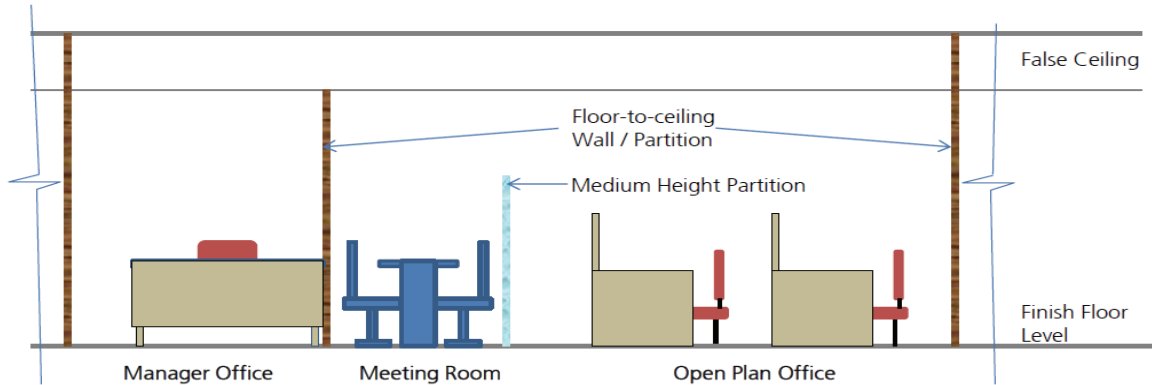
5.4.2 LPD of BEC Non-applicable Lighting Installations (BEC clause 5.4.2)

Given the BEC's non-applicability to these lighting installations, their inclusion in the LPD calculation is not required.

5.4.3 Separation Between Spaces (BEC clause 5.4.3)

For the purpose of LPD calculation, two adjoining spaces are considered as separate individual spaces when they are segregated by full height physical walls or partitions. In TG Figure 5.4.3 below, the Manager Office and the Open Plan Office are regarded as two separate spaces, given them being isolated with floor to ceiling partitions, and the LPD in each space is to be calculated separately. For the Meeting Room, given it being only isolated with a medium height partition from the working stations in the Open Plan Office, it is regarded as a part of the Open Plan Office, and in calculating the LPD the electrical power of the luminaires in the meeting zone and those in the work station zone can be added up and be divided by the sum of the areas of the two zones.

Figure 5.4.3 : Separation between spaces



5.4.4 Multi-functional Space (BEC Table 5.4)

A multi-functional space is one that can function as more than one of the space types in BEC Table 5.4; meaning of multi-functional space is also described in BEC Section 2. It is designed to allow different functional activities at different times, with each function served by a combination of luminaires in the same space. Noteworthy, a luminaire in a multi-functional space may serve more than one function. The LPD of each combination of luminaires should not exceed the maximum allowable value corresponding to the type of space illuminated by that combination of luminaires. A typical example is a multi-function room in a hotel, which can function as a banquet room, a ball room or a seminar room. When the room is used as a banquet room or a ball room, its LPD provided by the function-specific combination of luminaires (based on LPD standards of Initial version) should not exceed 23 W/m², and when used as a seminar room 16 W/m². An illustration of the LPD calculation is given in TG clause 5.6.

5.5 Lighting Control (BEC clause 5.5)

5.5.1 Control Points for Office (BEC clause 5.5.1)

(a) Required Quantity

BEC Table 5.5 specifies the equations for determining the minimum no. of lighting control points. Based on the calculations using these equations, TG Table 5.5.1 below gives the corresponding minimum no. of lighting control points for space areas up to 500m².

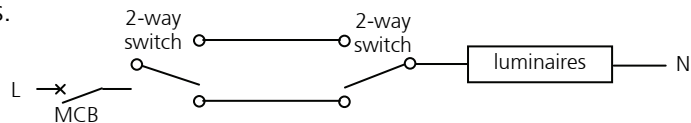
Table 5.5.1 : Minimum Nos. of Lighting Control Points per Space Area of Office			
<u>Area (m²)</u>	<u>Minimum no. of lighting control points</u>	<u>Area (m²)</u>	<u>Minimum no. of lighting control points</u>
> 0 - 15	1	> 180 - 210	12
> 15 - 30	2	> 210 - 240	13
> 30 - 45	3	> 240 - 270	14

<u>Area (m²)</u>	<u>Minimum no. of lighting control points</u>	<u>Area (m²)</u>	<u>Minimum no. of lighting control points</u>
> 45 - 60	4	> 270 - 300	15
> 60 - 75	5	> 300 - 330	16
> 75 - 90	6	> 330 - 360	17
> 90 - 105	7	> 360 - 390	18
> 105 - 120	8	> 390 - 420	19
> 120 - 135	9	> 420 - 450	20
> 135 - 150	10	> 450 - 500	21
> 150 - 180	11		

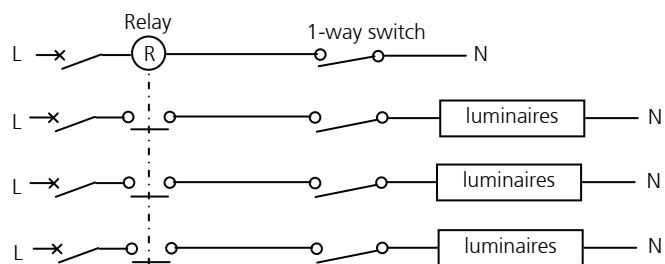
Note on Interpretation

A lighting control point can be in the form of a manual on/off switch, a 2-way control, and a relay or contactor switch.

The following lighting circuit with 2-way control is regarded as having two nos. lighting control points.



The following lighting circuit with a relay control (manual switching, sensor or timer operated etc.) is regarded as having 4 nos. lighting control points.



5.5.2 Allowable Reduced Nos. of Lighting Control Points for Office (BEC clause 5.5.2)

The required nos. of lighting control points in an office space per BEC Table 5.5 (TG Table 5.5.1) can be reduced, subject to the actual LPD value in the space being lower than the maximum allowable value of 15 W/m² (based on LPD standards of Initial version), and the allowable reduction ratio is give by –

$$\text{Allowable reduction ratio} = \frac{15 \text{ W/m}^2 - \text{actual LPD}}{15 \text{ W/m}^2}$$

Example (based on LPD standards of Initial version) below further illustrates the allowable reduction in nos. of control points –

Area of open plan office : 350 m²

Min no. of lighting control points required : 17 (refer TG Table 5.5.1)

Calculated actual LPD : 12 W/m²

Max allowable LPD : 15 W/m²

Allowable reduction ratio = $(15-12)/15 = 0.2$ (or 20%)

Min no. of lighting control points required after reduction = $17 \times (1-0.2) = 13.6$ or 14 with rounding off to an integer

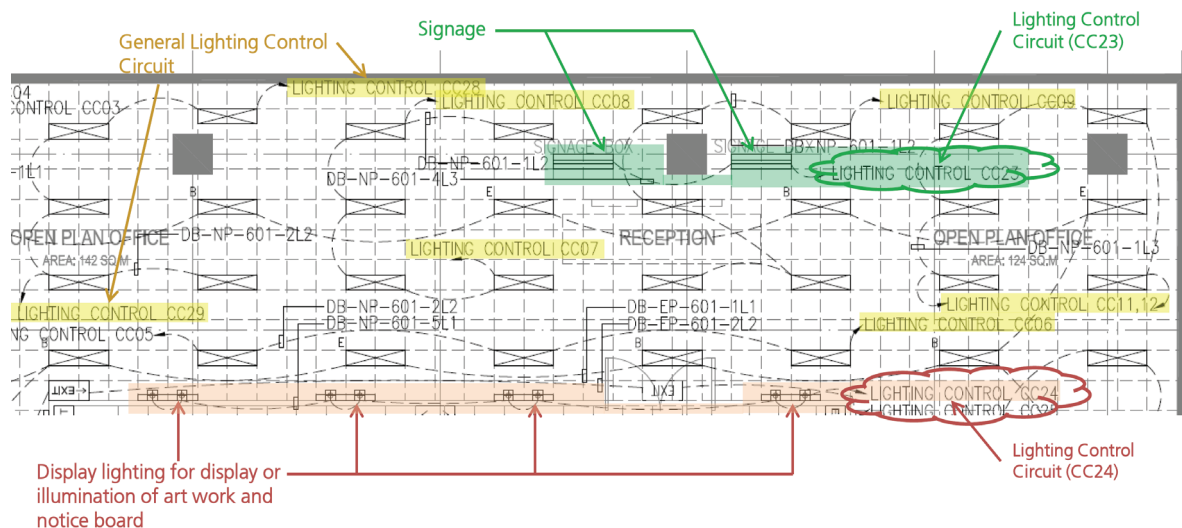
5.5.3 Lighting Control Points for Multi-functional Space (BEC clause 5.5.3)

The control circuitries of the luminaires in a multi-functional space should be such that each of the function-specific combinations of luminaires can operate independently from each other.

5.5.4 Separate Control for Ordinance-applicable Lighting and Ordinance Non-applicable Lighting (BEC clause 5.5.4)

The separate control requirement is to facilitate the flexibility in the operation of the applicable lighting and non-applicable lighting, such that each of these two categories can be switched on or off independently. TG figure 5.5.4 below shows the lighting layout of a sample office set-up where there are luminaires for general lighting, luminaires solely for signage and luminaires solely for display or illumination of art work and notice board, in which it can be seen that each of the latter two categories of luminaires has its own control circuitry.

Figure 5.5.4: Separate control for Ordinance-applicable lighting and Ordinance non-applicable lighting



5.6 Sample Calculation

Multi-functional Space

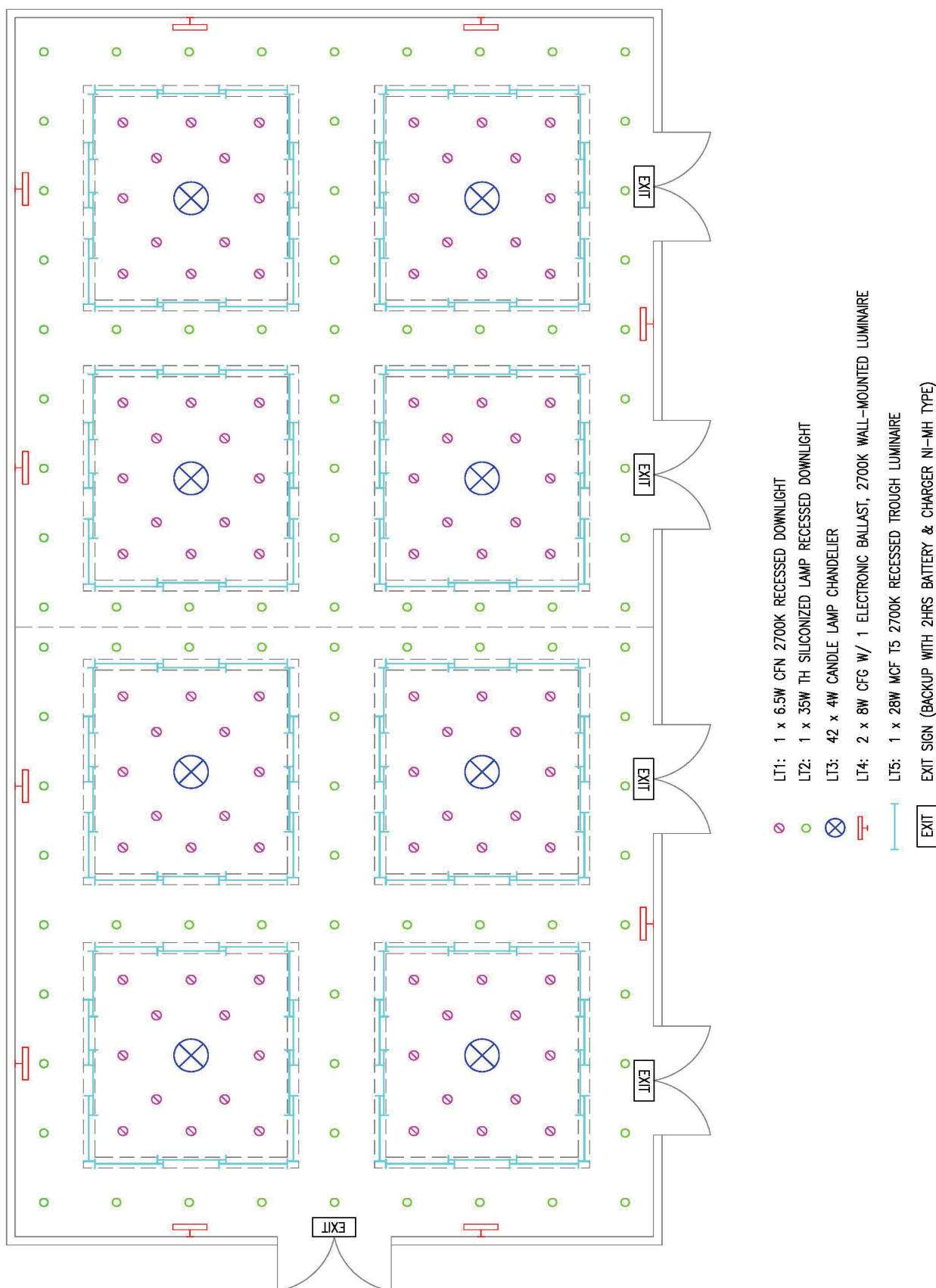
The lighting layout of a hotel's multi-functional space with 264 m² (measured 22 m by 12 m) internal floor area is shown in TG Figure 5.6. The room can be used either as a banquet room, a ball room or a seminar room. The room is served by luminaire types LT1, LT2, LT3, LT4 and LT5, with the following luminaire circuit wattage –

<u>Luminaire Designation</u>	LT1	LT2	LT3	LT4	LT5
<u>Per Luminaire Circuit Wattage (W)</u>	7.5	37	168	18	30
Remark : LT4 is solely used to provide a wall wash effect or to illuminate wall mounted painting. LT1 & LT2 mainly serve as general lighting, and LT3 serves both as general lighting and for decoration.					

TG Table 5.6.1 below shows the calculation of LPD (based on LPD standards of Initial version) for each of the three functions.

Table 5.6.1 : LPD Calculation for Multi-functional Space					
<u>Space Function</u>	<u>Function-specific Luminaires</u>			<u>LPD (W/m²)</u>	
	<u>Luminaire Designation</u>	<u>Quantity</u>	<u>Total Circuit Wattage (W)</u>	<u>Calculated</u>	<u>Max Allowable</u>
Banquet room	LT1	96	720	[720 + 3330 + 1344] / 264 = 20.4	23
	LT2	90	3330		
	LT3	8	1344		
	LT4	Excluded in LPD			
Ball room	LT2	90	3330	[3330 + 1344] / 264 = 17.7	23
	LT3	8	1344		
	LT4	Excluded in LPD			
Seminar room	LT1	96	720	[720 + 3360] / 264 = 15.5	16
	LT5	112	3360		

Figure 5.6: Lighting layout of a multi-functional space in a hotel



6. Energy Efficiency Requirements for Air-conditioning Installation

6.1 Scope of Application (BEC clause 6.1)

6.1.1 Comprehensive View on Applicability (BEC clause 6.1.1)

BEC Section 6 provides the guidelines for air-conditioning installations. To gain a comprehensive view in relation to the Ordinance, BEC clause 6.1 should be read in conjunction with –

- BEC Sections 3 & 4 that briefly describe the scope and limits of the application of the Ordinance based on its prescribed requirements in Parts 2 & 3; and
- TG Sections 3 & 4 that elaborate on the scope and limits of application and the necessary steps to demonstrate the compliance with the Ordinance and the BEC.

For reference, the interpretation of ‘air-conditioning installation’ under the Ordinance and the BEC is extracted below -

‘Air-conditioning installation’, in relation to a building, means fixed equipment, distribution network or control devices that cool down, heat up, humidify, dehumidify, purify or distribute air within the building;

6.1.2 Examples of BEC Applicable Installations (BEC clause 6.1.2)

In respect of certain types of air-conditioning installations, BEC clause 6.1.2 affirms for the avoidance of doubt the Ordinance’s applicability to these installations, and examples thereof are given in TG Table 6.1.2 below.

<u>Table 6.1.2 : Examples of BEC Applicable Air-conditioning Installations</u>	
<u>Examples</u>	<u>Justifications</u>
Smoke extract fan serving basement, used for general exhaust during normal operation and for smoke extract during fire mode	BEC clause 6.1.2 (a)
Split type air-conditioner above and serving a lift car	BEC clause 6.1.2 (b)
A split type air-conditioner, owned by the occupier or responsible person of a space in the building, having an indoor unit within and serving the space but with outdoor unit mounted outside the building boundary	BEC clause 6.1.2 (c)

6.1.3 Examples of BEC Non-applicable Installations (BEC clause 6.1.3)

BEC clause 6.1.3 lists certain air-conditioning installations to which the Ordinance does not apply, and examples of these installations are given in TG Table 6.1.3 below.

<u>Table 6.1.3 : Examples of BEC Non-applicable Air-conditioning Installations</u>	
<u>Examples</u>	<u>Justifications</u>
Chiller operating at high electrical voltage of 3.3 kV	BEC clause 6.1.3(a)
Air handling unit solely used for surgical operation in operating theatre in a hospital	BEC clause 6.1.3(b) (fulfilling item 2(a), Schedule 2 of the Ordinance)
Smoke extract fan serving basement described in TG Table 3.3	described in TG Table 3.3
Exhaust fan for fume cupboard solely for research in a university (and not for other purpose)	BEC clause 6.1.3(b) (fulfilling item 5, Schedule 2 of the Ordinance)

6.2 General Approach (BEC clause 6.2)

The energy efficiency requirements in BEC clauses 6.4 to 6.13 are based on the general approach to energy efficiency given in BEC clause 6.2.

6.3 Definitions (BEC clause 6.3)

BEC Section 2 provides the interpretations and abbreviations related to the BEC and the Ordinance, including those for air-conditioning installation.

6.4 System Load Calculation (BEC clause 6.4)

6.4.1 International Recognized Procedures (BEC clause 6.4.1)

The BEC specifies that the cooling/heating load calculations should be in accordance with international recognized procedures and methods such as described in ASHRAE Handbook Fundamentals, CIBSE Guide A etc., which are widely adopted by designers.

6.4.2 System Load Design Conditions (BEC clause 6.4.2)

The inclusion of load design conditions in BEC Table 6.4 is for purpose of avoiding over estimation that will lead to over-sizing of system and equipment. For outdoor summer, the REA/designer can choose between two design conditions: 35°C dry bulb with lower than 29°C wet bulb, or 29°C wet bulb with lower than 35°C dry bulb, the former

condition suiting a zone with sensible heat intensive loads and the latter a zone with latent heat intensive loads. The outdoor design conditions are applicable to all types of applications, while the indoor design conditions are confined to human comfort applications. Examples of non-human comfort applications are data centre, wine cellar (maintaining a lower temperature range e.g. 10-16°C at dedicated range of relative humidity), pathology room (maintaining a higher temperature e.g. 37°C to boost bacteria growth) etc.

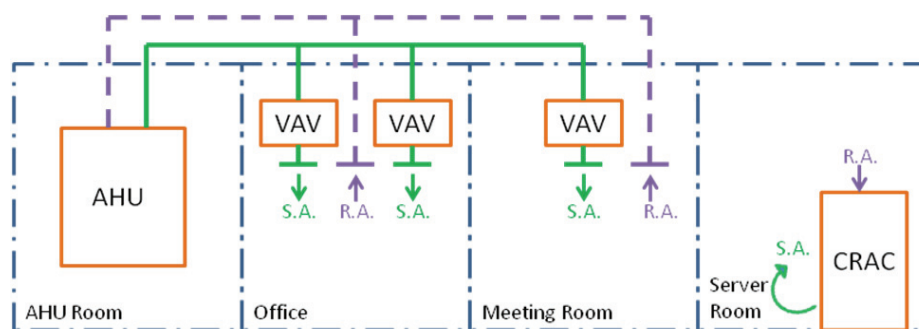
6.5 Separate Air Distribution System for Process Zone (BEC clause 6.5)

A process zone and a comfort only zone have different temperature and humidity requirements and operating characteristics, and the BEC requires the process zone to have an air distribution system separate from that of the comfort zone. The separate air distribution system requirement offers the benefit of better room condition control in the two different types of zone, and avoids unnecessary recooling or reheating.

6.5.1 Example of Separate Air Distribution System (BEC clause 6.5.1)

An example of a process zone is the computer server room with special temperature and humidity requirements. As shown in TG Figure 6.5.1 below, the process zone - the Server Room, is served by a computer room air conditioning unit (CRAC), and its adjoining spaces of Office and Meeting Room - the comfort only zone, is served by variable air volume (VAV) units in conjunction with an AHU located in an AHU room.

Figure 6.5.1: Separate air distribution system for computer Server Room



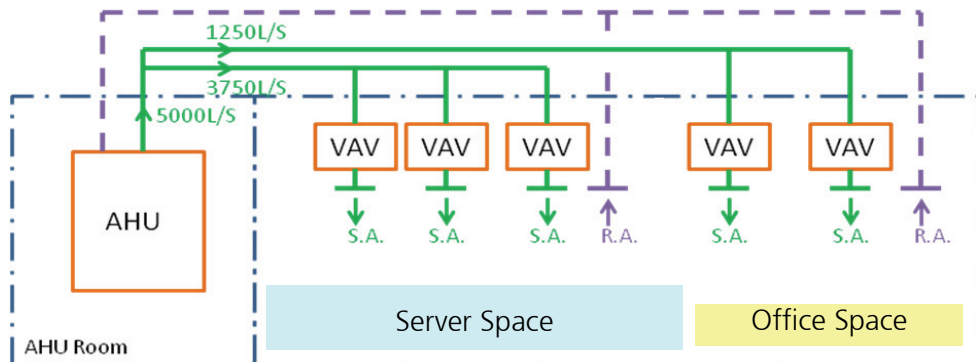
6.5.2 Exemption from Requirement of Separate Air Distribution System (BEC clause 6.5.2)

Providing the zoning flexibility for small air-conditioning systems, BEC clause 6.5.2 gives the following conditions under which the process zone and comfort only zone can share a common air distribution system -

- (a) the supply air to the comfort only zone is no more than 25% of the total air flow of the common air distribution system, as shown in the scenario in Figure 6.5.2 (a) below, which has the supply air to the Office space at 1250 L/s or 25% of the total

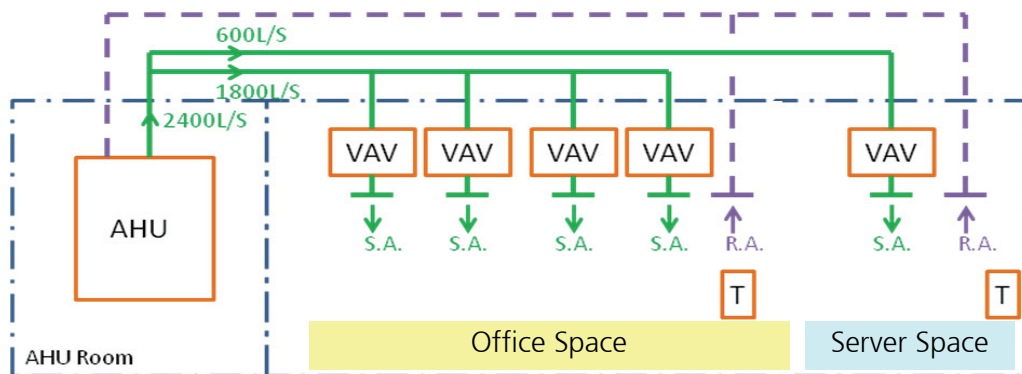
supply air flow of 5000 L/s; or

Figure 6.5.2 (a) : Supply air to comfort zone no more than 25% of total air flow



- (b) the comfort only zone has a small conditioned area of smaller than 100 m², which is typical for a small office having very few occupants within a server room, or
- (c) the supply air to the process zone is no more than 25% of the total air flow of the common system, as shown in the scenario in TG Figure 6.5.2 (c) below, which has the supply air to the Server space at 600 L/s or 25% of the total supply air of 2400 L/s, and the process zone has separate room temperature control and requires no reheat of the common system supply air.

Figure 6.5.2 (c) : Supply air to process zone no more than 25% of total air flow



The exemptions are to provide the flexibility for designing minor auxiliary spaces within a principal space, such as a server room set-up easily accommodating a small office space, and vice versa.

6.6 Air Distribution Ductwork Leakage Limit (BEC clause 6.6)

BEC Table 6.6 specifies the maximum allowable air leakage limits of ductwork that is designed to operate in excess of 750 Pa static pressure. The leakage limits are based on equations in DW 143 – A Practical Guide to Ductwork Leakage Testing (2000) published by Heating and Ventilating Contractors’ Association, UK. Static pressure of 750 Pa is commonly found in VAV ductwork systems, which are usually equipped with

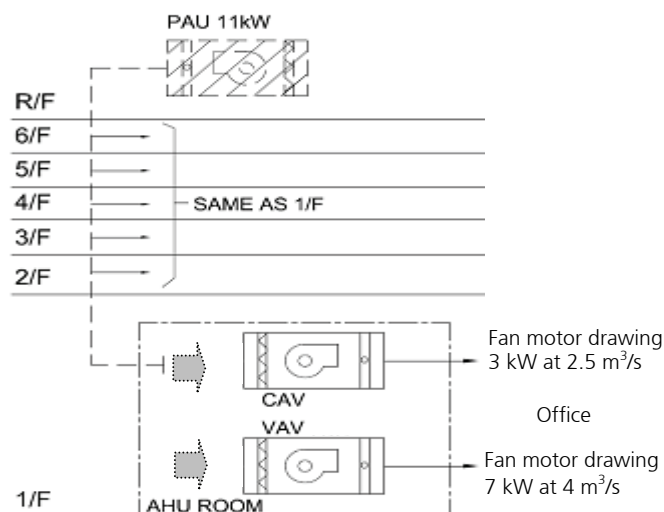
dampers to modulate the air flow in response to thermostatic sensing, and these dampers add resistance to the air flow. Ductwork are classified in terms of increasing operating static pressure into three classes namely Class I, Class II and Class III. Each class is assigned an equation based on which the allowable air leakage limit is calculated, such that the allowable leakage gets more stringent with the advancement from a lower class to a higher class that associates with a higher operating pressure.

6.7 Air Distribution System Fan Power (BEC clause 6.7)

(a) Maximum Allowable System Fan Motor Power (BEC clauses 6.7.1 to 6.7.3)

- i) BEC clauses 6.7.1 to 6.7.3 specify for a conditioned space the requirements on maximum allowable system fan motor power, of the air distribution system, the calculation of which includes the supply air fan and return air fan but not the fresh air fan and exhaust air fan. The requirements are not applicable to air distribution systems in unconditioned spaces. The motor power refers to the power drawn by the fan motor, when the AHU fan and its serving equipment in particular the coils are at clean condition; the power drawn by the fan motor is usually lower than the motor’s rated output power (shown on motor name plate) but higher than the actual power delivered by the fan. The VAV system given it drawing a lower motor power at part load is allowed a higher system fan power of 2.1 W/L/s whereas the constant air volume (CAV) is allowed 1.6 W/L/s.
- ii) Calculation of system fan motor power (P_T) for a system with supply air fan only

Figure 6.7 (a) : Illustration of system fan motor power



An illustration of a simple calculation of system fan motor power is shown in TG Figure 6.7(a). The figure shows two air distribution systems serving an office on 1/F, the CAV and the VAV systems, comprising respectively of a CAV AHU with its fan motor drawing 3 kW electrical power when delivering an air flow of 2.5 m³/s

and a VAV AHU with its fan motor drawing 7 kW electrical power when delivering an air flow of 4 m³/s.

System fan motor power for VAV = 7 kW / 4 m³/s = 1.75 W/L/s

System fan motor power for CAV = 3 kW / 2.5 m³/s = 1.2 W/L/s; the 1.6 W/L/s requirement does not apply, given the system fan motor power of 3 kW falling within the exemption criterion of less than 5 kW as described in TG clause 6.7(c) below.

The primary air AHU (PAU) and exhaust fans if any need not be included in the calculation of system fan motor power.

- iii) Fan motor power can also be determined based on fan curves that relate air flow to fan shaft power (FSP), for which the fan motor power can be calculated by first dividing the fan shaft power by the motor efficiency (η_m) and then by the efficiency of the mechanical drive (η_d , such as fan pulley/belt). An illustration of the calculation is shown in the latter part of (b) ii) below.
- iv) The example in TG clause 6.7(a) ii) has no return air fan, which if in place its fan motor power per L/s has to be added to that of the supply air fan, and the sum of the addition would be the total system fan motor power (P_T) for comparison with the 1.6 or 2.1 W/L/s figure. An illustration of the calculation with a return air fan is shown in the latter part of (b) ii) below.

(b) Pressure Drop for Air Treatment or Filtering (BEC clause 6.7.3)

- i) Air treatment such as heat wheel or heat exchanger and filtering systems may cause higher pressure drop in an air distribution system. The BEC recognizes the benefits of air treatment to indoor air quality and provides a clause for 'deductible' fan power to minimize the penalties on fan motor power brought on by air treatment equipment. BEC clause 6.7.3 allows the system pressure drop at clean condition caused by air treatment or filtering systems that exceeds 250 Pa to be deducted from the system fan motor power. The deductible fan motor power can be calculated using the following equation -

$$P_f = V \times (p_d - 250) / (\eta_m \times \eta_f \times \eta_d)$$

where

P_f = Deductible fan motor power for air treatment/filtering (W) in excess of 250 Pa

V = Air volume flow rate (m³/s)

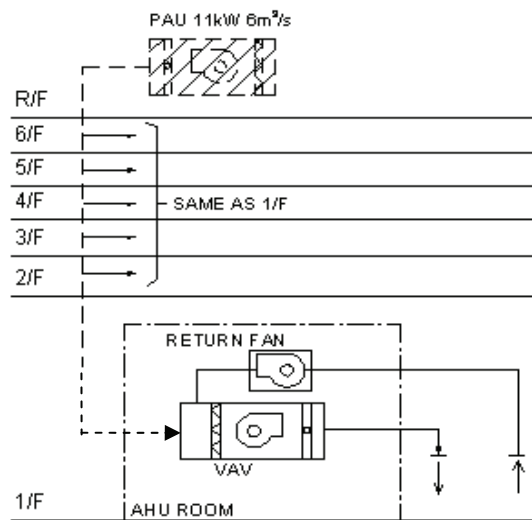
p_d = Air pressure drop (Pa) of the treatment/filtering system and/or heat wheel/exchanger system in clean condition

η_m = Motor efficiency η_d = Drive/belt efficiency η_f = Fan efficiency

ii) Example Illustrating Deductible Fan Motor Power and System Fan Motor Power

Consider a VAV system having a supply air AHU and a return air fan in TG Figure 6.7(b). The fan shaft power FSP_S of the AHU is 7kW at the design flow of $5.5\text{m}^3/\text{s}$, and the fan shaft power FSP_R of the return air fan is 4kW at the design flow of $3.5\text{m}^3/\text{s}$. The total filter pressure drop (p_d) including air bag filter, HEPA filter etc. is 450 Pa. The motor efficiency, drive/belt efficiency and fan efficiency of the supply fan is 0.92, 0.97 and 0.8 respectively, and the same of the return fan is 0.9, 0.97 and 0.7 respectively.

Figure 6.7 (b) : Illustration of deductible fan motor power



Calculation of deductible fan motor power

$$p_d = 450 \text{ Pa} \quad V = 5.5\text{m}^3/\text{s} \quad \eta_m = 0.92 \quad \eta_d = 0.97 \quad \eta_f = 0.8$$

$$P_f = V \times (p_d - 250) / (\eta_m \times \eta_d \times \eta_f) = 5.5 \times (450 - 250) / (0.92 \times 0.97 \times 0.8)$$

$$= 1,541 \text{ W or } 1.54 \text{ kW}$$

Calculation of system fan motor power (P_T) for a system with supply and return air fans and deductible fan motor power

$$P_T = FSP_S / (\eta_m \times \eta_d) - P_f + FSP_R / (\eta_m \times \eta_d)$$

$$= [7 / (0.92 \times 0.97)] - 1.54 + [4 / (0.9 \times 0.97)] \text{ kW}$$

$$= 7.84 - 1.54 + 4.58 \text{ kW}$$

$$= 10.9 \text{ kW}$$

$$\text{System fan motor power} = P_T / V = 10.9 / 5.5 \text{ kW/m}^3/\text{s}$$

$$= 1.98 \text{ W/L/s, which fulfils the } 2.1 \text{ W/L/s requirement}$$

- (c) Exemption from Maximum Allowable System Fan Motor Power Requirements (BEC clause 6.7.5)

BEC clause 6.7.5 specifies the conditions under which the maximum allowable system fan motor power requirement can be exempted.

