Technical Guidelines on Code of Practice for Building Energy Audit

2018

EMSD

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Technical Guidelines on Code of Practice for Building Energy Audit

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1 Introduction

1.1 Ordinance (Cap 610) and Code of Practice (EAC 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 the carrying out of energy audit for prescribed buildings in respect of their central building services installations. In Feb 2012, Electrical and Mechanical Services Department (EMSD) issued the "Code of Practice for Building Energy Audit, 2012 Edition", hereinafter referred as the "Energy Audit Code, 2012" or "EAC 2012". The Ordinance requires energy audits to be carried out in accordance with the EAC that sets out the technical guidance and details in respect of the energy audit requirements governing the central building services installations in buildings under the Ordinance.

An addendum, namely the "EAC 2012 Edition - Addendum No. EAC01", taking effect from 9 August 2013 was subsequently launched to deal with the exemption for a composite building with relatively minor scale of CBSI solely serving its commercial portion. The associated guidelines were incorporated into the technical guidelines and issued as TG-EAC 2012 (Rev. 1) which took effect from the same day.

An addendum, namely the "EAC 2012 Edition – Addendum No. EAC02", taking effect from 10 April 2015 was issued thereafter to further revise the exemption criteria for a commercial or composite building with relatively minor scale of CBSI.

The first thorough review on the EAC 2012 was conducted since the third quarter of 2014. The second edition of code, namely the "Code of Practice for Building Energy Audit, 2015 Edition" (hereafter referred as the "Energy Audit Code, 2015" or "EAC 2015"), taking effect from 11 June 2016 was issued thereafter to offer more clarity to the data collection process aiming at improving data accuracy.

After the second thorough review on the EAC 2015, the new edition of code, namely the "Code of Practice for Building Energy Audit, 2018 Edition" (hereinafter referred as the "Energy Audit Code 2018" or "EAC 2018"), was gazetted on 16 November 2018 to impose more stringent requirements on the technical aspects and the details on the carrying out of energy audits under the Ordinance.

The Ordinance also requires building services installations in prescribed buildings to comply with the "Code of Practice for Energy Efficiency of Building Services Installation", hereinafter referred as the "Building Energy Code" or "BEC", which was collectively issued with the EAC by EMSD. The new version of the code is the 2018 edition (known as the BEC 2018, in short) and was issued on the same day as the EAC 2018.

1.2 Technical Guidelines (TG-EAC 2018)

To assist in understanding the energy audit engineering requirements in the EAC against the legislative background of the Ordinance, EMSD in collaboration with various professional institutions, trade associations, academia and government departments issues technical guidelines correspondent to each Energy Audit Code edition. This publication - the "**Technical Guidelines on Code of Practice for Building Energy Audit, 2018 Edition**", in short **TG-EAC 2018**, is prepared as the supporting document for the EAC 2018. The TG-EAC 2018 provides an overview and certain explanations of the legislative requirements and the EAC 2018's engineering requirements, with illustrative tables, diagrams and examples, and in particular detail descriptions on the issuance of form and report in the demonstration of compliance. For purpose of ready cross reference, the headings of the clauses in the TG-EAC 2018 have the relevant EAC 2018 clause numbers marked in brackets alongside.

Serving as guidelines to the EAC 2018 and being not a legislative document, the TG-EAC 2018 should not take precedence over the Ordinance or the EAC 2018 in respect of interpretations of the intent and meaning of the requirements in the Ordinance and the EAC 2018. Being a guidelines document, the TG-EAC 2018 provides, in parallel to the basic understanding of the requirements of the EAC 2018, the good engineering practices for enhanced energy audit results.

A separate technical guidelines document supplementing the BEC 2018 in respect of energy efficiency of building services installations is also issued, which is outside the scope of the TG-EAC 2018.

1.3 EMSD Web-site

To have a holistic view of the requirements of the Ordinance, readers of the TG-EAC 2018 are encouraged to study the Ordinance and the EAC 2018, which can be browsed at the web-site of the Ordinance (https://www.emsd.gov.hk/beeo/). The web-site provides a briefing on the Ordinance, the EAC and the BEC, 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.

1.4 Nomenclature

The EAC 2018 and TG-EAC 2018 are abbreviated as EAC and TG respectively in this publication. When referring to a section, clause or table in the EAC, the section, clause or table would be prefixed with the designation EAC.

1.5 Minimum Standard of EAC

The EAC requirements, which are the minimum energy audit requirements under the Ordinance, are promulgated through the mandate. The EAC requirements should by no means be treated as the ultimate goal of checking of energy performance. To enhance the energy efficiency of their buildings in the combat of climate change, building owners, O&M personnels and the REA/designers are strongly encouraged to exceed these minimum checking requirements and to initiate as appropriate the implementation of the identified energy management opportunities, which though not mandatory can generate the actual energy savings.

1.6 Effective Date of EAC 2018

Since launching the EAC 2018 on 16 November 2018, nine-month grace period was introduced. The requirements set out under the EAC 2018 apply to the energy audit being completed on or after 16 August 2019.

1.7 Editions of the Technical Guidelines

The TG-EAC 2018 serves no purpose to replace the technical guidelines on previous EAC editions i.e. the TG-EAC 2012, TG-EAC 2012 (Rev. 1) and TG-EAC 2015. Instead, this publication is layout as a standalone document for reader's ease of understanding by avoiding cross referencing to previous editions of technical guidelines.

2 Interpretations and Abbreviations

2.1 Interpretations (EAC clause 2.1)

Section 2 of both the Ordinance and the EAC give the interpretations of terminologies adopted in the Ordinance and the EAC. These interpretations are also applicable to the TG. For ready reference, some of these interpretations are extracted (as shown in shaded boxes) below.

> 'Certificate of Compliance Registration' means a Certificate of Compliance Registration issued under section 10 and, where applicable, renewed under section 13 (of the Ordinance);

> '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;

> 'Energy Audit Form' means an Energy Audit Form issued under section 22 (of the Ordinance);

> 'energy management opportunities (EMO)' means the ways to achieve energy efficiency and conservation;

TG Remarks to 'EMO'

The interpretation for EMO is given in the EAC (and not the Ordinance).

'energy utilization index (EUI)', in relation to the total energy consumption of the central building services installations in a building, means dividing total energy consumption for a specific period by the total internal floor area of the building;

TG Remarks to 'energy utilization index'

The interpretation for energy utilization index is given in the EAC (and not the Ordinance).

'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 Ordinance (Cap 618); and

(b) any associated installation specified in a code of practice that is used for the operation of the lift or escalator;

'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);

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

'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 (EAC clause 2.2)

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

'AHU' refers to air handling unit

'BEC / BEC 2018' refers to Building Energy Code, 2018 Edition or Code of Practice for Energy Efficiency of Building Services Installation, 2018 Edition issued on 16 November 2018

'BMS' refers to building management system

'BSI' refers to building services installation

'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/ variable refrigerant flow system, unitary air conditioner, heat pump or central chilled or heated water plant)

'DMC' refers to deed of mutual covenant

'EA Form' refers to Energy Audit Form

'EA report' refers to energy audit report

'EAC / EAC 2018' refers to Energy Audit Code, 2018 Edition or Code of Practice for Building Energy Audit, 2018 Edition issued on 16 November 2018

'EMO' refers to energy management opportunity / opportunities

'EMSD' refers to Electrical and Mechanical Services Department

'EUI' refers to energy utilization index

'FCU' refers to fan coil unit

'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-EAC 2012' refers to the Technical Guidelines on Code of Practice for Building Energy Audit, 2012 Edition issued on 18 March 2013

'TG-EAC 2012 (Rev. 1)' refers to TG-EAC 2012 with Addendum No. TG-EAC01 incorporated and issued on 9 August 2013

'**TG-EAC 2012 (Rev. 2)**' refers to TG-EAC 2012 with Addendum No. TG-EAC02 incorporated and issued on 10 April 2015

'**TG-EAC 2015**' refers to the Technical Guidelines on Code of Practice for Building Energy Audit, 2015 Edition issued on 12 August 2016

'**TG**' or '**TG-EAC 2018**' refers to the Technical Guidelines on Code of Practice for Building Energy Audit, 2018 Edition

'**VAV**' refers to variable air volume

'**VRF System**' refers to variable refrigerant flow system as defined under the BEC 2018

3 Application

3.1 Scope of Application (EAC clause 3.1)

3.1.1 General

The EAC applies to the central building services installation (CBSI) in a building belonging to one of the categories prescribed in Schedule 4 of the Ordinance.

3.1.2 Commercial Buildings and Commercial Portions of Composite Buildings

(a) Commercial buildings and composite buildings in respect of their portions for commercial use are prescribed as the buildings requiring energy audit. For ready reference, Schedule 4 of the Ordinance, which prescribes the applicability, is extracted in TG Table 3.1.2 (a) below.

Table 3.1.2 (a) : Extract of Schedule 4 of the Ordinance (Cap 610)
Schedule: 4 BUILDINGS THAT REQUIRE ENERGY AUDIT 1. Commercial building. 2. A portion of a composite building that is for commercial use.

(For information, the Ordinance has a Schedule 1 of building categories, covering commercial buildings, composite buildings for residential or industrial use (common area), hotels, residential buildings (common area), industrial buildings (common area), education buildings, community buildings, hospitals etc. The categories of buildings in Schedule 1 have to comply with the energy efficiency requirements in the BEC. Comparing Schedule 1 and Schedule 4, it can be seen that Schedule 1 has a broader coverage of building categories, and includes in general the building categories in Schedule 4.)

(b) Examples of buildings to which the energy audit requirements of the Ordinance apply are quoted in TG Table 3.1.2 (b) below.

Table 3.1.2 (b) : Examples of Applicability of Energy Audit Requirements under the Ordinance

Building description	Applicability of energy audit requirement
Building comprising of office units and/or shopping & leisure units	Applicable to the CBSI of the entire building (given the building being a commercial building)

Building comprising of a residential tower block and a podium of shopping & leisure units	Applicable to the CBSI of the podium (given the podium being the portion of the building for commercial use)
Composite building for commercial use and industrial use	Applicable to the CBSI of the commercial portion

(c) To determine whether a building is a commercial building or a composite building having a portion that is for commercial use, 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.).

3.1.3 Central Building Services Installation (CBSI) in Commercial Building

Given the applicability cited in TG clause 3.1.1 above being on the CBSI, the differentiation of CBSI from the other building services installations would be required. 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;

Based on the interpretation of CBSI above, there are buildings with common area and buildings that have no common area.

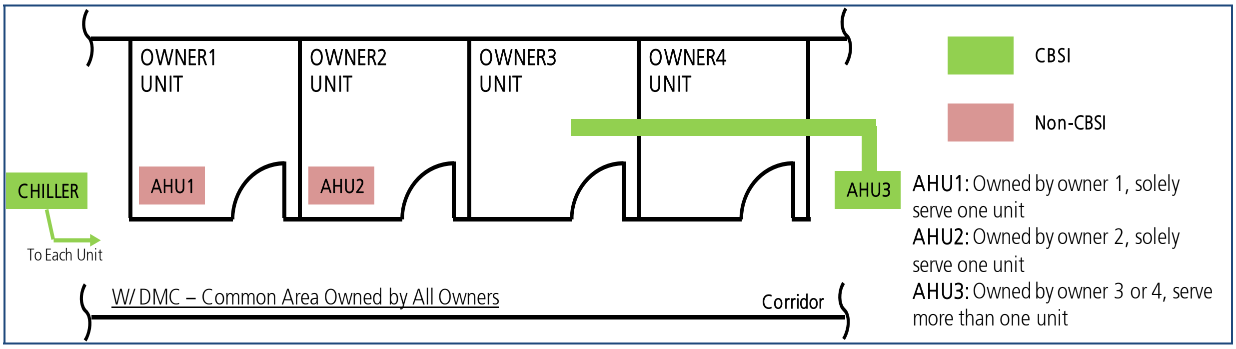
(a) Buildings with Common Area (with deed of mutual covenant)

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 3.1.3 (a) and TG Figure 3.1.3 (a) below.

Table 3.1.3 (a) : Examples of CBSI and non-CBSI for a Building with Common Area				
Commercial building (e.g. with office/shopping & leisure units) with common area 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.				
	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)

Figure 3.1.3 (a) : Diagram indicating examples of CBSI and non-CBSI for a Building with Common Area



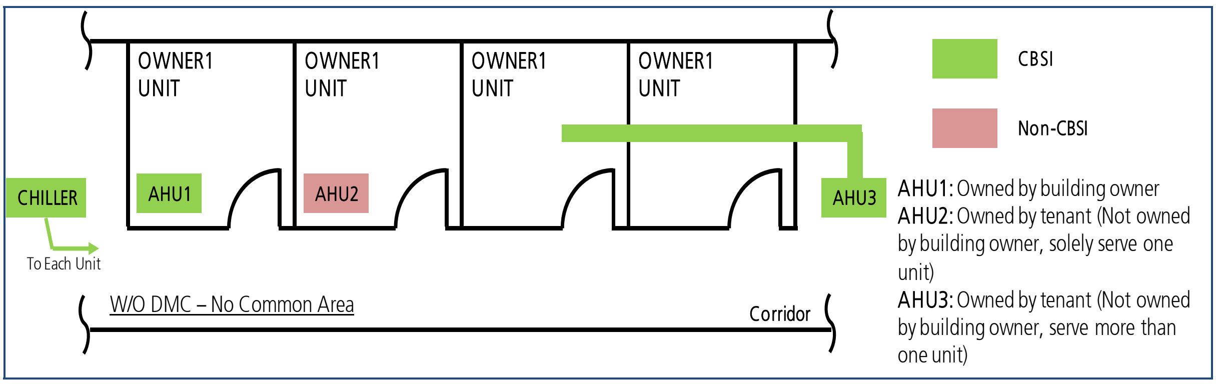
(b) Buildings without Common Area (without DMC)

A building without common area typically has no DMC. In an even simpler term, this may mean a single-owned building where the sole owner has no area within the building co-owns with others.

i) Examples of CBSI and non-CBSI for a building having units leased to tenants are given in TG Table 3.1.3 (b) and TG Figure 3.1.3 (b) below.

Table 3.1.3 (b) : Examples of CBSI and non-CBSI for a Building Without Common Area and Having Units Leased to Tenants				
Commercial building (e.g. with office/shopping & leisure units) without common area 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 a tenant who owns the circuit	Escalator within and solely serving a department store (a unit) that is leased to a tenant who owns the escalator

Figure 3.1.3 (b) : Diagram indicating examples of CBSI and non-CBSI for a Building without Common Area



ii) Consider a commercial building without common area, without units that have been specified in instrument(s) registered in the Land Registry as for the exclusive use of an owner, and have no areas leased to tenants. All the building services installations (under the Ordinance) in the building are regarded as CBSI. A typical example is the headquarter building of an international enterprise or an administration building of an education campus.

3.1.4 CBSI in Commercial Portion of Composite Building

Having provided the principles of CBSI in TG clause 3.1.3 above for a commercial building, the same principles apply to the commercial portion of a composite building.

3.2 Limit of Scope of Application (EAC clause 3.2)

3.2.1 TG clauses 3.1.1 and 3.1.2 introduce Schedule 4 of the Ordinance that prescribes the categories of buildings requiring energy audit. It follows that the categories of buildings outside Schedule 4 are not governed by the energy audit requirement.

3.2.2 Section 21 of the Ordinance prescribes that the energy audit requirement does not apply to a building that will cease to remain in Schedule 4 within a prescribed time.

3.2.3 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 3.2.3 below.

Table 3.2.3 : Extract of Section 4 and Schedule 2 of the Ordinance (Cap 610)
Section: 4 Limit of scope of application (1) This Ordinance does not apply to - (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 - (i) of not more than 3 storeys; (ii) having a roofed-over area of not more than 65.03 m^2; 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). (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. (3) This Ordinance does not apply to the building services installations specified in Schedule 2.

Extract of Schedule 2 of the Ordinance

Schedule: 2 BUILDING SERVICES INSTALLATIONS TO WHICH THIS ORDINANCE DOES NOT APPLY

1. An installation that is solely used for -
   (a) fire suppression;
   (b) fire extinguishing; or
   (c) fire suppression and extinguishing.
2. An installation that is solely used for -
   (a) surgical operation;
   (b) clinical treatment;
   (c) blood processing;
   (d) providing or maintaining appropriate environment settings for life protection; or
   (e) any combination of the purposes specified in paragraphs (a), (b), (c) and (d).
3. An installation that is used in a construction site for construction works only.
4. An installation that is solely used for industrial manufacturing.
5. An installation that is solely used for research in an educational institution.
6. A lighting installation that is solely used for -
   (a) illumination of an exhibit or product on display including special lighting for illuminating merchandise or art work;
   (b) decoration including special lighting for architectural feature or festival decoration effect;
   (c) visual production including special lighting for performance, entertainment or television broadcasting; or
   (d) any combination of the purposes specified in paragraphs (a), (b) and (c).
7. An installation that is solely used for -
   (a) air traffic regulation;
   (b) air traffic safety;
   (c) air traffic control; or
   (d) any combination of the purposes specified in paragraphs (a), (b) and (c).
8. An installation that is solely used for -
   (a) railway traffic regulation;
   (b) railway traffic safety;
   (c) railway traffic control; or
   (d) any combination of the purposes specified in paragraphs (a), (b) and (c).

In summary, section 4 of the Ordinance prescribes that the Ordinance 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 safety; or
- lighting installation solely for purpose of exhibit, decoration, or visual production.

3.2.4 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. The scope 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.

Table 3.3 : Examples of Building Services Installations to which the Ordinance Does Not Apply	
Building services installation	Justification
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)	Air movement equipment being part of a fire service installation not for normal operation. [Air-conditioning installation NOT within the scope of BEC clause 6.1.2 (a)]
Electrical circuit solely serving the above fan	Circuit fed by essential power supply and provides supply to equipment or installation which is NOT for routine normal operation. [Electrical installation NOT within the scope of BEC clause 7.1.2 (b)].
Remark: Examples of building services installations to which the Ordinance does not apply are also given in the publication Technical Guidelines on Code of Practice for Energy Efficiency of Building Services Installation.	

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 Part 4 covering sections 21 to 25), whereas the technical energy auditing procedures of the EAC are explained in TG sections 5 to 9.

