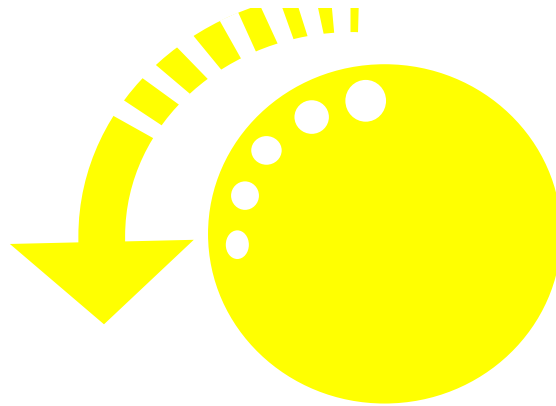


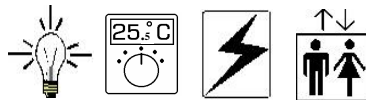
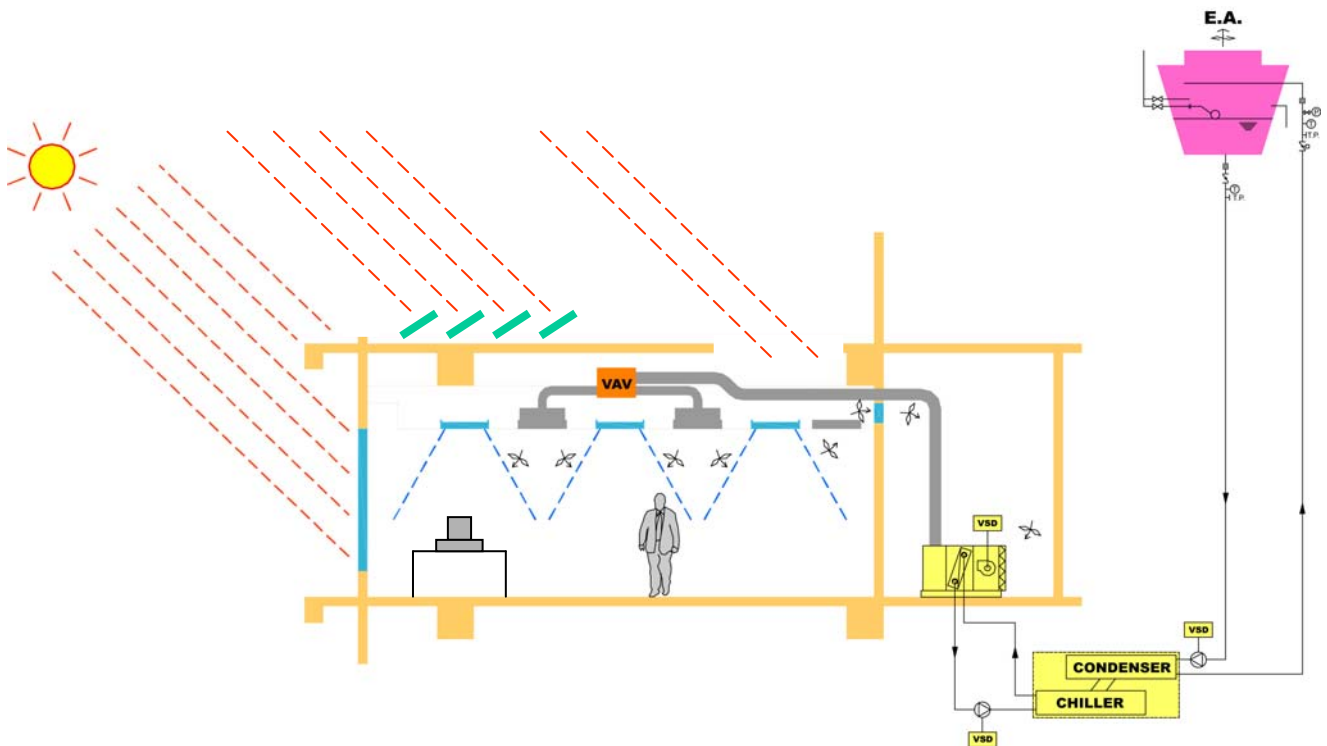
Guidelines on