An exemption is by virtue of the system fan motor power being less than 5 kW. Take for example a VAV air distribution system having FSP_S of 4 kW, FSP_R of 1.6 kW, and P_f of 1.4 kW at the designed flow of 2.2 m³/s; the motor efficiency and drive/belt efficiency of the supply fan is 0.92 and 0.97 respectively, and of the return fan is 0.9 and 0.97 respectively.

$$\begin{aligned}
 P_T &= FSP_S / (\eta_m \times \eta_d) - P_f + FSP_R / (\eta_m \times \eta_d) \\
 &= [4 / (0.92 \times 0.97)] - 1.4 + [1.6 / (0.9 \times 0.97)] \text{ kW} \\
 &= 4.48 - 1.4 + 1.83 \text{ kW} \\
 &= 4.92 \text{ kW, and falls within the exemption range of 5 kW,} \\
 &\text{which if not exempted could give a system fan motor power of } 4.92 / 2.2 \text{ or} \\
 &\text{2.23 W/L/s that does not fulfil the requirement of 2.1 W/L/s.}
 \end{aligned}$$

The other exemption is by virtue of the air distribution system comprising of FCUs only and each having motor power less than 1 kW.

- (d) Requirement for VAV Fan Motor (BEC clause 6.7.4)

BEC clause 6.7.4 specifies that a VAV fan motor should operate at no more than 55% of design input power at 50% of design air flow. This can usually be achieved by adopting as motor drive a frequency inverter type variable speed drive (attention should be paid to the inverter's generated harmonic currents which is discussed in TG Section 7). A reduction of fan power through air dampers or inlet guide vanes only may not achieve the 55% requirement. The 55% requirement is not applicable to motors at lower than 5 kW output power.

6.8 Pumping System Variable Flow (BEC clause 6.8)

6.8.1 Applicability (BEC clause 6.8.1)

BEC clause 6.8.1 requires that if a water side pumping system is designed for variable flow in response to cooling/heating load and the variable flow is effected through the opening, closing or modulation of control valve(s), it should be capable of operating at 50% or less of the design flow. The variable flow requirement refers to the whole pumping system, which may consist of multiple pumps and chillers, and the flow reduction may be achieved by chiller and pump sequencing, valves on/off/modulation or reduced speed operation of variable/multi speed pumps. Manual operation to effect the sequencing, on/off/modulation or reduced speed is not regarded as fulfilling the

requirement.

There are exemptions given under BEC clauses 6.8.1 (a), (b) and (c), from the 50% flow requirement. While the exemption in 6.8.1 (a) and (b) may apply for certain small pumping systems, the exemption in 6.8.1 (c) is on the merit of the energy efficiency feature of chilled water supply temperature reset control where the supply temperature can be reset at part load say from 7°C to 8°C which demands a lower compressor power input.

6.8.2 Requirement for Variable Speed Pump (BEC clause 6.8.2)

BEC clause 6.8.2 specifies that a variable speed pump should operate at no more than 55% of design input power at 50% of design water flow. This can usually be achieved by adopting as motor drive a frequency inverter type variable speed drive (attention should be paid to the inverter’s generated harmonic currents which is discussed in TG Section 7). A reduction of pump power through valves modulation only may not achieve the 55% requirement. The 55% requirement is not applicable to motors at lower than 5 kW output power.

6.9 Frictional Loss of Water Piping System (BEC clause 6.9)

The requirement is illustrated using table form in TG Table 6.9 below. The designer should adopt a reasonably large pipe size in order to comply with the requirement targeted at reducing pump energy. The requirement is applicable to chilled water pipework, heated water pipework and condenser water pipework.

Table 6.9 : Frictional Loss Requirement of Water Piping System		
<u>Piping Diameter (mm)</u>	<u>Greater than 50mm</u>	<u>50mm</u>
Frictional loss (Pa/m)	≤ 400 Pa/m	Not applicable
Water flow velocity (m/s)	≤ 3 m/s	≤ 1.2 m/s

6.10 System Control (BEC clause 6.10)

6.10.1 Temperature Control (BEC clause 6.10.1)

(a) BEC clause 6.10.1 requires each air-conditioning system to be individually controlled by at least one automatic temperature control device in a space. The temperature control device such as thermostat should have provisions for controlling temperature setting to 29°C in case of cooling, and controlling temperature setting to 16°C in case of heating. A wider range of setting allows higher flexibility of operation and avoids unnecessary energy consumption due to over cooling or over heating.

The requirement on wider range of setting in respect of unitary air-conditioner is not meant for a control device –

- that forms an integral part of the air-conditioner, or
- that is offered by the air-conditioner's manufacturer as a standard ancillary to the air-conditioner (and by ordering the air-conditioner the device would be available ex-factory in the same package of the air-conditioner).

(b) Dead band setting is usually applied to a space provided with both heating and cooling. The dead band provision avoids unnecessary cooling or heating due to transient unsteady swing of space temperature around the thermostatic set point, by specifying a range of temperature that neither cooling nor heating would be called upon – the dead band. The BEC specifies the dead band to be at least 2°C, which would be adequate to absorb typical transience. An exemption from the 2°C dead band requirement is allowed for temperature control device that requires a manual change-over between cooling and heating modes.

6.10.2 Humidity Control (BEC clause 6.10.2)

BEC clause 6.10.2 requires each air-conditioning system for removing or adding moisture to maintain specific humidity levels to be individually controlled by at least one automatic humidity control device. The humidity control device such as humidistat should have provisions for controlling humidity setting up to 60% in case of dehumidification, and controlling humidity setting down to 30% in case of humidification. A wider range of setting allows higher flexibility of operation and avoids unnecessary energy consumption due to over dehumidification or over humidification.

The requirement on wider range of setting in respect of a unitary equipment is not meant for a control device –

- that forms an integral part of the equipment, or
- that is offered by the equipment's manufacturer as a standard ancillary to the equipment (and by ordering the equipment the device would be available ex-factory in the same package of the equipment).

Humidity control is not common for the majority of applications in buildings in Hong Kong.

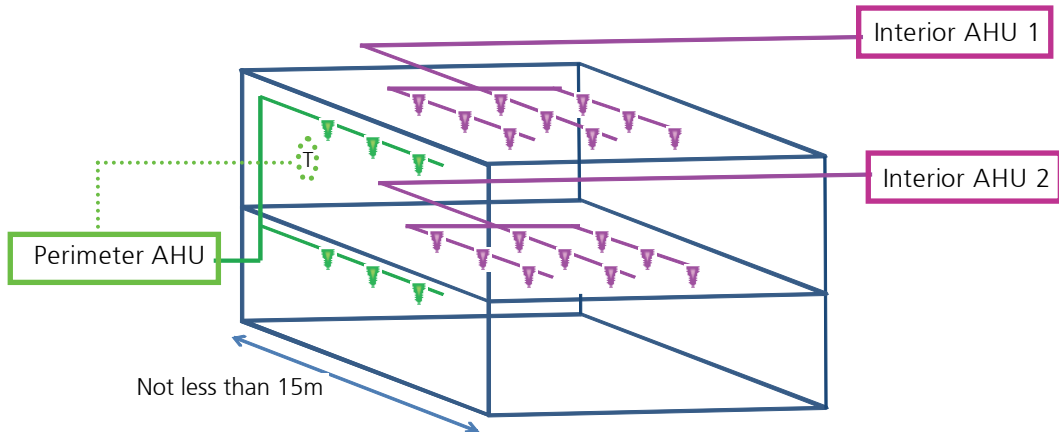
6.10.3 Zone Control (BEC clause 6.10.3)

(a) Individual Control and On Same Floor (BEC clauses 6.10.3.1 & 6.10.3.2)

BEC clause 6.10.3 requires each air-conditioning zone to be individually controlled by a temperature control device such as thermostat within a zone, and the spaces forming a zone should be on the same floor. An exemption from the same floor requirement is given, which is illustrated in TG Figure 6.10.3(a) below.

In TG Figure 6.10.3(a), the perimeter AHU serves the perimeter zone on both upper and lower floors, and is controlled by a thermostat within the zone, which can well reflect the zone temperature. There is a 15 m minimum contiguous length requirement for the concerned building exposure. Zones on facades with contiguous length of less than 15m cannot span more than one floor.

Figure 6.10.3 (a) : Allowable exemption from same floor requirement for a zone



(b) Simultaneous Heating and Cooling (BEC clause 6.10.3.3)

Simultaneous heating and cooling, which refers to the heating of previously cooled air or the cooling of previously heated air, is in general not allowed in a zone for human comfort application, as specified in BEC clause 6.10.3.3. Conditional allowance are given, however, on grounds of enhanced control or when the impact on extra energy consumption is minimized, as shown in TG Table 6.10.3(b) below.

Table 6.10.3 (b) : Allowance of Simultaneous Heating and Cooling		
<u>BEC clause</u>	<u>Conditional Allowance</u>	<u>Justifications</u>
6.10.3.3 (a)	VAV supply air reduced to no greater than 30% of peak supply air flow	VAV itself is an energy saving feature and with the reduction to 30% of peak air flow the extra cooling/heating energy for purpose of maintaining enhanced room condition is much reduced
6.10.3.3 (b)	Pretreated fresh air AHU	To maintain desired room relative humidity not at the sacrifice of fresh air supply
6.10.3.3 (c)	75% of energy for reheating from recovered or renewable energy source	Extra reheating energy is much reduced with the use of recovered or renewable energy (site-recovered energy source such as from exhaust air, and renewable energy source such as photovoltaic panel)

6.10.3.3 (d)	Zone has a peak supply air flow of 140L/s or less	Small system, e.g. for around 10 m ² floor space, has low impact on extra energy
6.10.3.3 (e)	Process requirements warranting specific humidity levels	Functional need for non-human comfort application

6.10.4 Off-hours Control (BEC clause 6.10.4)

(a) General Approach for Off-hour Control (BEC clauses 6.10.4.1 & 6.10.4.2)

For purpose of reduction of energy during off-hours, BEC clause 6.10.4 specifies that automatic controls should be provided for an air-conditioning system with cooling or heating capacity more than 10kW. Off-hours refer to time periods beyond normal occupancy hours and usually has a much lower energy demand. When the capacity is not more than 10kW, such as a system of split type air-conditioner or FCU, the adoption of manual off-hour control such as on/off switch is acceptable, provided that the control is readily accessible to the occupant or operator. With the controls in place, the air-conditioning system can be shut down or setback during the off-hours.

Timer control and occupancy sensor are common devices to facilitate the automatic control of shutdown for off-hours and resumption of service for normal hours. Examples of common setback features are the automatic adjustment of room temperature in the case of cooling, say from 23°C to 28°C, and the automatic reduction of air flow of an AHU, during the setback cycle after which the earlier settings for normal hours can automatically resume. For enhanced effect, automatic controls may integrate with the building’s overall building management system (BMS) with energy management function.

(b) Guest Rooms in Hotel, Guest House and Hostel (BEC clause 6.10.4.3)

For purpose of reduction of energy consumption when the guest room or suite is not occupied, BEC clause 6.10.4.3 requires the provision of a master control device in the guest room to turn off or setback the serving air-conditioning system. The setback may be by means of reduction of supply air, reduction of fan speed, or in case of cooling resetting of room temperature to a higher set point and in case of heating resetting to a lower set point. The card key device is a common type of master control device, which when inserted into a “switch slot” the air-conditioning can be turned on or resumed to normal setting, and vice versa if the card key is removed the air-conditioning can be setback or switched off.

6.11 Thermal Insulation (BEC clause 6.11)

6.11.1 Tabulated Insulation Thickness (BEC clause 6.11.1)

(a) General Requirements

- i) BEC clause 6.11.1 requires the minimum thickness of insulation to be applied to cold surfaces of pipework, ductwork and AHU to be in accordance with the tabulated values in BEC Tables 6.11a, 6.11b and 6.11c respectively, which specify the thickness with regard to the thermal conductivity of the insulating material, the surface coefficient of the insulation's external surface, the line temperature of the fluid carried, and the surrounding ambient conditions.
- ii) BEC Tables 6.11a, 6.11b and 6.11c are meant for insulation to site-installed pipework and ductwork and site assembled AHU/FCU casing, and not for manufacturer-applied insulation to pipework/ductwork/casing integral to chiller, unitary air-conditioner, AHU or FCU ex-factory.
- iii) Given insulation products usually come in cylindrical sections, tubes or sheets of standard thickness, which may not fully match all the tabulated thickness figures in BEC Tables 6.11a, 6.11b and 6.11c. As such, it would be common that the applied insulation has to be slightly thicker than the tabulated value.
- iv) The equations calculating the thickness are given in items (b) & (c) below, which are common heat transfer equations. For purpose of simplification, BEC clause 6.11.1 specifies as requirement the tabulated values and not the equations. The tabulation provides the convenience of knowing the required thickness without going through the reiterative calculations in item (b) below. Values of thermal conductivity and surface coefficient of the insulating materials could normally be found in product catalogues or supplier's technical brochures of these materials.

There are insulation materials with thermal conductivity λ or surface coefficient h different from those in the tables, and likewise there may be different line temperatures θ_l . Under the circumstances the equations in item (b) may be used to calculate the thickness; attention is drawn to the remark in item (d) below on ambient conditions to be adopted.

- v) BEC Table 6.11c specifies the insulation thickness (for ductwork and AHU casing) for a temperature difference (between the air inside duct/casing and its surrounding) of 20^oC and of 15^oC. Calculations for 10^oC temperature difference (typically for return air duct) is given in TG Table 6.11.1 (a) below, which may be deemed as a supplement to BEC Table 6.11c for thickness values at the temperature difference of 10^oC.
- vi) The calculated thickness decreases with decreasing temperature difference. A

minimum thickness of 13 mm is suggested for calculated thickness below this value.

- vii) BEC Table 6.11c governs, as per the introductory paragraph in BEC clause 6.11.1, ductwork carrying cooled air. BEC Table 6.11c thus does not govern ductwork carrying heated air. Ductwork not carrying cooled air but carrying fresh air are not governed, as such are less energy related, and likewise ductwork carrying exhaust air are not governed; nevertheless these ductwork may still have to be insulated to avoid condensation.

Table 6.11.1 (a) : Minimum Insulation Thickness for Ductwork and AHU										
Casing^{@1}										
Ambient Condition	Outdoor ^{@2}				Unconditioned Space ^{@2}				Conditioned Space ^{@2}	
Thermal conductivity λ (W/m-°C) ^{@3}	0.024		0.04		0.024		0.04		0.024	0.04
Surface coefficient h (W/m ² -°C) ^{@4}	9	13.5	9	13.5	5.7	10	5.7	10	any value	
Temperature difference between air inside duct/casing and surrounding of duct/casing	Insulation thickness (mm) ^{@1}									
10 °C	13	13	21	14	20	13	33	19	13	18
Remarks ^{@1 to @4}										
This table may be regarded as a supplement to BEC Table 6.11c and the same remarks therein apply to both tables.										

(b) Heat Transfer Equations for Pipework

The following approach using heat transfer Equations (a) and (b) has been used in arriving at the tabulated values in BEC Tables 6.11a and 6.11b. Equation (b) specifically accounts for the heat transfer over a circular surface.

- i) Calculate using equation (a) the provisional thickness χ (unit – mm) based on known values of the variables in Equation (a).

$$\chi = 10^3 \times \lambda/h \times \{(\theta_d - \theta_1)/(\theta_m - \theta_d)\} \dots\dots\dots \text{Equation (a)}$$

Where h = Surface coefficient of external surface of insulation - W/m²-°C

λ = Thermal conductivity of insulating material - W/m-°C

θ_d = Dew point temperature - °C

θ_1 = Temperature of the cold surface (line temperature) - °C

θ_m = Temperature of the ambient still air - °C

- ii) Roughly estimate the value of L_a based on general engineering practice, and calculate using Equation (b) the provisional thickness χ (unit – mm) based on known values of the variables in Equation (b).

$$\chi = 0.5 (d_o + 2L_a) \times \ln [1 + 2L_a/d_o] \dots\dots\dots\text{Equation (b)}$$

Where L_a = Estimated minimum thickness – mm, which will converge to become the actual value through iterations

d_o = Outside diameter of pipe or tube – mm

- iii) Compare the two calculated values of thickness in items (i) and (ii). The estimated L_a value will be deemed to be the actual thickness if the two χ values are reasonably close to each other. Should the two values not be reasonably close, conduct an iteration of Equation (b) with another estimated likely converging value of L_a .

(c) Heat Transfer Equation for Ductwork

Equation (a) above has been used in arriving at the tabulated values in BEC Table 6.11c. The use of Equation (b) is not required, as no circular surface is involved. Simply calculate using Equation (a) the thickness χ (unit – mm) based on known values of the variables in Equation (a).

(d) Ambient Conditions

The respective surrounding temperature and humidity are fixed for each of the ambient conditions of “outdoor”, “unconditioned space” and “conditioned space”. The adherence to a fixed temperature and humidity for an ambient condition serves to provide the uniformity in the determination of insulation thickness for that ambient condition.

A false ceiling void is normally regarded as an unconditioned space, unless it also serves as a return air plenum or its segregation is on perforated panels or slats.

6.11.2 Insulation for Outdoor or Unconditioned Space (BEC clause 6.11.2)

In order to prevent degradation of insulation due to moisture ingress, over time in particular, which is common for outdoor and unconditioned space applications, BEC clause 6.11.2 requires the insulation to be of water vapour retardant type, examples being the closed cell type insulation, fiberglass insulation with multi-layer double-side reinforced aluminium foil (to achieve water vapour permeance) and sealed at joints using aluminium foil adhesive tape, insulation coated with heavy duty mastic over reinforcing membrane etc. For insulation in plant rooms or areas with likely frequent visits by O&M personnel, it is a good engineering practice to further protect the insulation with metal cladding or cement plaster.

6.12 Air-conditioning Equipment Efficiency (BEC clause 6.12)

6.12.1 Minimum Allowable Efficiency at Standard Rating Condition

BEC Tables 6.12a and 6.12b specify the minimum full load coefficient of performance (COP) of an equipment at the corresponding standard rating condition. The COP is irrespective of the type of refrigerant e.g. R407c, R134a, R410a etc. used in the vapour compression cycle of the equipment. A standard rating condition is a reference condition of the COP, whereas the operation conditions are left to the discretion of the building operator. The standard rating conditions in the BEC are specific to Hong Kong weather and applications. The COP at the standard rating condition may be found in the equipment catalogue of suppliers or manufacturers, and should the data not be shown the supplier or manufacturer should be consulted for provision of more detailed technical brochure that contain the data. Attention is drawn to the remarks in the tables, in respect of the determination of COP for equipment with high static fans based on normal fans for free air flow.

6.12.2 Unitary Air-conditioner

(a) Room air-conditioner (BEC clause 6.12.2)

For a room type unitary air-conditioner or room air-conditioner, under the scope of the Mandatory Energy Efficiency Labelling Scheme under Energy Efficiency (Labelling of Products) Ordinance (Cap. 598), BEC clause 6.12.2 requires the equipment to fulfill Energy Efficiency Grade 1 or Grade 2 requirement.

Room air-conditioners under the Labelling Scheme include the single package window type and wall mounted split type, but not the ceiling mounted type, floor standing type, fan coil unit type, and types with ductwork for supply or exhaust air. The equivalent COP of Grade 1 and Grade 2 are given in TG Table 6.12.2 (a) below.

Table 6.12.2 (a) : Equivalent COP Range of Mandatory Energy Efficiency Labelling Scheme (MEELS) Grade 1 and Grade 2			
<u>Grade of MEELS</u>	<u>Type of Air Conditioner</u>	<u>Allowable Energy Consumption Index in MEELS</u>	<u>Equivalent COP Range at Rating Condition</u>
1	Window Type	≤ 85%	≥ 2.66
	Split Type		≥ 3.04
2	Window Type	95% to > 85%	2.38 to < 2.66
	Split Type		2.72 to < 3.04

(b) Other Unitary air-conditioner

The minimum full load COP for unitary air-conditioners of types other than the room air-conditioner type are specified in BEC Table 6.12a, which includes the single packaged type, ceiling mounted split type, floor standing type, fan coil unit type, ductwork connected type, variable refrigerant flow type, multi-split type and

heat pump type.

6.12.3 Chiller (BEC Table 6.12b)

BEC Table 6.12b specifies the COP for the common types of chillers in Hong Kong. The table has not included the less common chiller types such as absorption chiller, heat recovery chiller, ice making chiller, evaporatively-cooled chiller etc. The evaporatively-cooled chiller refers to a chiller with an evaporatively-cooled condenser that condenses the refrigerant in the condenser tubes by mechanically circulating over the exterior tube surfaces with a mixture of air and water.

6.13 Energy Metering (BEC clause 6.13)

(a) BEC clause 6.13 requires the provision of continuous monitoring devices for energy metering. A summary in table form is given in TG Table 6.13(a) below.

Table 6.13 (a) : Energy Metering for Air-conditioning Equipment and Chilled/Heated Water Plant		
<u>Equipment / Plant</u>	<u>Capacity</u>	<u>Parameters to be measured</u>
Chiller, heat pump or unitary air-conditioner	≥ 350kW (cooling /heating)	<u>Input, electrical</u> power (kW); energy (kWh)
Chilled/heated water plant		<u>Output, cooling/heating</u> power (kW); energy (kWh), COP

(b) Both BEC clauses 6.13.1 and 6.13.2 specify the same set of measuring parameters. For a measurement to be meaningful, the set of parameters in TG Table 6.13(a) above should be taken at the same instant of time. The measurement of input power would require the provision of an electrical power meter based on electrical current and voltage, and the measurement of output power would require the provision of a thermal power meter based on water flow rate and temperature difference. The measurement of energy, input or output, would require the power metering to incorporate an accumulative function for the measured data over time and an analytical function to convert the power over successive time intervals into energy terms for adding-up to give the cumulative energy value.

(c) The energy metering includes the data acquisition instrumentation that captures the raw information of electrical current and voltage for electrical power/energy, and of flow or water pressure and temperature for thermal power/energy. For temperature capturing, the temperature sensor is an instrumentation usually located in a well inside the water pipework, the sensor may be a thermocouple, a resistance temperature detector, a thermister etc., and for flow capturing, the instrumentation may be a flow meter of electromagnetic type, ultrasonic type,

vortex type, turbine type etc. The instrument should be suitably located, and in particular for water flow sensing should be longitudinally (in respect of pipe run) at certain pipe diameters beyond any in-line sharp bend or transition to avoid over turbulence that may render the measured data inaccurate. The raw data captured may be transmitted via transducers as appropriate to a localized device such as within the chiller control panel or the main body of the power/energy meter, for output to man-machine interface display, for data storage, and/or for calculation of power and energy. Capability of the energy metering, if any, of data logging and spreadsheet output would be an added benefit, with which better analyses of the equipment and plant performance can be conducted. The data may be further transmitted for enhanced monitoring and control to the central control & monitoring system or BMS with energy management function.

- (d) There are situations that due to limited plant room spacing it is practically difficult to fit in a flow meter to a chiller. BEC clause 6.13.3 addresses to these situations by making use of the gauged water pressure drop across the chilled water tubing of the evaporator to check against the manufacturer's pressure-flow curve to obtain the chilled water flow rate. These flow rate data together with the corresponding chilled water temperature readings at the inlet and outlet of the evaporator can be based upon to calculate the cooling energy output of the chiller. Likewise for a heat pump, its heating energy output can be calculated in a similar manner by making use of the data of pressure drop and temperature difference across its condenser.

7. Energy Efficiency Requirements for Electrical Installation

7.1 Scope of Application (BEC clause 7.1)

7.1.1 Comprehensive View on Applicability (BEC clause 7.1.1)

BEC Section 7 provides the guidelines for electrical installations. To gain a comprehensive view in relation to the Ordinance, BEC clause 7.1 should be read in conjunction with –

- BEC Sections 3 & 4 that briefly describe the scope and limits of the application of the Ordinance based on its prescribed requirements in Parts 2 & 3; and
- TG Sections 3 & 4 that elaborate on the scope and limits of application and the necessary steps to demonstrate the compliance with the Ordinance and the BEC.

For reference, the interpretation of ‘electrical installation’ under the Ordinance and the BEC is extracted below -

‘Electrical installation’, in relation to a building, means fixed equipment, distribution network or accessories for electricity distribution or utilization in the building;

7.1.2 Examples of BEC Applicable Installations (BEC clause 7.1.2)

In respect of certain types of electrical installations, BEC clause 7.1.2 affirms for the avoidance of doubt the Ordinance’s applicability to these installations, and examples thereof are given in TG Table 7.1.2 below.

<u>Table 7.1.2 : Examples of BEC Applicable Electrical Installations</u>	
<u>Examples</u>	<u>Justifications</u>
Circuit for luminaire, chiller, unitary air-conditioner, AHU, fan, air-conditioning pump, lift, escalator, plumbing pump, sump pump, gondola etc.	BEC clause 7.1.2 (a)
Circuit for lighting solely used for illuminating an exhibit or product on display	BEC clause 7.1.2 (a) (the Ordinance and the BEC applies not to the lighting but to the circuit)
Circuit for exhaust and smoke extract fan serving basement, used for general exhaust during normal operation and for smoke extract during fire mode	BEC clause 7.1.2 (b)
Circuit for maintained type emergency lighting, fireman’s lift (also used for routine service) etc.	BEC clause 7.1.2 (b)

7.1.3 Examples of BEC Non-applicable Installations (BEC clause 7.1.3)

BEC clause 7.1.3 lists certain electrical installations to which the Ordinance does not apply, and examples of these installations are given in TG Table 7.1.3 below.

Table 7.1.3 : Examples of BEC Non-applicable Electrical Installations	
<u>Examples</u>	<u>Justifications</u>
Equipment or cabling at high electrical voltage, such as chiller that operates at 3.3 kV and associated high voltage circuit	BEC clause 7.1.3(a)
Equipment or cabling at extra low voltage, such as of close circuit surveillance TV system, public address system etc. that operate at 24V	
Cabling, exhaust fan etc. that are provided by electricity supplier and installed in consumer's substation	BEC clause 7.1.3(b)
Motor of fire service pump and cabling solely for the pump	BEC clause 7.1.3(c) (fulfilling item 1 of Schedule 2 of the Ordinance)
Cabling solely for lighting solely used for surgical operation, cabling solely for dialysis machine, cabling solely for image-guided radiation therapy etc. (such as in a hospital)	BEC clause 7.1.3(c) (fulfilling item 2(a), 2(b) or 2(c) of Schedule 2 of the Ordinance)
Cabling solely for non-maintained type emergency lighting	BEC clause 7.1.3(c) (fulfilling item 2(d) of Schedule 2 of the Ordinance)
Cabling solely for an equipment (e.g. in an industrial unit) solely used for industrial manufacturing	BEC clause 7.1.3(c) (fulfilling item 4 of Schedule 2 of the Ordinance)
Cabling solely for a fume cupboard (e.g. in a university) solely used for research, and the fan motor solely serving the fume cupboard	BEC clause 7.1.3(c) (fulfilling item 5 of Schedule 2 of the Ordinance)
Generator set and outgoing cabling	Generator set is not an electrical installation for electricity distribution or utilization
Appliances not fixed in position such as portable desk lamp, portable ventilating fan, flexible extension lead with multi-socket adaptor	Portable appliances are not fixed equipment or fixed distribution network, and are thus not governed by the Ordinance

7.2 General Approach (BEC clause 7.2)

The energy efficiency requirements in BEC clauses 7.4 to 7.7 are based on the general

approach to energy efficiency given in BEC clause 7.2.

7.3 Definitions (BEC clause 7.3)

BEC Section 2 provides the interpretations and abbreviations related to the BEC and the Ordinance, including those for electrical installation.

7.4 Power Distribution Loss (BEC clause 7.4)

(a) Distribution Transformer (BEC clause 7.4.1)

To reduce power losses in transformers, including no-load and load-related I^2R losses and eddy-current losses, BEC clause 7.4.1 specifies the minimum transformer efficiency for a transformer provided by the developer or building owner, and the efficiency should be based on the testing in accordance with IEC Standard 60076-1 Ed. 2.1. Transformers provided by the electricity supplier are not governed by the BEC. It is common that the winding or copper loss in the transformer varies approximately as the square of the load current, which varies slightly with operating temperature, and the core or no-load loss is more or less steady at constant voltage and frequency.

(b) Maximum Allowable Circuit Copper Loss (BEC clauses 7.4.2 to 7.4.6)

i) General

To minimize the I^2R losses in electrical circuits, BEC clauses 7.4.2 to 7.4.6 specify the requirements of maximum allowable circuit copper loss in circuits, which are expressed as a percentage of the circuit active power - the percentage circuit copper loss is given by the ratio in percentage, of the total copper losses (in Watt) in the conductors of the circuit and the total active power (in Watt) transmitted along the circuit conductors, when the circuit is carrying the designed circuit current.

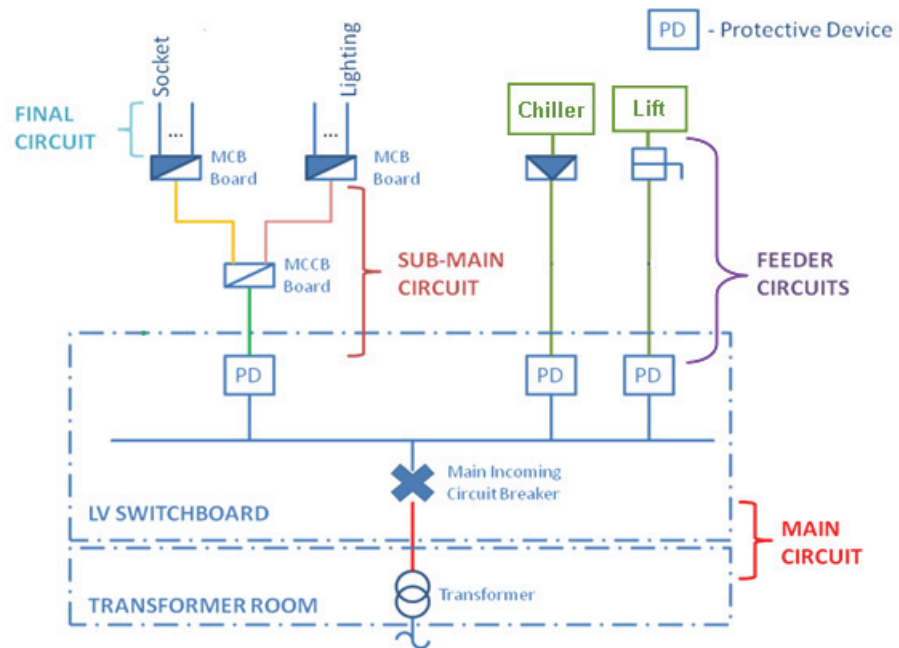
To fulfill the requirements, a circuit should be adequately sized. The I^2R losses are proportional to the resistance of the circuit's conductor, which is governed by its material and length. A circuit's current carrying capacity is also affected by the manner it is fixed, enclosed, clipped on tray, and grouped with other circuits, and the properties of its sheathing materials. In sizing of circuits, one based on conventional voltage drop criteria may not necessarily fulfill the % copper loss criteria, which demand in general a slightly larger conductor cross-sectional area. The losses in a circuit are commonly known as copper losses irrespective of the material of the circuit conductor such as aluminium which is not copper. Illustrative mathematical equations and calculations of circuit copper losses are also given hereinafter in TG clauses 7.8 and 7.9.

ii) Requirements for Different Types of Circuits

The copper loss requirements are summarized in TG Table 7.4 (b) ii) below for the different types of circuits - main circuit, feeder circuit, sub-main circuit, and final circuit, which are diagrammatically illustrated in TG Figure 7.4 (b) ii) below.

Table 7.4 (b) ii) : Summary of Maximum Allowable Circuit Copper Loss			
<u>Circuit Type</u>		<u>Connection</u>	<u>Copper Loss</u>
Main Circuit		Distribution transformer to low-voltage switch board (LV SwBd)	<ul style="list-style-type: none"> - $\leq 0.5\%$, of total active power, <li style="text-align: center;">or transformer room and main switch room directly beside, above or below each other, and - Neutral conductor to be sized with rating \geq rating of phase conductor
Feeder Circuit		From LV SwBd, or from isolator after main fuse ^{@3} of electricity supplier, direct to major equipment	$\leq 2.5\%$ of total active power ^{@1}
Sub-main Circuit	non-residential building	$\leq 100\text{m}$	$\leq 1.5\%$ of total active power
		$> 100\text{m}$	$\leq 2.5\%$ of total active power ^{@2}
	residential building		$\leq 2.5\%$ of total active power
Final circuit $> 32\text{A}$ (based on circuit protective device rating)		Local distribution board to equipment / outlet point (e.g. luminaire, socket)	$\leq 1\%$ of total active power
<p><u>Remarks :</u></p> <p>^{@1} requirement does not govern a circuit solely used for correction of reactive and/or distortion power</p> <p>^{@2} subject to sum of losses in sub-main and over 32 A final circuits, if any, $\leq 2.5\%$</p> <p>^{@3} refers to a mains supply via a direct feed cable of the electricity supplier, which is adopted when the supply does not involve a consumer sub-station.</p>			

Figure 7.4 (b) ii) : Illustration of different types of circuits specified in BEC clause 7.4



iii) Sub-main Circuit (BEC clause 7.4.4)

Inclusion of all components of a sub-circuit in the calculation of % copper loss

A sub-circuit may consist of a common portion with branch-offs. Consider a sub-circuit with an intermediate distribution board below. The approach in calculating sub-circuit copper loss, sub-circuit active power and sub-circuit % copper loss is shown in TG Table 7.4(b) iii).