4.1 Control Regime (EAC clauses 4.1 to 4.3)

4.1.1 Central Building Services Installation

The EAC requirements apply only to the central building services installation (CBSI) in a commercial building or the commercial portion of a composite building, and not to the CBSI in a non-commercial building or the non-commercial portion of a composite building. The energy audit should focus on the CBSI of a building. The interpretation of CBSI in the Ordinance is extracted in TG clause 3.1.3, which also gives examples on CBSI and non-CBSI.

TG Table 4.1.1 below summarizes the control regime based on CBSI in the concerned building category.

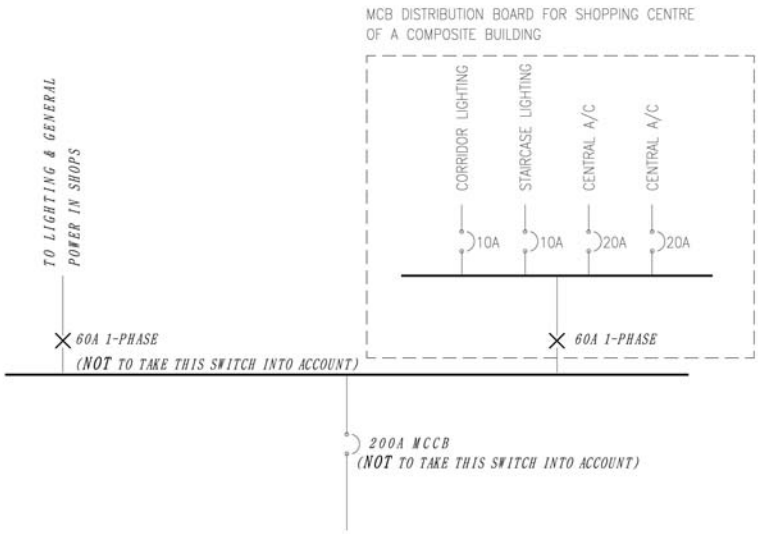
<table>
<tr><th colspan="5">Table 4.1.1 : Control Regime (Part 4, Cap 610) of Energy Audit Based on Building Category and CBSI</th></tr>
<tr><td colspan="2">Commercial building</td><td colspan="3">Composite building</td></tr>
<tr><td rowspan="2">Non-CBSI</td><td></td><td colspan="2">Commercial portion</td><td rowspan="2">Non-commercial portion</td></tr>
<tr><td colspan="2">CBSI</td><td>Non-CBSI</td></tr>
<tr><td>Carrying out of energy audit not mandatorily required</td><td colspan="2">Mandatorily required to carry out energy audit complying with the EAC</td><td colspan="2">Carrying out of energy audit not mandatorily required</td></tr>
</table>

4.1.2 CBSI in Composite Building

In the case of a composite building, pursuant to EAC clause 4.2, the energy audit requirement is applicable only to the CBSI solely serving the commercial portions of the building. It follows that the energy audit may exclude the CBSI serving both commercial portion and non-commercial portion (e.g. a lift serving both commercial storeys and residential storeys). However, for the case of a large central chilled/heated water plant serving both commercial and non-commercial portions (e.g. a plant serving both office portion and hotel portion), as a good practice, it is recommended to still include the plant in the energy audit if its cooling or heating rating is not less than 350 kW.

The measurement of the total rating of the electricity supply to the CBSI solely serving the commercial portions mentioned in the preceding paragraph may be illustrated by the following example. Suppose that there is only a 1-phase 60A 4-way sub-main miniature circuit breaker (MCB) distribution board and all the four MCBs therein solely supplying electricity to the central lighting installation and air-conditioning installation serving the common corridors and toilets of a shopping center in a composite building. The ratings of the four MCBs in the distribution board are combination of 10A and 20A, 1-phase. The rating of the sub-main switch of the distribution board is 60A, 1-phase. Then, the total rating of all the relevant circuit protective devices should be equal to that of the sub-main switch (which is nearer the supply side), i.e. 60A, 1-phase, but not the sum of rating of all the four MCBs. Other circuit protective devices nearer the supply side but not solely supplying electricity to the said central building services installation are not required to be taken into account. Please refer to TG Figure 4.1.2(a). However, if one of the MCBs in the aforesaid distribution board does not supply electricity to the said central building services installation, the total rating of all the relevant circuit protective devices should be equal to the sum of rating of the other three MCBs but not the rating of the sub-main switch since it does not solely supply electricity to the said central building services installation. Please refer to TG Figure 4.1.2(b).

Figure 4.1.2 (a) : A MCB board solely supplying electricity to the CBSI solely serving a shopping center in a composite building

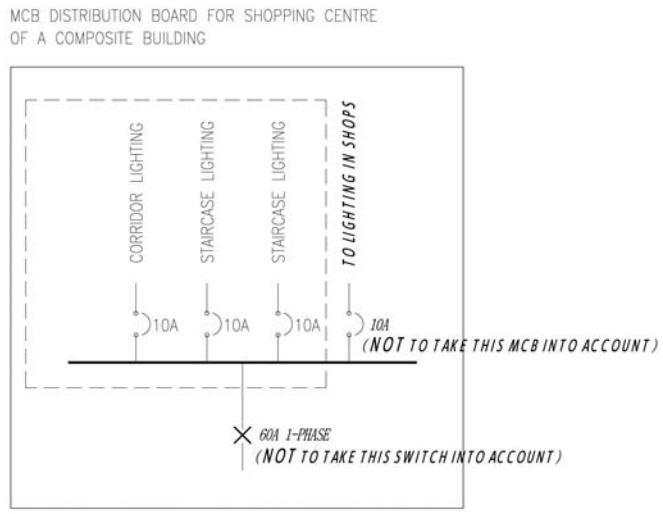


Total rating of the electricity supply to the CBSI

= Rating of the sub-main switch of the MCB board

= 60A, 1-phase

Figure 4.1.2 (b) : A MCB board not solely supplying electricity to the CBSI solely serving a shopping center in a composite building



Total rating of the electricity supply to the CBSI

= Total rating of the three MCBs solely supplying electricity to the CBSI

= 3 X 10A, 1-phase

= 30A, 1-phase

Please also note that a 3-phase switch is regarded as equivalent to three identical 1-phase switches. For example, the total rating of a 3-phase 30A switch is equivalent to 3 X 30A or 90A, 1-phase.

There are also commercial-residential composite buildings with the OA (issued under Buildings Ordinance (Cap 123)) having no restriction on the usage of a floor or unit, which may be changed freely between commercial and non-commercial purpose, and thus allowing commercial and non-commercial units to co-exist on the same floor. Since there is no definite demarcation between the commercial and non-commercial portions, a CBSI that does not solely serve the commercial portions is not subject to the mandatory energy audit requirement.

4.1.3 Building Complex

There are building blocks that collectively form a building complex. TG clause 4.3 below introduces the building block concept that may be applicable to a building complex. The demonstration of compliance based on the entity of a building complex and that based on an individual building block entity is quite different, as detailed in TG clauses 4.2 & 4.3 below.

4.2 Demonstration of Compliance (EAC clauses 4.1 to 4.3)

4.2.1 Process of Energy Audit and Parties Involved

TG Table 4.2.1 below describes the process of the energy audit, including the issuing and obtaining of EA Form and EA report (pursuant to Part 4 covering sections 21 to 25 of the Ordinance), in the demonstration of compliance with the requirements of the Ordinance and the EAC. EA Form is the abbreviation of Energy Audit Form, and EA report is the abbreviation of energy audit report. The compliance process involves the owner and registered energy assessor (REA), who have their respective legal responsibilities under the Ordinance.

Table 4.2.1 : Demonstration of Compliance with Energy Audit Requirements (Part 4, Cap 610)
• The owner of an applicable building is required to – - in respect of the CBSI# of the building, cause an energy audit to be carried out in accordance with the EAC at least once every 10 years, timeframe of first energy audit per section 22 (and Schedule 5) of the Ordinance, - engage a registered energy assessor (REA) # to carry out the energy audit (no need to include installations only serving an individual unit); - obtain an EA Form and an EA report from the REA carrying out the energy audit; and - exhibit the valid EA Form in a conspicuous position at the main entrance of the building. • The REA# (engaged by the owner of the building) is required to submit a copy of EA Form and the EA report to EMSD for record (fee for submission of EA Form and EA report to EMSD is not required, of which the endorsement from EMSD is also not required).
Remarks: # Interpretations of 'REA' is given in TG section 2 and 'CBSI' in TG clause 3.1.3. Under the Ordinance, the EA report and EA Form cannot be issued by a person who is not an REA. 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.

4.2.2 Timeframe of Energy Audit

(a) Carrying Out of Energy Audit

An energy audit for an applicable building's CBSI is to be carried out in accordance with the timeframe prescribed in sections 22(2) & 22(3) of Part 4 of the Ordinance. TG Table 4.2.2 below summarizes the timeframe based on the date of the "consent to the commencement of building works" for superstructure construction (given by the Building Authority) and the date of the issue to the building of its "occupation approval" (hereinafter abbreviated as OA). (Based on building age, buildings with consent given on or before 21 Sep 2012 may be regarded as existing buildings and buildings with consent given after the date regarded as newly constructed buildings.)

Table 4.2.2 : Timeframe for Carrying Out of Energy Audit (Cap 610)		
Date of Consent to the Commencement of Building Works for Superstructure Construction	Date of Issue of OA	Timeframe for Carrying Out of Energy Audit
Given on or before 21 Sep 2012 [@1]	On or after 1 Jan 1988	In 12 months from 21 Sep 2012
	After 31 Dec 1977 but before 1 Jan 1988	In 24 months from 21 Sep 2012
	After 31 Dec 1969 but before 1 Jan 1978	In 36 months from 21 Sep 2012
	On or before 31 Dec 1969	In 48 months from 21 Sep 2012
Given after 21 Sep 2012 [@2]	Any time after 21 Sep 2012	In 10 years after issue of COCR

Remarks:

21 Sep 2012 - is the date of the full operation of the Ordinance

Interpretation of 'consent to the commencement of building works' and 'OA (meaning occupation approval)' are given in TG section 2. For buildings not of the private sector, a consent carrying a similar effect in respect of approval of commencement of building works may be issued by the Architectural Services Department (for buildings constructed by the Department) or by the Hong Kong Housing Authority (for buildings constructed by the Authority); likewise a consent carrying a similar effect in respect of approval to occupy a premises may be issued by the Department or the Authority.

[@1] : For buildings that have their respective consents to the commencement of building works for superstructure construction given by the Authority on or before 21 Sep 2012, the timeframe is prescribed in section 22(3) and Schedule 5 of the Ordinance. These are the buildings without the COCR.

[@2] : For buildings that have their respective consents to the commencement of building works for superstructure construction given by the Authority after 21 Sep 2012, the timeframe is prescribed in section 22(2) of the Ordinance. These buildings are also governed by Parts 2 & 3 of the Ordinance, pursuant to which they have to obtain the COCR. The COCR – Certificate of Compliance Registration is a certificate issued by EMSD based on the merit of the building's compliance with the energy efficiency requirements prescribed in the Ordinance and the BEC in respect of the building services installations provided by the developer as at occupation approval.

(b) Completion of Energy Audit

An energy audit, having been carried out, should be completed, without unreasonable delay, within a reasonable time. The EAC recommends (EAC clause 8.1(m)) a completion of no later than 6 months after commencement.

4.2.3 EA Form and EA Report

(a) Upon completion of energy audit, the information collected and observations during the audit can facilitate the REA to produce two deliverables, namely the energy audit report or EA report in short and the EA Form or Energy Audit Form in short that bears the energy utilization index or EUI, on per annum basis, of the CBSI of the building or building block. The concept of building block is given in TG clause 4.3 below. As the EA Form has to be displayed and the EUI in the form can be easily compared among building blocks or buildings, it is expected that a benchmarking effect will be exerted on building owners and O&M personnels to improve the building's energy efficiency.

(b) The information collected and observations in the audit are to be analyzed and included in the EA report, which lists the energy management opportunities (EMO) identified in the audit. The implementation of EMO is not mandatory under the Ordinance, in consideration of their wide variety in terms of scope and cost. Nevertheless the ready availability of EMO listing is conducive to their implementation in parts if not all, given their energy saving being itself a paramount incentive.

(c) The EA report includes an executive summary, which pursuant to clause 8.2 of the EAC is itself a technical form (technical forms are further explained in TG clause 4.5). Items warranting attention in the writing up of EA report are further described in TG sections 7 and 8.

(d) Whilst most buildings can have its entity identified, there are buildings that form a building complex, which require special considerations in identifying their corresponding entities, and attention is drawn to TG clause 4.3 below citing the requirement of separate EA Forms and EA reports for the building blocks in a building complex.

4.3 Building Complex

A commercial or composite building complex may contain several physical blocks, with each block probably under different ownership or management, or issued with a separate OA according to the different phased completions of the complex. The building owner may choose to carry out an energy audit for all the blocks at the same time, or to carry out an energy audit separately for each block, and the following provide the guidelines.

4.3.1 Complex as Entity

It may be that some of these blocks in the complex can, based on TG Table 4.2.2 for an existing building complex, have the energy audit carried out at a later date e.g. in 24 months from 21 Sep 2012, while the other blocks have to be audited at an earlier date e.g. in 12 months from 21 Sep. The building owner(s) or property management of these building blocks may wish to carry out the audit for all the blocks or the complex at the earlier timeframe i.e. in 12 months from 21 Sep 2012. The situation is further illustrated in TG Table 4.3.1 below, for a building complex consisting of two building blocks namely A and B. Under the situation, a single energy audit may be carried out for the complex at the earlier timeframe, and a single EA Form and EA report may be issued to the complex.

Table 4.3.1 : Illustration of Timeframe of Energy Audit for Complex as Entity

	Date of OA	Original timeframe of energy audit based on TG Table 4.2.2, if separate energy audit is carried out for each block	Timeframe of energy audit, if a single energy audit is to be carried out for both blocks
Block A	1 Aug 1987	24 months from 21 Sep 2012	The earlier date of the original timeframe, in this situation 12 months from 21 Sep 2012
Block B	1 Feb 1988	12 months from 21 Sep 2012	

Needless to say, a single energy audit may be carried out for a complex that has all building blocks under the same timeframe in TG Table 4.2.2.

4.3.2 Individual Block as Entity

4.3.2.1 The building blocks in a building complex may have different energy audit timeframe based on TG Table 4.2.2 and/or may be under different ownership or management. Under the situation the owner or property management may choose to carry out a separate energy audit for each block, and the first step in identifying the scope of energy audit thus begins with demarcating the complex into the different building blocks, as each building block requires a separate EA Form and a separate EA report. (EA Form and

EA report are explained in TG clause 4.2.3 above.) The demarcation should be based on separation of blocks by configuration of –

i) physical separation (e.g. two towers with no physical connection), or
ii) separation between tower and podium,

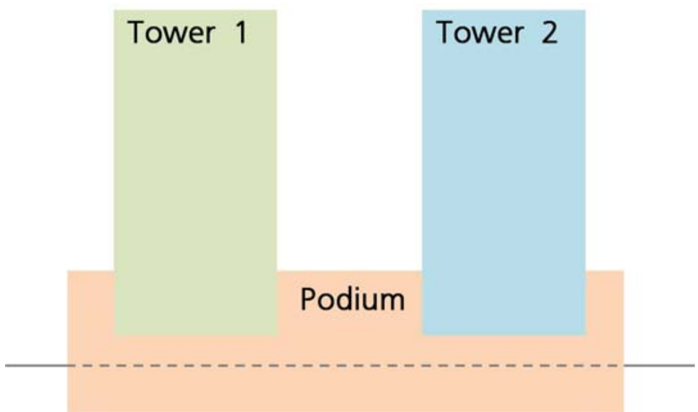
and the demarcation should also account for the energy import and export described in TG clause 4.4 below. With the demarcation, it follows that the energy audit requirements that are specified or cited for a building in the EAC and in the TG are applicable to each of the building blocks. The demarcation is further illustrated in TG clause 4.3.2.2 below.

The terms podium and tower above refer to common configuration of large commercial buildings in HK, 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 with smaller area than a podium floor; while office work is a common major usage of the tower there are also towers with residential units, hotel, shopping & leisure etc.

4.3.2.2 The following gives examples of the demarcation of a building complex into blocks.

(a) For a building complex consisting of three entities or blocks, namely tower 1, tower 2 and podium, as shown in TG Figure 4.3.2.2(a), an energy audit may be carried out for each building block, and an EA Form and EA report be issued for each, namely for podium block (may include basement floors), tower 1 block and tower 2 block. The building complex thus requires a total of 3 nos. EA Forms and 3 nos. EA reports.

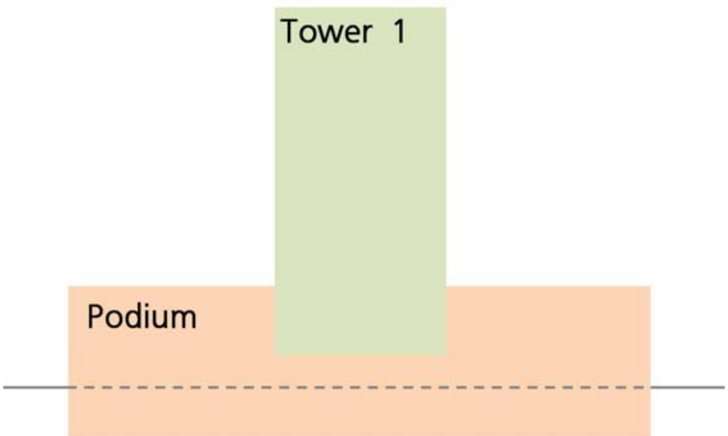
Figure 4.3.2.2 (a) : Two towers with common podium counted as 3 nos. building blocks



(b) Likewise for a building complex with a podium and 3 towers, the complex may require a total of 4 nos. EA Forms and 4 nos. EA reports, and for a building complex with 4 towers and 1 podium, a total of 5 nos. EA Forms and 5 nos. EA reports and so on.

(c) For a building complex consisting of a podium block and a single tower block, as shown in TG Figure 4.3.2.2 (c), even though both blocks are occupied at the same time, issued with a single OA, the complex may be considered as a podium-tower pair, and each block may be audited separately and requires a separate EA Form and EA report. Having specified (at the beginning of TG clause 4.3) that the building owner has the freedom to configure the building entity, the building owner is nevertheless encouraged to obtain (from the REA) a separate EA Form with executive summary (technical form EE-EAes) for each of the tower and the podium, and under the circumstance a single EA report covering both the tower and the podium would suffice.