Performance-based Building Energy Code

2007 EDITION



the
Supplement
to the
Code
document



EMSD



Guidelines on Performance-based Building Energy Code

Preface

The **Performance-based Building Energy Code** (PB-BEC) developed by the Electrical & Mechanical Services Department (EMSD) aims to provide an alternative means of **Building Energy Codes (BEC)** compliance based on the computation of the total building energy consumption. This performance approach considers the various components of building energy consumption, addresses to their interrelation, allows trade-off among them, and provides room for innovative design. The performance approach focuses on the total energy consumption of a building design, which is termed as the DESIGN ENERGY. A corresponding reference building, a generic building design of the same size and shape as the design building that fully complies with all the prescriptive requirements, can be developed and its energy consumption calculated, which is called the ENERGY BUDGET. The PB-BEC is deemed to be complied when $\text{DESIGN ENERGY} \leq \text{ENERGY BUDGET}$. The PB-BEC forms a part of a set of comprehensive BEC that addresses energy efficiency requirements in building services installations. The set of comprehensive BEC covers the Performance-based Building Energy Code, and the Codes of Practice for Energy Efficiency of Lighting Installations, Air Conditioning Installations, Electrical Installations, and Lift & Escalator Installations.

As a supplement to the PB-BEC, the EMSD has developed this handbook of Guidelines on Performance-based Building Energy Code (Guidelines). The intention of the Guidelines is to provide the input requirements for building energy simulation, and the explanations to the requirements in the PB-BEC. Examples of application using the PB-BEC are also included to demonstrate compliance method and trade-off procedures. The Guidelines shall be read in conjunction with the PB-BEC. It is hoped that designers will not only design installations that would satisfy the minimum requirements stated in the PB-BEC, but also pursue above the minimum requirements.

The Guidelines were first published in 2003. The 2005 edition of the Guidelines were issued with the issue of the 2005 edition of PB-BEC. This 2007 edition of Guidelines are issued to supplement the 2007 edition of PB-BEC.

To promote the adoption of the BEC, the Hong Kong Energy Efficiency Registration Scheme for Buildings was also launched. The Registration Scheme provides the certification to a building complying with one or more of the BEC.

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The Building Energy Codes, corresponding Guidelines and Registration Scheme documents are available for download at <http://www.emsd.gov.hk/emsd/eng/pee/eersb.shtml>

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1. Introduction

1.1 Performance-based Building Energy Code (PB-BEC) Compliance

In order to comply with PB-BEC, it is required that the energy consumption of the designed building is no more than the energy budget of its reference building. The reference building will be developed with similar characteristics as the designed building in respect of orientation, number of floors, floor area, occupancy and usage etc. The reference building will comply with the prescriptive Building Energy Codes (BEC) requirements. Whilst, the designed building will not be required to comply with all the prescriptive requirements of the BECs, there are certain basic requirements that apply to both the designed building as well as the reference building.

The fundamental design principle is that the designed building shall consume less energy than that of the reference building. Designers are allowed to adopt green and innovative facilities and features for the designed building. The flow process is shown in Figure 1.1.