Figure 7.4(b) iii): Sub-circuit with intermediate distribution board

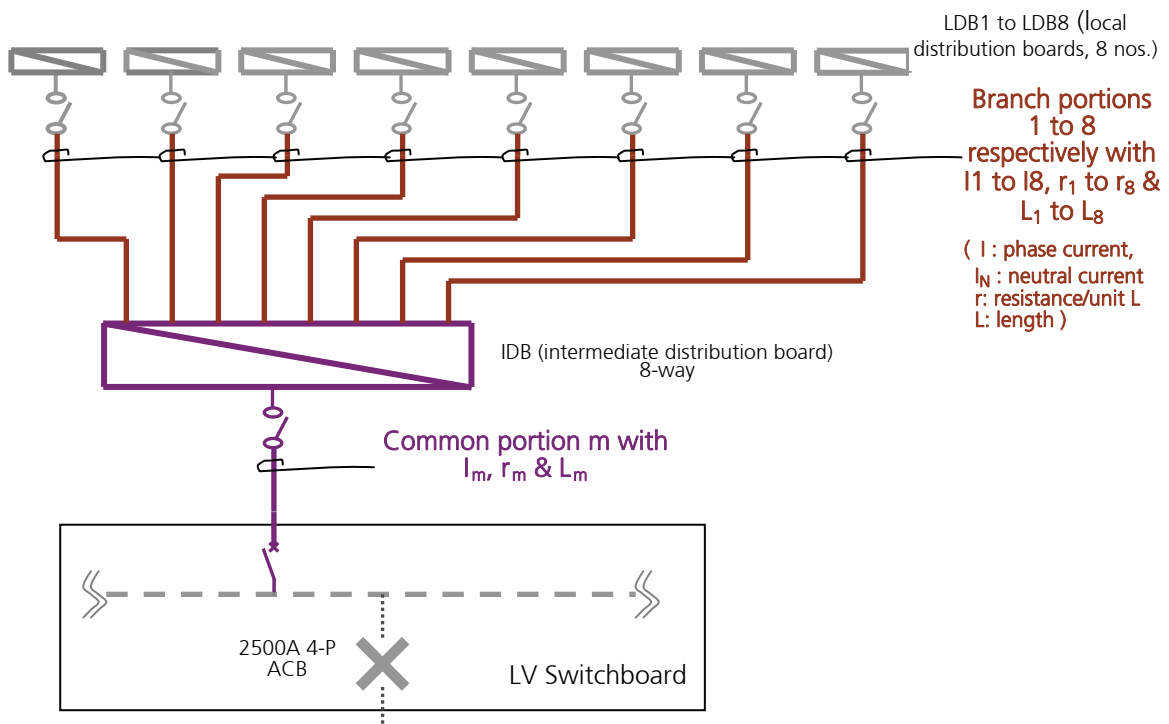


Table 7.4 (b) iii) : Calculation of % Copper Loss of Sub-circuit with Intermediate Distribution Board

(j standing for m, 1, 2, 3, 4, 5, 6, 7 or 8)	Root Mean Square (rms) Design Current I_{j_b} (A)	Resistance r_i ($m\Omega$ /metre)	Length L_j (metre)	Copper Loss P_{copper} (W)	Sub-circuit Active Power (W)
Common portion m	I_m	r_m	L_m	$(3 \times I_m^2 + I_{mN}^2) \times r_m \times L_m \times 1/1000$	$\sqrt{3} \times 380 \times I_{m1} \times \cos\theta$
Branch portion 1	I_1	r_1	L_1	$(3 \times I_1^2 + I_{1N}^2) \times r_1 \times L_1 \times 1/1000$	$(I_{m1}$ is the value of the fundamental component, and $I_{m1} \neq I_m$; I_m is the root mean square value of the fundamental and all harmonic components; and $\cos\theta$ is the displacement power factor.)
Branch portion 2	I_2	r_2	L_2	$(3 \times I_2^2 + I_{2N}^2) \times r_2 \times L_2 \times 1/1000$	
Branch portion 3	I_3	r_3	L_3	$(3 \times I_3^2 + I_{3N}^2) \times r_3 \times L_3 \times 1/1000$	
Branch portion 4	I_4	r_4	L_4	$(3 \times I_4^2 + I_{4N}^2) \times r_4 \times L_4 \times 1/1000$	
Branch portion 5	I_5	r_5	L_5	$(3 \times I_5^2 + I_{5N}^2) \times r_5 \times L_5 \times 1/1000$	
Branch portion 6	I_6	r_6	L_6	$(3 \times I_6^2 + I_{6N}^2) \times r_6 \times L_6 \times 1/1000$	
Branch portion 7	I_7	r_7	L_7	$(3 \times I_7^2 + I_{7N}^2) \times r_7 \times L_7 \times 1/1000$	
Branch portion 8	I_8	r_8	L_8	$(3 \times I_8^2 + I_{8N}^2) \times r_8 \times L_8 \times 1/1000$	
<p>Sub-circuit copper loss = $\sum P_{copper}$ (sum of above 9 portions)</p> <p>= $1/1000 \times \{ [(3 \times I_m^2 + I_{mN}^2) \times r_m \times L_m] + \sum [3 \times (I_{j_b} \times df)^2 + (I_{jN} \times df)^2] \times r_j \times L_j \}$ where j = 1 to 8</p>					
<p>Sub-circuit % copper loss = $\sum P_{copper} \div$ sub-circuit active power</p> <p>= $1/1000 \times \{ [(3 \times I_m^2 + I_{mN}^2) \times r_m \times L_m] + \sum [3 \times (I_{j_b} \times df)^2 + (I_{jN} \times df)^2] \times r_j \times L_j \}$</p> <p>$\div \{ (\sqrt{3} \times 380 \times I_{m1} \times \cos\theta) \}$</p>					
<p>Diversity factor df</p> <p>The diversity factor df of the common portion m should be applied to each of the design rms current I_{j_b} (with TPF & THD effect taken into account) flowing through each branch portion. Take for example with design current I_{1_b} to I_{4_b} all being 50A, and I_{5_b} to I_{8_b} all being 60A, and the adoption of 400A for I_m, the $df = 400 \div (4 \times 50 + 4 \times 60) = 0.91$.</p> <p>$I_{mN}$ and I_{jN} denote respectively the neutral current in the common portion m and the neutral current in branch portions 1 to 8. The inclusion of the neutral current I_N in this table serves to illustrate that the equations can cater for copper loss calculations involving I_N, which may not be neglected in the case of triplen harmonics or unbalanced single phase loads (discussed respectively in TG clauses 7.6(b) & 7.6 (f) in three-phase 4-wire circuits.</p> <p>The application of df to the branch portions tallies more with the actual scenario that has the total current in the common portion within 400 A. (The 50 A and 60A in the branch portions should have included the anticipated (or measured) power factor and harmonic currents.)</p>					

iv) Feeder Circuit (BEC clause 7.4.3)

A feeder circuit refers to one (usually from the LV switchboard) dedicated to feed a major current-using equipment or a collective group of such equipment. Examples of feeder circuits are –

- circuit dedicated for the central chiller plant such as one running from the LV switchboard and splitting up via a local distribution board (that may be a switchboard itself given the large power drawn by the plant) or motor control centre into its final circuit components to terminate at the various chillers and pumps,
- circuit dedicated for a group of lifts (or escalators) such as running from the LV switchboard and splitting up via a local distribution board or motor control centre into its final circuit components to terminate at the individual lifts (or escalators) of the group,
- circuit dedicated for a group of AHUs (each say driven by a motor exceeding 1 kW), running from the LV switchboard and splitting up via a local distribution board or motor control centre into its final circuit components to terminate at the individual AHUs of the group, or
- circuit dedicated for a group of plumbing/sewage pumps, running from the LV switchboard and splitting up via a local distribution board or motor control centre into its final circuit components to terminate at the individual pumps of the group.

Circuit feeding FCUs or lighting and small power

A circuit running from the LV switchboard feeding a group of FCUs (each usually drawn by a motor of less than 1 kW and usually via plug and socket) and feeding miscellaneous equipment or services is usually not regarded as a feeder. Likewise a circuit running from the LV switchboard and feeding luminaires or power sockets is not regarded as a feeder.

Inclusion of all components of a feeder in the calculation of % copper loss

A feeder circuit may have a configuration similar to that shown in TG Figure 7.4(b)iii) above, except that the branch portions 1 to 8 terminate at, instead of the local distribution boards, the respective current using equipment (i.e. LDB1 to LDB8 are replaced this time with current using equipment). The same approach indicated in TG Table 7.4(b)iii) above should be adopted in the calculation of % copper loss for the complete feeder circuit.

v) Final Circuit (BEC clause 7.4.5)

For final circuits, the copper loss requirement governs those with circuit protective device rating above 32A, meaning that circuits such as for lighting

and small power with design current lower than or at 32 A are not governed.

vi) Effect of Power Factor & Harmonics (BEC clause 7.4.6)

BEC clause 7.4.6 specifies that the effects of total power factor (TPF) and total harmonic distortion (THD) of current are to be accounted for in the calculation of % copper loss, which means that the loads of inductive nature and the loads of non-linear nature should be assessed in parallel with conventional resistive loads. In particular for the main circuit, the use of a neutral conductor with cross-sectional area less than that of the phase conductor is not allowed, given the possible large triplen harmonic currents that may exist in the main circuit's neutral conductor in a building with large proportion of non-linear loads that is quite common nowadays.

vii) Residential Buildings & Industrial Buildings Having a Common Area

In respect of a circuit, such as a sub-circuit, passing through or in the common area such as electrical switch room, common cable duct, common corridor etc., the maximum allowable circuit copper loss requirements (TG Table 7.1.2) govern the circuit's CBSI upstream portion in the common area (TG clause 3.1.2). The electricity supplier metering point may be a point to differentiate the CBSI upstream portion of a circuit from its downstream portion which may be regarded as a non-CBSI serving a unit; the demarcation is also mentioned in TG Table 4.2.4(a). The same principle applies to the residential portion of a composite commercial/residential building having a common area.

The same principle above applies to industrial buildings and the industrial portions of commercial/industrial composite buildings.

viii) Circuit under Responsibility of Two Parties

It is common that the upstream portion of a circuit, such as a sub-circuit or feeder, may be installed first, such as by the developer of the building, and its downstream portion at a later date as alteration or retrofitting works by another responsible person. The REA/designer appointed by the developer, building owner or responsible person of the upstream portion should when sizing the circuit include in the calculation of copper loss the future portion (to be installed by the future responsible person) which should be assumed a reasonable cross-sectional area and length. The building owner or responsible person of the upstream portion should maintain a proper record of the sizing and design allowance for copper loss for reference by the future REA/designer and responsible person.

On the other hand, the REA/designer appointed by the responsible person of the downstream portion of the circuit may have it sized with reference to the record (of the upstream portion) if available, which if unavailable the

REA/designer should exercise his/her professional judgement to reasonably estimate the copper loss of the upstream portion.

(c) Guidelines on Calculation of Copper Loss

Further guidelines on calculation of copper loss are given in TG clause 7.8.

7.5 Motor Installation (BEC clause 7.5)

The requirements in BEC clauses 7.5.1 and 7.5.2 are applicable to general purpose motors, including motors serving fixed equipment such as AHUs, fans, water pumps, gondolas etc. Exemptions are however given to motors serving fire service pumps, motors for high temperature operation, motors of chillers etc., as specified in the relevant clauses of the BEC.

7.5.1 Motor Efficiency (BEC clause 7.5.1)

BEC clause 7.5.1 specifies the minimum nominal full-load motor efficiency for single-speed three-phase totally enclosed induction motors, and the efficiency should be based on the testing results in accordance with international standards so specified. Having specified the types of motors governed, there are types not governed, examples of which are given in TG Table 7.5.1 below.

<u>Table 7.5.1 : Examples of Motors Not Governed by Minimum Efficiency Requirement</u>	
<u>Examples</u>	<u>Justifications</u>
Single-phase motor	Not of types included in BEC clause 7.5.1
6-pole three-phase motor	
2-speed motor	
Motor with rated output power < 0.75 kW	
Open type motor	
Motor with brushes, commutators, slip rings or electrical connections to the rotor	
Motor, in a submersible pump, which is enclosed in a waterproof enclosure and cannot be tested separately from the pump	Exemption specified in BEC clause 7.5.1
Motor, of a fan, with motor frame and fan mounting integrated in a single assembly, and cannot be tested separately from the fan	
Motor with operating ambient temperature above 40°C	

Losses in induction motors include losses that vary with the load and those that are relatively constant irrespective of the load, a common split being 70% to 30%. The electrical energy that is not converted to motion is mostly dissipated as heat. The

electrical load losses include the rotor resistance loss, the stator resistance loss and the stray losses. When under no load operation, these copper losses are very small. However once a load is applied, these losses, the I^2R losses, will increase as the square of the motor current. In addition there are iron losses in the magnetizing circuit of the motor, and these losses, the eddy current and hysteresis losses, are related to voltage and are therefore relatively constant irrespective of load. There are mechanical losses too, which are the friction in bearings, the turbulence around the rotor as it rotates and the windage of the cooling fan. The higher the motor efficiency, the lower would these losses be. Motors are affected by harmonic currents and unbalanced currents; TG clause 7.6 briefly describes the effects.

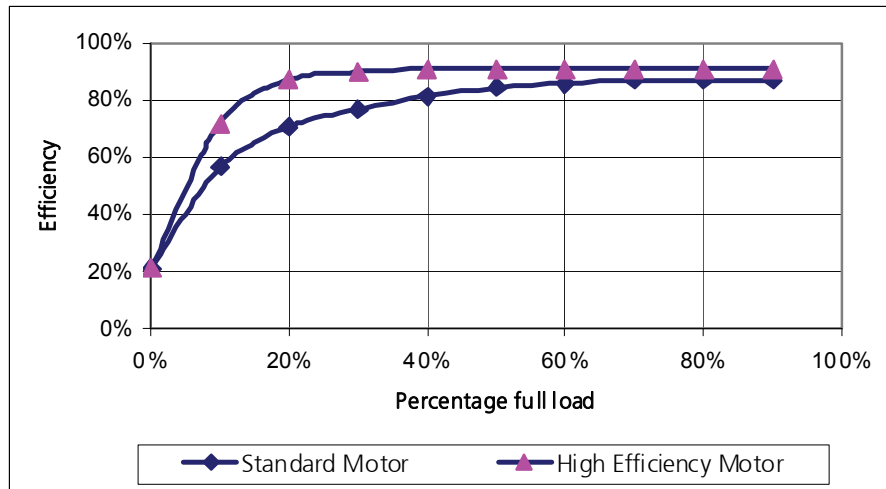
7.5.2 Motor Sizing (BEC clause 7.5.2)

- (a) BEC clause 7.5.2 specifies an allowable ratio of motor output power to anticipated system load power of maximum 125%, with permission to adopt the closest higher rating motor should the calculated output power not fall within the range of a standard motor. As an illustration of the permission, consider an anticipated system load of 5.8 kW. As 7.25 kW, given by 5.8×1.25 , is not within the standard range of motor, a standard motor at 7.5 kW can be selected.

The maximum allowable ratio requirement does not govern motors of 5 kW or less output power.

Efficiencies of motors vary with size, rating, load and make. TG Figure 7.5.2(a) shows a typical efficiency curve for motors with small to medium output power, from which it can be seen that the efficiency is close to constant down to about 70% full load and starts to decrease after this point, falling more rapidly at below 40%. It follows that provided motors are running at a reasonably constant load, oversizing by up to 25% will not seriously affect their efficiency, and with the maximum allowable ratio requirement, motors complying with the BEC would be operating at close to their optimum efficiency levels most of the time. On the contrary, oversized motors would operate at the low efficiency range most of the time. Other than consuming more energy to operate the motor, unnecessary motor oversizing would increase the initial cost of the motor itself, and the capital cost of the associated switchgear, starting devices and wiring, and may require higher capital cost for power factor correction (given the motor's power factor falling off more rapidly than its efficiency at reduced loads).

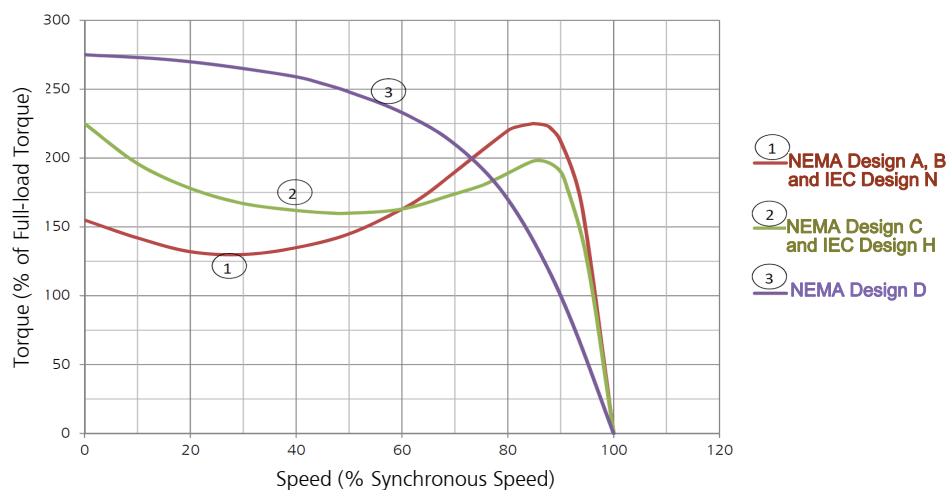
Figure 7.5.2 (a) : Typical motor efficiency curve for small to medium size motors



- (b) The maximum allowable ratio requirement governs general purpose motors and does not govern motors for loads that require a high starting torque, such as torque characteristics demonstrated by motors of IEC Design H, NEMA Design C, NEMA Design D or better.

The International Electrotechnical Commission (IEC) and the National Electrical Manufacturers Association, USA (NEMA) classify motors according to speed, torque, current, slippage etc. TG Figure 7.5.2(b) below illustrates typical speed-torque characteristic curves of IEC and NEMA Design motors, in which it can be seen that the NEMA Design C and Design D and IEC Design H motors offer a higher starting torque, for which the sizing do not have to be governed by the maximum 125% ratio requirement.

Figure 7.5.2 (b) Typical speed-torque characteristics for motors



7.5.3 Motors for Air-conditioning Equipment, for Fan of Distribution Transformer and for Lift & Escalator (BEC clause 7.5.3)

BEC clause 7.5.3 gives the exemptions from the motor efficiency requirement and the

power to load ratio requirement to motors of compressors of chillers or unitary air conditioners, motors of ventilation fans integrated with distribution transformers, and motors of lifts or escalators, provided that these equipment comply respectively with the relevant requirements of air-conditioning equipment efficiency, transformer efficiency, and electrical power of lift and escalator. The exemption is based on the rationale that these equipment are already governed in one way or another under the BEC.

7.6 Power Quality (BEC clause 7.6)

(a) General Requirements on TPF & THD (BEC clauses 7.6.1 and 7.6.2)

i) Applicability

BEC clauses 7.6.1 and 7.6.2 specify respectively the requirements on total power factor (TPF) and total harmonic distortion (THD) applicable to a circuit –

- of three-phase and connecting to the electricity supplier’s meter, or
- single or three-phase, at or above 400 A based on circuit protective device rating.

The requirements are, for the circuit when carrying the corresponding designed circuit current –

- a minimum allowable TPF of 0.85, and
- the THD of current, in percentage of the fundamental current of the circuit, to fulfill the corresponding maximum allowable values specified in BEC Table 7.6.2, which is reproduced (with slight reconfiguration) as follows :

<u>Designed circuit current I</u>	$I < 40A$	$40A \leq I < 400A$	$400A \leq I < 800A$	$800A \leq I < 2000A$	$I \geq 2000A$
<u>THD</u>	20%	15%	12%	8%	5%

The THD requirements serve to minimize the I^2R losses as a result of THD.

ii) Demonstration of Compliance

The demonstration of compliance can be by virtue of –

- a. installing the relevant correction devices, or
- b. installing the relevant connection points (for the correction devices).

iii) Circuits Not Governed

It follows that a circuit –

- having protective device rating lower than 400A and not connecting to electricity supplier’s meter, or
- connecting to electricity supplier’s meter but of single-phase

is not governed by the requirements.

iv) Correction Devices OR Connection Points for the Devices

The BEC does not mandate the installation of TPF and THD correction devices, as there would be practical difficulties in accurately assessing the capacity of the correction device during design stage at which the actual load characteristics of power factor and harmonics may not be known. Instead, the provision in the circuit of a connection point for TPF and a connection point for THD are specified in BEC clauses 7.6.1.3 and 7.6.2.3. Nonetheless the REA/designer may opt to install the correction devices. To minimize losses in the circuit as a result of low TPF and/or high THD, the correction devices or the connection points should be at the source motor control centre or at the local distribution board. TG clause 7.6 (c) below elaborates on the connection point for correction device.

v) Group Compensation of THD (BEC clause 7.6.2.4)

In the case of a circuit principally for motors with variable speed drives, group compensation of THD for the motors is allowed, provided that the percentage harmonic content of the 5th order harmonics (at the variable speed drive input terminals during normal operation within the variable speed range) is less than 35%. 6-pulse variable speed drives, which are commonly used in variable flow pumps and fans, tend to generate 5th order harmonics with influential magnitude (typically 20% of the fundamental current).

vi) Circuits of Lifts & Escalators

The requirements on TPF and THD do not govern a circuit serving a lift or escalator, provided that the corresponding requirements in BEC clauses 8.5.1 and 8.6 are fulfilled.

(b) Reactive Loads & Non-linear Loads

Electrical loads in a building typically consist of resistive loads, reactive loads and non-linear loads.

Depending on how the power in successive sinusoidal waveforms from the mains source is drawn by the connected load in a circuit, not all the transmitted power are used in doing productive work. For a circuit carrying a simple resistive load, such as a filament lamp bulb or a heater element, the power may be viewed as in the form of a pure sinusoidal wave, and the current and voltage waveforms are in phase, i.e. they change polarity at the same instant successively. For such a load, all the electrical power and energy drawn from the mains source are converted into productive work of light and heat.

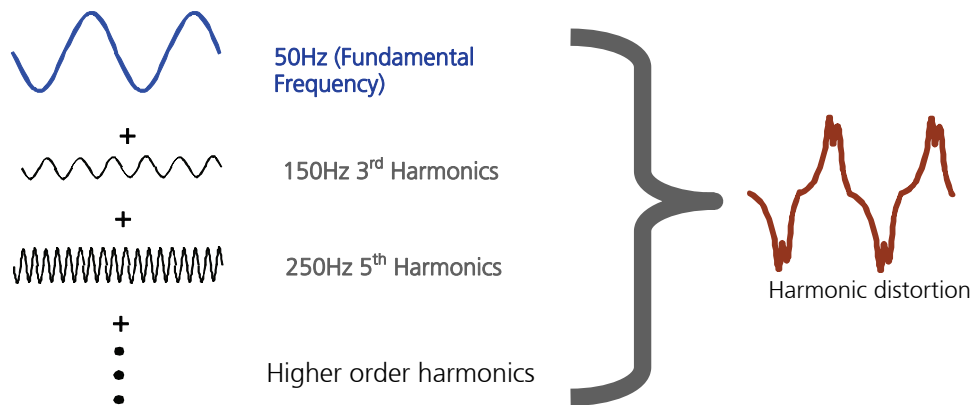
Contrary to the simple resistive load, a reactive load such as an induction motor behaves like a capacitor or inductor. Certain energy from the source or circuit would be temporarily stored by the reactive load at a certain instant of the power wave cycle, and would be returned back to the circuit a split second later in the same cycle. Repeating successively in each cycle, the energy stored and returned is not doing productive work but only adds to the current in the circuit. The term power factor, a ratio ranging from 0 to 1, is used to describe the extent of the productive work of a load. The ratio is given by the real power doing productive work to that of the apparent power that performs both productive and non-productive work, a close to 1 power factor implying an energy efficient load. For a linear circuit, the power factor also equals to the cosine function of the angle shift between the a.c. supply voltage and current in a power triangle. In a circuit supplying power to an induction motor, the current usually lags behinds the voltage. In the BEC, the term TPF of a circuit is interpreted as the ratio of the total active power of the fundamental wave, in Watt, to the total apparent power that contains the fundamental and all harmonic components, in Volt-Ampere. Harmonic current is described in the paragraph that follows.

With the advancement of power electronics, more and more non-linear loads are installed in buildings, typical ones being fluorescent lamps with controlgears, variable voltage variable frequency driving controllers of lifts & escalators, variable frequency variable speed drives for motors, personal computers, printers, fax machines etc., which rely on their built-in SMPS devices to configure the power cycles necessitated for the operation of the load. A SMPS or switching mode power supply device regulates the power from the source to the load, by converting the voltage and current characteristics of the power supply. The device continually switches between intensities of zero, low and full, resulting in the power supply having very little time at its full intensity, which minimizes the overall power and hence the energy drawn.

The change of waveform in a circuit with non-linear loads occurs in respect of both voltage and current. For simplicity purpose, the BEC specifies requirements only on distortion of current and not distortion of voltage, which usually would also be reduced upon improvement of current distortion.

For the non-linear circuit, the mains source current waveform is referred to as the fundamental waveform at the mains frequency, and the actual current in the circuit contains the components that are multiples of the mains frequency. In Hong Kong, the fundamental frequency is 50 Hz. The 2nd order harmonics would be at 100Hz, 3rd order harmonics at 150 Hz and so on.

Figure 7.6 (b) i) : Components of harmonic current



The term THD, in percentage of the fundamental current waveform, is used to describe the extent to which the waveform of the load deviates from its pure sinusoidal form as a result of the summation of all its harmonic effects. The concept of THD is diagrammatically shown in TG Figure 7.6(b) i) above. In equation form, the interpretation of THD of current is given in the BEC Section 2 as –

$$\%THD = \frac{\sqrt{\sum_{h=2}^{\infty} (I_h)^2}}{I_1} \times 100$$

where : I_1 = root mean square (r.m.s.) value of fundamental current
 I_h = r.m.s. value of current of the h^{th} harmonic order

The higher the %THD, the more the power or energy would be wasted in the electrical circuit. For a purely linear load, the I_h would be zero and hence the %THD also zero. With the presence of harmonic currents in a circuit, the apparent power needed to obtain the same active power to do productive work is significantly greater.

Accounting for the effects of TPF and THD, the approach for calculating circuit copper loss is elaborated in TG clause 7.8.

The typical adverse effects of harmonics in electrical circuits include degrading performance of equipment, overloading neutral conductors, creating unacceptable neutral-to-earth voltage, overheating motor windings, tripping fuses and circuit breakers incorrectly, damaging capacitor banks, causing malfunctioning of electronic equipment, creating undesirable electromagnetic wave interferences, overheating distribution transformers etc.

Given a sinusoidal wave having both polarities, the even order harmonics will usually be canceled. The majority of harmonic currents are odd-order harmonics, i.e. 3rd, 5th, 7th etc. Single-phase equipment such as personal computers and electronic ballasts are significant sources of triplen or odd multiples of the 3rd order

harmonics i.e. 3rd, 9th, 15th, 21st etc., and have magnitudes on the three phases additive in the neutral, resulting in a higher neutral current than the phase current. Harmonic voltages of the 5th, 11th, 17th etc. are negative sequence and would produce adverse effects such as negative torque in motors. The numbers of rectifiers (or pulse number) in an equipment with non-linear electrical characteristics determine the harmonic frequencies it generates. The harmonics, known as “characteristic harmonics” in many rectifiers can be represented using the equation $h = kq \pm 1$ where h is the order of the harmonics or harmonic number, k an integer starting from 1, and q the pulse number, and have decreasing magnitudes with increasing harmonic number. A 6-pulse variable speed drive (6 rectifiers) would produce 5th, 7th & 11th order (and other higher order) harmonics, each having magnitude respectively approximately 1/5 (0.2), 1/7 (0.143) & 1/11 (0.091) of that of the fundamental current. In terms of THD (when neglecting the other higher order harmonics, which have lower magnitudes), it would be $\sqrt{I_5^2 + I_7^2 + I_{11}^2} \times 100\% = \sqrt{0.2^2 + 0.143^2 + 0.09^2} \times 100\% = 26.2\%$. Likewise a 12-pulse drive (12 rectifiers) would generate 11th and 13th order harmonics with magnitudes respectively approximately 1/11 (0.091) and 1/13 (0.077) of that of the fundamental, and in terms of THD (when neglecting the other higher order harmonics) it would be $\sqrt{0.091^2 + 0.077^2} = 11.9\%$.

To have an appreciation of the effect of THD, take for example a 3-phase circuit having a design fundamental current of 100A to be wired with a 35 mm² 4/C PVC/SWA/PVC cable on a dedicated cable tray; the ambient temperature is 30°C, the circuit length is 40m, and the load has a DPF of 0.85. If the load is a linear load, the circuit copper loss would be 0.716 kW, whereas if the load has a 38.6% THD, the circuit copper loss would be 1.14kW or about 60% higher.

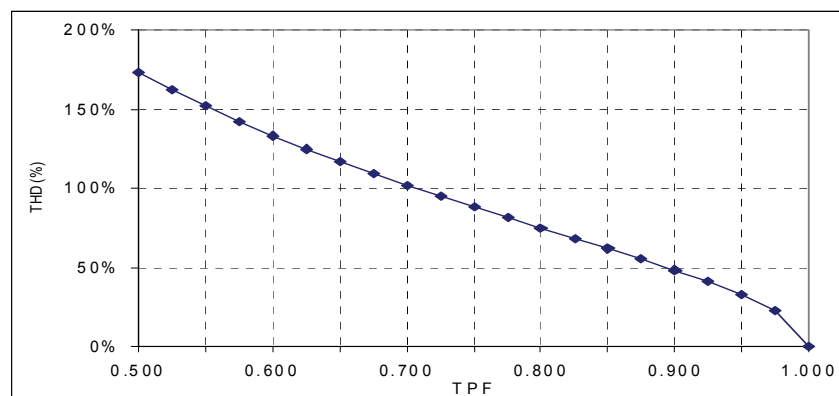
Impact of non-linear loads on TPF

In a circuit with non-linear loads, harmonic currents are induced and add to the fundamental current. The relationship between TPF and THD can be represented by the equation below.

$$TPF = \frac{\cos\theta}{\sqrt{1 + THD^2}} \quad \cos\theta \text{ being the displacement power factor (DPF)}$$

It can be seen that for a fixed $\cos\theta$, a high THD would result in a low TPF, the correction of which using a harmonic filter would be required. Figure 7.6(b)ii below gives an indication of the effect of THD on power factor for a unity DPF or $\cos\theta$. (TG clauses 7.8.2 and 7.8.3 further describe the TPF and THD calculations.)

Figure 7.6 (b) ii) : THD (y-axis) versus TPF (x-axis) for non-linear load

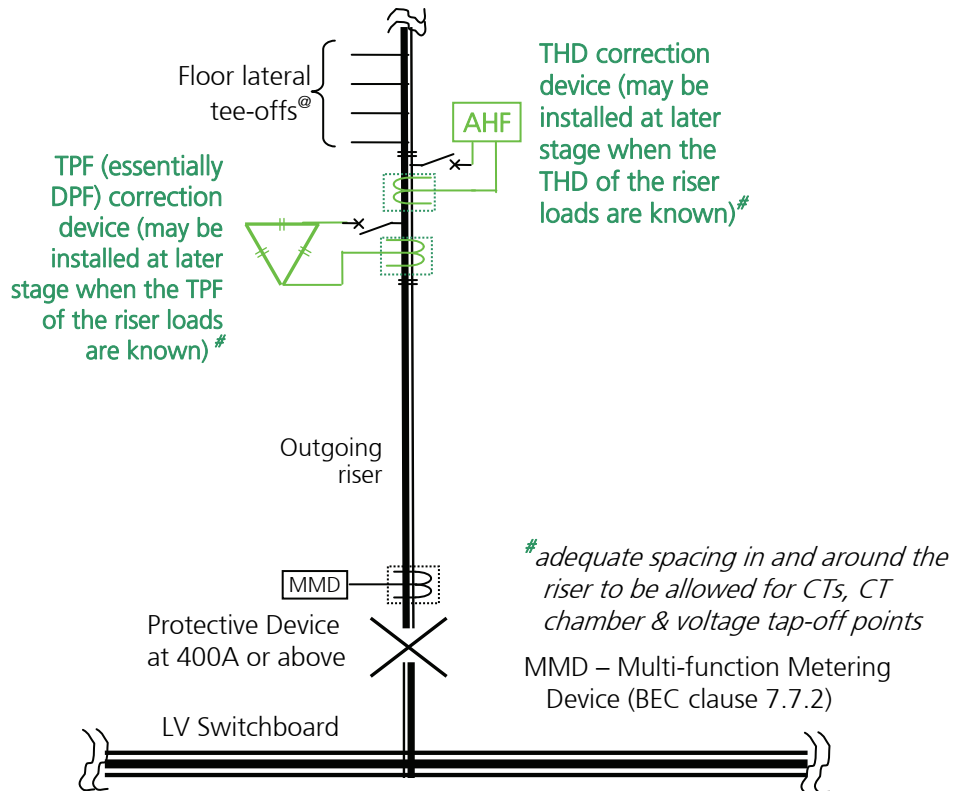


(c) Connection Points for Correction Devices (BEC clauses 7.6.1 & 7.6.2)

i) Circuits at or above 400 A (BEC clauses 7.6.1.2, 7.6.1.3, 7.6.2.2 & 7.6.2.3)

TG Figure 7.6(c) i) below shows the connection points (for TPF and THD correction devices) for a circuit at or above 400 A (circuit protective device rating) based on the requirements in BEC clauses 7.6.1.2, 7.6.1.3, 7.6.2.2 and 7.6.2.3. A common configuration in outgoing circuits of LV switchboard - a riser with floor lateral tee-offs, is used in the illustration. The connection points consisting two spare ways (one for TPF, essentially DPF, and one for THD) of appropriate rating should be installed at a point just before the first lateral tee-off. In parallel with the spare ways, adequate spacing in and around the riser should be allowed for the installation of current transformers (CT), CT chambers and voltage tap-off points for sensing of TPF and THD to operate the correction devices for which adequate spacing should also be allowed.