Figure 4.3.2.2 (c) : Podium and tower counted as two nos. building blocks



4.3.3 Grouping Blocks into One Entity

This is a configuration in between the complex as entity (TG clause 4.3.1) arrangement and the block as entity (TG clause 4.3.2) arrangement. The building owner(s) or property management may wish to group two or more blocks together into one entity for a single energy audit. The building owner(s) or property management may carry out a single energy audit involving one EA Form and one EA report for the constituent blocks provided that -

i) the earlier timeframe for carrying out of energy audit, so cited in TG clause 4.3.1, amongst the constituent blocks is adopted; and
ii) the demarcation of the remaining constituent blocks is based on the approach in TG clause 4.3.2.

An illustration is given in TG Table 4.3.3 below, for an existing building complex with three blocks, namely tower 1, tower 2 and podium, as shown in Figure 4.3.2.2(a).

<table>
<tr><th colspan="4">Table 4.3.3 : Illustration of Grouping of Blocks into One Entity</th></tr>
<tr><td></td><td>Date of OA</td><td>Original energy audit timeframe (TG Table 4.2.2)</td><td>Timeframe of energy audit, after grouping</td></tr>
<tr><td>Podium</td><td>1 Aug 1987</td><td>24 months (mths) from 21 Sep 2012</td><td rowspan="3">Grouping podium and tower 1 into one entity
Podium & tower 1 : 12 mths from 21 Sep 2012
Tower 2 : 12 mths from 21 Sep 2012
Grouping podium and tower 2 into one entity
Podium & tower 2 : 12 mths from 21 Sep 2012
Tower 1 : 12 mths from 21 Sep 2012
Grouping tower 1 and tower 2 into one entity
Tower 1 & tower 2 : 12 mths from 21 Sep 2012
Podium : 24 mths from 21 Sep 2012</td></tr>
<tr><td>Tower 1</td><td>1 Feb 1988</td><td rowspan="2">12 mths from 21 Sep 2012</td></tr>
<tr><td>Tower 2</td><td>1 Aug 1988</td></tr>
</table>

4.3.4 Building Block with Phased Completion

A building block may be completed and occupied in phases and issued more than one OA. Under the situation, a single energy audit should be carried out for the entire building block, and the energy audit timeframe for existing buildings should be based on the date of the later of the OAs. For newly constructed buildings, the timeframe should be based on the date of the earlier of the COCRs. An illustration of the situation for an existing building block is given in TG Table 4.3.4(a), and the illustration for a newly constructed building block is given in TG Table 4.3.4(b).

<table>
<tr><th colspan="3">Table 4.3.4 (a) : Illustration of Timeframe of Energy Audit for Phased Completion of a Building Block – Existing Buildings</th></tr>
<tr><td></td><td>Date of OA</td><td>Timeframe of energy audit based on the date of the later OA</td></tr>
<tr><td>Lower floors</td><td>1 Aug 1987</td><td rowspan="2">The date of the later OA, in this situation 1 Feb 1988, should be based upon in checking for the timeframe of energy audit, which with reference to TG Table 4.2.2, is 12 months from 21 Sep 2012.</td></tr>
<tr><td>Upper floors</td><td>1 Feb 1988</td></tr>
</table>

<table>
<tr><th colspan="3">Table 4.3.4 (b) : Illustration of Timeframe of Energy Audit for Phased Completion of a Building Block - Newly Constructed Buildings</th></tr>
<tr><td></td><td>Date of COCR Issue</td><td>Timeframe of energy audit based on the date of the earlier COCR</td></tr>
<tr><td>Lower floors</td><td>1 Dec 2013</td><td rowspan="2">The date of the earlier COCR, in this situation 1 Dec 2013, should be based upon in checking for the timeframe of energy audit, which with reference to TG Table 4.2.2, is in 10 years from 1 Dec 2013.</td></tr>
<tr><td>Upper floors</td><td>1 Dec 2014</td></tr>
</table>

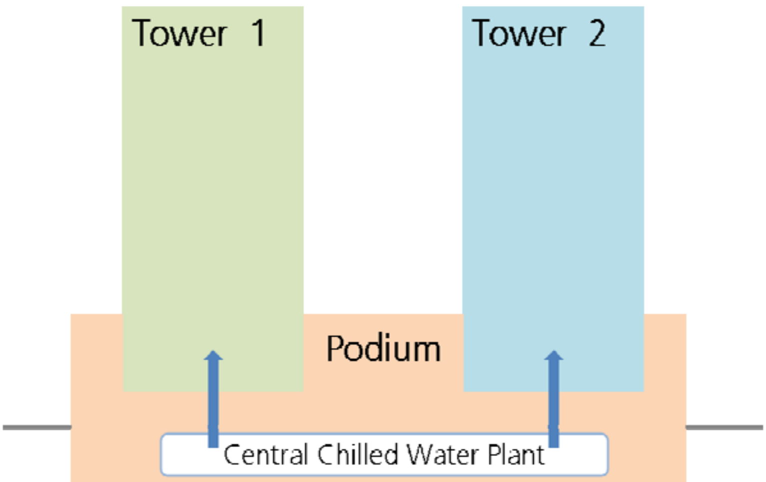
4.4 Energy Import and Export

Having introduced the concept of building block in TG clause 4.3.2, the energy audit should identify the energy consumption in each building block. It would not be uncommon that a building block has energy components that are exchanged, i.e. imported to or exported from the other building blocks in the same building complex across their block boundaries. The most common example of such energy exchange is the energy flow contained within chilled water systems.

For example, consider the building complex in TG clause 4.3.2.2, that consists of three blocks, namely tower 1 block, tower 2 block and podium block, for which an energy audit of each block may be conducted separately. The energy transfer in the chilled water among the three blocks are indicated in TG Figure 4.4 below.

The central chilled water plant is often located within the podium, and owned and operated by the owner of the podium. However, part of the chilled water generated is exported to the tower blocks. The energy audit for both the tower blocks and podium block should include the energy exchange within the chilled water. Further explanations of energy exchange are also given in TG clause 7.3.3 and clause 8.4.

Figure 4.4 : Diagram indicating energy export from podium and import to tower blocks



4.5 Specified Forms and Technical Forms

The issue of forms are required to demonstrate the compliance with the Ordinance and the EAC. 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 EAC. The EA Form, numbered EE5, is a specified form. The issue of form EE5 is to be accompanied with a technical form numbered EE-EA that serves as a checklist for the energy audit steps against which the REA has to indicate the compliance. There is another technical form numbered EE-EAes that is to accompany forms EE-EA and EE5. Form EE-EAes is simply the executive summary (mentioned in TG clauses 4.2.3(c), 8.1.1, 8.2, 8.3 and 8.4.1) of the EA report, and is a summary presented in a consolidated format for ready reference by the building owner and EMSD. (These forms can be downloaded at the web-site of the Buildings Energy Efficiency Ordinance.) TG Table 4.5 (a) and Table 4.5 (b) below show respectively the lists of specified forms and technical forms.

Table 4.5 (a) : List of Specified Forms (EAC Compliance), Cap 610	
Form No.	Type of Form
EE5	Energy Audit Form (EA Form)
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 (EAC Compliance)	
Form No.	Type of Form
EE-EA	Energy Audit Checklist for Energy Audit Code
EE- EAes	Executive Summary of Energy Audit Report (EA report) for Energy Audit Code (at the beginning of the EA report)

4.6 Summary of Requirements

In summary, the owner of building(s) should -

(a) check if the Ordinance is applicable to his/her building(s) –

i) by identifying if it is a commercial building, or is a composite building that has commercial portions, and for the latter identify the portions that are for commercial use (refer TG clauses 3.1.1 and 3.1.2), and

ii) by identifying 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 3.2.3 re sub-sections 4(1) and 4(2) of the Ordinance), or by virtue of ceasing to remain in Schedule 4 of the Ordinance (refer also TG clause 3.2.2); and

(b) for a building to which the Ordinance is applicable –

i) identify based on ownership or management perspective if a demarcation of the building block (from a building complex accommodating different neighbourhood building blocks) to be audited is required (TG clause 4.3);

ii) differentiate with the assistance of an REA wherever necessary the CBSI from the other building services installations (refer TG clause 3.1.3 and TG clause 4.1.1), and determine the scope of the energy audit (TG clause 7.1.1) for the CBSI, after taking into consideration the applicable exclusions in Schedule 2 of the Ordinance (refer also TG Table 3.2.3 re Schedule 2); and

iii) cause the energy audit to be carried out (TG clause 4.2.1) in accordance with the timeframe (TG clause 4.2.2), obtain from the REA carrying out the audit the EA report and EA Form (TG clause 4.2.3) and display the EA Form (pursuant to Part 4 of the Ordinance).

4.7 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;
- 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 Objectives of Energy Audit

5.1 EAC section 5 specifies the objectives of an energy audit. An energy audit involves the systematic review of the energy consuming equipment and systems in a building, with a view to identify energy management opportunities (EMO) which if implemented would generate energy saving. The review provides the useful information to the building owner for his/her consideration of the EMO's environmental and economic benefits in parallel with the overall management plan of the building and probably that of the corporation managing the building, and based on the consideration he/she can make the final decision of the EMO to be implemented to realize the benefits.

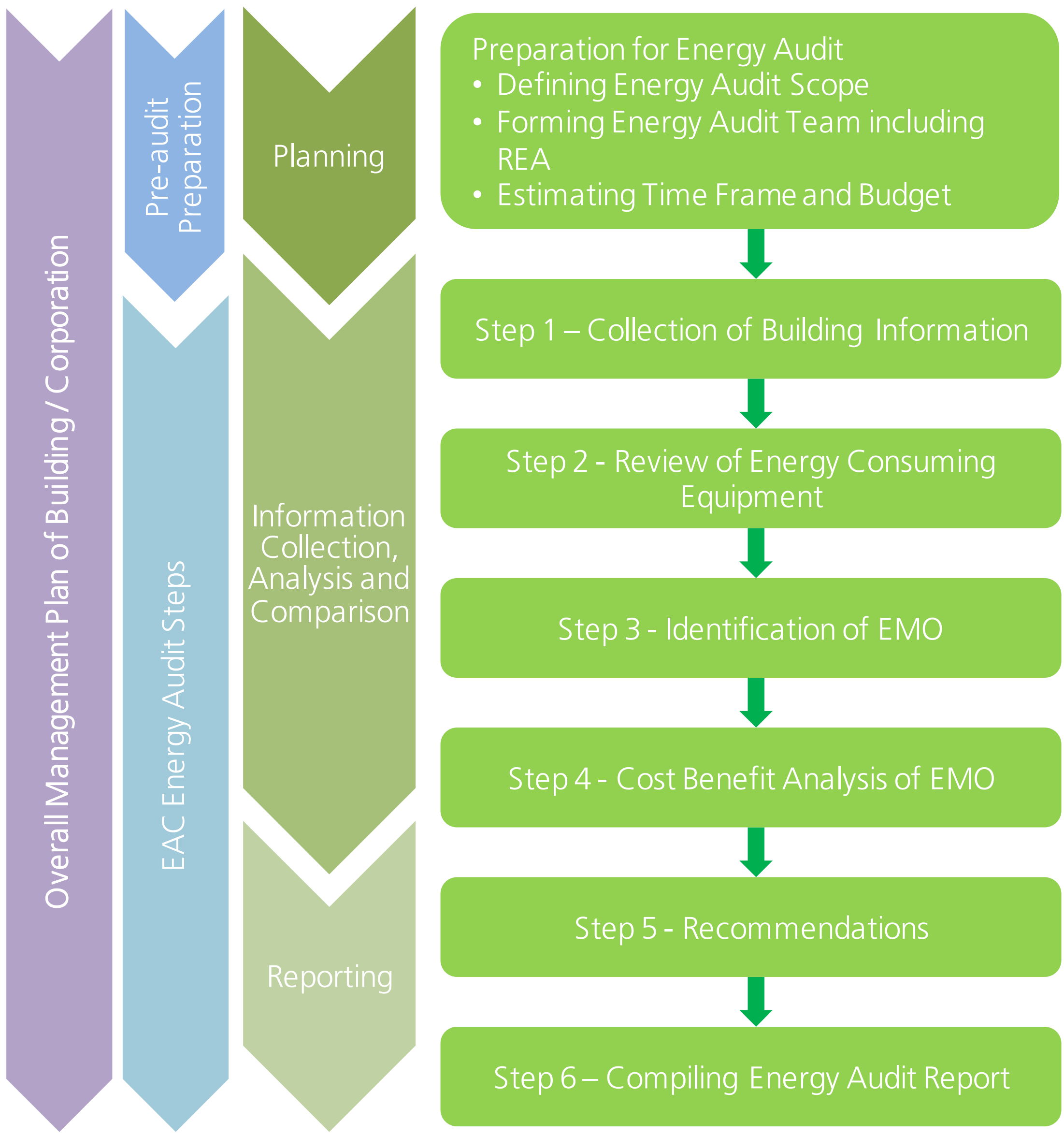
6 Overview of Energy Audit

6.1 Overview

(a) Planning and Steps of Energy Audit

TG Figure 6.1 below summarizes the energy audit steps specified in the EAC. Prior to the audit, certain preparation works may be required, which are also included in the figure. The 6 major steps for the energy audit are further discussed in TG section 7. The implementation of EMO is, though highly recommended, not a mandatory requirement.

Figure 6.1 : Overview of energy audit process



(b) Building Energy Management Programme

The mandatory timeframe of carrying out of energy audit "once every 10 years" serves simply to roll out the legislative energy audit requirement, and the "10 years" period is only a minimum requirement and should by no means be seen as a yardstick. As a good engineering practice outside the mandatory framework, building owners are encouraged to carry out energy audits more regularly, and the regular energy audit may be included in the building's energy management programme. A step beyond is that the energy audit and energy management programme may become an agenda item in the management plan of the building or of the portfolio of buildings of the corporation.

(c) When carrying out the energy audit, the REA should always bear in mind on what constitute an energy efficient mode of operation, the comparisons needed and the means for improvement.

6.2 EMO Categorization (EAC clause 6.2)

For ease of reference and management, EMO should be categorized based on their extent of involvement of resources for implementation, as specified in EAC clause 6.2, from Category I with minimal involvement to Category III with substantial involvement. The classification serves as a management tool for the building owner to make decisions in terms of required capital cost and associated energy saving implications. Some examples of EMO categorization are shown in TG Table 6.2 below.

Table 6.2 : Examples of EMO Categorization

Category	Examples		
I	Keep doors/windows closed (Air-conditioning)	Disconnect power supply to some lighting installations to reduce luminance in over lit or unoccupied areas (Lighting)	Reset to moderate air supply temperature for over-cooled areas (Air-conditioning)
II	Add occupancy sensor control for lighting (Lighting)	Check and reset as appropriate VAV static pressure control to reduce fan power (Air-conditioning)	Check and re-balance the chilled water supply system with adjustment as appropriate of valves to avoid over-cooled spots (Air-conditioning)
III	Install variable frequency type variable speed drive for chilled water pumps (Air-conditioning)	Analyse the power quality of the electrical system and add as appropriate correction devices for harmonics reduction and power factor improvement (Electrical)	Replace DC or AC 2-speed motor drive of lift with variable voltage and variable frequency type motor drive (Lift)

7 Energy Audit Requirements

7.1 General (EAC clause 7.1)

7.1.1 Preparation for Energy Audit

The building owner is recommended to determine, prior to the audit, the available resources and thus the scope of work of the energy audit, scope of work may be defined by factors of resource allocation and corporate commitment to sustainable development. The available resources may be in terms of staffing, out-sourcing to consultant or contractor, time frame, metering provisions and availability, budget allocation etc. The availability of equipment inventory records, equipment technical brochures & manuals, related drawings and system schematics, operation records etc. could be viewed as an informative resource which if adequately available could very much streamline the work of the REA. Facilitating the energy audit, it is recommended to form an energy audit team, with the view to solicit sound contributions from team members who should be encouraged to play their eminent roles. The success of the energy audit and the subsequent implementation of EMO very much depends on the contribution from the team members. The following are common administrative considerations in forming the team.

(a) Building a balanced team, which may include -

- building owner and property management – responsible for resource allocation and ultimate effectiveness of the energy audit and associated EMO implementation, and overall operation of the building;
- O&M (operation and maintenance) personnels – responsible for operation of CBSI, including the maintaining of suitable comfort for the building occupants, and the implementation of certain EMO;
- REA – plays the leading role in the energy audit, including identifying EMO;
- Contractor – an outsource to implement the EMO requiring more substantial resource involvement, who will play a post-audit prominent role; and
- Building occupants – who will be directly affected by the comfort level of the built environment and the energy expenditure.

(b) Assigning the duties of audit team members.

(c) Facilitating meetings for sharing of information and familiarization among different parties.

(d) Surveys or questionnaires to solicit information on comfort (thermal, lighting, air qualify etc.) and operation hours.

The REA and the energy audit team may recommend the scope of the energy audit such as the level of sophistication based on the resources allocated by the building owner or property management, after which the steps specified in the EAC should be followed. While an audit of an involved scope may study each component of a system e.g. each AHU irrespective of flow rate and capacity, an audit of less involved scope may focus more on system components that are energy intensive or likely to attract relatively significant energy saving. The REA may exercise his/her professional judgement on the items to be focused and those that require less attention.

7.1.2 Summary of Energy Audit Requirements (EAC clauses 7.1 to 7.7)

TG Figure 7.1.2 gives a diagrammatic summary of the requirements specified in EAC clauses 7.1 to 7.7.