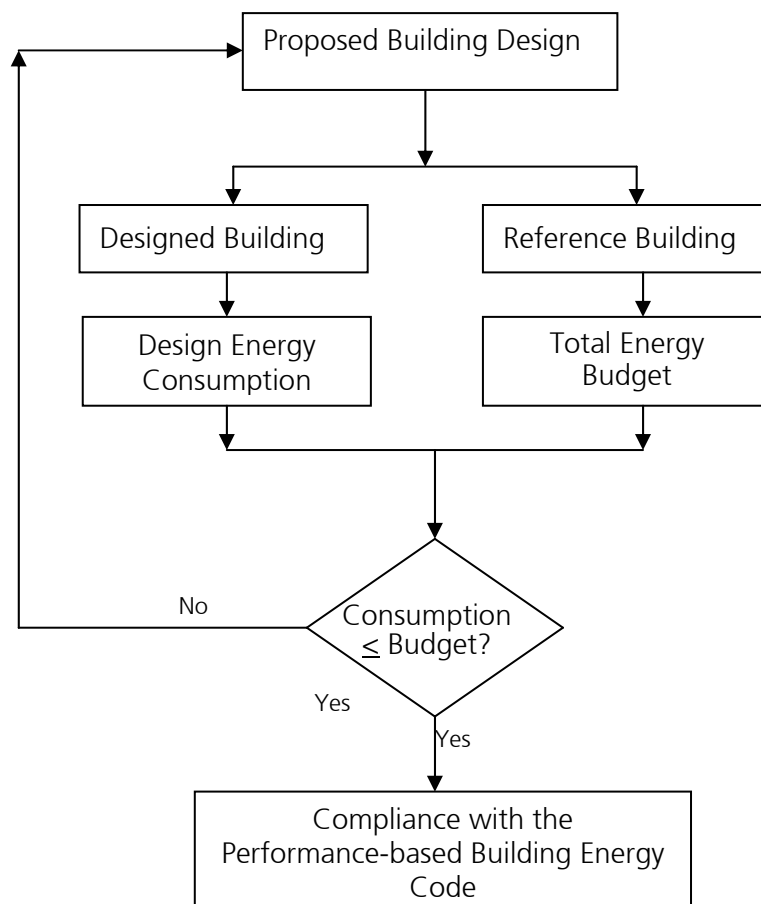


Figure 1.1 PB-BEC compliance process

With the PB-BEC method, a computer program is used to calculate the design energy consumption and energy budget for the designed and reference buildings respectively.

In general, the purpose of the performance compliance procedure is not to develop an accurate prediction of annual energy use for the building. Rather, the purpose is to develop fair and consistent evaluations of the effects of deviations (in whatever direction) from the prescriptive requirements. As such, many simplifying assumptions were made to rationalise the modelling exercise without compromising the intent.

The Guidelines will discuss how to ensure calculations are performed to produce a fair

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comparison between the designed and reference buildings, as well as when and how trade-offs may be made under the PB-BEC method.

Maximum Limit on Trade-off

As a good practice to encourage a variety of energy efficient practices and to avoid the dominance of a single practice, the percentage trade-off of total building energy based on the Reference building for each of the following features (to be inserted in Submission Form PB-5) should preferably not exceed 5%.

- *Accumulative savings from Lighting Power Density and from Daylighting Control of entire building,*
- *Accumulative savings from COP of refrigeration plant of the entire building, and*
- *Accumulative savings from building envelope of entire building.*

The above suggests a limitation on the allowable trade-off. The limitation implies that the designer could still adopt a feature with savings over 5%, but the percentage saving exceeding 5% would not contribute towards the Designed building's total building energy.

1.2 Building energy simulation

Building energy simulation is a tool for analysis of building energy consumption. It includes air-conditioning and other building installations such as lighting, electrical systems and service water heating systems. Due to its iteration nature and complexity, the use of computer software program is almost a must. Building energy simulation is usually performed to analyze the energy performance of a building dynamically and to understand the relationship between the design parameters and energy use characteristics of the building so as to improve the building design.

1.2.1 Basic concepts of energy calculation

The theory of building energy simulation is based upon the traditional methods of load and energy calculations in HVAC design. The purpose of energy calculation is to estimate the energy requirements of the building in order to meet the required cooling/heating loads throughout the year.

Building energy consumption is dynamic in nature. The simulation has to account for the variation of energy consumption with time and the effect of building thermal storage.

Hourly calculations over the whole year (8760 hours) for the analysis of annual load and energy consumption is usually required.

1.2.2 Simulation procedures

Figure 1.2 is a flow chart that illustrates the sequence of the analysis and calculations that are typically performed with a building energy simulation program.

In general, the procedure of the simulation will be as follows:

- (1) description of the building design and the assumptions;
- (2) preparation of the simulation inputs;
- (3) carrying out of the simulation; and
- (4) interpretation of the simulation results.