Figure 7.6 (c) i) : Connection points (for TPF & THD correction devices) for circuit at or above 400 A



Alternative to connection points just before the first lateral tee-off

Having indicated above the connection points just before the first lateral tee-off, the REA/designer can choose to provide the connection points –

- at each of the floor lateral tee-offs, or
- at each of the distribution boards downstream of the tee-off (which is a better arrangement as the correction would be closer to the source of the reactive or non-linear loads),

and should such an arrangement be adopted its adoption should be accompanied with adequate space provisions in and around the lateral tee-offs, for the spare ways, CTs, CT chambers, voltage tap-offs etc. for sensing of TPF and THD to operate the correction devices for which adequate spacing should also be allowed.

For a circuit at or above 400A, if all its lateral tee-offs are provided with correction devices or connection points, the requirement of having one upstream at just before the first lateral tee-off would be deemed as having fulfilled. An example of such is a three-phase sub-circuit dedicated for tenant units and having all lateral tee-offs provided with connection points as described in TG clause 7.6(c) ii) below. While it may be the responsibility of the tenant to fix the connection points, the provision of spacing (for the connection points) around the electricity supplier meter would be the responsibility of the building owner if the tenant’s local distribution board is in

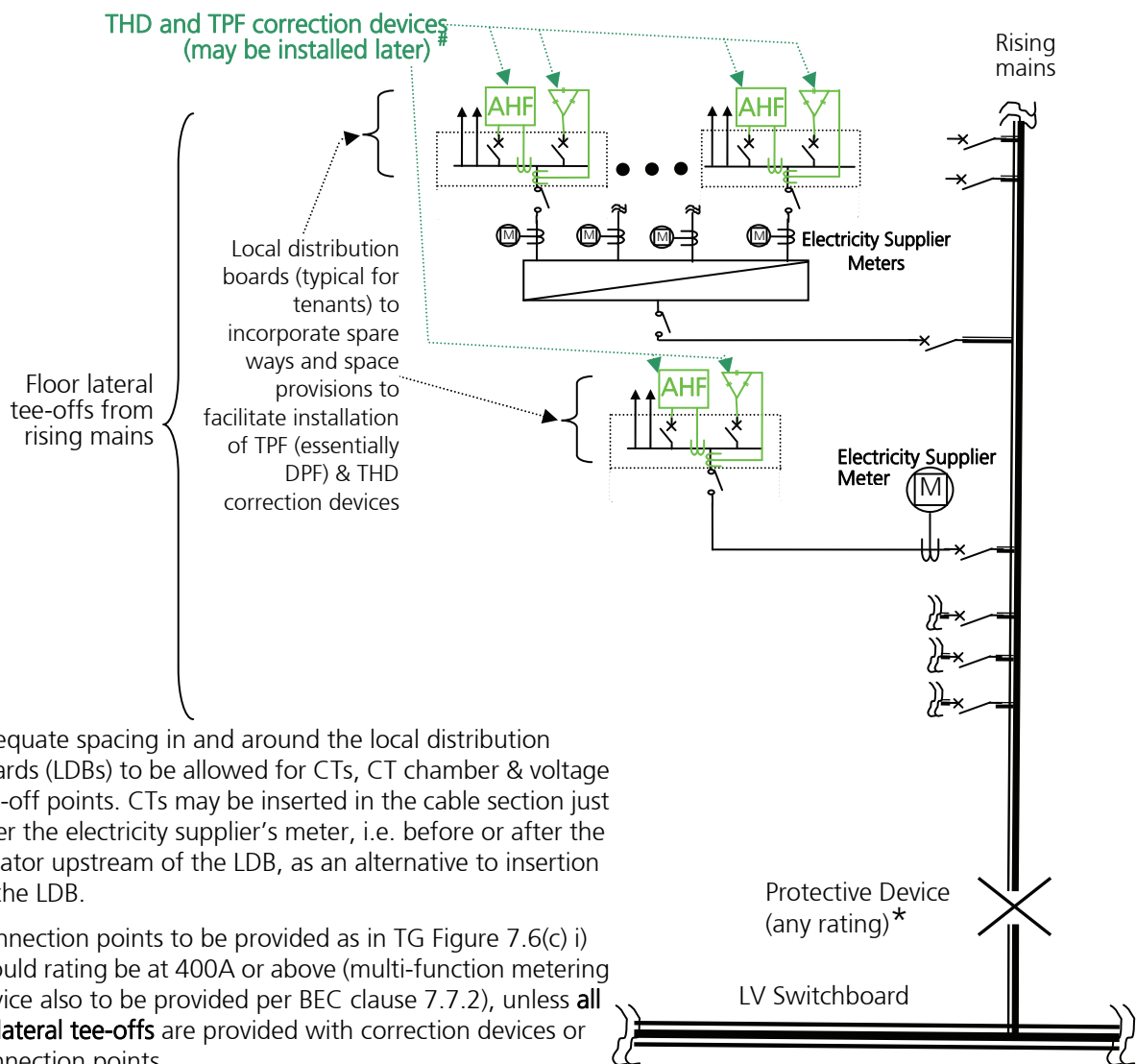
the electrical room or meter room.

Should there be space constraint for the CT chamber (400A or above) just before the first lateral tee-off, consideration may be given to provide the connection points at each of the floor lateral tee-offs, which demand a lower amperage and thus smaller (physical size) CT chambers.

Nevertheless after the completion of a project, there may be practical difficulty to control the TPF & THD in a circuit for the yet-to-be installed equipment and installations, in particular if the circuit does not involve a electricity supplier meter. Under the circumstance the demonstration of compliance may be by virtue of installing the relevant connection points (TG clause 7.6(a)ii)b. above) at the upstream of the circuit.

- ii) Three-phase Circuits Connecting to Electricity Suppliers' Meters (BEC clauses 7.6.1.1, 7.6.1.3, 7.6.2.1 and 7.6.2.3)

Figure 7.6 (c) ii) : Connection points (for TPF & THD correction devices) for three-phase circuits each connecting to electricity supplier's meter



TG Figure 7.6(c) ii) above shows the connection points for three-phase circuits each connecting to the meter of the electricity supplier. The illustration is based on the requirements in BEC clauses 7.6.1.1, 7.6.1.3, 7.6.2.1 and 7.6.2.3. In parallel with the spare ways, adequate spacing in and around the tee-off for the meter or at the distribution board downstream of the meter should be allowed for the installation of CTs, CT chambers and voltage tap-offs for sensing of TPF and THD to operate the correction devices for which adequate spacing should also be allowed.

The above requirement does not apply to single-phase circuits each connecting to the meter of the electricity supplier.

iii) Connection Points to be Shown in Drawings

Connection points and corresponding spacing provisions for correction devices should be clearly shown in drawings with both plan and sectional views, a typical illustration based on the configuration at rising mains in TG Figure 7.6(c)i) above is shown in TG Figure 7.6(c) iii) below.

Figure 7.6 (c)iii) : Typical electrical schematic and layout drawing for connection points at rising mains (with floor lateral tee-offs on 10/F and above floors)

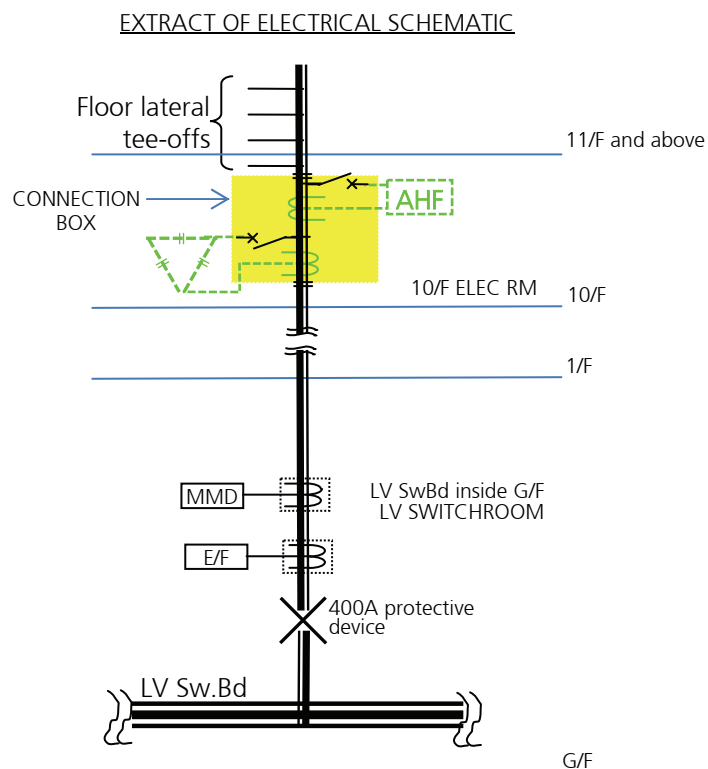
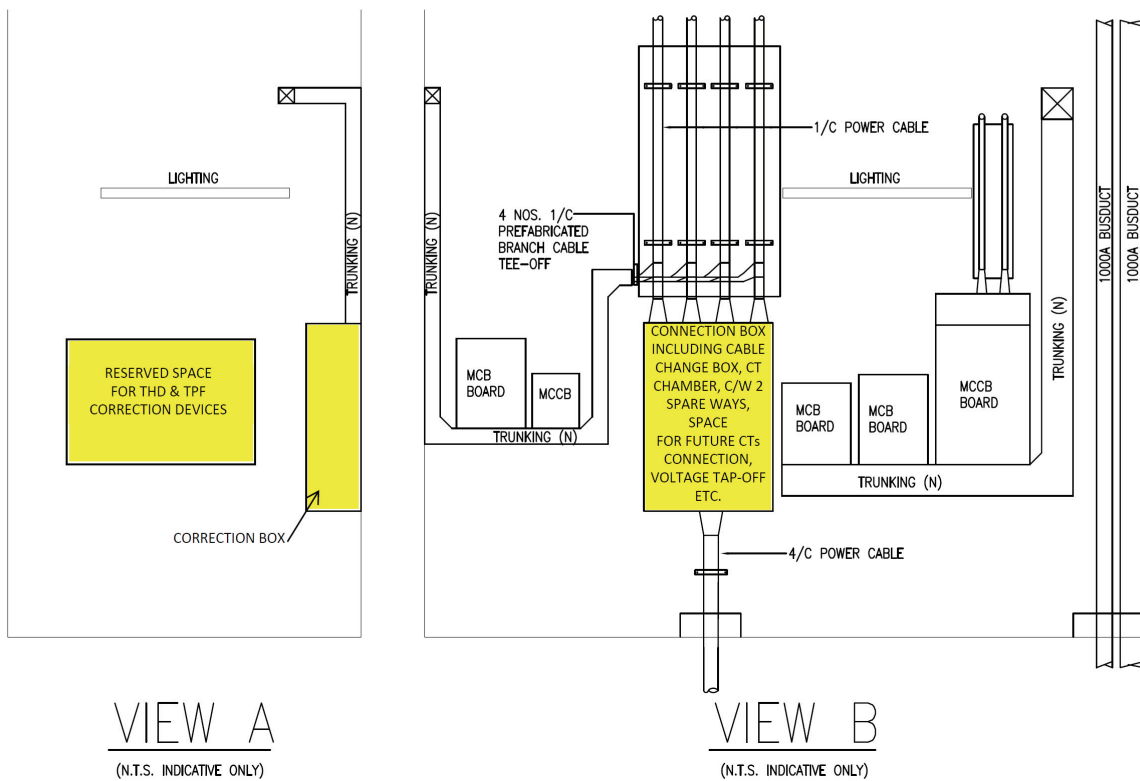
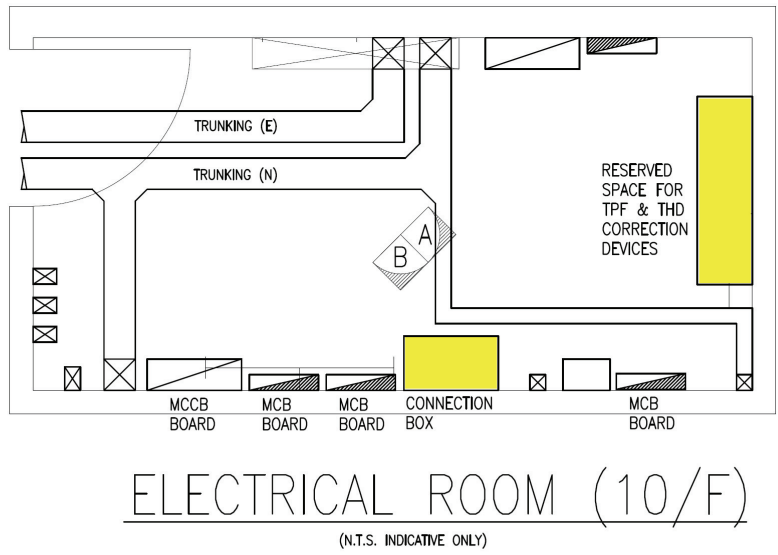


Figure 7.6 (c)iii) continued



(d) Residential Buildings & Industrial Buildings

The intent of the Ordinance is not to govern residential units in residential buildings or in residential portions of commercial/residential composite buildings. It follows that a circuit of a type specified in TG clause 7.6(a)i) serving a residential unit or units is not governed by the requirements of minimum allowable TPF and maximum allowable THD; however a circuit of the type serving equipment of the

common area is governed. For a building without common area the TPF and THD requirements do not govern its building services installations. The same principle above applies to industrial buildings and commercial/industrial composite buildings.

(e) Electricity Supplier Requirements on TPF & THD

The BEC requirements on TPF and THD tally with similar requirements in the supply rules of electricity suppliers in Hong Kong. The BEC focuses on improving the TPF and THD at the source i.e. the electrical load, and specifies the installation of correction devices close to the source at the motor control centre or local distribution board. The electricity supplier on the other hand pays more attention on limiting the magnitudes of low power factor or harmonic distortion at the consumer's metering point, which has but minimal effects on the I^2R losses in the circuits downstream of the meter.

(f) Requirement on Balancing of Single-phase Loads (BEC clause 7.6.3)

BEC clause 7.6.3 specifies that for three-phase 4-wire circuits at or above 400A (circuit protective device rating) with single-phase loads, the maximum allowable percentage current unbalance is 10%.

In BEC Section 2, current unbalance in three-phase 4-wire installation is interpreted as –

$$I_u = (I_d \times 100) / I_a$$

where I_u = percentage current unbalance

I_d = maximum current deviation from the average current

I_a = average current among three phases

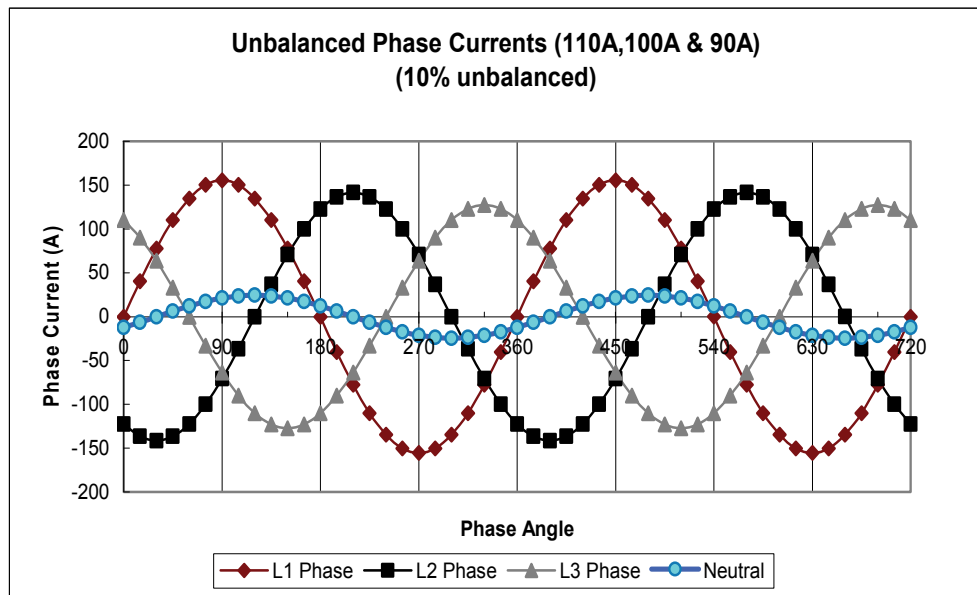
Unbalanced Distortion

The connection of single-phase loads of different characteristics and power consumption to the three-phase power distribution system may result in unequal currents flowing in the three-phase circuits and unbalanced phase voltages, i.e. unbalanced distortion. Adverse effects of unbalanced distortion include additional power losses and voltage drop in the neutral conductors, reduced forward operating torque and overheating of induction motors, excessive electromagnetic interference to sensitive electronic equipment causing error in power system measurement etc. In the case of three-phase induction motors, the unbalanced voltage creates an opposing negative sequence component which generates a negative torque that has to be absorbed by the motor at the expense of reduced output.

Single-phase loads are potential sources of unbalanced distortion and should be carefully planned at design stage for balancing.

To have an appreciation of the effect of unbalanced distortion, take for example a 10% unbalanced phase current in a three-phase 4-wire circuit with an average phase current of 100A, as shown in TG Figure 7.6 (f) below. The unbalanced distortion would produce a neutral current of about 17A and increase the total copper loss by about 1%. The effect of the 10% unbalanced distortion and the presence of harmonic distortion if say at 30% would produce a neutral current almost the same magnitude as the phase current resulting in much higher losses.

Figure 7.6 (f) : Diagrammatic illustration of 10% unbalanced phase current



7.7 Metering & Monitoring Facilities (BEC clause 7.7)

Aiming at achieving the purpose in BEC clause 7.2.2, BEC clause 7.7 specifies the requirements on metering and monitoring facilities for the different types of circuits, which are reproduced in TG Table 7.7 below.

The metering and monitoring facilities have to be physically installed, and the provision of hand-held meters only would not be regarded as meeting the requirement. While simple ammeters and voltmeters can measure currents and voltages that are sinusoidal, they alone cannot give accurate readings when harmonics are present and cannot give readings of energy, maximum demand, TPF and THD, which have to rely on meters with data-logging and analytical function, such as a digital power analyzer or multi-function meter complete with current transformers (CT) to measure the line currents. The meters should be able to measure the parameters with true root mean square values. In measuring the phase and neutral line currents, the four CT configuration that employs for each phase and neutral line a CT is a better option than the three CT configuration that employs only three CTs, one for each phase, with the value for the neutral calculated by the metering device; the three CT configuration given its popularity is an acceptable means for circuits not having heavy harmonic loads.

As a good engineering practice, the measured data may be transmitted for enhanced monitoring and control to the central control & monitoring system or BMS with energy management function.

Table 7.7 : Parameters Requiring Measurement in Different Types of Circuits		
<u>Type of Circuit</u>	<u>Circuit Protective Device Rating I</u>	<u>Metering Devices for Measuring the Following Parameters</u>
Main Circuit	I ≥ 400A (single or three-phase)	<ul style="list-style-type: none"> - Voltages (all phase-to-phase & phase-to- neutral) - Currents (three phases and neutral) - Total energy consumption (kWh) - Maximum demand (kVA) - TPF - THD (capable of measuring 31st and lower harmonic order)
Feeder and Sub-main Circuit (except for correcting reactive/ distortion power)		
	200A < I < 400A (single or three-phase)	<ul style="list-style-type: none"> - Currents (three phases & neutral) - Total energy consumption (kWh)

7.8 Guidelines on Calculation of Copper Loss

7.8.1 Conductor Resistance

TG Table 7.8 below tabulates the conductor resistance values for cables of types and configurations listed in Appendix 6 of the Code of Practice for the Electricity (Wiring) Regulations issued by EMSD (2009 Edition, hereinafter abbreviated as “Wiring Code”) that gives the cables’ voltage drop figures (mV/A-m), which are converted into their corresponding conductor resistance figures by dividing by a factor of $\sqrt{3}$. (The contents of Appendix 6 are a reproduction of relevant contents in BS7671 – IEE Wiring Regulations, of British Standards Institution (BSI) and The Institution of Engineering & Technology (IET).) It is the intent of the TG to give the resistance values of the common but not all types of conductors. In general, voltage drop figures in catalogues of cable or busbar manufacturers, without prejudice to any governing conditions if any so stated therein, may be divided by a factor of $\sqrt{3}$ to give the resistance figures.

The conductor resistance (mΩ/m) figures can be based upon in the sizing of cable for fulfilling the requirements on maximum allowable percentage copper loss.

Table 7.8 : Conductor (copper) Resistance for PVC and XLPE Cable at 50 Hz Single-phase or Three-phase a.c.						
Conductor cross- sectional area (mm ²)	Conductor Resistance (mΩ/m)					
	Multicore Armoured & Non-armoured #1		Single-core PVC/XLPE Non-armoured, with or without sheath #2			
	PVC cable at max. conductor operating temperature of 70°C	XLPE cable at max. conductor operating temperature of 90°C	PVC cable at max. conductor operating temperature of 70°C		XLPE cable at max. conductor operating temperature of 90°C	
			Enclosed in conduit/ trunking	Clipped direct or on tray, touching	Enclosed in conduit/ trunking	Clipped direct or on tray, touching
1.5	14.4	15.6	14.4	14.4	15.6	15.6
2.5	9	9	9	9	9	9
4	5.5	5.8	5.5	5.5	5.8	5.8
6	3.70	3.93	3.70	3.70	3.93	3.93
10	2.2	2.3	2.2	2.2	2.3	2.3
16	1.4	1.4	1.4	1.4	1.4	1.4
25	0.866	0.924	0.866	0.866	0.924	0.924
35	0.635	0.664	0.635	0.635	0.664	0.664
50	0.462	0.497	0.468	0.462	0.502	0.497
70	0.318	0.341	0.323	0.318	0.346	0.341
95	0.237	0.248	0.242	0.237	0.254	0.248
120	0.191	0.196	0.191	0.185	0.202	0.196
150	0.150	0.162	0.156	0.150	0.167	0.162
185	0.121	0.127	0.127	0.121	0.133	0.127
240	0.095	0.101	0.098	0.092	0.107	0.098
300	0.078	0.081	0.081	0.075	0.087	0.081
400	0.058	0.066	0.069	0.061	0.072	0.064
500	-	-	0.058	0.050	0.058	0.052
630	-	-	0.046	0.042	0.051	0.043
800	-	-	-	0.035	--	0.036
1000	-	-	-	0.030	-	0.032

#1 Based on Tables A6(2), A6(4), A6(6) & A6(8) in Appendix 6 of Code of Practice for the Electricity (Wiring) Regulations issued by EMSD, 2009 Edition (Wiring Code)
 #2 Based on Tables A6(1) & A6(5) in the Wiring Code.

7.8.2 Cable Sizing

The relationship among designed circuit current I_b , nominal rating of protective device I_n and effective current-carrying capacity of conductor I_z for an electrical circuit can be expressed as:

$$I_b \leq I_n \leq I_z$$

7.8.2.1 Conventional Method

Assumption: The supply voltages and load currents are sinusoidal and balanced among the three phases in a three-phase 4-wire power distribution system.

$$\text{Calculated minimum tabulated value of current: } I_{t(\min)} = I_n \times \frac{1}{C_a} \times \frac{1}{C_g} \times \frac{1}{C_i}$$

$$\text{Effective current-carrying capacity : } I_z = I_t \times C_a \times C_g \times C_i$$

Where I_t = the value of current tabulated in Appendix 6 of the Wiring Code

C_a = Correction factor for ambient temperature

C_g = Correction factor for grouping

C_i = Correction factor for thermal insulation

7.8.2.2 Power Factor and Losses due to Harmonic Distortion in Circuits with Non-linear Loads

Displacement Power Factor (DPF) & Total Power Factor (TPF)

Consider a circuit with non-linear load current I , which is the r.m.s. value of fundamental I_1 and all harmonic components I_2, I_3, I_4, \dots

Assumption: The circuit is fed from a line voltage U having a low value of distortion and only the fundamental sinusoidal value U_1 is significant:

Apparent Power: $S = UI$

$$\begin{aligned} S^2 &= (UI)^2 = U_1^2(I_1^2 + I_2^2 + I_3^2 + I_4^2 + \dots) \\ &= U_1^2 I_1^2 \cos^2\theta + U_1^2 I_1^2 \sin^2\theta + U_1^2(I_2^2 + I_3^2 + I_4^2 + \dots) \end{aligned}$$

According to this expression in the distorted circuit, the apparent power contains three major components:

(a) Active Power P in kW : $P = U_1 I_1 \cos\theta$

(This is the effective useful power)

(b) Reactive Power Q_1 in kVAR : $Q_1 = U_1 I_1 \sin\theta$

(This is the fluctuating power due to the fundamental component and coincides with the conventional concept of reactive power in an inductive circuit consumed and returned to the network during the creation of magnetic fields)

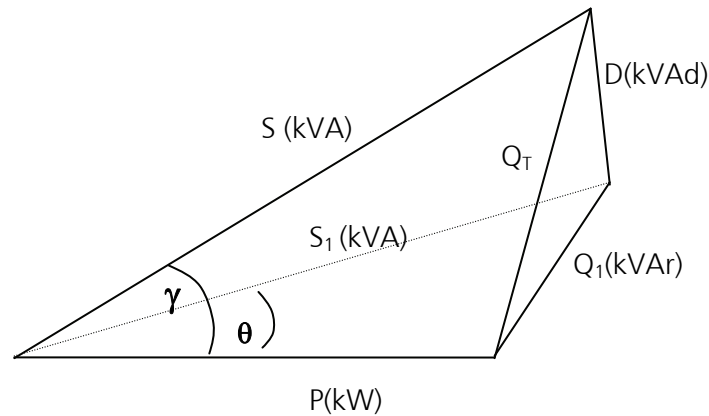
(c) Distortion Power D in kVA $D^2 = U_1^2 (I_2^2 + I_3^2 + I_4^2 + \dots)$

$D = U_1 \sqrt{(I_2^2 + I_3^2 + I_4^2 + \dots)}$ (This power appears only in distorted circuits and its physical meaning is that of a fluctuating power due to the presence of harmonic currents)

The relationship among these three power components can be shown in the following

power triangles in TG Figure 7.8.2.2 :

Figure 7.8.2.2 – Power triangles for apparent power, active power, reactive power & distortion power



(d) Fundamental Components : $S_1^2 = P^2 + Q_1^2$
with Displacement Power Factor (DPF) $\cos\theta = P/S_1$

(e) Fluctuating Power : $Q_T^2 = Q_1^2 + D^2$

(f) Power Triangle in Distorted Circuit : $S^2 = Q_T^2 + P^2$

with TPF $\cos \gamma = P/S$, which is always smaller than the DPF $\cos\theta$, and can be improved by either reducing the amount of harmonic distortion power (kVAd) or reactive power (kVAr)

The above expressions only give the approximate formulas neglecting any voltage distortion caused by voltage drop in line impedance. These harmonic voltages will give active and reactive components of power but the active power is generally wasted as heat dissipation in conductors and loads themselves.

7.8.3 Copper Loss Calculation

7.8.3.1 For a Three-phase Balanced & Linear Circuit:

Apparent power transmitted along the circuit conductors in VA, $S = \sqrt{3}U_L I_b$

Active power transmitted along the circuit conductors in W, $P = \sqrt{3}U_L I_b \cos\theta$

Total copper losses in conductors in W, $P_{copper} = 3 \times I_1^2 \times r \times L$

where U_L = Line to line voltage, 380V

$I_b = I_1$ = Design circuit current of the linear circuit in ampere (no distortion)

$\cos\theta$ = Power factor of the circuit

r = a.c. resistance per metre at the conductor operating temperature

L = Length of the cable in metre

Percentage copper loss with respect to the total active power transmitted,

$$\% \text{ loss} = \frac{3 \times I_1^2 \times r \times L}{\sqrt{3} U_L I_1 \cos\theta}$$

$$\text{Therefore, max. } r \text{ (m}\Omega\text{/m)} = \frac{\text{max. \% loss} \times U_L \times \cos\theta \times 1000}{\sqrt{3} \times I_1 \times L}$$

Appropriate conductor size can then be selected from TG Table 7.8 based on calculated value of r.

Correction for copper loss calculation due to various conductor operating temperature can be carried out as follows:

Conductor operating temperature at design current I_b , which = I_1 , is given by:

$$t_1 = t_a + \frac{I_1^2}{I_t^2} (t_p - 30)$$

where t_a = actual or expected ambient temperature

t_p = maximum permitted conductor operating temperature

ambient temperature = 30°C

The resistance of a copper conductor R_t at temperature t_1 is given by:

$$R_t = R_{20} [1 + \alpha_{20} (t_1 - 20)]$$

where R_{20} = conductor resistance at 20°C

α_{20} = temperature coefficient of resistance of copper at 20°C
(0.00393/°C)

or alternatively,

$$R_t = R_0 (1 + \alpha_0 t_1)$$

where R_0 = conductor resistance at 0°C

α_0 = temperature coefficient of resistance of copper at 0°C (0.00428/°C)

$$\text{Therefore ratio, } \frac{R_t}{R_p} = \frac{1 + \alpha_0 t_1}{1 + \alpha_0 t_p} \approx \frac{230 + t_1}{230 + t_p}$$

7.8.3.2 For a Three-phase Balanced Non-Linear Circuit Having Known Harmonic Current:

Apparent power transmitted along the circuit conductors in VA,

$$S = \sqrt{3} U_L I_b$$

$$\text{where } I_b = \sqrt{\sum_{h=1}^{\infty} I_h^2} = \sqrt{I_1^2 + I_2^2 + I_3^2 + \dots}$$

$$\text{From definition: THD} = \frac{\sqrt{\sum_{h=2}^{\infty} (I_h)^2}}{I_1}$$

$$\text{Therefore, } I_b = I_1 \sqrt{1 + \text{THD}^2}$$

$$\text{And, the fundamental current } I_1 = \frac{I_b}{\sqrt{1 + \text{THD}^2}}$$

Assuming voltage distortion is small, $U_L = U_1$, and active power transmitted along the circuit conductors in W is given by:

$$P = \sqrt{3} U_L I_1 \cos\theta$$

where U_L = Supply line voltage at 380V

I_1 = Fundamental phase current of the circuit in ampere

$\cos\theta$ = DPF

$$\text{And, TPF} = \frac{P}{S} = \frac{\cos\theta}{\sqrt{1 + \text{THD}^2}}$$

Assuming the skin and proximity effects are small, total copper losses in conductors including neutral in W is given by:

$$P_{\text{copper}} = (3 \times I_b^2 + I_N^2) \times r \times L$$

where I_N = Neutral current of the circuit in ampere

$$= 3 \times \sqrt{I_3^2 + I_6^2 + I_9^2 + \dots}$$

I_b = Design r.m.s. phase current of the circuit in ampere

r = a.c. resistance per metre at the conductor operating temperature

L = Length of the cable in metre

Percentage copper loss with respect to the total active power transmitted,

$$\% \text{ loss} = \frac{(3 \times I_b^2 + I_N^2) \times r \times L}{\sqrt{3} U_L I_1 \cos\theta}$$

$$\text{Therefore, max. } r \text{ (m}\Omega\text{/m)} = \frac{\text{max. \% loss} \times \sqrt{3} \times U_L \times I_1 \times \cos\theta \times 1000}{(3 \times I_b^2 + I_N^2) \times L}$$

Appropriate conductor size can then be selected from TG Table 7.8 based on calculated value of r .