Figure 7.1.2 : Summary of energy audit requirements

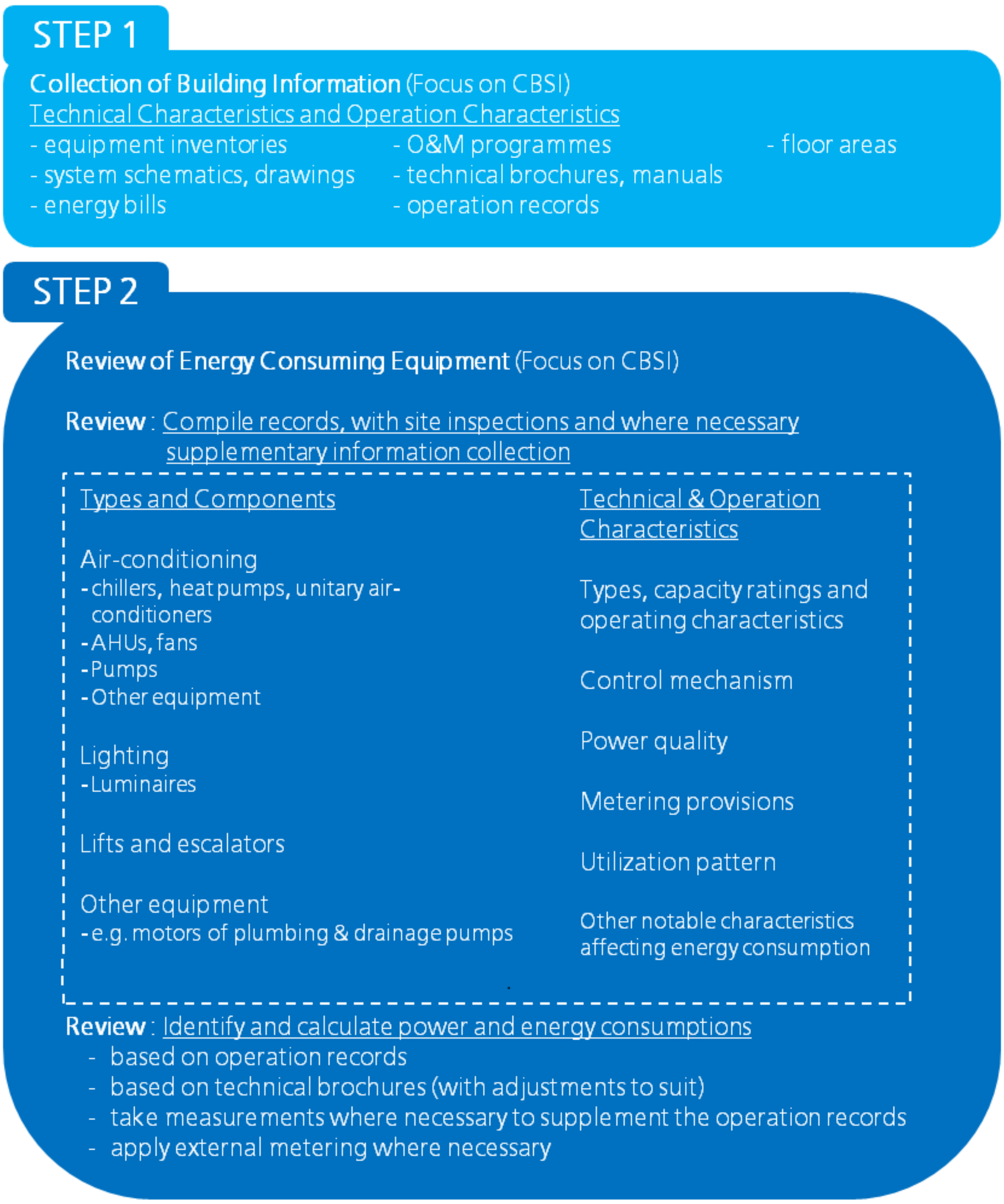


Figure 7.1.2 (continued) : Summary of energy audit requirements

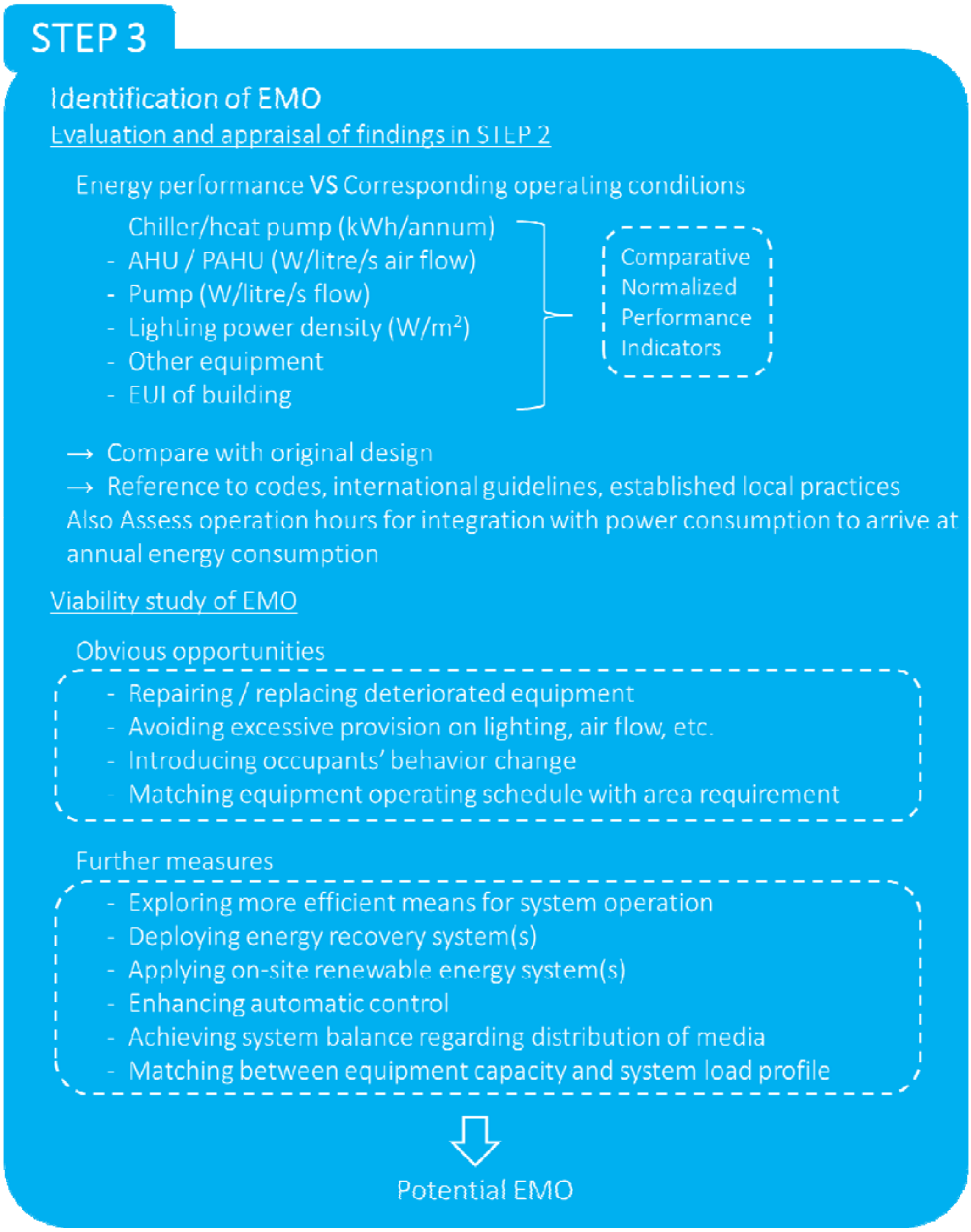


Figure 7.1.2 (continued) : Summary of energy audit requirements

STEP 4

Cost Benefit Analysis of EMO

- Estimation of energy saving

Energy Saving = Measured / collected energy use before implementation of EMO - Estimated energy use after implementation of EMO

* Consider service life and degradation of equipment

- Categorization into Cat I, Cat II and Cat III
- Cost benefit analysis (for Cat II and Cat III)

Cost VS Energy Saving

→ Specify energy price used for evaluation
→ Record conditions for consistent comparison
→ Cover a complete operating cycle
→ Indicate methodology of energy projection

Measurement interval
Metering information
Utilization patterns
Ambient temperature
Conditioned area
Lighting levels
Ventilation rate
Occupancy type

STEP 5

Recommendations

- Due regard : energy saving, cost benefit, robustness of energy data
- Describe intended result and procedures
  e.g. inspection, function test, data trending
- Summarize measurement device / parameter / time interval
- Make use of O&M activities
- Suggest future studies

STEP 6

Energy Audit Report

- Executive Summary
- Objective and scope
- Equipment / systems operating characteristics
- Robust energy data record by measurement / operation record
- Potential EMO : energy savings and cost benefit analyses
- Recommendation with due regard to O&M programme & follow-up

7.2 **Step 1** – Collection of Building Information (EAC clause 7.2)

The information collected serves to reveal the energy use characteristics of the building's CBSI and forms the backbone of the energy audit. The more comprehensive and representative the information is, the more accurate the analyses would be, which would result in the identification of more efficient EMO having good energy saving. TG Table 7.2 below gives the remarks, essentially the justifications, for collecting of information.

<table>
<tr><th colspan="3">Table 7.2 : Remarks on Building Information to be Collected</th></tr>
<tr><th colspan="2">Building information to be collected – (extracted from EAC clause 7.2)</th><th>Remarks</th></tr>
<tr><td>(a)</td><td>record of EMO already implemented in the last 36-month or to be implemented, and corresponding energy audit report if available</td><td>The past report and records could be clues to potential EMO.</td></tr>
<tr><td>(b)</td><td>– inventories of the energy consuming equipment, and
– manuals or technical brochures indicating their configurations and characteristics</td><td>– The inventories if available could save the REA much time in the listing of the energy consuming equipment.
– The technical brochures, catalogues and manuals could provide valuable information in the understanding of the energy consuming equipment's technical characteristics, which may include :
• configurations or types and capacity ratings,
• manufacturer recommended operating conditions,
• performances including power drawn at different operating conditions of temperature, flow, pressure etc.,
typical ones being lighting power, motor power and efficiency at different loadings, coefficients of performance of chiller/VRF system & unitary air-conditioner at different loadings, fan power at different loadings, pump power at different loadings etc.</td></tr>
</table>

(c)	drawings and system schematics showing the layouts of the energy consuming equipment and systems, and drawings showing the layout of the building	The schematics and drawings of energy consuming systems and equipment help to understand what constitute the system and how they are configured to integrate with and serve the various spaces of the building. Typical examples are schematics of air-conditioning water side and air side systems, electrical schematics, lighting layout plans, building floor layout plans, etc.
(d)	equipment day-to-day operation records, including room temperature settings and corresponding room temperatures, chilled water supply & return temperature settings and corresponding water temperatures, supply & return air temperature settings and corresponding air temperatures, building & equipment operation hours etc.	While (b) & (c) above are more on the technical characteristics, (d) & (e) focus on the operation characteristics. It is with reference to the intrinsic technicalities in (b) & (c) that the REA can assess if there are deviations from favourable operating conditions. The deviations may be in terms of energy, power, flow, temperature, pressure, level of service etc. or changes thereof over representative time intervals, and are commonly reflected in the day-to-day operation records. In addition, knowledge of the general occupancy of the building would be beneficial, which may explain the increase or reduction of energy consumption due to non-routine changes to occupancy or usage.
(e)	energy consumption data in last 36-month or since operation of the building should such period be less than 36-month	These are normally the data from metering or energy bills, and are good monthly indications of the overall building energy performance.
(f)	operation & maintenance programmes including timing of major alterations, additions or replacements for the building	While past information may explain why there were reductions or increases in energy consumption, information for the future could serve to plan ahead the implementation of the relevant EMO, which if tied in with the programme may much reduce its capital cost investment.

(g)	areas of relevant spaces attributing to the internal floor area of the building	– The information is useful for the identification of the lighting power density and the estimation of cooling load of a space.
(h)	total internal floor area of the building	– Internal floor area is, pursuant to section 2 of the EAC, interpreted as the floor area of all enclosed spaces measured to the internal faces of enclosing external and/or party walls. In this context, the area occupied by a column also counts towards the internal floor area, whereas the area should normally not include roof area, outdoor gardening area and balcony. The EUI is calculated based on the internal floor area of the building, which includes the areas of separately owned units as well as the common areas.

7.3 **Step 2 –** Review of Energy Consuming Equipment (EAC clause 7.3)

In parallel with the information collection, site inspections to verify the information should be conducted. Based on the information collected and the site inspections, the REA could develop his/her appreciation of the building layout, the central chilled water or heated water plant, the common types of luminaires, the electrical distribution network, the lift and escalator systems etc. The appreciation should focus around the items of the CBSI. Attention should also be paid on the availability of metering facilities and the associated measured or measurable parameters.

7.3.1 Technical Characteristics and Operation Characteristics (EAC clause 7.3.1)

7.3.1.1 Records of technical and operation characteristics of the energy consuming equipment and systems can be compiled based on the collected information and findings in site inspections, and potential EMO could be identified by reviewing the operation characteristics.

(a) Soft tools to control hardware

Given the technical characteristics being the intrinsic technicalities of an equipment or a system, which may be regarded as the hardware, the operation characteristics of "set points" and "operating schedule" may be viewed as the soft tools for interfacing with the O&M personnels and occupants who can adjust them to provide the dedicated service to meet the load of the equipment, system or building.

<u>Set Points</u>

Set points describe how a system or equipment is operated. Review of set points can provide information on the differences between operation and design intent. Common set points may include -

- space air temperature,
- fan static pressure (flow control),
- chilled water supply temperature,
- pump static pressure (flow control),
- enabling condition of equipment (e.g. chilled water temperature for automatic chiller sequencing),
- space carbon dioxide level,
- space lighting level, etc.

Operating Schedules

Comparing the actual operating schedule against the design operating schedule can identify periods when the service for a space is not required and the serving equipment can be switched off. The operating schedules provided by O&M personnels may also be checked against the feedbacks from the occupants of the building for consistency. Common operating schedules may include -

- space occupied hours on weekday and weekend,
- equipment operation hours (e.g. air-conditioning, lighting and socket loads, etc.),
- equipment control (e.g. timer, load detection, etc.), etc.

(b) Operating Conditions

Set points directly affect the operating conditions of an equipment or system. Operating conditions may also relate to the building environment. Common operating conditions may include -

- outdoor weather condition such as outdoor temperature,
- temperature in plant room,
- pressure such as water head due to building height,
- load demand,
- conditions dictated on an equipment by another equipment, etc.

(c) Load patterns

Load patterns refer to the energy demand patterns, the thermal load of air-conditioning and the lighting load in particular, of various energy consuming equipment and systems, which are operated to provide the service or function of the building. Loads are time dependent, but tend to demonstrate certain trends.

The efficiency levels of many equipment, air-conditioning in particular, vary at different load intensities and operating conditions of temperature, pressure, speed etc. and their part load efficiencies are thus of particular interest.

While electricity and lighting loads can be obtained either by measurements or checking against specifications in product catalogues, thermal loads may require a combination of measured parameters including flow and temperature difference.

Common loads may include -

- space cooling loads and space peak cooling load,
- electric lighting loads,
- motor loads,
- equipment power loads (e.g. fan, pump, heater, etc.), etc.

Ideally, the soft tools of set points and operating schedules should tally with the loads. Nevertheless, it is common that some of these soft tools are not optimized to meet the various changing load patterns over time, part loads in particular.

Summarizing as shown in TG Figure 7.3.1.1, better insight of the energy performance of an equipment or system can be developed by reviewing its operation characteristics which interact and affect each other. TG Table 7.3.1.1 lists examples of common operation characteristics associated with potential EMO.

Figure 7.3.1.1 : Interaction of operation characteristics of energy consuming equipment and system

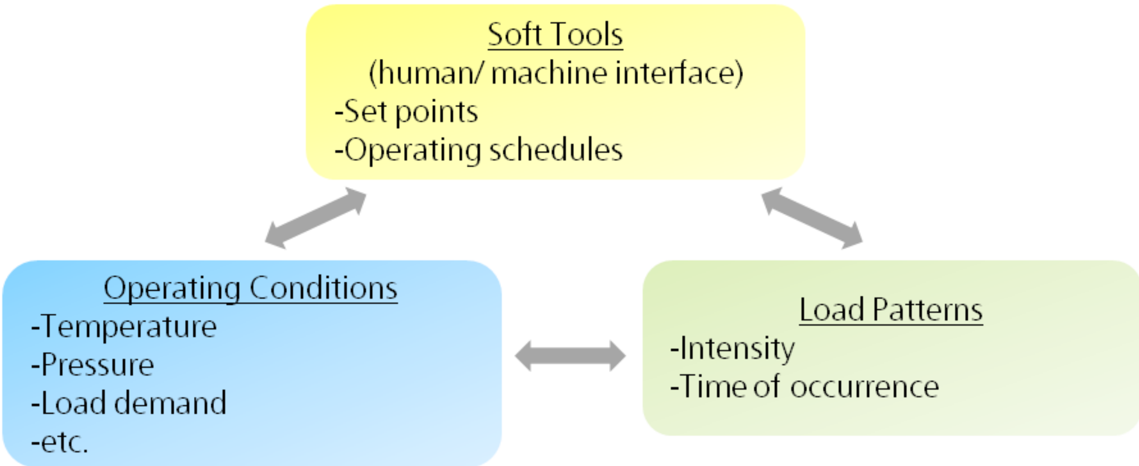


Table 7.3.1.1 : Examples of Common Operation Characteristics Associated with Potential EMO

Energy consuming equipment/system	Operation characteristics
Chillers/ VRF systems, unitary air-conditioners, heat pumps	Operation time and load pattern, chilled water supply temperature, chilled water return temperature, chilled water flow rate, condensing water supply temperature, condensing water return temperature, condensing water flow rate, chiller sequencing control
AHUs and fans	Operation time and load pattern, air flow rate, pressure, variable speed control setting

Air conditioning water pumps	Operation time and load pattern, water flow rate, pump pressure
Luminaires	Operation time and load, lighting illumination level, daylight illumination level, time / daylight control setting
Electrical circuits	Operation time and load
Lift and escalator installation	Operation time and load, destination and travel information

7.3.1.2 Depending on the scope of coverage, the energy audit may touch on the characteristics of the building envelope including external shading, given the envelope's impact on air-conditioning energy and probably lighting energy. However, as the building envelope is not a building services installation, its detailed study is not a requirement under the EAC.

7.3.2 Identification and Calculation of Power and Energy Consumption (EAC clause 7.3.2)

7.3.2.1 Where appropriate, power and energy consumption values can be calculated based on available consumption values shown in technical brochures with adjustments to suit the actual operating conditions such as operation hours reflected in the operation records. Equipment nameplates also provide valuable information, in particular when drawings or documented records are not available. For example the lighting power of a space may be assessed by identifying the wattage of different luminaires based on wattage figures shown in technical brochures. Alternatively, the wattage may be based on visual inspection and professional judgement, and the assessment may be supplemented, for certain representative luminaire types, with demounting or actual measurement to check the wattage.

In some cases the information shown on the equipment nameplates, technical brochures or documented records cannot meet the level of adequacy in reflecting the actual operating conditions of the building services energy consumption equipment/systems. Under this circumstance, taking field measurement at representative instants and calculation should be applicable. If the field measurement and calculation of equipment power consumption is adopted, methodology of calculation shall be included in the energy audit report (e.g. fan & motor (combined) efficiency = (measured flow rate x measured total pressure) / measured motor input power).

The actual measurement of the power consumption should be carried out under equipment peak load condition, and the conditions under which the measurement is taken should be indicated in the EA report. If repeating the peak load condition is found not viable during the period of energy audit, professional judgment should be applied to project such condition with the methodology and assumption being elaborated in the EA report.

The same principle is applicable to equipment capacity where the rated capacity should be adopted as the preferable approach while the measured / calculated capacity can be adopted with justification and methodology being elaborated in the EA report.

For the methodology of data measurement and calculation of energy, it is suggested to refer to the following (but not limited to) recognized international standards for details:

- International Performance Measurement & Verification Protocol – Concepts and Options for Determining Energy & Water Saving
- ASHRAE Guideline 14 – Measurement of Energy and Demand Savings

7.3.2.2 (a) It is a good practice to equip a building with full metering to continuously log data on power and energy consumptions and operation characteristics of each equipment and system. However, in practice, the logged data or technical records may be incomplete. Under the situation, additional measurements may be required, or should there be no in-situ metering, external metering may have to be used.

(b) Field measurements of the parameters of air-flow, pressure difference, supply and return temperatures of coil and air ducts, power consumption etc., and power inputs and/or energy consumptions can be taken at representative instants and appropriate time intervals that well reflect the extent and intensity of the equipment or system's operation characteristics. The measured data when compared with performance characteristics in technical brochures can give indicative information for estimating or extrapolating the energy efficiency trend of the equipment or system, and potential EMO can be developed based on the trends by optimizing the controlled parameters such as temperature, flow and pressure.

(c) It is a good practice to ensure the meterings are well maintained and calibrated regularly, to avoid misinterpretation of inaccurate measurements.

(d) There are generally two types of measurement, namely snap-shot measurement and trend measurement.

Snap-shot measurements are useful in assessing conditions where there are minor variations over time, examples including the lighting level within a space that is not strongly affected by daylight, the room temperature of a space with insignificant temperature variation over a representative time period, the connected power consumption of a fully occupied floor etc. Handheld meters are often used to take snap-shot measurements.

Trend measurements can give the performance trend of the equipment under various operating conditions, example being fan efficiency under various fan speeds and loads. Trend measurements may also be of long trend or short trend types. Long trend measurements such as monthly provide information of seasonal variations, while short trend measurements such as few hours or a week shed light on the operation schedule and corresponding variations on a day or in a week.

The international standards as mentioned in TG clause 7.3.2.1 illustrate the measurement techniques of various parameters which include air flow rate / water flow rate, air / water temperature and power consumption. These standards provide guidance, depending on the parameters and condition, to the measurement works such as mean for the selection of suitable metering for measurement under different conditions, precaution and consideration of measurement, schedule of measurement and calibration of instrumentation etc.

(e) The REA should determine if a particular data or parameter requires snap-shot, long trend or short trend measurements, with due regard to the scope of the energy audit.

(f) The REA should determine the methodology of the measurement and describe the methodology in the EA report.

(g) Trend measurements can be taken using metering with data-logger or metering with data logging through building management system (BMS).

A metering with data-logger, usually of stand-alone type and battery operated, may be for single or multiple parameter measurement, and the measured data are stored in the logger or are transferred to the connected computer / potable device via Wi-Fi. The user can usually configure the measuring intervals.

A metering with data logging through BMS can archive the measured trend data in a server for each measuring point or family of points, and should a good coverage of parameters be included the logging can provide comprehensive monitoring on the operation characteristics reflected by the measuring point(s). However, the REA must exercise judgement in processing the large amount of data generated by the BMS.

7.3.3 Metering for Shared Service

(a) Building complex

For a building complex with shared services which “import” and “export” energy between blocks in the complex (TG clause 4.4), additional measurements may be required to assess the energy consumption of the CBSI of the building block being audited. It is a good practice to have these “imported” or “exported” energy measured. A typical example of shared service is the chilled water supply in air-conditioning, which can be measured through thermal energy meters. TG clause 8.4 provides guidance on how these measurements could be reported, and the reporting is a requirement in the EAC (EAC clause 8.1(g)).

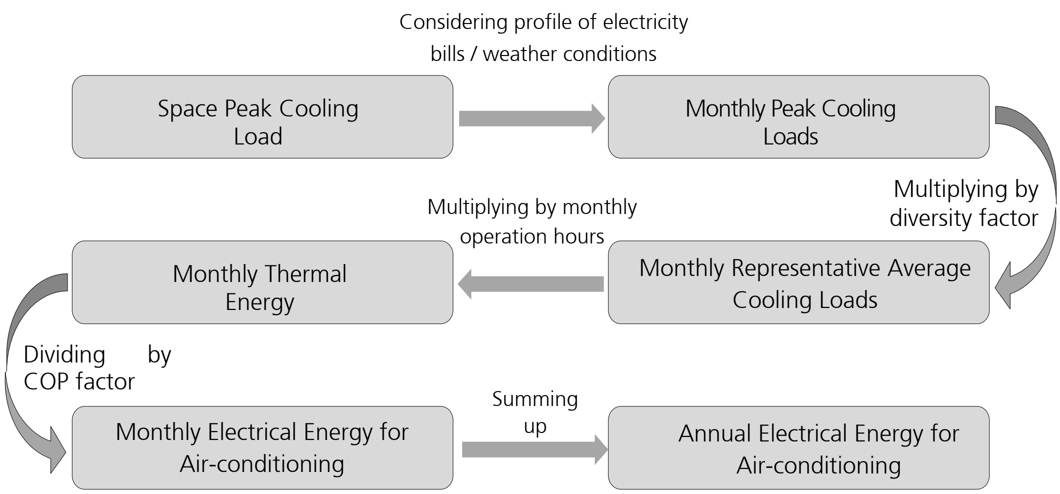
(b) Supply to Units

Along similar line, the energy supply to or the shared service with a building's units has to be reported, and to have the energy measured is a good practice. EAC clause 8.1(h) requires the indication of the energy supply from the CBSI to the building's units of tenants as a percentage of the CBSI's total energy consumption.

There are situations that measured records are not available and measurements cannot be taken given resource constraints. Under these situations, the electricity for lighting and power socket loads (if these are on the building owner's account) can be obtained by certain metering of the electrical circuits of the units. As for air-conditioning energy such as chilled water supply, for each unit or for a group of units, the assessment of thermal air-conditioning energy may be based on professional judgement.

One of the means, as illustrated in TG Figure 7.3.3(b), of the assessment of thermal air-conditioning energy based on professional judgement is to estimate the monthly peak cooling loads of the unit(s). The monthly peak cooling loads may be obtained through a broad professional estimate of the space peak cooling load requirement in kW of the unit(s). Information on the cooling capacity of air-conditioning equipment such as FCU(s), AHU(s) etc. serving the unit(s), if available, would very much shed light on the space peak cooling load requirement. In parallel, the monthly variation profile of the load may be established by referencing to the monthly electricity bills of the past year(s) if available (which inherently reflect the higher consumptions in hot months and lower consumptions in cool months). By applying the profile to the space peak cooling load, the monthly peak cooling loads may be obtained. Should resources be available, the monthly peak cooling loads may also be calculated based on cooling load software program.

Figure 7.3.3 (b) : Example illustrating estimation of electrical energy for air-conditioning to units



Each of the monthly peak cooling load figures may be applied a diversity factor to give the monthly representative average cooling load, which may then be multiplied by the number of monthly operational hours to give the monthly thermal energy. Each of the monthly thermal energy data may be divided by a COP factor to obtain the monthly electrical energy for air-conditioning, which may then be summed up to give the annual electrical energy for air-conditioning. There are no precise definitions of the diversity factor and the COP factor, which may be figures accrued based on experiences of similar air-conditioning applications. While the diversity factor is an indication of the load intensity, and is a value less than unity, the COP factor is a value representing in a way the average chiller plant energy performance, and may be varied in the order of around 2.0 to 2.5 for air-cooled plant and 3.0 to 4.0 for water-cooled plant.

Supplementing the above process, the thermal energy may be measured for a representative period in a certain month to cross-check the monthly thermal energy in that particular month (obtained based on the above process), and the broad professional estimate of the peak cooling load, diversity factor and COP factor may be adjusted to suit, which could further serve as a good reference in reviewing the data of the other months.

There are also other methods of rough estimation of thermal or electrical energy for air-conditioning, such as based simply on rule-of-thumb energy per m^2 for the usage & occupancy of the unit(s), with adjustment for operation hours, or based on rule-of-thumb cooling capacity reflected in the pipe sizing of the chilled water supply to the unit(s), with due regard of the cooling load per unit area. The calculated annual electrical energy for air-conditioning using the means of space peak cooling load requirement, diversity factor and COP factor may be compared with the estimation based on these rule-of-thumb figures, and may be adjusted as appropriate by fine-tuning the cooling load, the diversity factors or the COP factors so as to bring the calculated and estimated values more in line with each other.

On the other hand, the estimate of air-conditioning energy may also be determined using building energy simulation software with broad assumptions of the building characteristics relevant to the unit(s).

7.4 Step 3 – Identification of EMO (EAC clause 7.4)

The results of the review in Step 2 provide valuable consolidated information on energy consuming patterns of various equipment and systems, and form the base of evaluation and appraisal for identifying EMO in Step 3.

7.4.1 EMO Based on Power and Energy Consumptions

Comparison of power and energy consumptions using performance indicators, with design and with established standards may be adopted in the evaluation and appraisal.

(a) Comparative Normalized Performance Indicators

EAC clause 7.4.1 introduces the requirement of performance indicator. It may be difficult to assess performance based only on the intensity of the power or energy of a system or equipment, as a large system or equipment serving a large area would consume more power or energy than a small one that serves a small area. The intensity given its association with the volume of service may be normalized to arrive at a weighted performance indicator such that comparisons may be made among the indicators across different volumes of service for EMO identification. Examples of comparative normalized performance indicators are given in TG Table 7.4.1.2(a) below.

Table 7.4.1.2 (a) : Examples of Normalized Performance Indicators

System / equipment	Power intensity	Normalization	Performance indicator
Air distribution system	Watt (electrical) consumed by motors of fans of the system	Apply weighting with air flow rate	Electrical power per unit air volume flow – Watt per litre/s
Water distribution system	Watt (electrical) consumed by motors of pumps of the system	Apply weighting with water flow rate	Electrical power per unit water volume flow – Watt per litre/s
Lighting	Watt (electrical) consumed by luminaires	Apply weighting with area	Electrical power per unit area – Watt per m^2 (i.e. lighting power density)
Entire building	Total energy consumption	Apply weighting with area	EUI – MJ or kWh per m^2 per month or annum

7.4.2 Comparison with Design and Established References

Checking against design data (should such be available) for deviations provides useful references in the evaluation. EAC clause 7.4.2 recommends the comparison with codes, guidelines and practices of international standards, or established local standards or trade good practices. These are illustrated in later section at TG Table 7.4.7.

7.4.3 Involvement of Responsible Person Participation

Modifying the behaviour of tenants or responsible persons of units in the building may generate much energy saving, examples being the adjustment of AHU operating hours and resetting of space temperatures in tenant units. Energy metering records are good indications of the tenants' energy consumption pattern. A list of potential EMO may be suggested to the tenant for follow-up or further study.

7.4.4 EMO Associated with Equipment Replacement or Addition

(a) The replacement with a more energy efficient model or configuration or the addition of equipment or facility usually associates with relatively higher capital investment. The following would warrant attention -

- potential energy saving,
- increased or decreased future operation and maintenance cost,
- pay-back period,
- compatibility with existing equipment or components, and
- impact on routine building operation.

Examples of common EMO include replacement of incandescent lighting fixtures with fixtures using LED, installation of variable frequency type variable speed drive for fans and pumps, replacement of an air-cooled chiller with a water-cooled chiller with cooling tower etc.

(b) Sometimes the energy input to a system can be minimized if all or parts of this input is supplied by capturing the exhausted energy from other equipment, and the energy gain and associated equipment constitute an EMO. For example, the heat from the condenser side of water-cooled chilled water plant can be captured to preheat the service hot water, and in an air-conditioning system the cool exhausted air can be used to pre-cool the warm outdoor air through heat exchanger heat wheel. Note that the provision of energy recovery may require significant plant reconfigurations and new equipment installation, and thus spatial requirements and compatibility with existing equipment should be carefully reviewed, which may be an item of further detailed study.

(c) There are situations that on-site generation of energy can reduce the building's demand from electricity grid. The reduction may include the kVA demand cost charged by the electricity supplier. One common example is to install photovoltaic panels to convert solar energy to electricity. Other examples involve solar hot water, wind turbine or biofuel energy generation. Corporate image is usually a consideration in the adoption of renewable or alternative energy.

The capturing of exhausted energy and installation of renewable energy facilities and on-site generation of energy generally involve a significant cost investment, and appropriate cost analysis to understand the financial implication is required.

7.4.5 EMO by Operation & Maintenance

The guiding principle of identifying EMO is how to maintain energy efficiency and conservation, efficiency meaning using less for the same level of service, and conservation meaning using only on a need basis.

(a) The following are common approaches to identify potential EMO-

i) Good Operating Conditions

Check if any equipment is not properly maintained, which if not would consume unnecessary energy. Accumulation of dirt, poor lubrication, excessive leakage, presence of excessive noise or vibration etc. are signs of improper maintenance.

ii) Excessive Service

Check if the equipment or system is providing excessive service such as -

- too cold or too warm,
- too bright,
- excessive volume flow, etc.

(b) The following are common potential EMO based on the above common approaches.

i) Improvement of Maintenance

Examples are lubrication of bearings, adjustment of pulley belt tension, cleaning of heat transfer coil surfaces, aligning shafts of fan and driving motor etc. Checking of O&M task records may provide a preliminary indication of adequacy of maintenance.

ii) Occupant Behaviour Modification

The modification in behaviour can be as simple as opening windows for natural ventilation on cool but not cold or hot days, switching off lighting or equipment when not in use etc., which carry no to low cost implications.

7.4.6 EMO by Matching of Operation Characteristics

(a) This approach is to check for matching of operation characteristics, accounting for original design intent (should design documents of drawings or specifications etc. be available), such as -

i) Operating schedules matching load pattern,

ii) Set points generating desired output such as a space’s operating temperature, supply air temperature or air or water flow, etc.,

iii) Controlled parameter, e.g. chilled water supply, fan static pressure etc., within desired range of operation, etc.

(b) The following are common potential EMO based on the above approach-

i) Adjustment of Soft Tools

Examples of adjustment of soft tools of set points or operating schedules are -

- modifying space temperature set points to provide a wider control band under acceptable comfort boundaries, slightly increasing chilled water supply temperature when outdoor temperature falls below certain value,
- adjusting of fan or pump speed,
- switching off, via timer control, equipment not in use, etc.

ii) Enhanced Automatic Control

Proper control measures optimize the power consumption of equipment or system serving a space, and avoid consumption in excess of that required to satisfy functional and comfort needs. These measures include -

- effective demand control; examples are using occupancy/photo sensor to switch off lamps or to dim down lighting level based on the space's occupancy or daylight penetration, using carbon dioxide sensor to control the quantity of outdoor fresh air intake based on the space's occupancy, etc.;
- optimizing of quantity of equipment put into operation to capture the energy efficiency gain of the equipment running at their respective high efficiency range;
- integrated control of operating parameters to minimize power consumption of the system rather than the individual equipment; examples are optimizing condensing water supply temperature to minimize the overall power consumption of the chiller and the cooling tower, and optimizing chilled water supply temperature to minimize the overall power consumption of the chiller, the chilled water pump and the AHU, etc.

EMO on enhanced automatic control of an equipment or system, integrated control in particular, usually involve modification of control logic or set points, and sometimes involve incorporation of sensors or controllers. To assess the opportunity for enhanced automatic control, a review of the existing control may be carried out, such as reviewing the provision or location of sensor, the set point range, and the control logic. Alternatively, an analysis may be carried out to identify if the power consumption of the equipment is reducing sufficiently along with the reducing demand, if its operating efficiency is being maintained at close to maximum, or the energy efficiency of the equipment or its serving system may be compared with other similar equipment or systems. EMO on enhanced automatic control generally involve software more than hardware, and hence typically incur relatively lower capital cost and impact on operation.

iii) Reconfiguration of Equipment and System

The unmatching of operation characteristics may sometimes be improved by -

- equipment re-commissioning,
- system re-balancing, such as for air flow or water flow,
- re-setting of the control algorithm of the equipment or system, etc.

Typical work may involve resetting set points of certain controlled parameters of temperature or pressure and valves or dampers opening positions. While certain checking and adjustment can be carried out over night or weekend, major reconfiguration works involving laborious detailed checking and adjustment may demand higher resource allocation of staff, time and measuring devices, and may be a recommendation item of further study for incorporation in the building's overall management programme.

iv) Replacement of Components or Equipment

A component of an equipment or the equipment itself may have a very low efficiency, which is reflected in the operation characteristics. It may also be that the component or equipment is much oversized. The guidance in TG clause 7.4.4 would be relevant for EMO involving replacement or supplementing with a more energy efficient component or equipment.

7.4.7 Examples of Evaluation & Appraisal for Potential EMO Identification

TG Table 7.4.7 below lists examples of evaluation & appraisal to identify potential EMO.