Correction for copper loss calculation due to various conductor operating temperature can be carried out as follows:

Conductor operating temperature at phase current I_b & neutral current I_N is given by:

$$t_1 = t_a + \frac{(3I_b + I_N)^2}{(3I_t)^2} (t_p - 30)$$

where t_a = actual or expected ambient temperature

t_p = maximum permitted conductor operating temperature

The resistance of a copper conductor R_t at temperature t_1 is given by:

$$R_t = R_0 (1 + \alpha_0 t_1)$$

where R_0 = conductor resistance at 0°C

α_0 = temperature coefficient of resistance of copper at 0°C
(0.00428/°C)

Therefore ratio,
$$\frac{R_t}{R_p} = \frac{1 + \alpha_0 t_1}{1 + \alpha_0 t_p} \approx \frac{230 + t_1}{230 + t_p}$$

7.8.4 TPF & THD Inclusion in Copper Loss Calculation

For a circuit connected with a low power factor load and/or a non-linear load of influential scale, its TPF and THD of current should be included in the calculation of copper loss for cable sizing. Should a precise assessment at design not be feasible due to lack of information, the REA/designer should exercise due diligence by sizing the circuit based on the minimum allowable TPF and maximum allowable THD figures in BEC clause 7.6.1.1 & 7.6.2.2 respectively.

Having focused on the designed circuit current, the BEC does not establish the rules for part load operation. It is assumed that during part load, the TPF and the THD, which may be respectively lower for TPF and higher for THD than the corresponding figures in BEC clause 7.6.1.1 & 7.6.2.2, the magnitude of the current and power is usually lower than at full load and thus has a lower impact.

7.9 Illustrative Example on Calculation of Copper Loss

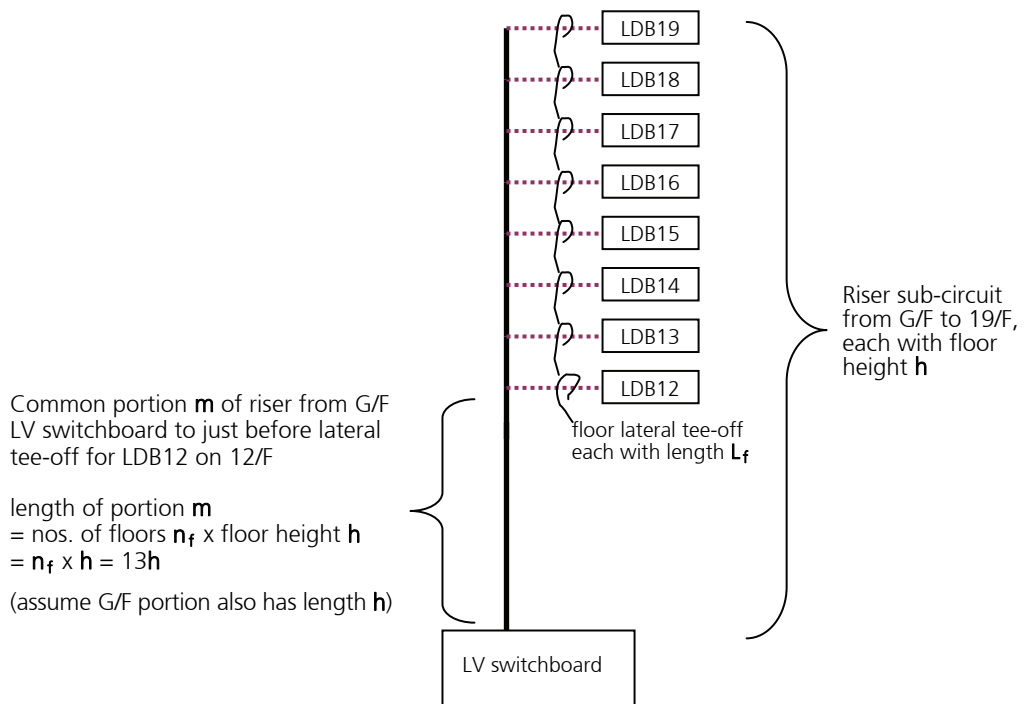
The following gives an illustration of copper loss calculation based on the approach indicated in TG clause 7.8. Consider for a non-residential building a sub-circuit in the form of a riser feeding local distribution boards (LDB) namely LDB12 to LDB19 on 8 nos. floors namely 12/F to 19/F, one LDB for each floor, each of the floor lateral tee-offs having the same length. For illustration simplicity, it is assumed that –

- each of the floor LDB demands at full load a fundamental current I_1 of 45A 3-phase,
- a diversity factor **df** of 0.85 is to be applied to the floor loads to arrive at the load of the sub-circuit (**df** is described in TG Table 7.4(b)iii),
- the ambient condition t_a is 30°C,
- multicore PVC/SWA/PVC copper cable with max conductor operating temperature of 70°C is used, with mounting on perforated cable tray,
- all correction factors C_a , C_p , C_g & C_i (described in TG clause 7.8.2.1 and the Wiring Code) are all at unity,

- the skin effect and proximity effect of any harmonic currents are negligible, and harmonic distortion of voltage is neglected, and
- information on the power factor and harmonic contents of the loads in the lateral circuits are not available, which means that they have to be estimated based on the approach described in TG clause 7.8.4. A schematic of the sub-circuit is given in TG Figure 7.9.1 below.

Determine the cable sizes of the riser and the lateral tee-offs.

Figure 7.9.1 : Schematic of sub-circuit for illustration of design considerations, cable selection, and copper loss calculations



The design considerations, the cable selection, and the copper loss calculations are illustrated respectively in TG Tables 7.9.1(a) to (c).

Table 7.9.1 (a) : Illustration of Conductor Design Considerations				
DESIGN CONSIDERATIONS	Abbrev.	Equation described in TG clause 7.8.3 / Relevant TG paragraphs	Floor tee-off	Riser
Floor height (metre)	h	Not applicable (NA)	NA	3
Nos. of floors from G/F to floor of first lateral tee-off	n_f		NA	13
Length of floor lateral tee-off (metre)	L_f		10	NA
Nos. of tee-offs, one per floor, for all the eight floors from 12/F to 19/F	n_t		NA	8
Conductor ambient temperature (°C)	t_a	TG clause 7.8.3	30	
Allowable copper loss (%)	%loss	TG Table 7.4 (b) ii)	1.5%	
Diversity factor	df	TG Table 7.4(b) iii)	NA	0.85
Fundamental current (A)	I₁	TG clause 7.8.3	45	306
Total harmonic distortion (%)	THD	$THD = \frac{\sqrt{\sum_{h=2}^{\infty} (I_h)^2}}{I_1}$ TG clauses 7.8.3 & 7.8.4	15%	NA
Neutral current	I_N	$I_N = 3 \times \sqrt{I_3^2 + I_6^2 + I_9^2 + \dots}$ TG clause 7.8.3	0	0
Design root mean square phase current (A)	I_b	$I_b = I_1 \times \sqrt{(1+THD^2)}$	45.5	309.4
Protective device rating (A)	I_n	$I_b \leq I_n$	55	320
Total power factor	TPF	TG clauses 7.8.3 & 7.8.4	0.85	NA
Displacement power factor	DPF cosθ	$\cos\theta = TPF \times \sqrt{(1+THD^2)}$	0.86	NA
Effective length of whole sub-circuit (metre) (for purpose of quick estimation of Max r only, equation alongside does not appear in TG clause 7.8.3)	EL	$EL = h \times (n_f + 7/8 + 6/8 + 5/8 + 4/8 + 3/8 + 2/8 + 1/8) + L_f$	59.5	
Max resistance (mΩ per metre) of conductor	Max r	$\frac{\%loss \times \sqrt{3} \times 380 \times I_1 \times \cos\theta \times 1000}{(3 \times I_b^2 + I_N^2) \times L}$	1.0332	0.1519
<p>Remark to <u>Max r</u></p> <p>The Max r value is for purpose of quick estimation of conductor resistance in selecting the cable size. The r values in cable selection and copper loss calculations in TG Tables 7.9.1(b) & 7.9.1(c) below are the values in TG Table 7.8 or the Wiring Code and not the Max r value. For the lateral tee-off, the %loss value in calculating Max r is not 1.5% but adjusted by a ratio of L_f/EL or 0.168 to better represent the lateral tee-off's apportionment.</p> <p>Remark to <u>I_N</u> (neutral current)</p> <p>For simplicity it is assumed the neutral current is negligible. Nevertheless the equations of Max r (above), t₁ (TG Table 7.9.1(b)) and P_{copper} (TG Table 7.9.1(c)) account for the inclusion of I_N in the calculation, which may not be negligible in case of triplen harmonics or unbalanced distortion.</p>				

Table 7.9.1 (b) : Illustration of Cable Selection (4/C PVC/SWA)				
CABLE SELECTION	Abbrev.	Equation described in TG clause 7.8.3 / Relevant TG paragraphs	# Tee-off 16 mm²	Riser 150 mm²
Conductor resistance (mΩ per metre)	r	TG Table 7.8 and Wiring Code	1.4	0.15
Permitted conductor temperature (°C)	t_p	TG clause 7.8.3 and Wiring Code	70	70
Conductor tabulated current carrying capacity (A)	I_t		83	332
Conductor operating temperature (°C) at I_b	t₁	$t_1 = t_a + \frac{(3I_b + I_N)^2}{(3I_t)^2} (t_p - 30)$	42.02	64.74
Ratio of conductor resistance at t₁ to t_p	R_t/R_p	$\frac{R_t}{R_p} \approx \frac{230 + t_1}{230 + t_p}$	0.907	0.982
Remark# to 16 mm² cable selection				
A cable of smaller size having a r value greater than Max r is selected as a trial, as the actual current with the application of diversity factor df would be lower than I_b ; the cable can be upgraded if needed based on actual P_{copper} calculated in TG Table 7.9.1(c). (Later calculations in TG Table 7.9.1(c) justify the trial selection of 16mm ² .)				

Table 7.9.1 (c) : Illustration of Copper Loss Calculations						
COPPER LOSS CALCULATIONS	Current I_b (df applied) (A)	Resistance r (R_t/R_p applied) at t₁ (mΩ per metre)	Length L (metre)		Copper loss P_{copper} (Watt)	Sub-circuit active power P (Watt)
common portion m (G/F to 12/F of 13 floors)	309.4	0.147	n_f x h	39	1650.9	$\sqrt{3} \times 380 \times I_{m1} \times \cos\theta$ 173,108
12/F lateral tee-off	38.7	1.269	L_f	10	57.0	
13/F riser portion	270.7	0.147	h	3	97.2	
13/F lateral tee-off	38.7	1.269	L_f	10	57.0	
14/F riser portion	232.1	0.147	h	3	71.4	
14/F lateral tee-off	38.7	1.269	L_f	10	57.0	
15/F riser portion	193.4	0.147	h	3	49.6	
15/F lateral tee-off	38.7	1.269	L_f	10	57.0	
16/F riser portion	154.7	0.147	h	3	31.7	
16/F lateral tee-off	38.7	1.269	L_f	10	57.0	
17/F riser portion	116.0	0.147	h	3	17.9	
17/F lateral tee-off	38.7	1.269	L_f	10	57.0	

18/F riser portion	77.4	0.147	h	3		7.9		
18/F lateral tee-off	38.7	1.269	L_f	10		57.0		
19/F riser portion	38.7	0.147	h	3		2.0		
19/F lateral tee-off	38.7	1.269	L_f	10		57.0		
Total						2,384		
% Copper Loss = 1.38%								

In conclusion for the sub-circuit, 150 mm² cable is to be adopted for the riser and 16 mm² cable for the floor lateral tee-off, achieving a percent copper loss of 1.38% (TG Table 7.9.1 (c)), meeting the 1.5% requirement.

8. Energy Efficiency Requirements for Lift and Escalator Installation

8.1 Scope of Application (BEC clause 8.1)

8.1.1 Comprehensive View on Applicability (BEC clause 8.1.1)

BEC Section 8 provides the guidelines for lift and escalator installations. To gain a comprehensive view in relation to the Ordinance, BEC clause 8.1 should be read in conjunction with –

- BEC Sections 3 & 4 that briefly describe the scope and limits of the application of the Ordinance based on its prescribed requirements in Parts 2 & 3; and
- TG Sections 3 & 4 that elaborate on the scope and limits of application and the necessary steps to demonstrate the compliance with the Ordinance and the BEC.

For reference, the interpretation of ‘lift and escalator installation’ under the Ordinance and the BEC is extracted below -

‘lift and escalator installation’ has the same meaning in the Ordinance, which means a system of equipment comprising –

- (a) a lift or escalator as defined in section 2(1) of the Lifts and Escalators (Safety) Ordinance (Cap 327); and
- (b) any associated installation specified in a code of practice that is used for the operation of the lift or escalator;

TG Remarks to ‘lift and escalator installation’

With the Lifts and Escalators Ordinance (Cap 618) enacted on 18 April 2012, Cap 618 repeals Cap 327 starting on 17 Dec 2012.

8.1.2 Examples of BEC Applicable Installations (BEC clause 8.1.2)

In respect of certain types of lift and escalator installations, BEC clause 8.1.2 affirms for the avoidance of doubt the Ordinance’s applicability to these installations, and examples thereof are given in TG Table 8.1.2 below.

<u>Table 8.1.2 : Examples of BEC Applicable Lift and Escalator Installations</u>	
<u>Examples</u>	<u>Justifications</u>
Bed passenger lift in a hospital	BEC clause 8.1.2 (a)
Freight lift serving common lift lobbies in an industrial building	
Vehicle lift carrying vehicles	

Observation lift at the building facade	BEC clause 8.1.2 (c)
Escalator (owned by the building owner) at the building facade	

Having not specified otherwise in respect of non-applicability, BEC Section 8 should also be applicable to a double-deck lift having two attached cars one on top of the other.

8.1.3 Examples of BEC Non-applicable Installations (BEC clause 8.1.3)

BEC clause 8.1.3 lists certain lift and escalator installations to which the Ordinance does not apply, and examples of these installations are given in TG Table 8.1.3 below.

<u>Table 8.1.3 : Examples of BEC Non-applicable Lift and Escalator Installations</u>	
<u>Examples</u>	<u>Justifications</u>
Mechanized vehicle parking system in a car park	BEC clause 8.1.3 (a) (A mechanized vehicle parking as defined in Cap 618 is a mechanical plant that has a power operated mechanism for conveying a vehicle to a parking space within the plant.)
Service lift for transporting food in a restaurant	BEC clause 8.1.3 (b) (A service lift as defined in Cap 618 is a lift having a rated load of not more than 250 kg and restricted physical dimensions, and is not meant for the transporting of persons.)
Stairlift at a stairway	BEC clause 8.1.3 (c) (A stairlift as interpreted in BEC Section 2 is specifically for transporting an ambulant disabled person or person in a wheelchair.)
Industrial truck load freight lift in an industrial building, (for loading and unloading by an industrial truck)	BEC clause 8.1.3 (d) (An industrial truck load freight lift as interpreted in BEC Section 2 can cater for uneven distributed over the lift floor, and the weight of any single piece of freight and its truck can exceed a quarter of the rated load of the lift.)
Lift at the backstage of performing arts centre / stadium	BEC clause 8.1.3 (e) (A lift in a performance stage as interpreted in BEC Section 2 is designated to serve the performers of a show on stage.)
Lifting platform usually serving a wheelchair, for use by persons with physical disability	BEC clause 8.1.3 (f) (A powered lifting platform not having a lift car; interpretation of powered lifting platform is also given in

Scissor lift	BEC Section 2.)
Rack and pinion lift	BEC clause 8.1.3 (g) (A rack and pinion lift is a lift not operated on traction drive by suspension ropes or not operated by hydraulic piston, but operated on a system of rack and pinion.)
Temporary construction hoist lift at construction site	BEC clause 8.1.3 (h); as prescribed in item 3, Schedule 2 of the Ordinance, the Ordinance does not apply to installation solely used in a construction site for construction works only.

8.2 General Approach (BEC clause 8.2)

The energy efficiency requirements in BEC clauses 8.4 to 8.7 are based on the general approach to energy efficiency given in BEC clause 8.2.

8.3 Definitions (BEC clause 8.3)

BEC Section 2 provides the interpretations and abbreviations related to the BEC and the Ordinance, including those for lift and escalator installation.

8.4 Electrical Power (BEC clause 8.4)

8.4.1 Traction Drive Lift (BEC clause 8.4.1)

8.4.1.1 Maximum Allowable Electrical Power (BEC clause 8.4.1.1 and BEC Table 8.4.1)

In respect of the running active electrical power of the motor drive of a traction drive lift when carrying rated load and travelling upward at rated speed, BEC clause 8.4.1 specifies in BEC Table 8.4.1 its maximum allowable value across a range of rated loads and rated speeds. The meanings of rated load and rated speed are defined in Cap 618. The motor drive by its interpretation in BEC Section 2 means the motor plus its driving controller. Information on running active electrical power, which includes the electrical losses of the driving controller, can be obtained from lift suppliers, and be verified from actual site testing. The imposing of the requirement can minimize the electrical losses in the driving controller, minimize the frictional losses in the mechanical power transmission and discourage the oversizing of lift motors.

As an example illustrating the requirement in BEC Table 8.4.1, it can be read off from the table that the maximum allowable electrical power of a lift with rated load at 1200 kg and 1.75 m/s rated speed is 20.9 kW.

8.4.1.2 Exemption from Maximum Allowable Electrical Power (BEC clause 8.4.1.2)

(a) The exemption from the maximum allowable electrical power requirement is given in BEC clause 8.4.1.2 (a) to a traction lift fulfilling all the conditions below –

- having rated speed not less than 9 m/s,
- serving a zone distance of over 50-storey or over 175m,
- above zone distance counted between the top-most or bottom-most landing and the principal or ground landing, and
- it can serve as a fireman's lift, or it is a sky lobby shuttle serving two principal stops (such as ground landing and sky lobby landing, sky lobby amidst the top floors).

(b) The exemption from the maximum allowable electrical power requirement is also given in BEC clause 8.4.1.2 (b) to a traction lift with rated load at or above 5000 kg and at rated speed of 3 m/s or above. Examples of a lift so exempted would be a large passenger lift for over 60 passengers, or a heavy duty vehicle lift or freight lift.

8.4.2 Hydraulic Lift (BEC clause 8.4.2 and BEC Table 8.4.2)

8.4.2.1 Maximum Allowable Electrical Power (BEC clause 8.4.2 and BEC Table 8.4.2)

In respect of the running active electrical power of the motor of the oil pump of a hydraulic lift when carrying rated load and travelling upward at rated speed, BEC clause 8.4.2 specifies in BEC Table 8.4.2 its maximum allowable value across a range of rated loads. The meanings of rated load and rated speed are defined in Cap 618. Information on running active electrical power can be obtained from lift suppliers, and be verified from actual site testing. The imposing of the requirement can minimize the frictional losses in the power transmission and discourage the oversizing of oil pump and pump motor. The requirement is irrespective of whether the hydraulic mechanism is direct acting on the bottom of the lift car, acting on the side of the lift car, or indirect acting through suspension means.

8.4.3 Escalator (BEC clause 8.4.3 and BEC Table 8.4.3)

In respect of the running active electrical power of the steps driving motor of the escalator when carrying no-load and travelling at rated speed, BEC clause 8.4.3 specifies in BEC Table 8.4.3 its maximum allowable value. BEC Table 8.4.3 gives the maximum allowable values across a range of escalator nominal widths, rises and speeds, for the non-public service escalator, the public service escalator and the heavy duty escalator. The meaning of rated speed is defined in Cap 618, and the meanings of nominal width and rise refer to the same meanings so conveyed in the Code of Practice on the Design and Construction of Lifts and Escalators issued by EMSD. The meaning of public service escalator is given in BEC Section 2, which refers to one that forms part of a public traffic system such as connecting a building to a traffic station or public transport interchange. The heavy duty escalator with its characteristics given in BEC Table 8.4.3 refers to one for heavy duty and demand in a railway station. Information on running active electrical power can be obtained from escalator suppliers, and can be verified from actual site testing. Based on the heavier demand

and duty of the passenger load, the public service escalator is accorded a higher allowable electrical power than the non-public service escalator, and likewise the heavy duty escalator is accorded a higher allowable electrical power than the public service escalator. In the case of a multi-speed energy efficient escalator, the maximum allowable electrical power applies to the power consumption at the highest speed.

8.4.4 Passenger Conveyor (BEC clause 8.4.4 and BEC Table 8.4.4)

In respect of the running active electrical power of the steps driving motor of the passenger conveyor when carrying no-load and travelling at rated speed, BEC clause 8.4.4 specifies in BEC Table 8.4.4 its maximum allowable value. BEC Table 8.4.4 gives the maximum allowable values across a range of conveyor nominal widths, lengths, and speeds, for the non-public service passenger conveyor, and the public service passenger conveyor. The meaning of rated speed is defined in Cap 618, and the meanings of nominal width and length refer to the same meanings so conveyed in the Code of Practice on the Design and Construction of Lifts and Escalators issued by EMSD. The meaning of public service passenger conveyor is given in BEC Section 2, which refers to one that forms part of a public traffic system such as connecting a building to a traffic station or public transport interchange. Information on running active electrical power can be obtained from passenger conveyor suppliers, and can be verified from actual site testing. In the case of a multi-speed energy efficient passenger conveyor, the maximum allowable electrical power applies to the power consumption at the highest speed.

The maximum allowable running active electrical power requirement applies to passenger conveyors at inclinations up to 6° from horizontal, and does not apply to ones at higher inclination.

BEC Table 8.4.4 gives the maximum allowable electrical power for passenger conveyors with nominal widths at 800mm, 1000mm and 1400mm. There are passenger conveyors between 1000 and 1400mm, and their allowable values can be obtained by interpolating the control values for 1000mm and 1400mm. Take for example a non-public service passenger conveyor at 1200mm width with length 10m and at 0.5 m/s rated speed. From BEC Table 8.4.4, the allowable value for 1000mm is 2565W and that for 1400mm is 3206W. By interpolating the two values, the allowable value for 1200mm is $(2565 + 3206) \div 2 = 2886\text{W}$.

8.5 Utilization of Power (BEC clause 8.5)

8.5.1 Total Power Factor (BEC clause 8.5.1)

(a) General Requirements

The requirements on total power factor (TPF) given in BEC clause 8.5.1 is

summarized in TG Table 8.5.1(a) below.

Table 8.5.1 (a) : Requirements on Total Power Factor		
<u>Equipment</u>	<u>Operating condition</u>	<u>Requirements</u> (BEC clauses 8.5.1.1 to 8.5.1.3)
Lift	When carrying rated load at rated speed and travelling upward	The TPF of the motor drive circuit (at the isolator connecting to the building's electrical supply circuit) should not be less than 0.85. (motor drive means motor plus driving controller) If the manufacturer-provided driving controller when coupled with the motor meets the TPF requirement, the installation of a correction device is not required. A correction device if needed can be installed at the motor control centre of the motor drive to improve the TPF to 0.85 (BEC clause 8.5.1.3).
Escalator	When operating under brake load at rated speed and for equipment with a rise with steps or pallets moving upward	
Passenger Conveyor		

TPF accounts for the combined effect of the displacement power factor (DPF) of the motor (of the driven equipment, i.e. the lift, escalator or passenger conveyor) and the THD of the driving controller, and as such the DPF is greater in value than the TPF (TPF and THD are also described in TG clauses 7.6 and 7.8). The DPF of a properly sized induction motor delivering at the operating condition (in TG Table 8.5.1(a)) the output power to the driven equipment is usually quite close to its value at full (motor) load. The equipment supplier should assess the TPF based on the THD of the driving controller and the DPF of the equipment motor. For lifts the TPF can be verified based on actual measurement at rated load rated speed upward, whereas for escalator and passenger conveyor given practical site difficulty in providing the brake load condition, it may be necessary to rely more on the assessment, an approach of which is given in TG clause 8.5.1(b) below.

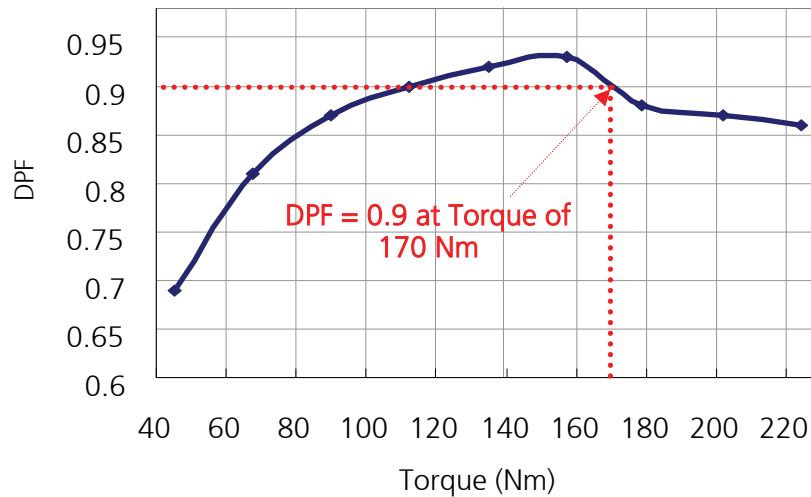
(b) Motor DPF for Assessment of TPF for Escalator and Passenger Conveyor

The applicable DPF of the motor, when driving a load equivalent to the brake load of the escalator or passenger conveyor, can usually be identified from the motor data sheet that records the testing parameters of the motor, which is usually available from the motor manufacturer and typically gives a range of values of DPF and load or torque (Newton-metre). (The data sheet usually gives, alongside the load values, also the values of RPM, running current, input power, output power, efficiency, % slip, voltage etc.) The brake load of an escalator or passenger conveyor is usually known at the design stage, and by identifying this brake load value against the range of values of motor torque in the motor data sheet the corresponding DPF can be identified.

Take for example an escalator having a brake load of 170 Newton-metre (Nm), which is the torque load demanded on its driving motor. An extract of the motor torque and DPF values from the motor data sheet is as follows -

Torque (Nm)	45.0	67.4	89.9	112.4	134.9	157.4	178.9	201.9	224.1
DPF	0.69	0.81	0.87	0.90	0.92	0.93	0.88	0.87	0.86

Figure 8.5.1 (b) : DPF versus torque of motor driving escalator



A curve of DPF against torque is compiled in TG Figure 8.5.1 (b) from which it can be observed that at a torque of 170 Nm the corresponding DPF is 0.9.

Based on this identified DPF, the escalator supplier can after accounting for the THD of the driving controller (at the same brake load) assess the TPF of the motor drive assembly.

The above approach should work well for an equipment operating on mains sinusoidal voltage at its brake load. For an equipment operating on inverter (driving controller) supplied voltage that may not be purely sinusoidal, the inverter output voltage, subject to no oversizing of motor, may be set at close to mains voltage during the brake load. The BEC maximum allowable electrical power requirement (TG clauses 8.4.3 & 8.4.4) serves to discourage motor oversizing.

8.5.2 Lift Decoration Load (BEC clause 8.5.2)

The interpretation of decoration load in BEC Section 2 is extracted below for ready reference.

‘lift decoration load’ means the loads of the materials used in a lift car for decorative purpose and not essential to lift operative functions delineated in the Code of Practice on the Design and Construction of Lifts and Escalators, EMSD, which should include the floor tiles, additional ceiling panels, additional car wall decorative panels

and their corresponding materials for backing and/or fixing, but however exclude the balancing weights in association with provision of air-conditioning to the lift car.

The decoration load is a “dead load” that consumes power in counteracting its weight irrespective of whether the travelling lift is carrying passengers/goods or not. The maximum allowable decoration load is specified in BEC Table 8.5.2. TG Table 8.5.2 below gives the calculated values of decoration load based on the equations in BEC Table 8.5.2.

Table 8.5.2 : Allowable Lift Decoration Load (based on BEC Table 8.5.2)													
<u>Lift Rated Load (kg)</u>	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700
<u>Allowable Decoration Load (kg)</u>	250	300	350	400	450	500	550	600	600	600	600	600	600
<u>Lift Rated Load (kg)</u>	1800	1900	2000	2100	2200	2300	2400	2500	3000	3500	4000	4500	5000
<u>Allowable Decoration Load (kg)</u>	600	628	656	683	710	736	762	788	906	1012	1110	1184	1250

As opposed to the adoption of traditional heavy stone panel as the interior floor and side wall of the lift car, other lighter alternatives such as slightly thinner stone panel, light-weight stone panel (with aluminium backing) or vinyl tiling (for floor) may be considered to reduce the weight of this “dead load”. For the wall in particular, which demands a lower durability when compared with the floor, the light-weight stone panel or a lower percentage of tiled wall are good alternatives. The REA/designer should convey the requirement of decoration load to the architect or building owner well before the finalization of the architectural design of the lift car. The REA/designer may ask the architect or building owner to provide the car interior’s layout drawing and material specification as a substantiation of meeting the decoration load requirement.

8.5.3 Lift Parking Mode (BEC clause 8.5.3)

BEC clause 8.5.3 requires that at least one lift of a lift bank during low traffic period should be operable at parking mode. A lift bank as interpreted in BEC Section 2 means a lift system with two or more lifts serving a zone, including lifts that may serve more than one zone but for the time in question serving only the specific zone. With the lift idled at parking mode, its ventilation or air-conditioning can be shut off and its driving controller’s electronics may enter into an energy saving mode.

The parking mode may be actuated by lift auto programming, or by manual switching at the lift supervisory panel or at the control switch in the lift lobby or building

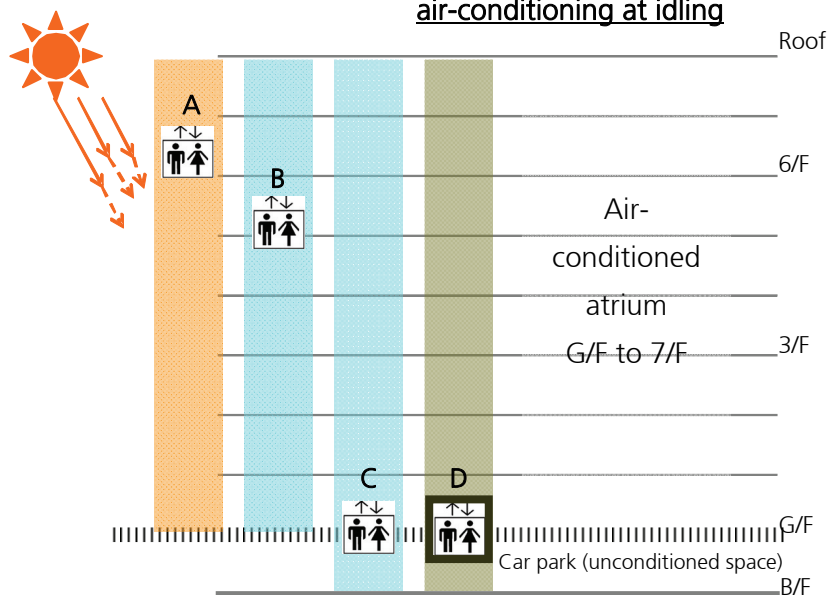
management counter. The parking mode may be discontinued when the low traffic period ends. With auto programming, the starting or ending of low traffic period may be set based on the time of the day or the number of landing and/or car calls. With manual switching, the setting to parking mode may be based on the time of the day (e.g. midnight hours). A low traffic period may be identified by the traffic demand on the lift bank falling to below a certain level, say 20%, of the lift bank’s handling capacity, which is the total number of passengers the lift bank can transport within a representative period of time (such as 5 minutes) at the peak traffic period; in simple terms (for reference by frontline building operators), a low traffic period may be identified by the passengers incoming rate falling to below say 20% of that at the peak time.

8.5.4 Lift Ventilation & Air-conditioning (BEC clause 8.5.4)

Aiming at provision only on a need basis, BEC clause 8.5.4 specifies that the ventilation or air-conditioning in a lift after having idled for a specific period should be automatically shut off, until the lift is reactivated.

To maintain thermal comfort in lift cars exposed to solar heat gain or infiltration from the surrounding unconditioned space, an observation lift under such exposure are exempted from the requirement in BEC clause 8.5.4. The observation lift refers to a lift with see-through glazed car wall/door and within a usually glazed or partially glazed lift well. The exemption is illustrated in TG Figure 8.5.4 using four lifts serving an air-conditioned atrium, three being observation lifts A, B & C with see-through glazing walls and the remaining an ordinary lift D. Lifts C and D serve both the car park at B/F (un-conditioned space) and the atrium, and lift A (at the building façade and exposed to atmosphere) and lift B (well within the air-conditioned atrium) serve only the atrium.

Figure 8.5.4 : Exemption from automatic shut-off of lift ventilation and air-conditioning at idling



<u>Lift designation</u>	<u>Exemption from Automatic Shut-off</u>	<u>Justifications / Remarks</u>
Observation lift A (with glazed car wall)	Yes	Travelling through outdoor space
Observation lift B (with glazed car wall)	No	Not travelling through outdoor or unconditioned space
Observation lift C (with glazed car wall)	Yes	Travelling through un-conditioned space, the carpark
Ordinary lift D (without glazed car wall)	No	Not an observation lift

The triggering condition of the shut-off for ventilation and for air-conditioning are different, for ventilation it is after the lift having idled 2 minutes whereas for air-conditioning it is after 10 minutes and accompanied with a further requirement of air-conditioning resumption no earlier than 5 minutes after the shut-off. Serving to delay the stopping and starting of the compressor of the lift’s unitary air-conditioner, the 10-minute delay to shut-off and 5-minute delay to restart are to strike a balance between the maintaining of air-conditioning thermal comfort, the saving of air-conditioning energy (when lift is idled), and the sustaining of the compressor’s operating life which would much shorten if stopped and started too frequently.