Table 7.4.7 : Examples of Evaluation & Appraisal for Potential EMO Identification

Equipment / system		Evaluation & Appraisal for Potential EMO Identification
(a)	Chiller	Chiller COP Evaluation & appraisal may be : (i) based on measured chilled water supply & return temperatures and chilled water flow rates to calculate the corresponding cooling load values throughout the measurement period; (ii) determine the percentage load by dividing the cooling load by the nominal full load cooling capacity stated in manufacturer's chiller technical brochure;

		(iii) for water-cooled chiller determine the COP values at corresponding condenser water return temperatures by dividing cooling load by the measured power consumption; (iv) for air-cooled chiller determine the COP values at corresponding condenser air intake temperatures by dividing cooling load by the measured power consumption; (v) check the COP values shown in technical brochure (performance curve) at relevant percentage loads and operating conditions; and (vi) compare COP values in (iii) or (iv) against (v); a lower than brochure COP (v) of the calculated COP ((iii) or (iv)), with due regard for normal wear & tear, may be a suggestion of potential EMO; the lower efficiency may also tally with observations of inefficient operating conditions such as relatively high compressor discharge pressures or temperatures. Certain further checking or common EMO may be: checking condenser or cooling tower fans, checking lubrication of shaft bearings of compressor impeller, cleaning condenser fins, cleaning evaporator/condenser tubes, further checking of impeller bearings and impeller, etc. The above further checking to reveal the potential EMO can be carried out during regular overhaul according to O&M programme, and the REA may suggest advancing the O&M programme for earlier checking.
(b)	Air distribution system (e.g. PAHUs, typical AHUs, large ventilation fans)	<u>Efficiency of fan / air distribution system</u> Based on measured parameters within a representative period including air pressure difference across the fan, air flow rate, fan revolution speed and power consumption of fan motor. The data, with certain allowance of motor efficiency, may be compared with the fan curve in manufacturer's technical brochure, for an appreciation of the fan efficiency. If the observed efficiency is lower than that in the fan curve, further checking may be required. The lower efficiency may also tally with observations of inefficient operating conditions such as excessive noise and vibration. Potential EMO may be: checking lubrication of fan bearings, checking cleanliness of filters (if any), checking and adjusting fan/motor alignment, tightening or replacing (if worn out) the fan/motor belt to ensure proper contact between belt and pulley, replacing the

		worn out fan bearings etc. Also check if the fan speed can be lowered, as power drawn by the fan is arithmetically proportional to the cube of its rotational speed. <u>Efficiency of air distribution system</u> The power of a fan (full load) may be calculated based on the value shown in technical brochure or on actual site measurement, and the power of the air distribution system may be obtained by summing up the powers of the different fans in the system. Likewise the air flow rate handled by the system may be obtained based on fan technical brochures or on actual measurement. Based on the figures of summed up fan power and system air flow, the system performance indicator in W per litre/s may be obtained and compared with a benchmark figure such as the recommended value in the BEC (1.6 W per l/s for CAV and 2.1 for VAV). A calculated value higher than the benchmark is a suggestion of potential EMO. (Having cited the BEC, attention is drawn that the BEC benchmark for purpose of the EAC is for reference only and not an absolute requirement, as the BEC is for a new installation whereas the EAC is for an existing installation which might not have been designed to the standard of the BEC.) The comparison may also be made with experience accrued benchmark values developed by the REA or O&M personnels. The potential EMO may be a result of an over-sizing at design, which would attract much energy saving by reducing the fan speed, replacing with smaller motor etc.
(c)	Air-conditioning water distribution system (e.g. chilled water pumps, condenser water pumps)	<u>Efficiency of pump</u> Similar approach to (b) above may be adopted to evaluate pump efficiency by making reference to the pump curve in manufacturer's technical brochure. Any low efficiency if identified may also tally with observations of inefficient operating conditions such as excessive noise and vibration, excessive water leakage via bearings etc.. Potential EMO may be: checking lubrication of pump bearings, replacing the seal of pump casing to stop water leakage, checking and adjusting pump/motor alignment, replacing the worn out pump bearings, replacing the worn out pump impeller (due to corrosion) etc. Also check if the pump speed can be lowered, as power drawn by the pump is arithmetically proportional to the cube of its

		rotational speed. <u>Efficiency of pump system</u> A comparison of W per liter/s flow may be conducted as for the air distribution system in (b) above, in which case the benchmark may be based on the accrued experience of the REA or O&M personnels.
(d)	Luminaires in a space	<u>Lighting power density (LPD)</u> The LPD may be calculated by dividing the space luminaires' total electrical power consumption by the internal floor area of the illuminated space. The electrical power consumption can be worked out based on lighting layouts and luminaire catalogues, or on actual measurement of the power in the lighting circuits. The calculated LPD may be compared with the corresponding value suggested in the BEC (e.g. 9W/m^2 for office with internal floor area above 200 m^2) . A higher than the BEC value is an indication of potential EMO. The illumination level in the space may be checked against design, or against established lighting standard such as CIBSE or IESNA lighting code. A higher illumination level than design or the lighting standard is a confirmation of the potential EMO, which may be realized by disconnecting or removing some lamps/luminaires, using task lighting to reduce background lighting level, replacement with lower wattage lamps etc.
(e)	Energy performance of other equipment/ systems	- A 24-hour or over week-end continuous monitoring (say measurement every 5 to 15 minutes) of the overall power or energy consumption of a building may be conducted to observe whether the consumption profile is as expected, e.g. whether the consumption is at the expected reduced level during the off-hours. An abnormal consumption profile may be an indication of equipment or systems having not been turned off as needed, and warrants more systematic monitoring of the electrical circuits, and the potential EMO may be using timer switches to de-energize power supply during off-hours to these equipment (most commonly copying machines, printers & water dispensers etc.), activating hibernation modes (for computers, copying machines etc.) etc.

		- Checking for presence of excessively low power factor in electrical circuits with medium and large size motors. - Checking for presence of excessively high harmonic contents in electrical circuits with electronic equipment such as variable frequency drives.
(f)	EUI of the building	Monthly EUIs and yearly EUIs for the recent years may be extracted to observe the variations across different buildings of the same type, or across same building in different years' records, and a significant deviation may be a sign of the building warranting higher attention on how it is using energy.

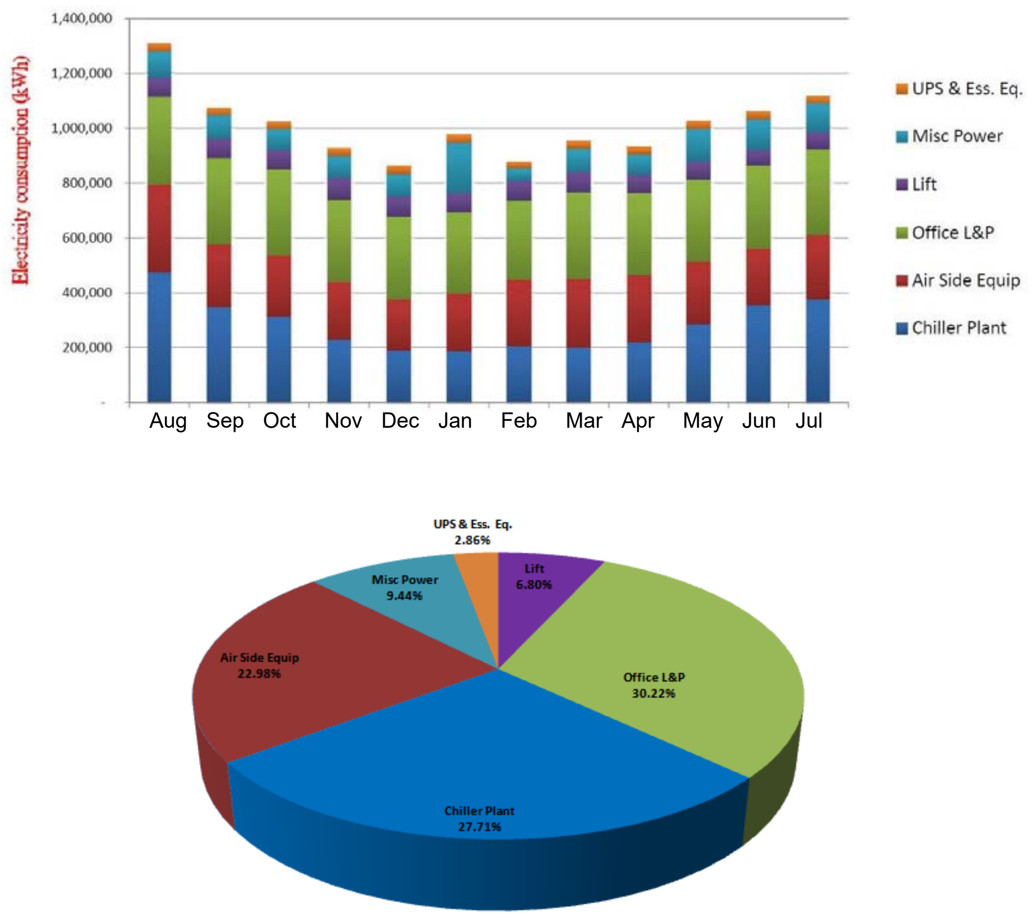
7.4.8 Good Practice (Load Inventory)

Load inventory is a systematic way of collecting and organizing energy use information, in terms of "where" and "how much" energy being consumed among various systems.

Such inventories can be classified as-

(a) Electrical Load Inventory

Figure 7.4.8 (a): Electrical load inventory results



The inventory will be based on a period of time (i.e. a month, a year) which better corresponding to the utility billing period and typical to the cycle of operation. The major categories of electricity use in the building will be identified and sort under the grouping on type of installation, occupant activities in different functional area, etc.

After the consolidation of all categories of loads into the load inventory, the respective proportion (or percentage) with the overall electricity consumption can be clearly illustrated for analysis. The portion with high-consumption loads is considered to be the best saving opportunities with higher priorities (i.e lighting, chiller plant, etc).

Meanwhile, the EMO can be identified at first with the necessity of energy being provided and examined each load in the inventory with the following factors:

i) Operating Hours: For the loads that are being operated outside the normal operating hours are always good candidates for efficiency improvement. (i.e. switch-off lighting / equipment at lunch time, schedule of AC operation to suit the holiday plan, etc);

ii) Load Grouping: Large group of loads (i.e. lighting) that have similar operating hours may group to same circuits to switch on/off together but in return, it has decrease the flexibility. Sometimes, the re-zoning or imposing automatic control to loads may prevent inappropriate load grouping and avoid energy wastage;

iii) Night Load: Justifying loads based on demand profile (should such be available) may reduce unnecessary loads operated during night or unoccupied hours.

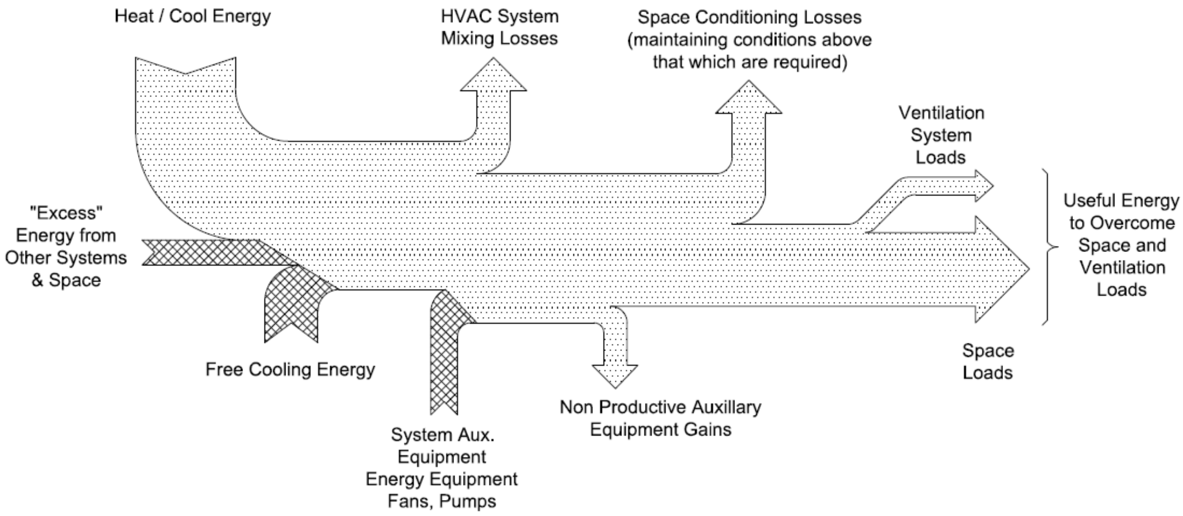
(b) Thermal Energy Use Inventory

Identify the thermal energy flows associated with each energy use and quantify the energy outflows through an energy flow diagram (Figure 7.4.8 (b)). A useful diagram will show the complete picture of major internal energy flows and those from and to the environment. EMOs can be identified from either type of energy flow-

i) Reducible energy: The flow of energy can directly reduce the energy input. Potential EMOs can be found by considering several factors, such as (a) Temperatures – to adjust the indoor air-conditioning set point or set back during unoccupied period; (b) Flow rates – to adjust the rate of ventilation for fresh air by CO_2 sensor; (c) Time – to match the operating time with the building occupancy closely.

ii) Recoverable energy: A flow of waste heat, the reduction of which will not directly reduce the energy input. Energy savings can be achieved through heat recovery measures, such as heat wheel, heat recovery chiller.

Figure 7.4.8 (b): Sankey Diagram of HVAC Energy Flows



7.5 **Step 4 -** Cost Benefit Analysis of EMO (EAC clause 7.5)

With the potential EMO in place, their energy savings can be calculated and implementing costs assessed to identify their effectiveness. For Cat II and Cat III EMO in which significant capital cost is involved, a cost benefit analysis should be carried out to compare the implementing cost against the estimated energy saving. Generally, simple payback period method can be used for EMO with short payback periods, while net present value or internal rate of return methods may be used for EMO involving long payback periods. Apart from energy saving and cost benefit, installation and replacement difficulties and the building owner's management objective are also the considerations for an EMO.

(a) Net Present Value (NPV)

The NPV takes into account more systematically the time of cash flows, cost of money including interest on the capital cost investment, life time of equipment/installation, etc., which can better reflect the effectiveness of the investment. This method gives a present value to future earnings that are expected to be derived from an investment.

$$NPV = \sum_{t=0}^{n} NCF_t \times 1/(1 + i)^t$$

where NCF = net cash flow at year end t (positive for savings and negative for expenditure)

i = interest rate

n = years of economic life of equipment/installation

The NPV concept recognizes that the longer the time the money is paid back the less attractive the investment becomes, as returns for each year are progressively discounted with time.

(b) Internal Rate of Return (IRR)

The IRR is a measure of the return in percentage to be expected on a capital investment. This takes into account the similar aspects as for NPV, with

$$NPV = \sum_{t=0}^{n} NCF_t \times 1/(1 + IRR)^t = 0$$

The higher the IRR the more cost effective is the investment.

Many financial calculators and spreadsheet computer programmes can calculate both NPV and IRR quite readily.

(c) Energy Saving Calculation

Energy saving should be the difference between current energy use from collected or measured data and estimated energy use after implementation of an EMO. The following table (Table 7.5) summarizes the examples of three major types of energy saving and their respective means of energy saving calculation. As several variables regarding the measurement conditions may differ between the original stage and the EMO implementation stage, an energy model or correlation should be developed to consider those variables to the collected or measured energy use, such that the inherent uncertainty could be quantified.

Table 7.5 : Examples of Energy Saving calculation

Energy saving type		Methodology for energy saving calculation	Variables to be correlated to energy use
Type	Example		
Efficiency Improvement	Lighting retrofit	The total power input of current lighting fixtures should be metered or measured. Occupancy schedule can be estimated by surveying with operator or derived from the measurement data under BMS / data logger. The total power input of the proposed system should be estimated using lighting simulation or other applicable means. The proposed energy use for the new system can be	(a) Occupancy schedule (b) Lighting Control (i.e. day-light / occupancy sensor, automatic time scheduling system, etc.)

		derived by multiplying the power input with occupancy schedule.	
	Chiller replacement	Chillers can give out different COPs at different chilled water supply / return temperature or under the part load condition. The power consumption, chilled water flow rate, chilled water supply / return temperature, part load ratio, and energy use of the original chiller should be metered or record. The replaced chiller can use the recorded data for proposed energy estimation.	(a) Chilled water supply / return temperature (b) Chilled water flow rate (c) COP of chillers at full load & part load condition (d) Chiller on/off sequencing
Time/demand based control	HVAC time schedule	The original HVAC energy use against operation time should be metered. The proposed energy saving will be the time difference when the HVAC is proposed to be shut off or start.	(a) Energy use of HVAC equipment (b) Utilization pattern (operating hours)
Fuel switching (i.e. use of renewable energy)	Solar hot water system	The hot water use within the building or area is metered. By adopting the solar hot water system, the energy use of the heating source can be lowered by pre-heating of water.	(a) Type and capacity of installed solar hot water system (b) Solar irradiance (c) Orientation of solar collectors

(d) Energy Saving and Payback calculation

Service life and performance degradation should be applied into energy saving and payback calculation. For instance, when conducting light retrofitting payback calculation, the service life of typical LED fixtures should be higher than T5. When conducting solar photovoltaic panel energy saving estimation, its solar energy conversion efficiency will be lowered with time. (i.e. outputting less energy every year due to degradation of panel as shown in manufacturer's technical information.)

(e) Energy Price

The energy saving from an EMO is normally reflected as kilo-watt hour (kWh), whilst the payback calculation should be discussed in term of currency. The most up-to-date and appropriate energy cost should be used for the payback calculation.

(f) Comprehensive Data Measurement on Operating Cycle

A complete operating cycle should be measured for each potential EMO. For instance, the data collected / measured for a chiller plant should cover an operating cycle of at least one year, since the chilled water temperature varies with outdoor conditions. If measurement for a full operating cycle cannot be achieved, the REA can either reference to a historic data, or perform energy modelling to project the remaining operating cycle. Within the above period for energy audit, the metering point, metering information and measurement interval to come up with the energy use should be recorded. For instance, the cooling energy consumption from a chiller plant may be measured with an energy meter with data-logging device which can consolidate the cooling energy in terms of chilled water temperature and flow rate. The measurement could take place at 15-min interval with the power consumption simultaneously for determining the plant COP for a duration of whole year to cover its full operation cycle.

7.6 Step 5 – Recommendations (EAC clause 7.6)

7.6.1 It is a good practice for the REA to present the findings of the energy audit to the owner or property management of the building in meeting(s). These meeting(s) may discuss the priorities of the potential EMO with due regard to the planned O&M activities and the management objective of the owner or property management, and can shed light on the focuses including but not limited to energy savings, cost benefits and robustness of the energy data of the owner or property management and help to categorize and prioritize the EMO.