8.6 Total Harmonic Distortion (BEC clause 8.6)

The requirements on total harmonic distortion (THD) given in BEC clause 8.6 is summarized in TG Table 8.6.1 below.

<u>Table 8.6.1 : Requirements on Total Harmonic Distortion</u>			
<u>Equipment</u>	<u>Operating condition</u>	<u>Requirements</u> (BEC clauses 8.6.1 to 8.6.3)	
		The THD in each phase produced by the motor drive at the isolator connecting the lift, escalator or passenger conveyor to the building’s electrical supply circuit should be limited to the following (BEC Tables 8.6.1 & 8.6.2) -	
Lift	Carrying rated load at rated speed and travelling upward	<u>Circuit fundamental current I</u>	<u>THD (%) in each phase</u>
		$I < 40A$	40%
		$40A \leq I < 80A$	35%
		$80A \leq I < 400A$	22.5%
		$400A \leq I < 800A$	15%

Escalator	Carrying no load at rated speed	<u>Circuit fundamental current I</u>	<u>THD (%) in each phase</u>	
		$I < 40A$	35%	40%
(supply direct from building's feeder circuit)			(supply not direct from building's feeder circuit)	
35%				
Passenger Conveyor	$40A \leq I < 80A$	35%		
	$80A \leq I < 400A$	22.5%		

If the manufacturer-provided driving controller when coupled with the motor meets the THD requirement, the installation of a correction device is not required.

A correction device if needed can be installed at the motor control centre of the motor drive to improve the THD to the above corresponding tabulated levels.

The equipment supplier should assess the THD of the driving controller. The THD, measurable up to 31st harmonics, can be verified based on actual measurement, for lifts at rated load rated speed upward, and for escalators and passenger conveyors at no load rated speed. The THD of the driving controller contributes to the TPF of the circuit as stipulated in TG clause 8.5. (THD is also described in TG clauses 7.6 and 7.8).

For lifts, the THD requirement catering for the I²R losses is based on rated load, whereas for escalators and passenger conveyors given their frequent operation at no or low load it is based on no-load condition.

8.7 Metering & Monitoring Facilities

- (a) For purpose of better energy efficiency management, BEC clause 8.7 specifies the requirements on metering and monitoring facilities for each of the lifts, escalators or passenger conveyors, which are reproduced in table form in TG Table 8.7 below.

While simple ammeters and voltmeters can measure currents and voltages, which are sinusoidal, they alone cannot give accurate readings when harmonics are present, and also they cannot give readings of energy, maximum demand, TPF and THD, which have to rely on meters with data-logging and analytical function, such as a digital power analyzer or multi-function meter complete with current transformers (CT) to measure the line currents. The meters should be able to measure the parameters with true root mean square values.

It is common that the circuit from the isolator (connecting the lift, escalator or passenger conveyor to the building's electrical supply circuit) to the driving controller is a 3-wire circuit. A 3-CT meter configuration that employs three CTs, one for each phase with the value for the neutral calculated by the metering device, is generally acceptable.

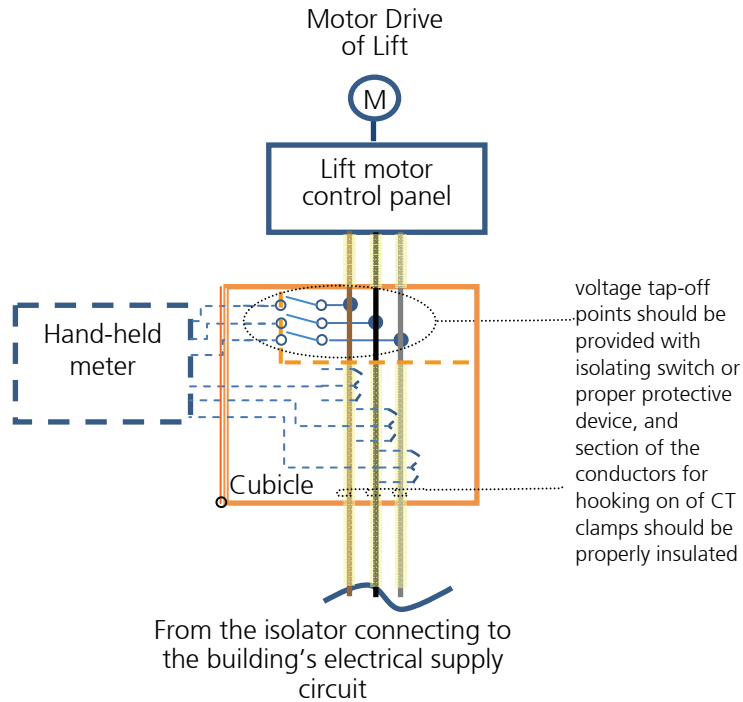
Table 8.7 : Provisions for and Parameters Requiring Measurement, for the Electrical Supply Circuit for the Motor Drive of Each Lift, Escalator or Passenger Conveyor

<p>Provision of :</p> <ul style="list-style-type: none"> - metering devices (devices well fixed and secured in positions as a permanent installation), <p>Or</p> <ul style="list-style-type: none"> - provision for measurement (facilitating the carrying out of measurement using hand-held or plugged-in metering) which should constitute an electrical cubicle, or junction box <ul style="list-style-type: none"> ◆ through which the electrical supply circuit for the motor drive passes, ◆ right beside or nearby the control panel/motor control centre of the motor drive, and ◆ equipped to facilitate the ready connection and subsequent removal of the metering devices for measurement not entailing a stoppage or disruption to the operation of the equipment, except <ul style="list-style-type: none"> ● for an escalator or a passenger conveyor with its control panel / motor control centre housed in a machinery space or return station or in an escalator/conveyor enclosure the stoppage or disruption is allowed for the opening up of the landing plate or inspection door to access the cubicle or junction box 	<ul style="list-style-type: none"> - Voltages (all phase-to-phase & phase-to-neutral) - Currents (three phases and neutral) - Power (kW) - Total energy consumption (kWh) - Maximum demand (kVA) - TPF - THD (capable of measuring 31st and lower harmonic order)
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As a good engineering practice for permanent installation, the measured data may be transmitted for enhanced monitoring and control to the central control & monitoring system or BMS with energy management function.

For the provision for measurement, the cubicle or junction box should have sufficient space for the application of clamping device around the circuit conductors for current measurement, and for the application of tapping or clipping device to the conductors for voltage measurement; to avoid touching the live parts, the section of the conductors for hooking on of CT clamps should be properly insulated and the voltage tap-off points should be provided with isolating switch or proper protective device. An illustration of a cubicle (or junction box) as the provision for measurement is shown in TG Figure 8.7 (a) below.

Figure 8.7 (a) : Illustrative diagram of provision for measurement in a cubicle



(b) Site measurements on electrical power, TPF and THD to demonstrate the fulfilling of the corresponding requirements in BEC Section 8 are generally acceptable subject to as a minimum –

- the metering device for the measurement can account for harmonic currents up to the 31st order i.e. 31 x 50 Hz, and
- the total kVA in arriving at TPF is based on the average line voltage and the average line current of all three phases, i.e. -
 - average line voltage = $(V_{12} + V_{23} + V_{31}) / 3$,
 - average line current = $(I_{L1} + I_{L2} + I_{L3}) / 3$, and
 - total kVA (apparent power) = $\sqrt{3} \times \text{average line voltage} \times \text{average line current}$

8.8 Emerging Good Engineering Practice for Normalization & Monitoring of Lift Energy Consumption

A relatively new idea has emerged in recent years in respect of normalizing the lift energy consumption based on its energy consumed per unit load per unit distance travelled. As introduced in section 13.5.2 of CIBSE Guide D 2010, the idea was put forth in an article (by Lam, So and Ng) for an international elevator congress[®]. A benchmarking parameter, *J/kg-m*, has been suggested, which can reflect the energy performance of a lift or a bank of lifts accounting for both the power consumption of the motor drive as well as the intelligence of the supervisory controls.

Information on three parameters are needed to evaluate *J/kg-m*, namely energy consumption in Joule (3.6 MJ is equivalent to 1 kWh), car load W in kilogram (kg) and

distance D travelled in metres (m). Within a time period T , the total energy E_T consumed by one lift or a bank of lifts can be measured. Within T , there are n number of brake-to-brake journeys, which starts at the moment when the brake is released at the departing floor until it is applied again at the destination floor. For each journey, the i^{th} journey, car load W_i , and distance travelled D_i irrespective of direction, can be measured. The following equation relates the three parameters -

$$J/kg-m = \frac{E_T}{\sum_{i=1}^n W_i D_i}$$

T can be as short as half an hour, an hour, a day or even a week. But once T is determined, it should remain unchanged as far as possible for subsequent comparisons. Lift operators/owners may continuously monitor the normalized energy consumption based on these parameters and once a data pool big enough is available, it is possible to establish a benchmark for comparison among different lifts. Again, the same T should preferably be used when comparing the energy performance of different lifts or lift banks.

The lower the $J/kg-m$ figure, the lower would be the energy consumption of the lift; certain previous measurements indicate figures ranging from 30 to around 150.

Having introduced the good engineering practice, the above is not a requirement in BEC Section 8.

[@] Lam D.C.M., So A.T.P., Ng T.K., "Energy conservation solutions for lifts and escalators of Hong Kong Housing Authority", *Elevator Technology 16, Proceedings of 16th World Congress on Elevator Technologies*, The International Association of Elevator Engineers, Helsinki, June, 2006, pp. 190-199

9. Performance-based Approach

9.1 Scope of Application (BEC clause 9.1)

BEC Section 9 provides the guidelines for the performance-based approach, which is regarded as an alternative approach to meeting all the prescriptive requirements in Sections 5 to 8 in respect of installations of lighting, air-conditioning, electrical and lift and escalator.

For a building design that fully complies with BEC Sections 5 to 8, the seeking of BEC compliance under the performance-based approach is not required. Nevertheless the calculation of the energy performance of the building design based on the modeling and simulation techniques specified in BEC Section 9 is encouraged as a good engineering practice.

9.1.1 Comprehensive View on Applicability

To gain a comprehensive view embracing the performance-based approach in relation to the Ordinance, BEC clause 9.1 should be read in conjunction with –

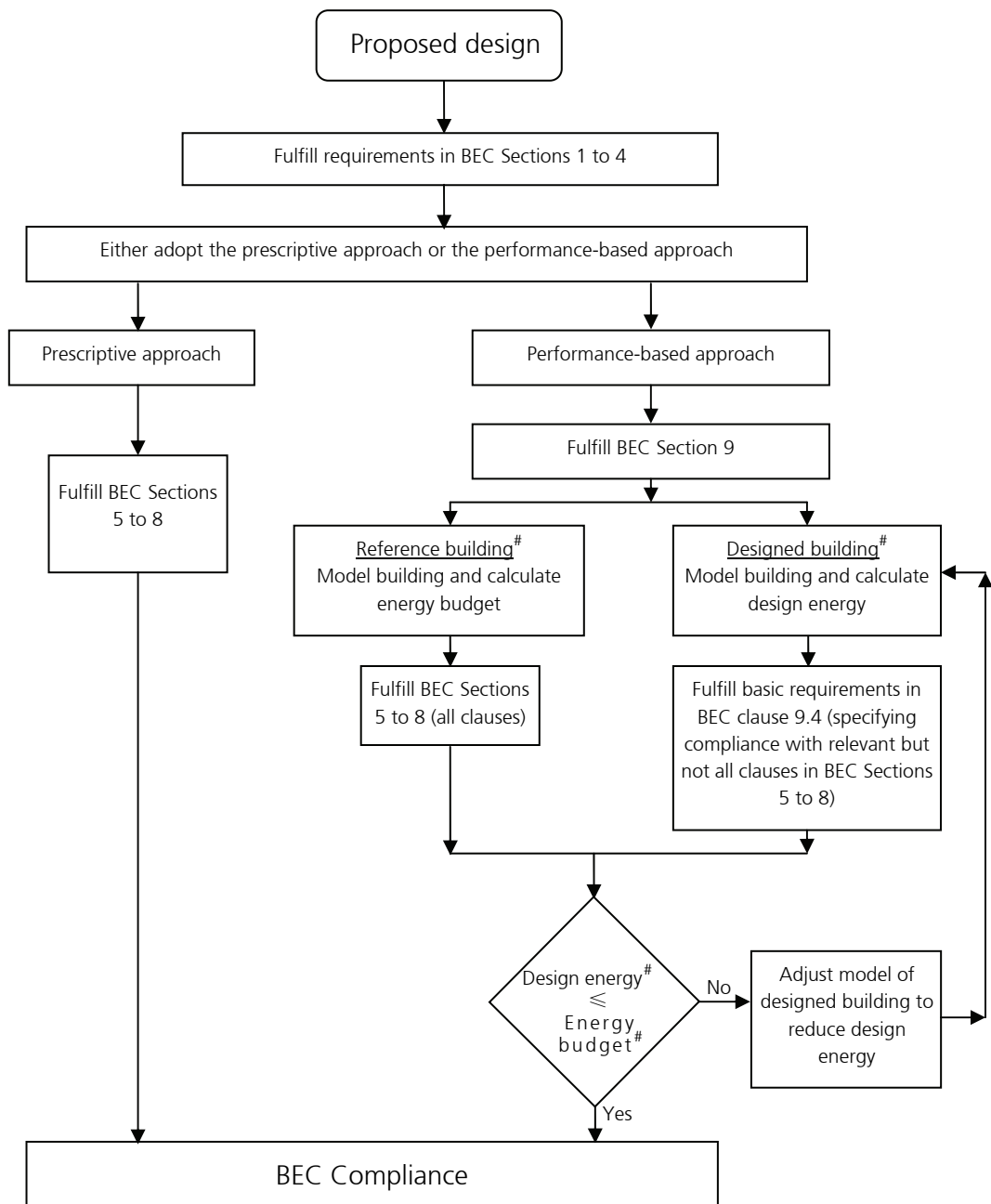
- BEC Sections 3 & 4 that briefly describe the scope and limits of the application of the Ordinance based on its prescribed requirements in Parts 2 & 3;
- BEC clauses 5.1 to 5.3, 6.1 to 6.3, 7.1 to 7.3 and 8.1 to 8.3, the clauses on scope of application, general approach and definitions in the respective sections, their applicability of which are affirmed for the avoidance of doubt in BEC clause 9.1.2; and
- TG Sections 3 & 4 that elaborate on the scope and limits of application and the necessary steps to demonstrate the compliance with the Ordinance and the BEC.

9.2 General Approach (BEC clause 9.2)

The requirements specific for the performance-based approach in BEC clauses 9.4 and 9.5 are based on the general approach to energy efficiency given in BEC clause 9.2. TG Figure 9.2 below gives a flow chart indicating the process of BEC compliance by virtue of the performance-based approach as an alternative to the prescriptive full compliance with BEC Sections 5 to 8.

With the focus on requiring the calculation of the annual total energy consumption of the building under design, the designer can tell and thus the building owner can be informed at the design stage of the energy performance of the designed building, and the choice of the final design can be based on an evaluation of the energy performances of the different design options.

Figure 9.2 : BEC compliance approach



Remarks -

Designed building means the building or unit for which compliance with this BEC based on the performance-based approach BEC Section 9 is being sought, and includes its building envelope, building services installations and energy consuming equipment.

Reference building means a building design of the same size and shape as the designed building or unit, modeled in accordance with the requirements given in BEC Section 9 and with corresponding building services installations fully satisfying the energy efficiency requirements given in BEC Sections 5 to 8.

Design energy means the total energy consumption of the designed building modeled in accordance with the requirements given in BEC Section 9.

Energy budget means the total energy consumption of the reference building modeled in accordance with the requirements given in BEC Section 9.

9.3 Definitions (BEC clause 9.3)

BEC Section 2 provides the interpretations and abbreviations related to the BEC and the Ordinance, including those for the performance-based approach.

9.4 Basic Requirements (BEC clause 9.4)

The basic requirements in BEC Table 9.4 are simply the prescriptive energy efficiency requirements that are applicable to the designed building. By not including as basic requirements in BEC Table 9.4 all the clauses in BEC Sections 5 to 8, the exemption is granted, subject to the fulfilling of the condition specified in TG clause 9.5, to the requirements on –

- lighting power density (BEC clause 5.4)
- air distribution system fan power (BEC clause 6.7), and
- air-conditioning equipment efficiency (BEC clause 6.12).

The above exempted items are termed as trade-off allowable requirements in BEC clause 9.4.2. The designed building does not necessarily have to comply with these trade-off allowable requirements whereas it is a must for the reference building. The trade-off allowable requirements plus the basic requirements constitute the energy performance requirements in BEC Sections 5 to 8.

The above exemption serves to provide certain design flexibility to limited items, with the view of encouraging innovative design, example of one being a lighting installation that has a higher installed lighting power density but a lower actual energy consumption as a result of its energy efficient lighting control.

9.5 Comparison of Design Energy & Energy Budget (BEC clause 9.5)

BEC clause 9.5 requires the comparison of the “building design to be adopted” or the designed building, with “itself at a slightly different condition” or the reference building. The slightly different condition refers to the full compliance with all the prescriptive requirements in BEC Sections 5 to 8, whereas on the other hand the designed building can be exempted from certain requirements, the trade-off allowable requirements. Having so given the exemption, the adoption of the exemption can be selective and not exhaustive; an example being that the adoption of the exemption on lighting power density can be confined to say a small percentage instead of all of the lighting spaces of the designed building.

BEC clauses 9.5.1 and 9.5.2 and BEC Appendix A give the requirements on the modeling of both the designed building and the reference building and the calculation of their corresponding annual total energy consumptions, respectively the design energy and the energy budget. The essence of the performance-based approach is that the design energy should not exceed the energy budget (as specified

in BEC clause 9.5.3), which means that the designed building is at least as energy efficient as its reciprocal building, the reference building, and the achievement is by means of adopting for certain relevant items a more energy efficient design than one that complies with the applicable relevant requirement in BEC Section 5 to 8. As an encouragement to the more energy efficient design, it is allowed to trade-off its energy reduction with that of the trade-off allowable requirements described in BEC and TG clause 9.4.

Additional rules for the trade-off are given in BEC clauses 9.5.4. Below give certain guidelines to these rules.

OTTV

The trade-off of energy with a better OTTV is limited to not more than 5% of the energy budget. The limitation is to direct the focus of enhanced energy efficient design more on the building services installations rather than just relying on OTTV improvement, as Cap 610 is a building services installation oriented ordinance.

The trade-off of energy with a better OTTV is not allowed for buildings not under the scope of coverage of the Building (Energy Efficiency) Regulation (Cap 123M) that mandates the OTTV requirements. Given Cap 123M governs only the commercial buildings and hotels with first building plans submitted after 21 July 1995, the following buildings are not governed by the mandatory OTTV requirements and thus would not be allowed the trade-off of energy with a better OTTV –

- buildings not categorized as commercial building or hotel, and
- commercial buildings and hotels not governed by Cap 123M.

Trade-off items under same ownership

The items or installations involved in the trade-off process should be under the same ownership. For example, the energy increase of a tenant owned lighting installation (usually in the tenant occupied space) cannot be off-set with the energy reduction from the central chiller plant owned by the building owner.

Subsequent alteration or replacement

Any subsequent alteration, replacement or adjustment of items or installations previously involved in a trade-off should always result in an overall design energy not exceeding the energy budget. For example, if a photovoltaic system previously involved in a trade-off is to be demolished for whatever reasons, the building's calculated annual total building energy consumption should be reassessed to identify if the design energy has exceeded the energy budget as a result of the demolition, and if yes certain compliance retrofitting should be carried out to reduce the design energy to not exceeding the energy budget. Another example is a retrofit of the lighting installation previously involved in a trade-off, which should not be retrofitted

with less energy efficient luminaires to increase the design energy to above the energy budget.

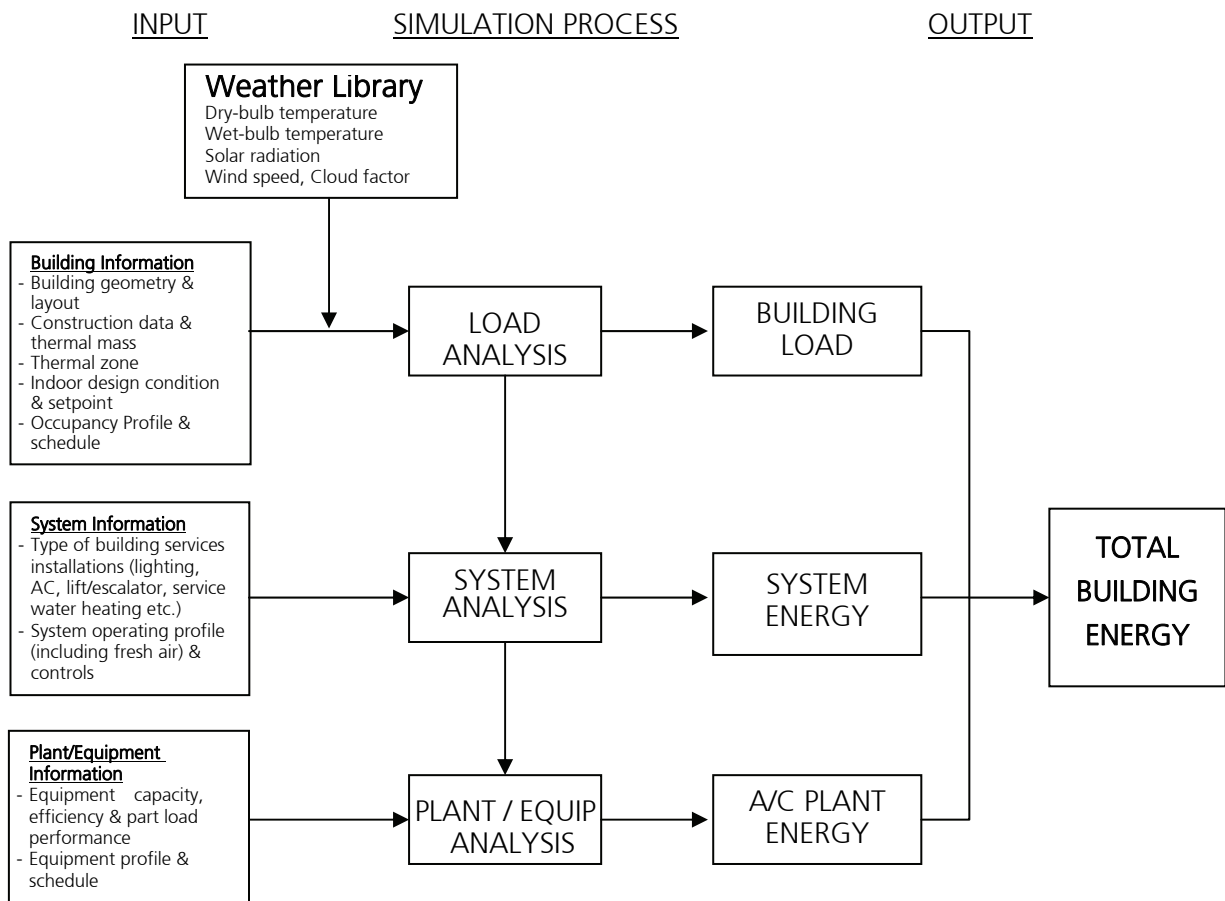
Items not installed

An item or installation not yet installed should not be involved in the trade-off, as its installation at a later date cannot be guaranteed.

9.6 Numerical Method for Building Energy Analysis (BEC Appendix A)

BEC Appendix A gives the guidelines on the numerical method for building energy analysis which usually relies on computer simulation. A snapshot of the simulation process is shown in TG Figure 9.6 below.

Figure 9.6 : Simulation process in numerical method for building energy analysis



TG Table 9.6 below shows certain public domain available computer simulation programs commonly used in Hong Kong by building designers in the calculation of annual total building energy consumption. Their listing serves only as a reference source of simulation programs, and does not imply they fully meet ALL the requirements in BEC Appendix A.

Table 9.6 : Commonly Used Building Energy Simulation Programs	
Program	Information Source
DOE-2. PC version/interface of DOE-2 and DOE-2 derivatives : <ul style="list-style-type: none"> • eQuest • VisualDOE 	(supported by U.S. Department of Energy) http://doe2.com/ http://www.archenergy.com/products/visualdoe/
EnergyPlus	(supported by U.S. Department of Energy) http://www.energyplus.gov/
HAP	http://www.commercial.carrier.com/commercial/hvac/general/0%2C%2CCLI1_DIV12_ETI496_MID4355%2C00.html
TRACE 700	http://www.trane.com/Commercial/DNA/View.aspx?i=1136
TRNSYS	http://www.trnsys.com/
Tas	http://www.edsl.net/
ESP-r	http://www.esru.strath.ac.uk/Programs/ESP-r.htm
IESVE	http://www.iesve.com/
Ener-Win	http://pages.suddenlink.net/enerwin/
BEEP	http://www.bse.polyu.edu.hk/research/BEP/BEEP/BEEP.htm (though accounted for in cooling load & cooling energy calculation, lighting electrical energy is not summed up & output as a single consumption figure)

While some programs are more user-friendly, they tend to have certain limitations, example being eQuest’s limited capability to fully model individual chiller’s part load performances (which may be less a concern if the trade-off does not involve chiller energy use).

Some programs may have certain minor inadequacy, which however may not significantly affect the overall simulation results when the data input is handled with care and professional skill.

Weather file

Weather data of the example or typical weather year of Hong Kong should be used in the numerical analysis. The weather data file can be plugged into the simulation program for the analysis. A source on the public domain for downloading a Hong Kong weather file is as follows –

http://apps1.eere.energy.gov/buildings/energyplus/cfm/weather_data3.cfm/region=2_asia_wmo_region_2/country=CHN/cname=China

10. Energy Efficiency Requirements for Major Retrofitting Works

10.1 Scope of Application (BEC clause 10.1)

10.1.1 Comprehensive View on Applicability and BEC Table 10.1

BEC Section 10, BEC Table 10.1 in particular, on major retrofitting works provides the comprehensive view on what constitute major retrofitting works based on the 500 m² works area criterion and the main CBSI component criterion. BEC Table 10.1 lists the details on the category of the works, the relevant conditions for applicability of BEC requirement, and the applicable BEC requirements and corresponding BEC clause numbers. (CBSI is explained in TG clause 4.2.4.) This section, TG Section 10, gives the further guidance on how to check if a works item falls within the scope of major retrofitting works based on BEC Table 10.1.

A textual description of the checking process in BEC Table 10.1 is given in TG clause 10.1.2 below. To provide a diagrammatic view of the checking process, a flow chart is given in TG clause 10.1.3. Examples of work items regarded as major retrofitting works are also given in TG clauses 10.1.4 and 10.1.5.

Attention is drawn that works that appear to fall within major retrofitting works by virtue of meeting the 500 m² criterion or CBSI main component criterion may not necessarily fulfil the conditions for applicability, which simply means that there are no applicable BEC requirements. For easy cross-reference, the item and sub-item numbering in BEC Table 10.1 are same as those in TG Figure 10.1. It should also be noted that in BEC Table 10.1 the capacity related conditions for applicability, namely 3 kW lighting circuit in sub-item (a)(i), 60 kW cooling/heating in sub-item (a)(ii), 400 A electrical circuit rating in sub-item (b)(i) and 350 kW cooling/heating in sub-item (b)(ii) refer to the capacity of the replacement or replacing equipment.

10.1.2 Textual Description of Checking Process in BEC Table 10.1

10.1.2.1 When referring to BEC Table 10.1, first identify if the works are preliminarily regarded as major retrofitting works by the works area criterion of 500 m², or by the CBSI main component criterion; for the former item (a) of the table is applicable, and for the latter item (b) of the table is applicable. The following paragraphs give the approach for works with item (a) applicable, of which a similar approach may be adopted for works with item (b) applicable.

Under either items (a) or (b), there are respectively five columns. In checking the applicability of the requirements cited in columns four and five in the table, the category of the works in column one and the conditions for applicability should be first checked. The conditions for applicability are given in columns two and three (for certain rows the contents under both columns are integrated in a single cell for

simplicity).

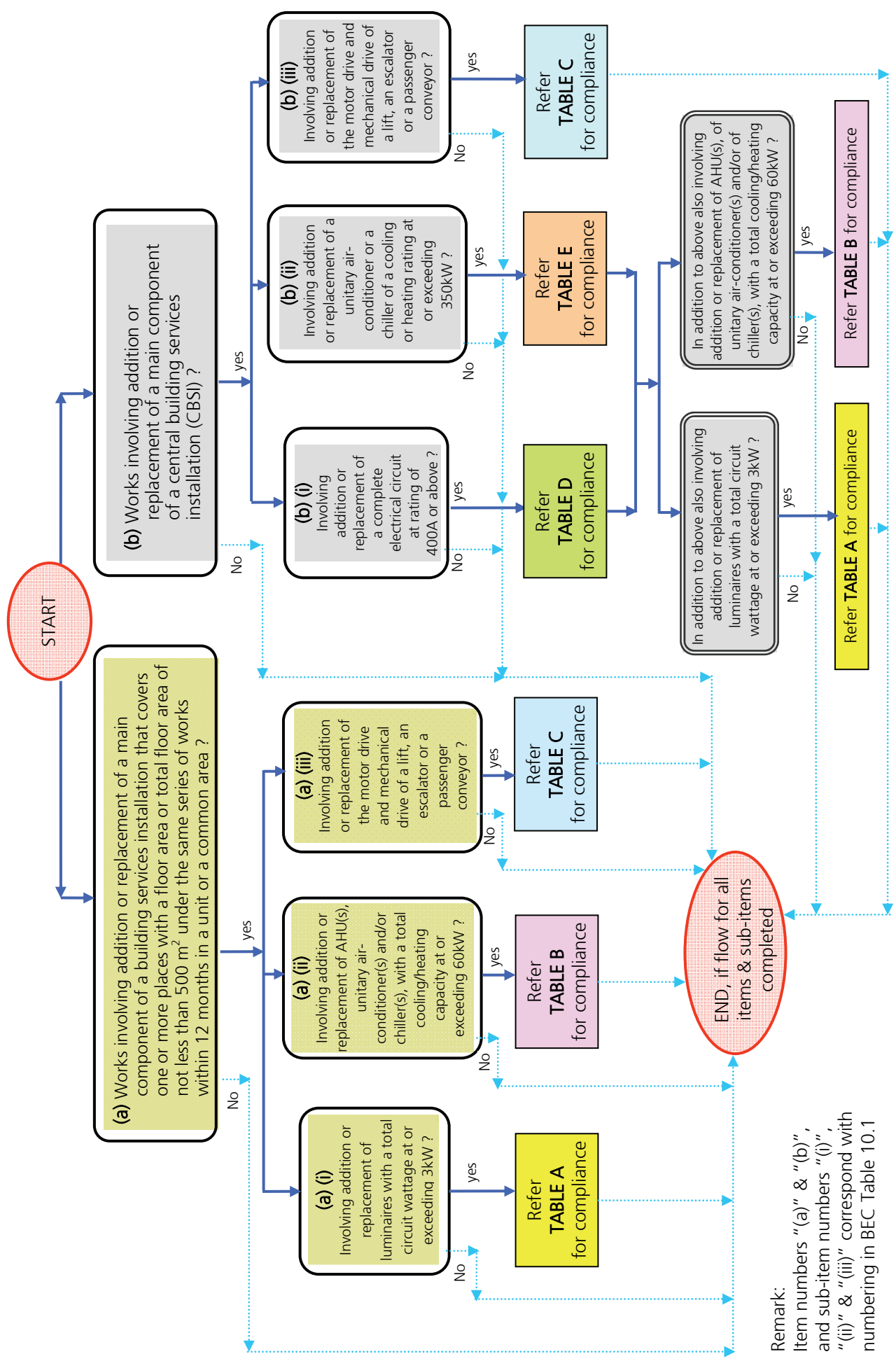
- 10.1.2.2 Take for example a retrofit of building services installations involving a works area of 500 m², which fulfills item (a), and involving the addition or replacement of luminaires. The retrofit thus fulfills the descriptions in sub-item (i) under item (a). From here proceed to the cell in column two, which reads "*total circuit wattage of the additional or replacement luminaires at or exceeding 3kW*". Should the total circuit wattage of the retrofit be less than 3kW, the retrofit would not be regarded as major retrofit works. Should the total circuit wattage be of 3kW or more, proceed further to column three, which has two rows, and the contents in each should be examined. The cell in the first row reads "*no existing luminaires in the area, or the sum of circuit wattage of additional or replacement luminaires is more than 50% of the original luminaires in the area*". It follows that should the additional or replacement luminaires be not more than 50% of the original luminaires in circuit wattage the retrofit is not regarded as major retrofitting works, whereas should the retrofit involves a more than 50% of the original luminaires in circuit wattage the retrofit is regarded as major retrofit works and has to comply with the requirements cited in the cells in columns four and five, that is the lighting power density (LPD) in the space has to comply with the requirements specified in BEC clause 5.4. Finishing off with this row, proceed to the cell in the next row of column three, which reads "*the area has no existing luminaires, or the work involves a complete rewiring of the existing lighting circuits in the area*", and should the condition not be applicable there is no further requirement, whereas should the condition be fulfilled the requirements cited in the cells in columns four and five should be complied with, that is the lighting control of the retrofit should comply with the requirements specified in BEC clause 5.5. Attention is drawn that should the works area be an aggregate of floor area of several places, the condition for applicability in column three would apply to each of these places, and it follows that the place not fulfilling the conditional applicability would not be governed by the respective BEC requirement in columns four and five.
- 10.1.2.3 Should the above retrofit involves, in addition to lighting, the addition or replacement of AHU(s), unitary air-conditioner(s) and/or chiller(s), the retrofit also fulfills the descriptions in sub-item (ii) under item (a). From this point proceed to the cell in the column two, which reads "*total cooling/heating capacity of the additional or replacement air handling unit(s), unitary air-conditioner(s) and/or chiller(s) at or exceeding 60kW*". Should the 60kW rating not be fulfilled there is no further requirement in respect of air-conditioning, whereas should the 60 kW rating be fulfilled each of the conditions cited in the cells in column three should be checked and the respective requirements in the cells in columns four and five be complied with accordingly.
- 10.1.2.4 Should the above retrofit involves, in addition, also the works described in sub-item (iii) under item (a), the conditions under the item should also be checked and the

applicable requirements be complied with.