7.6.2 The above meeting(s) may identify opportunities to lower an EMO's implementation cost by tying in the implementation with certain O&M activities. For example, retrofit with LED lamps instead of bulk replacement of fluorescent tubes during scheduled maintenance programme.

7.6.3 Each EMO should be supplemented with operation details and intended result, such that the expected energy saving benefits of the EMOs can be realized. Main aspects to be considered for implementing EMOs include the intention (why), type (what), location (where), timeline (when) and budget (how much) of each EMO.

Such procedures may involve inspection, functional performance testing, and/or data trending with analysis and with the required measurement duration specified. For instance, a chiller system should go through inspection and functional performance testing that follow its designed operation sequence, including but not limited to its part-load performance, staging command, temperature reset control, etc. Trending of measured data can further help understand the background and history of equipment operation and condition which can be used for analysis and fine-tuning of the control setting.

7.6.4 The measurement device / parameters / time interval for each potential EMO should be indicated in the energy audit report such that the energy saving is on the same basis for comparison.

An example for measurement of chiller plant performance will include energy meter for cooling energy and/or flow meter & temperature sensor for the chilled water flow rate & supply/return temperature, power analyzer to individual chillers and water pumps as well as to individual cooling tower fans & condenser pumps (if it is a water cooled chiller plant) for checking the simultaneous power consumption with BMS / data logger. External weather conditions should be recorded since it will also affect the system performance of the cooling towers & chillers. It is preferable that the measurements to be carried out for one-year covering a full seasonal changes for projecting the coming year's energy consumption of equipment.

7.6.5 Based on the discussions in TG clauses 7.6.1 and 7.6.4, the REA should have a clearer picture of the intention of the owner or property management. Due to data, time or financial limitations, certain potential EMO may need more detailed analyses, and such may be documented as recommendations for further studies.

7.7 Step 6 - Compiling Energy Audit Report (EAC clause 7.7)

Based on the recommended EMO in Step 5, an energy audit report should be issued to document the findings and recommendations of the energy audit. As a good practice, the REA's recommendations should be well structured and organized into strategic areas. The report should include the executive summary (TG clause 8.2) and may include the template(s) for additional information (TG clause 8.5).

8 Energy Audit Report

8.1 Information for Report (EAC clause 8.1)

8.1.1 The items to be included in the report are given in EAC section 8. The report should begin with the executive summary in the format specified (TG clause 8.2). The remaining of the report should cover the details leading to the summarized items in the executive summary, as well as the contents that are not covered in the executive summary. The attention of the REA is drawn to the following in the preparation of the report.

8.1.2 The scope of audit may include, in addition to the citing in EAC clause 8.1(a), a description of the resources allocation such as time, staffing and metering, and level of sophistication (TG clause 7.1.1). A summary of the assumptions and estimating methods related to shared service (TG clause 7.3.3 and clause 8.4) and energy import and export may also be included.

8.1.3 The description of building characteristics (EAC clause 8.1(b)) in respect of "hours of operation per day" may refer to normal working hours, which are generally the office operation hours for an office building or opening hours for a shopping mall.

8.1.4 The general description of building (EAC clause 8.1(b)) and equipment/systems (EAC clause 8.1(c)) may include the following, covering areas or items with EMO in particular -

- zoning of systems according to building height or usage;
- air-conditioning installation : system configuration e.g. primary / secondary loop, types of system e.g. VAV, CAV, FCU etc, types of controls, types and numbers of chillers/VRF system, unitary air-conditioner, pumps, heat rejection methods, etc. and their locations;
- lighting installation : general lighting configuration for common types of space, description may be, for example, general office spaces served by fluorescent tube lighting troughs, public circulation area in shopping mall served by compact fluorescent lamp down-lights supplemented with tungsten halogen down-lights etc.
- electrical installation : numbers of transformers and low voltage main switchboards and their locations;
- lift installation and escalator installation : capacity, zoning, quantity, floors/areas served and types of drive;
- service water heating system, if any : type of heating equipment e.g. gas boiler, electric heater etc, system configuration; and
- other notable energy consuming equipment/systems, e.g. motors of plumbing & drainage pumps.

8.1.5 If the operation records and the equipment rated power consumptions are considered not of the level of adequacy in reflecting the actual operating conditions, the methodology of the measurement should be properly described and the measurement data should be properly recorded.

8.1.6 If there are a number of energy bills that contribute to the total energy consumption of the CBSI, all the energy bills should be included in the appraisal.

8.1.7 EAC clause 8.1(m) recommends the completion of the audit in no later than 6 months after the energy bill reference month i.e. after the commencement of the energy audit.

8.2 Executive Summary (EAC clause 8.2)

The executive summary of the energy audit report should be in the specified format of a technical form numbered EE-EAes (TG clause 4.5), and be included at the beginning of the report.

Form EE-EAes requires the information input of equipment capacity and power consumption. Such information should ideally be taken from equipment technical brochure / manual, which if not available (such as for minor equipment e.g. FCU, small capacity fan, motor smaller than 5kW etc.) may be taken from nameplate, measured data, reference to similar equipment, or, by professional judgement of the REA as a last resort. Based on the capacity and power figures, the performance indicators of major CBSI components can be calculated and provided in the form (version V.0). The concept of performance indicator is introduced in EAC clause 7.4.1 and TG clause 7.4.1.2. In addition, the form also includes a section for the provision of information on the operation characteristics of categorized major usages of CBSI-served areas. The availability of the information on performance indicators and area operation characteristics can very much shed light on the evaluation and appraisal in the energy audit.

In completing form EE-EAes, attention is drawn that the EUI's denominator of total floor area refers to the total of the whole building, which includes both the common area and should the building has tenant units also these units. For a building complex (TG clause 4.3.1) or a particular block in a building complex (TG clause 4.3.2), the EUI's denominator of total floor area refers for the former to the total of the building complex and for the latter to the total of the building block audited. Likewise for an entity of building blocks (TG clause 4.3.3), the EUI's denominator refers to the total of the constituent blocks in the entity.

The figures for input as energy consumption in form EE-EAes is further discussed in TG clause 8.3 for a typical building and 8.4 for a building complex. Attention is drawn that the energy contributing to the EUI should normally exclude the electricity or energy not on account of the building owner, such as consumption of tenant units' office equipment and appliances (computers, copiers, water dispensers, cookers etc.) and equipment of non-CBSI; examples of non-CBSI are given in TG clause 3.1.3. On the other hand, electricity or energy that are consumed by office equipment & appliances and are on account of the building owner should normally be included as the energy contributing to the EUI.

8.3 Typical Building

This clause serves to give an example to illustrate the integrating of the different energy components in a typical building to arrive at the annual energy consumption figures (re row 6 in form EE-EAes) in the executive summary. The portion of form EE-EAes on historical energy consumption analysis is extracted in TG Table 8.3.1 below for ready reference.

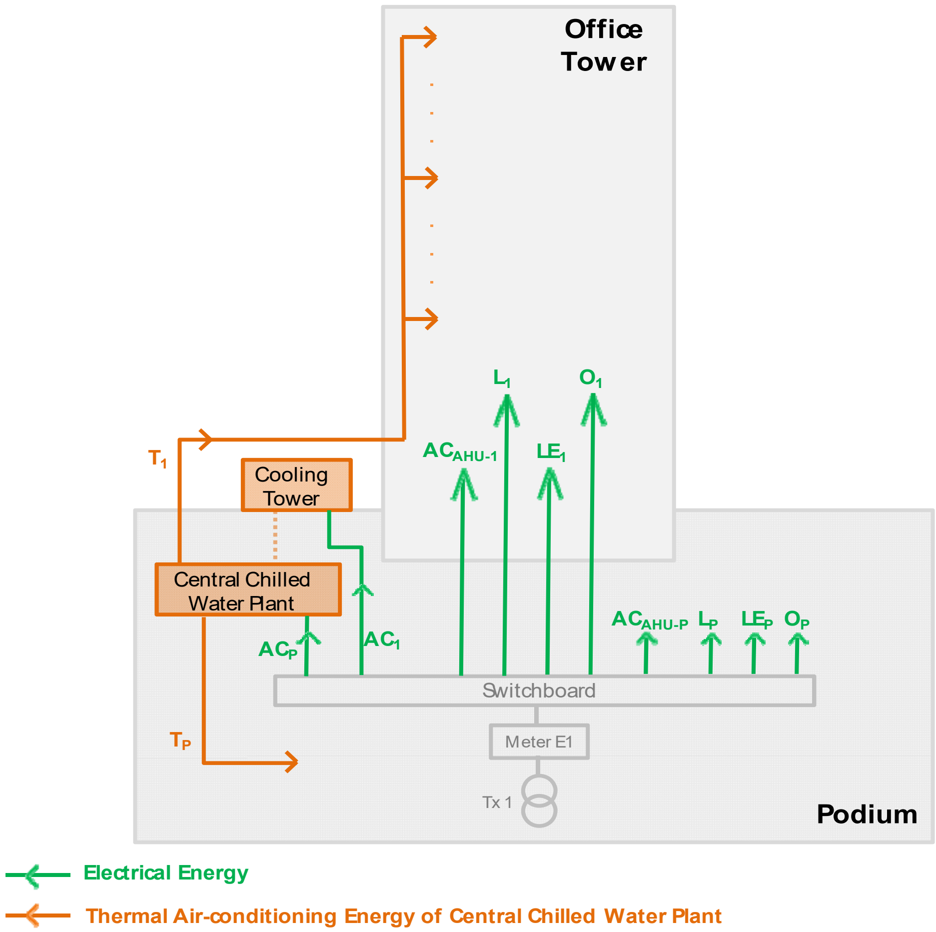
Table 8.3.1 : Extract of Form EE-EAes Historical Energy Consumption Analysis

Part 2 – Historical Energy Consumption Analysis^29					(EAC Clasue 8.1(g))
1)	**Annual electricity consumptiuon of last 36-month (kWh/annum)** (EAC Clause 8.1(g)i))		(kWh/annum) Past 1st 12-month	(kWh/annum) Past 2nd 12-month	(kWh/annum) Past 3rd 12-month
2)	**Annual consumption of energy^30 other than electricity, of last 36-month (MJ/annum)** (EAC Clause 8.1(g)ii))		(MJ/annum) Past 1st 12-month	(MJ/annum) Past 2nd 12-month	(MJ/annum) Past 3rd 12-month
3)	**Annual total energy consumption, of last 36-month (MJ/annum) (sum of figures in 1) & 2))** (EAC Clause 8.1(g)ii))		(MJ/annum) Past 1st 12-month	(MJ/annum) Past 2nd 12-month	(MJ/annum) Past 3rd 12-month
4)	**Annual Energy Utilisation Index (EUI) of last 36-month (MJ/m²/annum) (EAC Clause 8.1(g)ii))** (Value in kWh/m²/annum can be obtained by dividing the MJ/m2/annum figure by 3.6)		(MJ/m²/annum) Past 1st 12-month	(MJ/m²/annum) Past 2nd 12-month	(MJ/m²/annum) Past 3rd 12-month
5)	**Monthly EUI of past 1st 12-month period (MJ/m²/month)** (EAC Clause 8.1(g)iii))	1st mth	2nd mth	3rd mth	4th mth
		5th mth	6th mth	7th mth	8th mth
		9th mth	10th mth	11th mth	12th mth ^31
6)	**Annual energy consumption breakdown, of past 1st 12-month period (MJ/annum)** (EAC Clause 8.1(g)iv))	Air-conditioning^32	Lighting	Lift & Escalator	Others^33
7)	**Energy supply from CBSI to building's units, as a percentage of the total energy consumption of past 1st 12-month period (EAC Clause 8.1(h))**				(%)
8)	**Energy bill reference month** (month for which the most recent energy bill has been issued by the energy supply utility prior to commencement of energy audit, i.e. the 12th month of item 5) **ending on**				(dd/mm/yyyy)

Consider an energy audit for a building entity of a typical building that consists of a podium of shopping & leisure units and a tower of office units, and both are occupied at the same time, i.e. with the same OA, and are under the management of a single property management. The energy consumption is illustrated using the following figures and tables –

- TG Figure 8.3.1 : conceptual diagram illustrating the CBSI including configuration;
- TG Table 8.3.1 (a) : describing the configuration of the main power supply and central chilled water plant (of the CBSI) of the building;
- TG Table 8.3.1 (b) : describing the concerned energy components (of the CBSI) of the building; and
- TG Table 8.3.1 (c) : calculation of energy consumption of the building

Figure 8.3.1 : CBSIs and major energy components of sample building



For simplicity purpose, the electrical power supply to units of tenants are not shown in the figure and tables, and thus AC_P, AC_1, AC_{AHU-P}, AC_{AHU-1}, L_P, L_1, LE_P, LE_1, O_P and O_1 are energy components of the CBSI and not of the tenant units.

Table 8.3.1 (a) : Configuration of Main Power Supply and Central Chilled Water Plant of Sample Building	
Podium	- 1 x 1500 kVA transformer Tx1 - Tx 1 supplies power to the central chilled water plant and to terminal side air-conditioning equipment of Podium - Components of central chilled water plant: chillers & associated equipment (pumps etc. in Podium) and cooling tower consuming (in 1-year) at the plant side electricity AC_P and AC_1 (cooling tower) respectively, generate chilled water with thermal energy T_P consumed by Podium and thermal energy T_1 consumed by Office Tower - Components of terminal side air-conditioning equipment: AHUs & associated equipment that serve spaces within the Podium
Office Tower	- Components of terminal side equipment: AHUs and associated equipment that serve spaces within Office Tower - (Does not have major components of central chilled water plant)

Table 8.3.1 (b) : Energy Components in Sample Building	
Energy component	Description
AC_P	Electrical energy consumed by the central chilled water plant, including chillers, condensing water pumps, and chilled water pumps (excluding cooling tower)
AC_1	Electrical energy consumed by the cooling tower (mainly for fan motors) of the central chilled water plant [the cooling tower (located on roof of Podium) forms part of the central chilled water plant]
T_p	Thermal air-conditioning energy@ (generated by the central chilled water plant) serving the spaces in Podium
T_1	Thermal air-conditioning energy@ (generated by the central chilled water plant) serving the spaces in Office Tower
AC_{AHU-P}	Electrical energy consumed by the AHUs and ventilation fans (mainly for motors of AHU fans and ventilation fans) in Podium
AC_{AHU-1}	Electrical energy consumed by the AHUs and ventilation fans (mainly for motors of AHU fans and ventilation fans) in Office Tower
L_P	Electrical energy consumed by the luminaires in Podium
L_1	Electrical energy consumed by the luminaires in Office Tower
LE_P	Electrical energy consumed by the lifts & escalators mainly serving Podium
LE_1	Electrical energy consumed by the lifts & escalators mainly serving Office Tower (may have landing in Podium)
O_P	Electrical energy consumed by other equipment in Podium

Table 8.3.1 (b) : Energy Components in Sample Building	
Energy component	Description
O_1	Electrical energy consumed by other equipment in Office Tower
@ Electrical power (drawn by the plant) multiplied by the plant's coefficient of performance gives the thermal power which when integrated over a year gives the thermal energy	

Table 8.3.1 (c) : Calculation of Energy Consumption of the Building	
Annual energy consumption of past 1st 12-month period	Energy consumption (E_{con})
a) Total air- conditioning (electrical energy)	$AC_P + AC_1 + AC_{AHU\text{-}P} + AC_{AHU\text{-}1}$
b) Total lighting	$L_P + L_1$
c) Total lift and escalator	$LE_P + LE_1$
d) Others	$O_P + O_1$
TOTAL	∑ [a) + b) + c) + d)] (equivalent to figure for Past 1st 12-month in item 3) in Table 8.3.1)
Energy supply from CBSI to building's units, as a percentage of the total energy consumption of past 1st 12-month period	$[(T_1 \times 0.9) + (T_P \times 0.7)] / (T_1 + T_P) \times$ $[AC_P + AC_1 + AC_{AHU\text{-}P} + AC_{AHU\text{-}1}]$ $/ \sum [\ a) + b) + c) + d)\ ] \times 100\ \%$ Remarks : Above is based on - Only thermal energy in the form of chilled water is supplied to tenant units and measurements indicate that 90% of thermal energy T_1 is for tenant units in Office Tower, and 70% of thermal energy T_P is for tenant units in Podium.

The figures (in items a), b), c) & d)) in TG Table 8.3.1(c) may be input direct to row 6 of the executive summary indicated in TG Table 8.3.1. There may be situations that direct energy metering or measured data are not available, and under these situations the estimation approach described in TG clause 8.4.2.5(b) and (c) may be referenced in arriving at the figures.

The above grouping of the Podium and the Tower to form a building entity for the energy audit is for purpose of simple illustration only. The issue of a separate EA Form and form EE-EAes for each of the Podium and the Tower is, however, strongly encouraged, as described in TG clause 4.3.2.2(c).

8.4 Building Blocks in Building Complex

TG clause 4.3.2 introduces the building block as entity concept and that separate energy audits may be performed for each block, with a separate EUI reported for each block. The EUI is to be calculated based on the block's internal floor area and likewise the net energy consumption of the block. Depending on the configuration of the CBSI, the net energy consumption may involve the "import" and "export" of energy between the building blocks of the same building complex. To reflect the "actual" energy performance of a building block, the "net" energy consumption taking into account the "imported" and "exported" energy should be reported.

8.4.1 Executive Summary Based on Net Energy Consumption

Based on the above concept, the information to be input to the executive summary in form EE-EAes on historical energy consumption analysis should be the data for the net energy consumption. The calculation approach of net energy consumption for a building block (TG clause 4.3.2) is given in TG clause 8.4.2 below. The energy figure in each of the box of form EE-EAes should be the relevant net energy consumption figure that has accounted for import and export cited in TG clauses 4.4 and 8.4.2.

8.4.2 Calculation of Net Energy Consumption

8.4.2.1 Consider the building complex in TG clause 4.3.2 that consists of three building blocks, namely Tower 1, Tower 2 and Podium. Based on this sample building complex, the calculation of net energy consumption accounting for energy import and export is illustrated using the following figures and tables -

- TG Figure 8.4.2 : conceptual diagram illustrating the concerned CBSIs including configuration, energy components and locations in the building complex & blocks;
- TG Table 8.4.2(a) : describing the configuration of the main power supply and central chilled water plant (of the CBSIs) of the building complex & blocks;
- TG Table 8.4.2(b) : describing the concerned energy components (of the CBSIs) of the building complex & blocks; and
- TG Tables 8.4.2(c) to 8.4.2(e) : conveying the intent of what constitute the import and the export in the calculation of net energy consumption of the building blocks.