10.1.3 Flow Chart on Checking Process in BEC Table 10.1

TG Figure 10.1 below gives, in the form of a flow chart, the guidance on the checking process of BEC Table 10.1, with examples indicating the flow chart process given in TG clauses 10.1.4 and 10.1.5.

Figure 10.1 : Flow chart illustrating what are regarded as major retrofitting works and the corresponding BEC requirements based on BEC Table 10.1



Remark:
Item numbers "(a)" & "(b)",
and sub-item numbers "(i)",
"(ii)" & "(iii)" correspond with
numbering in BEC Table 10.1

Figure 10.1 : Flow chart illustrating what are regarded as major retrofitting works and the corresponding BEC requirements based on BEC Table 10.1 (Continued)

TABLE A		TABLE B		TABLE C		TABLE D		TABLE E	
Condition for Applicability	no existing luminaires in the area, or the sum of circuit wattage of additional or replacement luminaires is more than that of 50% of the original luminaires in the area	Condition for Applicability	involving addition or replacement of unitary air-conditioner and/or chiller	Condition for Applicability	the work involving a traction drive lift with machine above and with 1:1 or 2:1 suspension roping system, a hydraulic lift, an escalator or a passenger conveyor	Condition for Applicability	the work involving a complete main circuit, except for cable route between existing transformer room and associated LV switch room with length exceeding 20 m	Condition for Applicability	applicable in any conditions
Applicable BEC Requirement	lighting power density, BEC clause 5.4	Applicable BEC Requirement	air- conditioning equipment efficiency, BEC clause 6.12	Applicable BEC Requirement	electrical power, BEC clause 8.4	Applicable BEC Requirement	distribution loss, BEC clause 7.4.2	Applicable BEC Requirement	air- conditioning equipment efficiency, BEC clause 6.12
Condition for Applicability	the area has no existing luminaires, or the work involves a complete rewiring of the existing lighting circuits in the area	Condition for Applicability	the additional or replacement AHU(s) forming a complete air distribution system in the context of BEC clause 6.7	Applicable BEC Requirement	total power factor, BEC clause 8.5.1	Condition for Applicability	the work involving a complete feeder	Condition for Applicability	the work involving the replacement of air-conditioning equipment the addition or complete replacement of corresponding water side pumping system
Applicable BEC Requirement	lighting control, BEC clause 5.5	Applicable BEC Requirement	separate air distribution system for process requirements, BEC clause 6.5	Applicable BEC Requirement	lift ventilation and air-conditioning, BEC clause 8.5.4	Condition for Applicability	the work involving a complete final circuit	Applicable BEC Requirement	frictional loss of water piping system, BEC clause 6.9
Condition for Applicability	the work involving additional water pipework	Condition for Applicability	the work involving a traction drive lift, a hydraulic lift, an escalator or a passenger conveyor	Applicable BEC Requirement	total harmonic distortion, BEC clause 8.6	Condition for Applicability	the work involving a complete feeder, or involving a complete sub-circuit and all its downstream final circuits	Condition for Applicability	ditto, the corresponding water side pumping system forming an independent system
Applicable BEC Requirement	frictional loss of water piping system, BEC clause 6.9	Condition for Applicability	the work involving addition of a lift or replacement of a lift car	Applicable BEC Requirement	metering & monitoring facilities, BEC clause 8.7	Condition for Applicability	the work involving a main circuit, a feeder or a sub-circuit, with addition of corresponding switch cubicle for the circuit termination at the main LV switchboard	Applicable BEC Requirement	pumping system variable flow, BEC clause 6.8
Condition for Applicability	the work involving complete replacement of corresponding water side pumping system	Applicable BEC Requirement	thermal insulation, BEC clause 6.11	Applicable BEC Requirement	lift decoration load, BEC clause 8.5.2	Condition for Applicability	the work involving metering & monitoring facilities, BEC clause 7.7	Applicable BEC Requirement	thermal insulation, BEC clause 6.11
Applicable BEC Requirement	thermal insulation, BEC clause 6.11	Condition for Applicability	the work involving additional or replacement pipework, ductwork or AHU	Applicable BEC Requirement	motor efficiency, BEC clause 7.5.1	Condition for Applicability	the work involving balancing of single-phase loads, BEC clause 7.6.3	Applicable BEC Requirement	motor efficiency, BEC clause 7.5.1
Condition for Applicability	the work involving addition or replacement of water pump with new motor, or of fan with new motor	Applicable BEC Requirement	motor efficiency, BEC clause 7.5.1	Applicable BEC Requirement	metering & monitoring facilities, BEC clause 7.7	Condition for Applicability	the work involving metering & monitoring facilities, BEC clause 7.7	Applicable BEC Requirement	motor efficiency, BEC clause 7.5.1

10.1.4 Examples of Major Retrofitting Works by Virtue of Fulfilling the 500 m² Works Area Criterion

Examples of work items regarded as major retrofitting works are given in TG clauses 10.1.4.1 to 10.1.4.4.

- 10.1.4.1 Consider a retrofit involving the replacement of a number of AHUs serving specific units, which have a total cooling capacity of 300 kW. The replacement includes the AHU fan motors, and each AHU serves specific unit(s). There are no changes to the existing pipework, ductwork and electrical circuitries for each of the AHUs, except at the interfacing with the new AHU where certain modification works are required to facilitate the replacement. The total works area for the retrofit is 550 m² and the works are of the same series within a 12-month period.

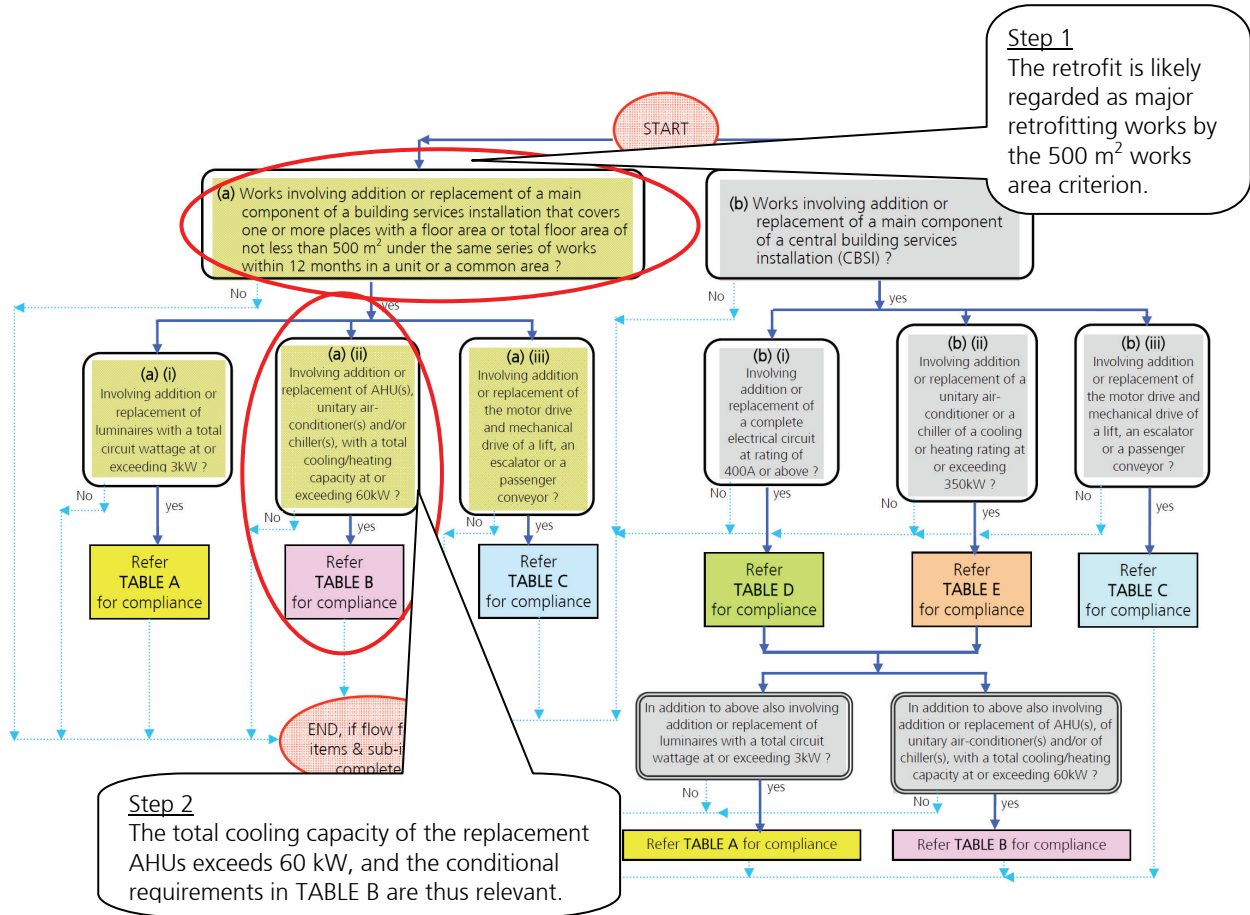
The applicability, based on TG Figure 10.1, of the category of work, the conditions for applicability, and the applicable requirements are indicated in TG Figure 10.1.4.1, against a miniature background of TG Figure 10.1, in which the applicable boxes and cells in the figure are circled with insertion of explanatory text boxes.

As shown in TG Figure 10.1.4.1, the retrofit is likely regarded as major retrofitting works by the works area criterion of 500 m². However the AHUs are not regarded as a CBSI since each AHU serves specific unit(s). The total cooling capacity of the replacement AHUs fulfills the condition for applicability of at or exceeding 60 kW (sub-item (a)(ii) in BEC Table 10.1), and thus the requirements in TG Figure 10.1 TABLE B are relevant – the interfacing pipework and ductwork are governed by BEC clause 6.11 in respect of requirements on thermal insulation, and the motors of the AHUs are governed by BEC clause 7.5.1 in respect of motor efficiency. The energy efficiency requirements in the other rows of TABLE B are not applicable, given the conditions of applicability being not fulfilled.

Attention is drawn that a fan coil unit (FCU) is analogous to an AHU in the BEC, and a retrofit of FCU should be handled in the same manner as for the AHU, except that the BEC does not have specific requirements in respect of motor efficiency on FCU motors (commonly single-phase and with rated output less than 0.75 kW (BEC Table 7.5.1)).

- 10.1.4.2 Consider the same retrofit above, but this time certain luminaires within the works area are to be replaced too, and the total circuit wattage of the replacement luminaires is 2 kW. In this example, the applicable energy efficiency requirements are same as in the example above. The luminaires' total circuit wattage is less than 3 kW, which does not fulfill the condition for applicability of at or exceeding 3 kW (sub-item (a)(i), Table 10.1), and hence the luminaires are not governed by the energy efficiency requirements in TG Figure 10.1 TABLE A.

Figure 10.1.4.1 : Illustration, against background of TG Figure 10.1, of energy efficiency requirements for examples in TG clause 10.1.4.1



Step 2
The total cooling capacity of the replacement AHUs exceeds 60 kW, and the conditional requirements in TABLE B are thus relevant.

TABLE A		TABLE B		TABLE C		TABLE D		TABLE E	
Condition for Applicability	Applicable BEC Requirement	Condition for Applicability	Applicable BEC Requirement	Condition for Applicability	Applicable BEC Requirement	Condition for Applicability	Applicable BEC Requirement	Condition for Applicability	Applicable BEC Requirement
no existing luminaires in the area, or the sum of circuit wattage of additional or replacement luminaires is more than that of 50% of the original luminaires in the area	lighting power density, BEC clause 5.4	involving addition or replacement of unitary air-conditioner and/or chiller	air- conditioning equipment efficiency, BEC clause 6.12	the work involving a traction drive lift with machine above and with 1:1 or 2:1 suspension roping system, a hydraulic lift, an escalator or a passenger conveyor	electrical power, BEC clause 8.4	the work involving a complete main circuit, except for cable route between existing transformer room and associated LV switch room with length exceeding 20 m	distribution loss, BEC clause 7.4.2	applicable in any conditions	air- conditioning equipment efficiency, BEC clause 6.12
the area has no existing luminaires, or the work involves a complete rewiring of the existing lighting circuits in the area	lighting control, BEC clause 5.5	the additional or replacement AHU(s) forming a complete air distribution system in the context of BEC clause 6.7	separate air distribution system for process requirements, BEC clause 6.5	the work involving a traction drive lift, a hydraulic lift, an escalator or a passenger conveyor	total power factor, BEC clause 8.5.1	the work involving a complete feeder	distribution loss, BEC clause 7.4.3	the work involving for the additional or replacement air-conditioning equipment the addition or complete replacement of corresponding water side pumping system	frictional loss of water piping system, BEC clause 6.9
		the work involving additional water pipework	air distribution system fan power, BEC clause 6.7		lift ventilation and air-conditioning, BEC clause 8.5.4	the work involving a complete sub-circuit	distribution loss, BEC clause 7.4.4	energy metering, BEC clause 6.13	
		the work involving a complete replacement of corresponding water side pumping system	frictional loss of water piping system, BEC clause 6.9		total harmonic distortion, BEC clause 8.6	the work involving a complete final circuit	distribution loss, BEC clause 7.4.5	ditto, the corresponding water side pumping system forming an independent system	pumping system variable flow, BEC clause 6.8
		the work involving additional or replacement pipework, ductwork or AHU	thermal insulation, BEC clause 6.11	the work involving addition of a lift or replacement of a lift car	metering & monitoring facilities, BEC clause 8.7	the work involving a complete feeder, or involving a complete sub-circuit and all its downstream final circuits	total power factor, BEC clause 7.6.1	the work involving addition or replacement of pipework, ductwork or AHU	thermal insulation, BEC clause 6.11
		the work involving addition or replacement of water pump with new motor, of AHU with new motor, or of fan with new motor	motor efficiency, BEC clause 7.5.1		lift decoration load, BEC clause 8.5.2	the work involving a main circuit, a feeder or a sub-circuit, with addition of corresponding switch cubicle for the circuit	total harmonic distortion, BEC clause 7.6.2	the work involving addition or replacement of water pump with new motor, of AHU with new motor, or of	motor efficiency, BEC clause 7.5.1
							balancing of single-phase loads, BEC clause 7.6.3		
							metering & monitoring facilities, BEC clause 7.7		

Step 2a
The interfacing pipework and ductwork are governed by BEC clause 6.11 in respect of requirements on thermal insulation, and the motors of the AHUs are governed by BEC clause 7.5.1 in respect of motor efficiency.

10.1.4.3 Consider a retrofit involving a replacement of luminaires that covers three places with a total floor area of 550 m² under the same series of works within 12 months. The total circuit wattage of the replacement luminaires is 4.5 kW. In replacing the luminaires the existing wiring are reused in Place one and Place three, where in Place two the lighting circuitry to all replacing and remaining luminaires are completely rewired. TG Table 10.1.4.3 below illustrates the checking of the conditions for applicability, for the corresponding energy efficiency requirements in the BEC.

Table 10.1.4.3 : Illustration for a Lighting Retrofit : Checking of Conditions for Applicability, for the Energy Efficiency Requirements				
		<u>Place one</u>	<u>Place two</u>	<u>Place three</u>
<u>Space type</u>		Office 1	Office 2	Corridor (internal corridor connecting Office 1 and Office 2)
<u>Works area (internal floor area)</u>		470 m ²	50 m ²	30 m ²
<u>Original luminaires</u>	<u>Circuit wattage</u>	7.8 kW	0.8 kW	0.36 kW
	<u>50% of above</u>	3.9 kW	0.4 kW	0.18 kW
<u>Circuit wattage of replacement or replacing luminaires</u>		4 kW	0.2 kW	0.3 kW
<u>Checking of Condition for applicability</u>	<u>sub item (a)(i)</u>	Condition fulfilled, total circuit wattage of the works area of the three places is 4.5 kW and exceeds 3 kW		
	<u>TABLE A</u>	<u>LPD requirements in BEC clause 5.4</u>		
		4 kW is greater than 50% of original luminaires circuit wattage i.e. 3.9 kW, hence Place one is governed	0.2 kW is not greater than 50% of original luminaires circuit wattage i.e. 0.4 kW, hence Place two is not governed	0.3 kW is greater than 50% of original luminaires circuit wattage i.e. 0.18 kW, hence Place three is governed
		<u>Lighting control requirements in BEC clause 5.5</u>		
	Work does not involve a complete rewiring, hence the lighting control is not governed	Work involves a complete rewiring, hence the lighting control is governed	Lighting control requirement is not applicable to Corridor; also the work does not involve a complete rewiring and hence irrespective of the aforesaid its lighting control is not governed	

The retrofit falls within the criteria of major retrofitting works. The process is also shown in TG Figure 10.1.4.3. Having spotted in above table certain BEC non-governed items, to have all the works complying with TG Figure 10.1 TABLE A would be a good engineering practice involving less administrative effort.

Figure 10.1.4.3 : Illustration, against background of TG Figure 10.1, of energy efficiency requirements for examples in TG clause 10.1.4.3

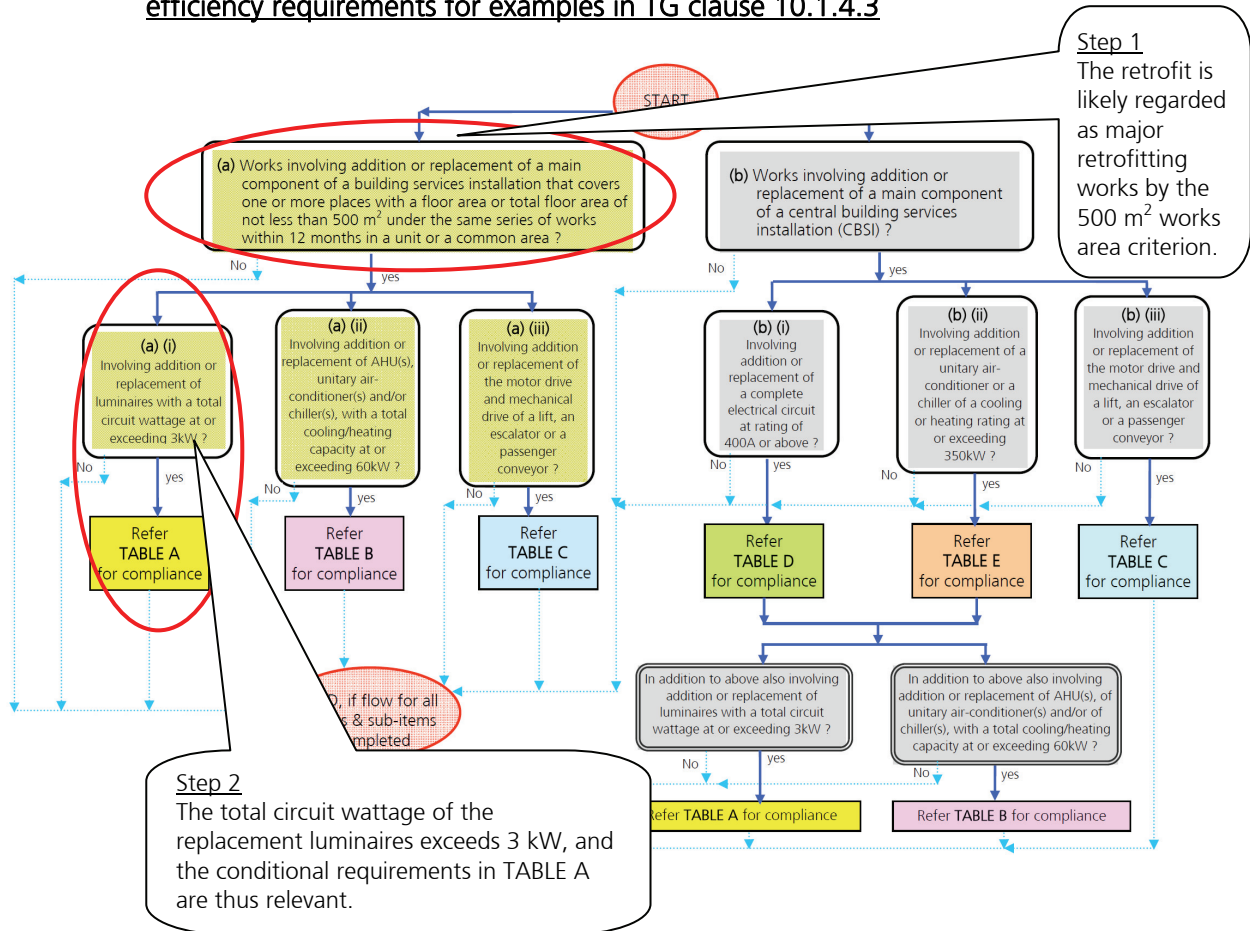


TABLE A	
Condition for Applicability	Applicable BEC Requirement
no existing luminaires in the area, or the sum of circuit wattage of additional or replacement luminaires is more than that of 50% of the original luminaires in the area	lighting power density, BEC clause 5.4
the area has no existing luminaires, or the work involves a complete rewiring of the existing lighting circuits in the area	lighting control, BEC clause 5.5

TABLE B	
Condition for Applicability	Applicable BEC Requirement
involving addition or replacement of unitary air-conditioner and/or chiller	air-conditioning equipment efficiency, BEC clause 6.12
the additional or replacement AHU(s) forming a complete air distribution system in the context of BEC clause 6.7	separate air distribution system for process requirements, BEC clause 6.5
	air distribution system fan power, BEC clause 6.7
the work involving additional water pipework	frictional loss of water piping system, BEC clause 6.9
the work involving a complete replacement of corresponding water side pumping system	
the work involving additional or replacement pipework, ductwork or AHU	thermal insulation, BEC clause 6.11
the work involving addition or replacement of water pump with new motor, or of AHU with new motor, or of fan with new motor	motor efficiency, BEC clause 7.5.1

TABLE C	
Condition for Applicability	Applicable BEC Requirement
the work involving a traction drive lift with machine above and with 1:1 or 2:1 suspension roping system, a hydraulic lift, an escalator or a passenger conveyor	electrical power, BEC clause 8.4
the work involving a traction drive lift, a hydraulic lift, an escalator or a passenger conveyor	total power factor, BEC clause 8.5.1
	lift ventilation and air-conditioning, BEC clause 8.5.4
	total harmonic distortion, BEC clause 8.6
	metering & monitoring facilities, BEC clause 8.7
the work involving addition of a lift or replacement of a lift car	lift decoration load, BEC clause 8.5.2

TABLE D	
Condition for Applicability	Applicable BEC Requirement
the work involving a complete main circuit, except for cable route between existing transformer room and associated LV switch room with length exceeding 20 m	distribution loss, BEC clause 7.4.2
the work involving a complete feeder	distribution loss, BEC clause 7.4.3
the work involving a complete sub-circuit	distribution loss, BEC clause 7.4.4
the work involving a complete final circuit	distribution loss, BEC clause 7.4.5
the work involving a complete feeder, or involving a complete sub-circuit and all its downstream final circuits	total power factor, BEC clause 7.6.1
	total harmonic distortion, BEC clause 7.6.2
	balancing of single-phase loads, BEC clause 7.6.3
the work involving a main circuit, a feeder or a sub-circuit, with addition of corresponding switch cubicle for the circuit termination at the main LV switchboard	metering & monitoring facilities, BEC clause 7.7

TABLE E	
Condition for Applicability	Applicable BEC Requirement
applicable in any conditions	air-conditioning equipment efficiency, BEC clause 6.12
the work involving for the additional or replacement air-conditioning equipment the addition or complete replacement of corresponding water side pumping system	frictional loss of water piping system, BEC clause 6.9
	energy metering, BEC clause 6.13
ditto, the corresponding water side pumping system forming an independent system	pumping system variable flow, BEC clause 6.8
the work involving addition or replacement of pipework, ductwork or AHU	thermal insulation, BEC clause 6.11
the work involving addition or replacement of water pump with new motor, or of AHU with new motor, or of fan with new motor	motor efficiency, BEC clause 7.5.1

Step 2a
Please refer to TG Table 10.1.4.3 on illustration of checking for condition of applicability, for corresponding energy efficiency requirements.

- 10.1.4.4 Consider the same retrofit in TG clause 10.1.4.1 above with AHU replacement, but this time the majority of the existing luminaires within the works area are replaced and the replacement luminaires have a total circuit wattage of 5 kW, and in replacing the luminaires the existing wiring to the luminaires are reused. The total circuit wattage of the replaced luminaires was 7 kW. The works area consists of several places accommodating the AHUs and associated replacement pipework and ductwork. The process is shown in TG Figure 10.1.4.4.

In this example, the energy efficiency requirements in TG clause 10.1.4.1 above apply, and in addition as the replacement luminaires have a total circuit wattage fulfilling the condition for applicability of at or exceeding 3 kW (sub-item (a)(i), BEC Table 10.1), the conditions for applicability in TG Figure 10.1 TABLE A are to be further examined. In examining TABLE A, the checking approach in TG Table 10.1.4.3 could be adopted, with identification of the circuit wattages of the original luminaires in each place of the works area. (As TG Table 10.1.4.3 has a good illustration of the approach, information of the circuit wattages in these places are omitted in this example that serves mainly to illustrate the applicability of more than one sub-items, namely (a)(i) and (a)(ii), at the same time.)

Figure 10.1.4.4 : Illustration, against background of TG Figure 10.1, of energy efficiency requirements for example in TG clause 10.1.4.4

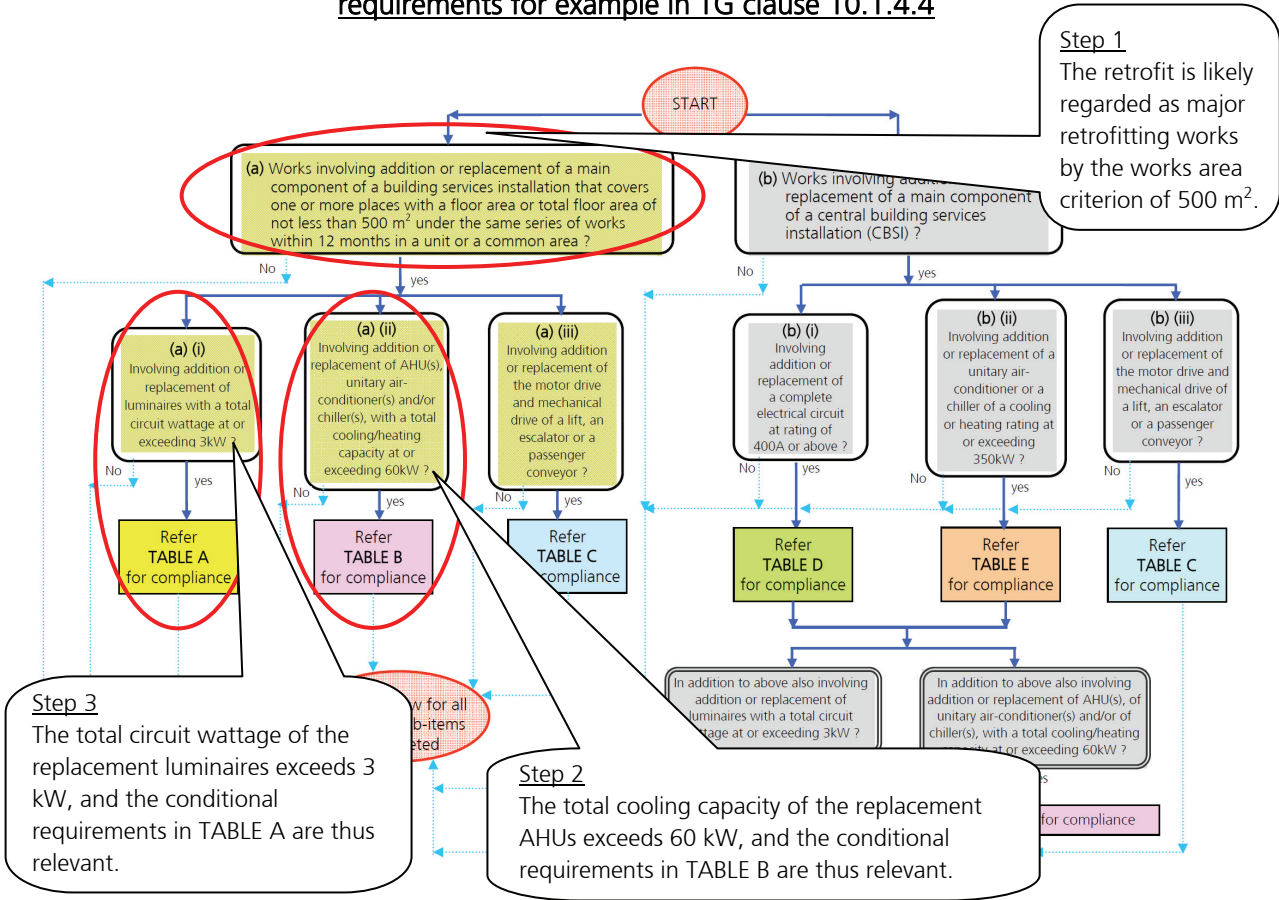


TABLE A	
Condition for Applicability	Applicable BEC Requirement
no existing luminaires in the area, or the sum of circuit wattage of additional or replacement luminaires is more than that of 50% of the original luminaires in the area	lighting power density, BEC clause 5.4
the area has no existing luminaires, or the work involves a complete rewiring of the existing lighting circuits in the area	lighting control, BEC clause 5.5

TABLE B	
Condition for Applicability	Applicable BEC Requirement
involving addition or replacement of unitary air-conditioner and/or chiller	air-conditioning equipment efficiency, BEC clause 6.12
the additional or replacement AHU(s) forming a complete air distribution system in the context of BEC clause 6.7	separate air distribution system for process requirements, BEC clause 6.5 air distribution system fan power, BEC clause 6.7
the work involving additional water pipework	frictional loss of water piping system, BEC clause 6.9
the work involving a complete replacement of corresponding water side pumping system	ditto, the corresponding water side pumping system forming an independent system
the work involving additional or replacement pipework, ductwork or AHU	thermal insulation, BEC clause 6.11
the work involving addition or replacement of water pump with new motor, or of fan with new motor	motor efficiency, BEC clause 7.5.1

TABLE C	
Condition for Applicability	Applicable BEC Requirement
the work involving a traction drive lift with machine above and with 1:1 or 2:1 suspension roping system, a hydraulic lift, an escalator or a passenger conveyor	electrical power, BEC clause 8.4
the work involving a traction drive lift, a hydraulic lift, an escalator or a passenger conveyor	total power factor, BEC clause 8.5.1 lift ventilation and air-conditioning, BEC clause 8.5.4 total harmonic distortion, BEC clause 8.6 metering & monitoring facilities, BEC clause 8.7
the work involving addition of a lift or replacement of a lift car	lift decoration load, BEC clause 8.5.2

TABLE D	
Condition for Applicability	Applicable BEC Requirement
the work involving a complete main circuit, except for cable route between existing transformer room and associated LV switch room with length exceeding 20 m	distribution loss, BEC clause 7.4.2
the work involving a complete feeder	distribution loss, BEC clause 7.4.3
the work involving a complete sub-circuit	distribution loss, BEC clause 7.4.4
the work involving a complete final circuit	distribution loss, BEC clause 7.4.5
the work involving a complete feeder, or involving a complete sub-circuit and all its downstream final circuits	total power factor, BEC clause 7.6.1 total harmonic distortion, BEC clause 7.6.2 balancing of single-phase loads, BEC clause 7.6.3
the work involving a main circuit, a feeder or a sub-circuit, with addition of corresponding switch cubicle for the circuit	metering & monitoring facilities, BEC clause 7.7

TABLE E	
Condition for Applicability	Applicable BEC Requirement
applicable in any conditions	air-conditioning equipment efficiency, BEC clause 6.12
the work involving for the additional or replacement air-conditioning equipment the addition or complete replacement of corresponding water side pumping system	frictional loss of water piping system, BEC clause 6.9 energy metering, BEC clause 6.13
ditto, the corresponding water side pumping system forming an independent system	pumping system variable flow, BEC clause 6.8
the work involving addition or replacement of pipework, ductwork or AHU	thermal insulation, BEC clause 6.11
the work involving addition or replacement of water pump with new motor, or of AHU with new motor, or of fan with new motor	motor efficiency, BEC clause 7.5.1

Step 3a
A checking of TABLE A is to be carried out for the condition for applicability and the corresponding BEC requirements, for each of the places constituting the works area. The checking approach shown in TG Table 10.1.4.3 could be followed.

Step 2a
The interfacing pipework and ductwork are governed by BEC clause 6.11 in respect of thermal insulation, and the motors of the AHUs are governed by BEC clause 7.5.1 in respect of motor efficiency.

10.1.5 Examples of Major Retrofitting Works by Virtue of Fulfilling the Main CBSI Component Criterion

Examples of work items are given in TG clauses 10.1.5.1 to 10.1.5.2.

- 10.1.5.1 Consider a retrofit involving the replacement of a chiller of 400 kW cooling capacity. The retrofit also includes the replacement of the chilled water pump (with reuse of existing pump motor) serving the chiller, the replacement of a number of AHUs with total cooling capacity at 100 kW. For one of the AHUs namely AHU1, all the ductwork of the air distribution system are also replaced; AHU1 is the only AHU in the air distribution system. For each of the other AHUs, there are no changes to the existing ductwork, except at the interfacing with the new AHU where certain modification works are required to facilitate the replacement. For the chiller, the chilled water pump and all the AHUs, there are no changes to the existing pipework and electrical circuitries, except at the interface with the new equipment where certain modification works are required to facilitate the replacement. The retrofit also includes the replacement of the luminaires in the central chilled water plant room and AHU rooms, and the total circuit wattage of the replacement luminaires is 3.5 kW. The process is shown in TG Figure 10.1.5.1, in which the reader can also easily identify the applicable energy efficiency requirements based on the approaches introduced in the earlier examples in TG clause 10.1.4.

Figure 10.1.5.1 : Illustration, against background of TG Figure 10.1, of energy efficiency requirements for example in TG clause 10.1.5.1

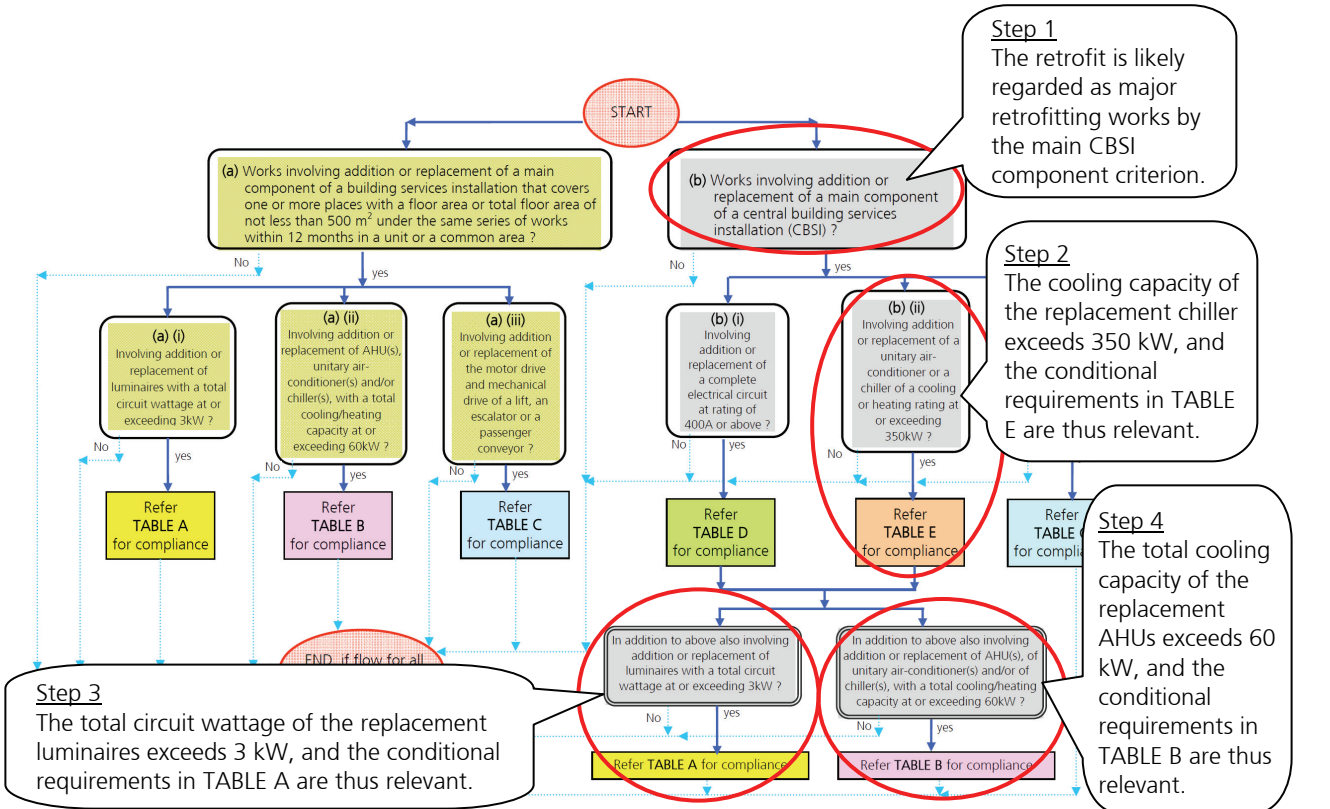


TABLE A	
Condition for Applicability	Applicable BEC Requirement
no existing luminaires in the area, or the sum of circuit wattage of additional or replacement luminaires is more than that of 50% of the original luminaires in the area	lighting power density, BEC clause 5.4
the area has no existing luminaires, or the work involves a complete rewiring of the existing lighting circuits in the area	lighting control, BEC clause 5.5

TABLE B	
Condition for Applicability	Applicable BEC Requirement
involving addition or replacement of unitary air-conditioner and/or chiller	air-conditioning equipment efficiency, BEC clause 6.12
the additional or replacement AHU(s) forming a complete air distribution system in the context of BEC clause 6.7	separate air distribution system for process requirements, BEC clause 6.5
	air distribution system fan power, BEC clause 6.7
the work involving replacement of water piping	frictional loss of water piping system, BEC clause 6.9
the work involving complete replacement of corresponding water side pumping system	
the work involving addition or replacement of lift or escalator	thermal insulation, BEC clause 6.11
the work involving addition or replacement of lift or escalator	motor efficiency, BEC clause 7.5.1

Condition for Applicability	Applicable BEC Requirement
the work involving a traction drive lift with machine above and with 1:1 or 2:1 suspension roping system, a hydraulic lift, an escalator or a passenger conveyor	electrical power, BEC clause 8.4
the work involving a traction drive lift, a hydraulic lift, an escalator or a passenger conveyor	total power factor, BEC clause 8.5.1
	lift ventilation and air-conditioning, BEC clause 8.5.4
	total harmonic distortion, BEC clause 8.6
	metering & monitoring facilities, BEC clause 8.7
the work involving addition of a lift or replacement of a lift car	lift decoration load, BEC clause 8.5.2

Condition for Applicability	Applicable BEC Requirement
the work involving a complete main circuit, except for cable route between existing transformer room and associated LV switch room with length exceeding 20 m	distribution loss, BEC clause 7.4.2
the work involving a complete feeder	distribution loss, BEC clause 7.4.3
the work involving a complete sub-circuit	distribution loss, BEC clause 7.4.4
the work involving a complete final circuit	distribution loss, BEC clause 7.4.5
the work involving a complete feeder, or involving a complete sub-circuit and all its downstream final circuits	total power factor, BEC clause 7.6.1
	total harmonic distortion, BEC clause 7.6.2
	balancing of single-phase loads, BEC clause 7.6.3
the work involving a main circuit, a feeder or a sub-circuit, with addition of corresponding switch cubicle for the circuit termination at the main LV switchboard	metering & monitoring facilities, BEC clause 7.7

TABLE E	
Condition for Applicability	Applicable BEC Requirement
applicable in any conditions	air-conditioning equipment efficiency, BEC clause 6.12
the work involving the additional or replacement air-conditioning equipment	frictional loss of water piping system, BEC clause 6.9
the work involving the addition or complete replacement of corresponding water side pumping system	energy metering, BEC clause 6.13
ditto, the corresponding water side pumping system forming an independent system	pumping system variable flow, BEC clause 6.8
the work involving addition or replacement of pipework, ductwork or AHU	thermal insulation, BEC clause 6.11
the work involving addition or replacement of water pump with new motor, or AHU with new motor, or of fan with new motor	motor efficiency, BEC clause 7.5.1

Step 3a
A checking of TABLE A is to be carried out, for the condition for applicability and the corresponding BEC requirements, for each of the places constituting the works area. The checking approach shown in TG Table 10.1.4.3 could be followed.

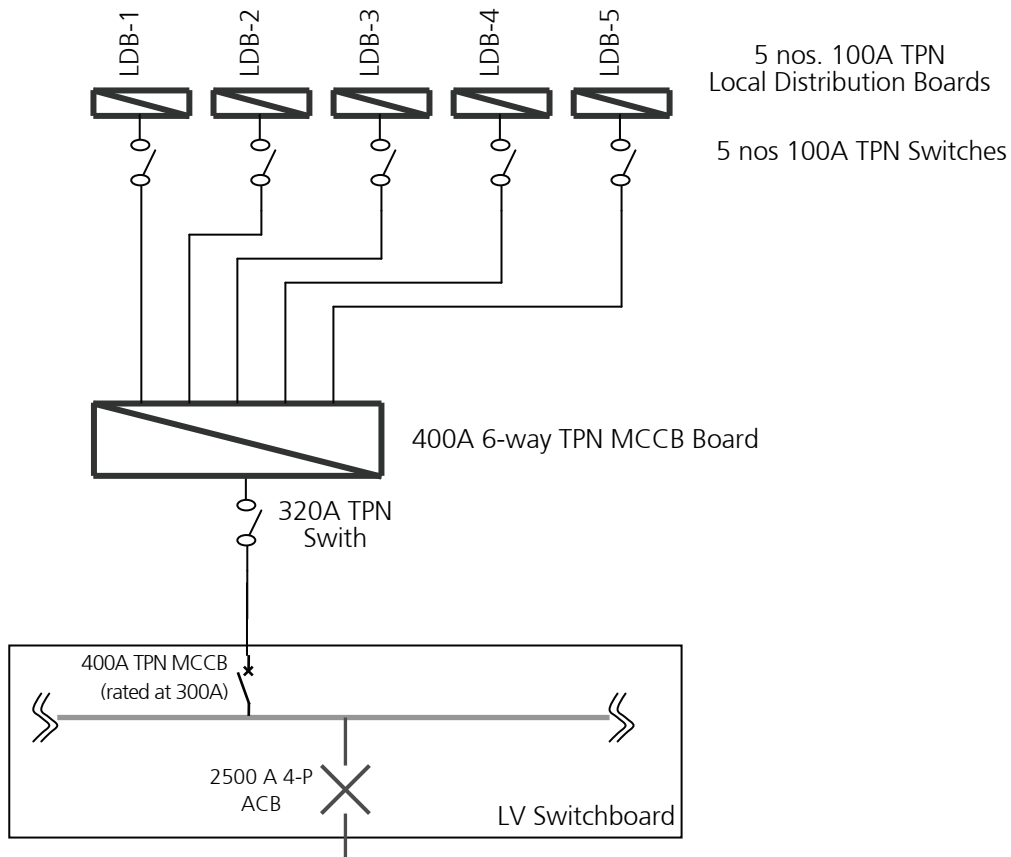
Step 4a
AHU1 is governed by BEC clause 6.7 in respect of air distribution system fan power.

Step 2a
The replacement chiller is governed by the COP requirements in BEC clause 6.12.

Step 2b
The interfacing pipework and ductwork are governed by BEC clause 6.11 in respect of thermal insulation, and the motors of the AHUs are governed by BEC clause 7.5.1 in respect of motor efficiency.

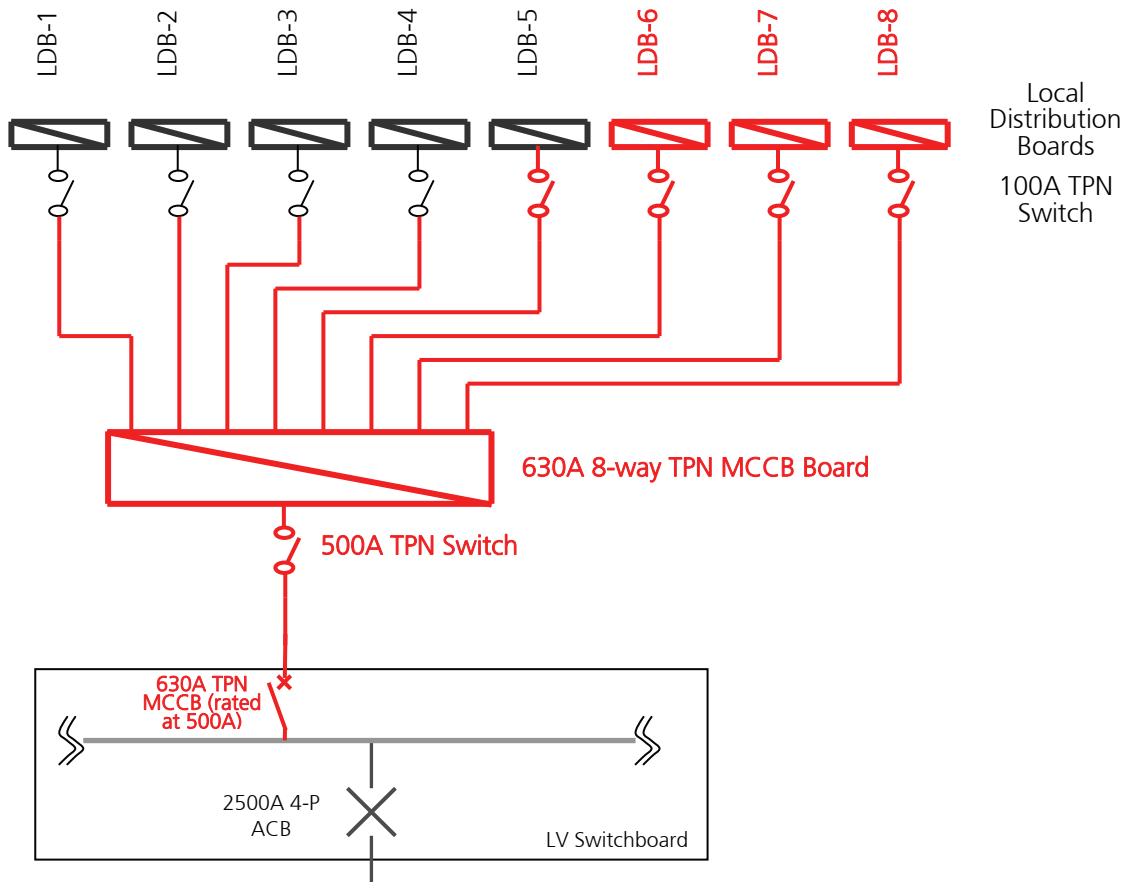
10.1.5.2 Consider a retrofit involving the addition of distribution boards and modification of a CBSI electrical circuit. The existing circuitry is indicated in TG Figure 10.1.5.2 (a), in which is shown an outgoing circuit from the main LV switchboard via a 300A TPN MCCB to a 400A 6-way TPN MCCB board feeding 5 nos. CBSI local distribution boards LDB-1 to LDB-5. The retrofit also includes the replacement of certain luminaires in the plant rooms, lift lobbies and corridors, and the total wattage of the replacement luminaires is 4 kW.

Figure 10.1.5.2 (a) : Schematic wiring diagram, existing



In the retrofit, the circuit is to provide electrical supply to three more local distribution boards. The existing 400A MCCB (rated at 300A) in the main LV switchboard is to be replaced with a 630A MCCB (rated at 500A), and the existing 400A 6-way TPN MCCB board to be replaced with a 630A 8-way TPN MCCB board. 3 nos. new local distribution boards LDB-6 to LDB-8 are to be added. All the existing interconnecting cabling are to be replaced, and in addition for LDB-5 the 100A TPN switch is to be replaced too. The new electrical supply circuitry after the retrofit is shown in TG Figure 10.1.5.2 (b), with the new and replacement items indicated in red colour.

Figure 10.1.5.2 (b) : Schematic wiring diagram of retrofit



Complete 400A Sub-circuit

The process in considering whether the retrofit is major retrofitting works is shown in TG Figure 10.1.5.2 (c). The retrofit falls within the scope of major retrofitting works by virtue of fulfilling the CBSI main component criterion – addition or replacement of complete circuit at 400A. The 400A is based on the rating of the circuit protective device; if the 400 A MCCB is rated down say to 300A the circuit is not at 400A and would not be considered as major retrofitting works.

Attention is drawn that should the retrofit not involve the replacement of the existing 400A TPN MCCB (rated at 300A) in the LV switchboard with the replacing 630A TPN MCCB (rated at 500A), the sub-circuitry would not be a complete circuit. To be considered as a complete sub-circuit, the replacement or addition of a MCCB, fuse or switch at the LV switchboard should be involved. Likewise if one of the circuit portions from the 630A MCCB board to any one of LDB-1 to LDB-5 not be replaced, the retrofit would not be considered as a complete sub-circuit. On the other hand, the addition or replacement of local distribution board(s) is not a must in the consideration of a complete sub-circuit, and if the retrofit above does not involve the addition of LDB-6 to LDB-8 the sub-circuitry is still considered as a complete circuit. It is only the retrofit involves a complete circuit, addition or replacement, at or above 400A that it would be considered as major retrofitting works.

Figure 10.1.5.2 (c) : Illustration, against background of TG Figure 10.1, of energy efficiency requirements for example in TG clause 10.1.5.2

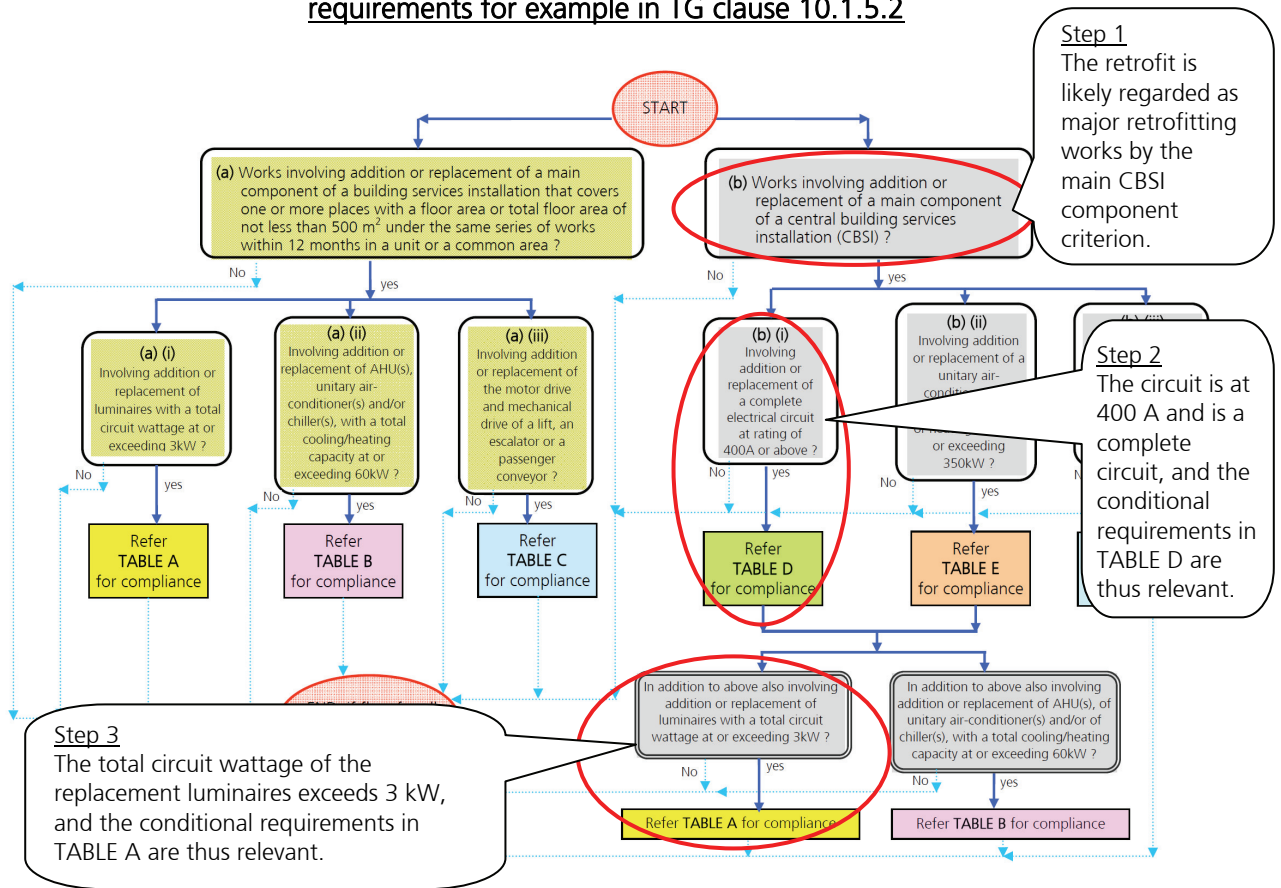


TABLE A		TABLE B		TABLE C		TABLE D		TABLE E	
Condition for Applicability	Applicable BEC Requirement	Condition for Applicability	Applicable BEC Requirement	Condition for Applicability	Applicable BEC Requirement	Condition for Applicability	Applicable BEC Requirement	Condition for Applicability	Applicable BEC Requirement
no existing luminaires in the area, or the sum of circuit wattage of additional or replacement luminaires is more than that of 50% of the original luminaires in the area	lighting power density, BEC clause 5.4	involving addition or replacement of unitary air-conditioner and/or chiller	air-conditioning equipment efficiency, BEC clause 6.12	the work involving a traction drive lift with machine above and with 1:1 or 2:1 suspension roping system, a hydraulic lift, an escalator or a passenger conveyor	electrical power, BEC clause 8.4	the work involving a complete main circuit, except for cable route between existing transformer room and associated LV switch room with length exceeding 20 m	distribution loss, BEC clause 7.4.2	applicable in any conditions	air-conditioning equipment efficiency, BEC clause 6.12
the area has no existing luminaires, or the work involves a complete rewiring of the existing lighting circuits in the area	lighting control, BEC clause 5.5	the additional or replacement AHU(s) forming a complete air distribution system in the context of BEC clause 6.7	separate air distribution system for process requirements, BEC clause 6.5	the work involving a traction drive lift, a hydraulic lift, an escalator or a passenger conveyor	total power factor, BEC clause 8.5.1	the work involving a complete feeder	distribution loss, BEC clause 7.4.3	the work involving the additional or replacement air-conditioning equipment the addition or complete replacement of corresponding water side pumping system	frictional loss of water piping system, BEC clause 6.9
		the work involving additional water pipework	air distribution system fan power, BEC clause 6.7		lift ventilation and air-conditioning, BEC clause 8.5.4	the work involving a complete sub-circuit	distribution loss, BEC clause 7.4.4	energy metering, BEC clause 6.13	
		the work involving a complete replacement of corresponding water side pumping system	frictional loss of water piping system, BEC clause 6.9		total harmonic distortion, BEC clause 8.6	the work involving a complete final circuit	distribution loss, BEC clause 7.4.5	ditto, the corresponding water side pumping system forming an independent system	pumping system variable flow, BEC clause 6.8
		the work involving additional or replacement pipework, ductwork or AHU	thermal insulation, BEC clause 6.11		metering & monitoring facilities clause	the work involving a complete feeder, or involving a complete sub-circuit and all downstream final circuits	total power factor, BEC clause 7.6.1	the work involving addition or replacement of pipework, ductwork or AHU	thermal insulation, BEC clause 6.11
		the work involving addition of	motor efficiency,	the work involving addition of a lift or replacement of a lift car	lift drive, BEC clause 8.7	the work involving a complete feeder, or involving a complete sub-circuit and all downstream final circuits	total harmonic distortion, BEC clause 7.6.2	the work involving addition or replacement of water pump with new motor, or of fan with new motor	motor efficiency, BEC clause 7.5.1
						the work involving a complete feeder, or involving a complete sub-circuit and all downstream final circuits	balancing of single-phase loads, BEC clause 7.6.3		
						the work involving a complete feeder, or involving a complete sub-circuit and all downstream final circuits	metering & monitoring facilities, BEC clause 7.7		

Step 3a
A checking of TABLE A is to be carried out, for the condition for applicability and the corresponding BEC requirements, for each of the places constituting the works area. The checking approach shown in TG Table 10.1.3.2 could be followed.

Step 2a
The 8 nos circuits from the 630A MCCB to the LDBs are governed, in respect of maximum allowable copper loss, by BEC clause 7.4.4. The 3 nos final circuits from LDBs 6, 7 & 8 are also governed, in respect of maximum allowable copper loss, by BEC clause 7.4.5; nevertheless should there be no circuits over 32A there is no actual requirement.

10.1.6 Major Retrofitting Works Fulfilling Both Works Area Criterion and Main CBSI Component Criterion

For retrofitting works fulfilling both criteria, the following of the work flow in examples in TG clause 10.1.5 for the main CBSI component criterion would suffice, given such having included the checking for the applicable requirements based on luminaires circuit wattage (Table A in TG Figure 10.1), capacity of AHU/chiller/unitary air-conditioner (Table B in TG Figure 10.1), and capacity of lift/escalator (Table C in TG Figure 10.1).

10.1.7 Same Series of Works in 12-month

BEC Table 10.1 Remark 4 gives certain guidance on –

- the “same series of works”, and
- the “same series of works within 12-month” concept, which is more precisely the 500 m² counting period.

BEC Table 10.1 Remark 4 is extracted in TG Table 10.1.7 (a) below for ready reference.

Table 10.1.7 (a) : Extract of BEC Table 10.1 Remark 4
<p>The “12-month” period under a same series of works specified in item (a) of this table may be counted from the commencement date of either one of the works under the same series of works.</p> <p>The floor area covered by any works of the same series of works commenced within this 12-month period (the first day and the last day inclusive) should be counted towards the “total floor area” covered by the same series of works within this 12-month period.</p> <p>If some works under the same series of works have commenced within a 12-month period in a unit or a common area and their works areas aggregate to not less than 500 m², then besides these works all other works of the same series of works in the same unit or common area, even not commenced within the said 12-month period, should also comply with requirements specified above for item (a).</p>

Consider a series of works involving four places namely A, B, C & D each having working period and space area shown below. Three cases namely Case I, Case II and Case III (for these four places) in corresponding TG Tables 10.1.7 (b) to (d) below illustrate the approaches to determine, with reference to BEC Table 10.1 Remark 4, if the works fall within the scope of major retrofitting works. Case III in particular gives the guideline in respect of work items having an overall working period exceeding the 12-month period which may not necessarily covers all the work items; the guideline is, in the assigning of work items for the 12-month or more precisely the 500 m² counting

period, to accord the priority to those larger area places (amidst all places) that more readily aggregate to the 500 m² criterion.

Table 10.1.7 (b) : Retrofitting Works Case I				
<u>Place</u>	<u>Working period</u>	<u>Works internal floor area</u>	<u>Remarks on same series of works in a 12-month period</u>	<u>Form of Compliance (FOC)</u>
A	1 Jan – 31 Mar 2013	150 m ²	500 m ² counting period (max 12-month) starts on 1 Jan 2013 and ends on 31 Dec 2013.	The works in all places A to D should be covered by one FOC.
B	1 May – 31 Jul 2013	200 m ²	Works area within this 500 m ² counting period is thus 150m ² + 200m ² + 250m ² = 600 m ² .	
C	15 Dec 2013 – 31 Jan 2014	250 m ²	500 m ² works area criterion of major retrofitting works is fulfilled for works in places A to C, which are thus governed by BEC Table 10.1 item (a).	
D	1 Feb – 31 Mar 2014	100 m ²	As works in place D together with works in places A to C form the same series of work, BEC Table 10.1 item (a) also governs works in place D.	

Table 10.1.7 (c) : Retrofitting Works Case II				
<u>Place</u>	<u>Working period</u>	<u>Works internal floor area</u>	<u>Remarks on same series of works in a 12-month period</u>	<u>Form of Compliance (FOC)</u>
A	1 Jan – 31 Mar 2013	100 m ²	500 m ² counting period (max 12-month) starts on 1 Jan 2013 and ends on 31 Dec 2013.	FOC is not required.
B	1 May – 31 Jul 2013	150 m ²	Works area within this 500 m ² counting period is thus 100m ² + 150m ² + 200m ² = 450 m ² .	
C	15 Dec 2013 – 31 Jan 2014	200 m ²	500 m ² works area criterion of major retrofitting works is not fulfilled for works in places A to C, which are thus not governed by BEC Table 10.1 item (a) (the fulfilling of which is strongly encouraged as a good engineering practice).	
D	1 Feb – 31 Mar 2014	100 m ²	Despite works in place D together with works in places A to C form the same series of work, its work period is outside the 500 m ² counting period. Its works area would not count towards the 500 m ² works area criterion, and BEC Table 10.1 item (a) would not govern works in place D. Nevertheless should it have a larger works area, a different commencement date of the 500 m ² counting period (max 12-month) would be adopted	

			as shown in Case III, which has a totally different scenario.	
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Table 10.1.7 (d) : Retrofitting Works Case III				
<u>Place</u>	<u>Working period</u>	<u>Works internal floor area</u>	<u>Remarks on same series of works in a 12-month period</u>	<u>Form of Compliance (FOC)</u>
A	1 Jan – 31 Mar 2013	100 m ²	<p>The earliest date of the corresponding places' working period commencement dates should not always be taken as the start of the 500 m² counting period (max 12-month) in the counting of the aggregate floor area towards the 500 m² criterion. In Case III here, the working period commencement date of 1 May 2013 of place B should be taken as the start date, as the aggregate of place B and those places with works that follow more readily add up to over 500 m² (150m² (B) + 200m² (C) + 200m² (D) = 550 m²). BEC Table 10.1 item (a) governs these places. (Here the 500 m² counting period starts on 1 May 2013 and ends on 31 Mar 2014.)</p> <p>Reverting to place A, as it together with places B to D form the series of work, BEC Table 10.1 item (a) also governs works in place A.</p> <p>It may be that when the series of works starts (i.e. as at 1 Jan 2013), the works areas of places B to D are yet to be confirmed. Under the situation it is better to have the relevant building services installation in place A to comply with the relevant requirements in BEC Table 10.1 item (a), to avoid the possible non-compliance that can only be known upon confirmation of the works areas.</p>	The works in all places A to D should be covered by one FOC.
B	1 May – 31 Jul 2013	150 m ²		
C	15 Dec 2013 – 31 Jan 2014	200 m ²		
D	1 Feb – 31 Mar 2014	200 m ²		

10.1.8 Retrofitting Works Involving Wiring Only (Wiring-only Works)

- (a) Wiring-only works are not regarded as “major retrofitting works”. For example, when a tenant moves in a new office, if he/she retains the existing building services installations (such as luminaires, FCUs, VAV units etc.) provided and fixed in position by the developer, owner or preceding tenant and his/her retrofitting works only involve the inter-connecting power supply/control wiring for the existing installations, his/her such wiring-only works are not regarded as “major retrofitting works”. Nevertheless, if the retrofitting works are not confined to wiring only, care should be exercised to check if the criteria of major retrofitting

works (explained in TG clause 4.2.5 and TG section 10) are met.

- (b) On the other hand, in case of a new building project as at issue of OA, the building services installations fixed in position (such as hung with stay wires from ceiling slab and lined up with false ceiling grids) in a unit (e.g. office) by the developer are regarded as part of the works completed by the developer and should be included in the stage two declaration even if the relevant wiring is left to be completed by the future tenant.
- (c) Likewise to (b), in case of major retrofitting works in a unit (e.g. office) as at the completion of the works, the building services installations fixed in position (such as hung with stay wires from ceiling slab and lined up with false ceiling grids) in the unit by the owner of the unit are regarded as part of the major retrofitting works completed by the owner of the unit and should be included in the respective FOC even if the relevant wiring is left to be completed by the future tenant.

10.2 Performance-based Approach (BEC clause 10.2)

Performance-based approach is applicable to major retrofitting works. Certain guidance in respect of retrofitting is given in BEC Appendix A clauses A1.4, A3.1.1, A3.2.5(a), A3.2.6(a), A3.2.9 and A3.2.10. With clauses A3.2.5(a) and A3.2.6(a) specifying the adoption of the as-built system in the modelling, the trade-off if any in design energy would confine to items within the same series of major retrofitting works.



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