For simplicity purpose, the electrical power supply to units of tenants are not shown in the figure and tables, and thus AC_P, AC_1, AC_{AHU-P}, AC_{AHU-1}, L_P, L_1, LE_P, LE_1, O_P, O_1 etc. are energy components of the CBSI and not of the tenant units.

Figure 8.4.2 : CBSIs and major energy components of sample building complex

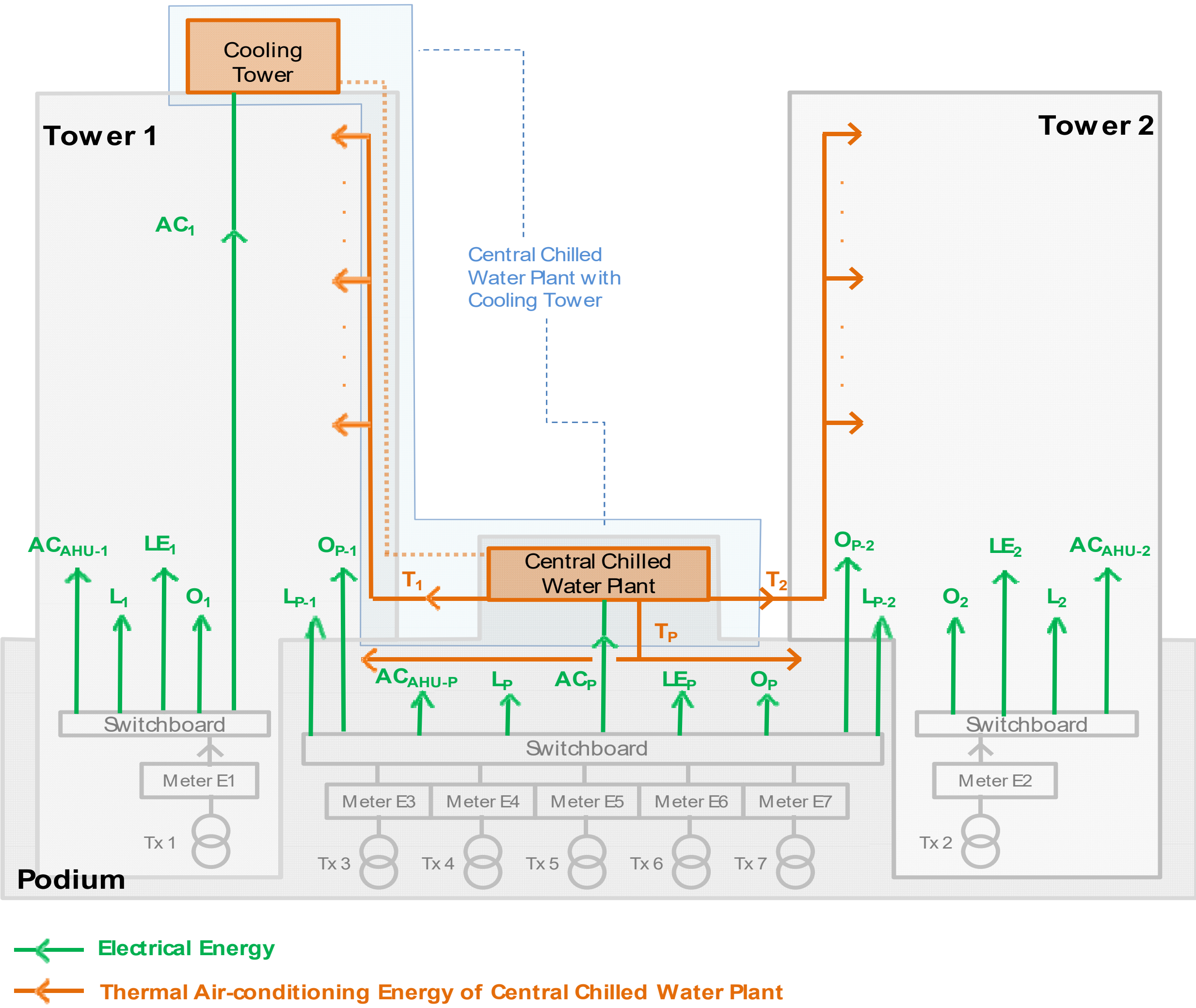


Table 8.4.2 (a) : Configuration of Main Power Supply and Central Chilled Water Plant of Sample Building Complex	
Podium	- 5 x 1500 kVA transformers nos. Tx3 to Tx7 - Tx3 to Tx7 supply power to the central chilled water plant and to certain portions of Tower 1 and Tower 2 (e.g. lower floors plumbing service pumps, lighting in certain common lobbies and staircases) - Components of central chilled water plant: chillers and associated equipment (pumps etc.) in Podium consuming (in 1-year) at the plant side electricity AC_P, generate chilled water with thermal energy T_P consumed by Podium, and thermal energy T_1 and T_2 exported to Tower 1 and Tower 2 respectively - Components of terminal side equipment: AHUs & associated equipment that serve spaces within the Podium
Tower 1	- 1 x 1500 kVA transformer Tx1 - Components of central chilled water plant: cooling tower with power supply (to cooling tower fans) from Tx1 - Components of terminal side equipment: AHUs and associated equipment that serve spaces within Tower 1
Tower 2	- 1 x 1500 kVA transformer Tx2 - Components of terminal side equipment: AHUs and associated equipment that serve spaces within Tower 2 - (Does not have major components of central chilled water plant)

Table 8.4.2 (b) : Energy Components in Sample Building Complex		
Energy component	Description	Power supply transformer
AC_P	Electrical energy consumed by the central chilled water plant, including chillers, condensing water pumps, and chilled water pumps (mainly located in Podium, excluding cooling tower)	Tx3 to Tx7
AC_1	Electrical energy consumed by the cooling tower (mainly for fan motors) of the central chilled water plant [the cooling tower (located on roof of Tower 1) forms part of the central chilled water plant (mainly located in Podium), but its power supply is via Tx 1 that is located in Tower 1]	Tx1
T_p	Thermal air-conditioning energy[@] (generated by the central chilled water plant) serving the spaces in Podium	Tx3 to Tx7 for chillers & pumps, Tx1 for cooling
T_1	Thermal air-conditioning energy[@] (generated by the central chilled water plant) serving the spaces in Tower 1	

T_2	Thermal air-conditioning energy@ (generated by the central chilled water plant) serving the spaces in Tower 2	tower
AC_{AHU-P}	Electrical energy consumed by the AHUs and ventilation fans (mainly for motors of AHU fans and ventilation fans) in Podium	Tx3 to Tx7
AC_{AHU-1}	Electrical energy consumed by the AHUs and ventilation fans (mainly for motors of AHU fans and ventilation fans) in Tower 1	Tx1
AC_{AHU-2}	Electrical energy consumed by the AHUs and ventilation fans (mainly for motors of AHU fans and ventilation fans) in Tower 2	Tx2
L_P	Electrical energy consumed by the luminaires in Podium	Tx3 to Tx7
L_{P-1}	Electrical energy consumed by the luminaires in Tower 1	Tx3 to Tx7
L_{P-2}	Electrical energy consumed by the luminaires in Tower 2	Tx3 to Tx7
L_1	Electrical energy consumed by the luminaires in Tower 1	Tx1
L_2	Electrical energy consumed by the luminaires in Tower 2	Tx2
LE_P	Electrical energy consumed by the lifts & escalators mainly serving Podium	Tx3 to Tx7
LE_1	Electrical energy consumed by the lifts & escalators mainly serving Tower 1 (may have landing in Podium)	Tx1
LE_2	Electrical energy consumed by the lifts & escalators serving Tower 2 (may have landing in Podium)	Tx2
O_P	Electrical energy consumed by other equipment in Podium	Tx3 to Tx7
O_{P-1}	Electrical energy consumed by other equipment in Tower 1	Tx3 to Tx7
O_{P-2}	Electrical energy consumed by other equipment in Tower 2	Tx3 to Tx7
O_1	Electrical energy consumed by other equipment in Tower 1	Tx1
O_2	Electrical energy consumed by other equipment in Tower 2	Tx2
@ Electrical power (drawn by the plant) multiplied by the plant's coefficient of performance gives the thermal power which when integrated over a year gives the thermal energy		

8.4.2.2 Collaboration of Owners of Building Blocks

The building block owners and the REAs should devise appropriate means to assess the consumed, imported, and exported energy. This can take the form of direct measurements, or allocation based on load, capacity or floor area to assess the values of the energy components.

The assessment of imported and exported energy is likely to involve data held by other building blocks. For example, the Podium owner holds the data of chillers and pumps, while the Tower 1 owner holds the data of the cooling tower. Owners of different blocks are encouraged to collaborate and share the data where possible.

8.4.2.3 Air-conditioning Energy

For a typical air-conditioning arrangement, energy consumption can be broadly divided into consumption at the terminal side and consumption at the central chilled water or heated water plant side. Energy flows associated with chilled and heated water across building blocks are considered as energy import or export. For simplicity, descriptions in this section are based on a building with only chilled water plant and no heated water plant.

The terminal side equipment are the AHUs and associated equipment such as ventilation fans that solely serve the spaces within respective building blocks.

The central chilled water plant side equipment are the chillers, pumps and cooling towers – the equipment that produce chilled water which is shared between the building blocks.

The net electrical air-conditioning energy for each building block in the building complex can be determined by the following steps -

step 1: Identify and quantify the electrical energy consumed by the central chilled water plant side equipment within the individual building block: for Podium it is AC_P, for Tower 1 it is AC_1 and for Tower 2 there is no such energy component.

step 2: Identify and quantify the electrical energy consumed by the terminal side equipment within the individual block: for Podium it is AC_{AHU-P}, for Tower 1 it is AC_{AHU-1}, and for Tower 2 it is AC_{AHU-2}.

step 3: Identify the electrical energy consumed by the central chilled water plant side equipment that are external to the building block: for Podium, it is the air-conditioning energy AC_1 of the cooling tower in Tower 1 (and no energy is involved for Tower 2); for Tower 1 it is the air-conditioning energy AC_P of the chillers and associated equipment (pumps etc.) in Podium (and no energy is involved for Tower 2); and for Tower 2 it is the air-conditioning energy AC_P of the chillers and associated equipment (pumps etc.) in Podium and the air-conditioning energy AC_1 of the cooling tower in Tower 1.

step 4: Identify and quantify the thermal air-conditioning energy for each building block: for Podium it is T_P , for Tower 1 it is T_1, and Tower 2 it is T_2.

step 5: Calculate the electrical air-conditioning energy consumption for each block: the calculations are indicated in rows a) of TG Tables 8.4.2 (c) to 8.4.2 (e) respectively for Podium, Tower 1 and Tower 2, under column heading of "Energy consumption".

step 6: With the figures arrived in step 5, the values in respect of air-conditioning for energy import, energy export and net energy consumption can be calculated, and the calculations are shown in rows a) in TG Tables 8.4.2 (c) to 8.4.2 (e) under respective column headings.

For a building entity supplied with sea water (for air-conditioning heat rejection) from a standalone pump house, the energy of the sea water pumps pumping the water to the building entity would normally be regarded as energy import to the building. Likewise the chilled water supplied by a district cooling system (e.g. at Kai Tak Development) to the building entity would normally be regarded as energy import to the building.

8.4.2.4 Energy of Lighting, Lift & Escalator and Others

Similar to the identification and quantification for air-conditioning energy, the energy for lighting, lift & escalator and others can be determined, and the calculations are shown in rows b), c) and d) in TG Tables 8.4.2 (c) to 8.4.2 (e).

Table 8.4.2 (c) : Energy Consumption, Import and Export and Net Energy Consumption of Podium

Annual energy consumption of past 1st 12-month period	Energy consumption (E_{con})	Energy import (E_{im})	Energy export (E_{ex})	Net energy consumption ($E_{con} + E_{im} - E_{ex}$)
a) Total air-conditioning	$AC_P + AC_{AHU-P}$	$AC_1 \times [T_P/(T_1+T_2+T_P)]$	$AC_P \times [(T_1+T_2)/(T_1+T_2+T_P)]$	$AC_P + AC_{AHU-P} + AC_1 \times [T_P/(T_1+T_2+T_P)] - AC_P \times [(T_1+T_2)/(T_1+T_2+T_P)] = (AC_P + AC_1) \times [T_P/(T_1+T_2+T_P)] + AC_{AHU-P}$
b) Total lighting	$L_P + L_{P-1} + L_{P-2}$	nil	$L_{P-1} + L_{P-2}$	L_P
c) Total lift and escalator	LE_P	nil	nil	LE_P
d) Others	$O_P + O_{P-1} + O_{P-2}$	nil	$O_{P-1} + O_{P-2}$	O_P
TOTAL	∑ [a) + b) + c) + d)]	∑ [a) + b) + c) + d)]	∑ [a) + b) + c) + d)]	∑ [a) + b) + c) + d)]

Table 8.4.2 (d) : Energy Consumption, Import and Export and Net Energy Consumption of Tower 1				
Annual energy consumption of past 1st 12-month period	Energy consumption (E_{con})	Energy import (E_{im})	Energy export (E_{ex})	Net energy consumption ($E_{con} + E_{im} - E_{ex}$)
a) Total air-conditioning	$AC_1 + AC_{AHU-1}$	$AC_P \times [T_1/(T_1+T_2+T_P)]$	$AC_1 \times [(T_2+T_P)/(T_1+T_2+T_P)]$	$(AC_P + AC_1) \times [T_1/(T_1+T_2+T_P)] + AC_{AHU-1}$
b) Total lighting	L_1	L_{P-1}	nil	$L_1 + L_{P-1}$
c) Total lift and escalator	LE_1	nil	nil	LE_1
d) Others	O_1	O_{P-1}	nil	$O_1 + O_{P-1}$
TOTAL	∑ [a) + b) + c) + d)]	∑ [a) + b) + c) + d)]	∑ [a) + b) + c) + d)]	∑ [a) + b) + c) + d)]

Table 8.4.2 (e) : Energy Consumption, Import and Export and Net Energy Consumption of Tower 2				
Annual energy consumption of past 1st 12-month period	Energy consumption (E_{con})	Energy import (E_{im})	Energy export (E_{ex})	Net energy consumption ($E_{con} + E_{im} - E_{ex}$)
a) Total air-conditioning	AC_{AHU-2}	$AC_P \times [T_2/(T_1+T_2+T_P)] + AC_1 \times [T_2/(T_1+T_2+T_P)]$	nil	$(AC_P + AC_1) \times [T_2/(T_1+T_2+T_P)] + AC_{AHU-2}$
b) Total lighting	L_2	L_{P-2}	nil	$L_2 + L_{P-2}$
c) Total lift and escalator	LE_2	nil	nil	LE_2
d) Others	O_2	O_{P-2}	nil	$O_2 + O_{P-2}$
TOTAL	∑ [a) + b) + c) + d)]	∑ [a) + b) + c) + d)]	∑ [a) + b) + c) + d)]	∑ [a) + b) + c) + d)]

Attention is drawn that if the REA is developing similar tables for the calculation in his/her specific energy audit, he/she may consider adopting the same energy unit in each cell of the table, i.e. all in kWh or all in MJ; 1 unit of kWh equals 3.6 MJ units.

8.4.2.5 Estimations for Imported and Exported Energy

It is a good practice to obtain the energy data of the energy components in TG Figure 8.4.2 via actual measurements. However, as direct energy metering or archived measured data of the energy components may not always be available, alternative approaches such as described in items (a), (b) or (c) below may be used.

(a) Should resources be available, measurements of parameters associated with the energy components may be carried out to supplement the estimation. Such parameters may include energy, power, flow, temperature difference etc. They should be made at representative instants and at appropriate intervals. For example, if long trend metering of chilled water supply to Tower 1 is not feasible, the REA may consider taking short trend representative measurements of temperature difference and flow rate of the chilled water supply to Tower 1 to estimate T_1.

(b) Depending on resources allocated to the energy audit, estimations can also be supplemented with computer simulations, such as cooling load calculation or energy consumption of a space or component. For example, the REA may not have access to information on COP_p of the central chilled water plant in Podium. In such a case, the REA may consider estimating COP_p through a simple energy modeling by making suitable assumptions on the characteristics of the central chilled water plant.

(c) The REA may exercise his/her professional judgement in adopting common trade practice to estimate the energy data. An example of trade practice is also given in TG clause 7.3.3(b).

8.5 Template for Additional Information

Facilitating the provision of more information as a supplement to the executive summary, optional templates titled "Additional Information to Executive Summary of Energy Audit Report" are available for download at the web-site of the Ordinance.

The template provides the guidance in the calculation of performance indicators such as system EUI, system COP, system Watt per unit flow etc., which are not covered in form EE-EAes, and are useful in the evaluation and appraisal of the relevant equipment/systems. The concept of performance indicator is introduced in EAC clause 7.4.1 and TG clause 7.4.1.2.

The use of the templates to provide the information in the specified formats is strongly encouraged, which may be included, in the EA report, preferably as a section immediately after the executive summary. The templates may be expanded by the REA to suit building entities involving multi building blocks.

9. Energy Audit Form (EAC section 9)

The Energy Audit Form or EA Form is a specified form under the Ordinance, and the form is numbered EE5 (TG clause 4.5). The REA carrying out the energy audit has to sign on the form with a declaration of the completion of energy audit and the assessed EUI per annum of the building. Attention is drawn that the EUI's denominator of total floor area refers to the total of the whole building or building block, which includes both the common area and should the building has tenant units also these units. The form also bears the name and address of the building or building block audited.

For a building complex demarcated into several building blocks or entity (TG clauses 4.3.2, 4.3.3, 4.4 and 8.4), each block or entity should have a separate EA Form and thus a separate EUI figure, and the description of the name of the block (in the EA Form) should be able to distinguish the block from the other blocks in the same complex.

The exhibiting of the EA Form at a conspicuous position at the main entrance of the building (and for building blocks in a complex at the corresponding main entrance of the building block) is a requirement under the Ordinance.

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