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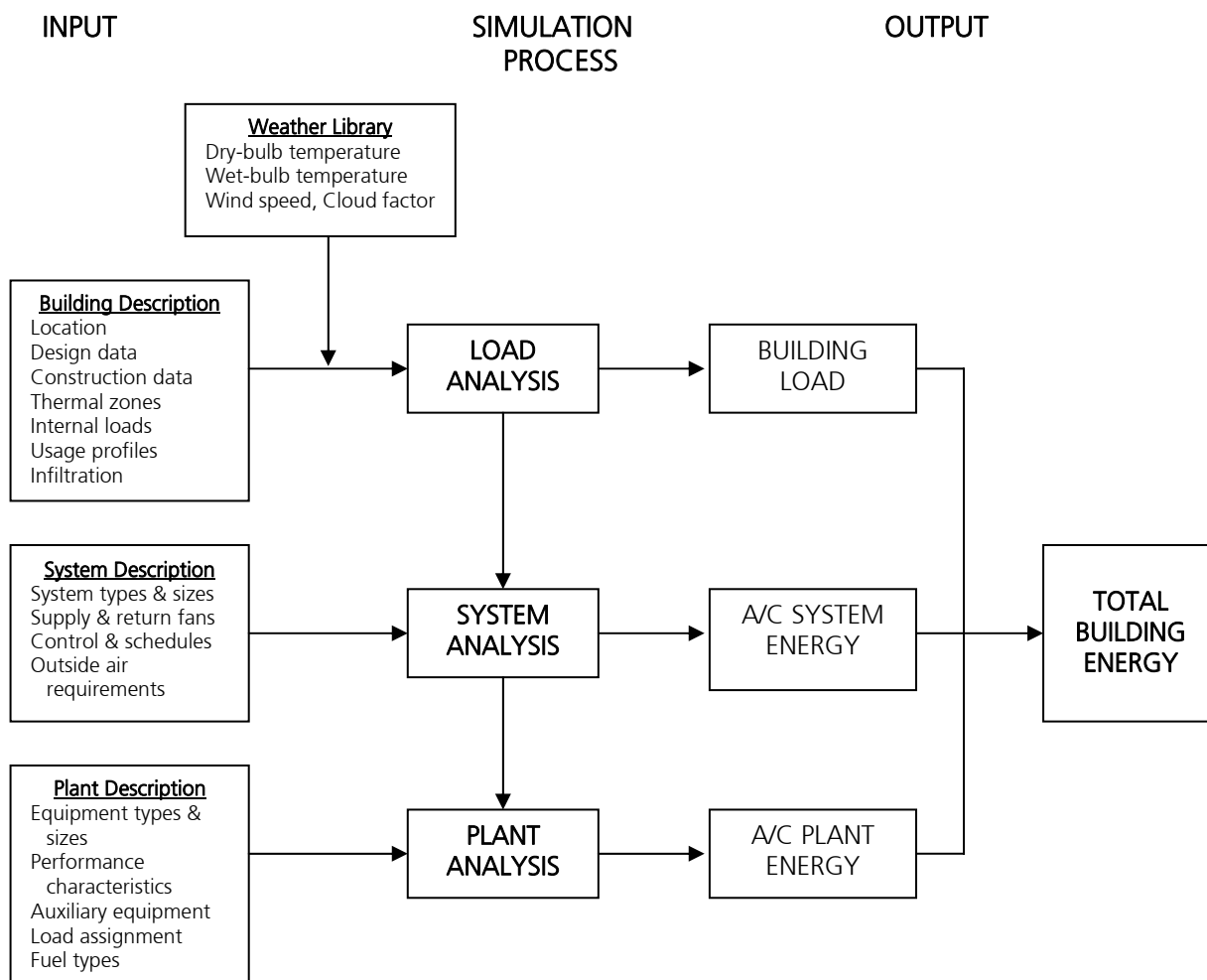


Figure 1.2 Flow chart for building energy simulation program

1.2.3 Simulation tools

Simulation tools are the computer programs used for the energy calculation. At present there are a number of simulation programs, each having its own characteristics and specialties and being under continual refinement. Table A1 shows a list (not exhaustive) of programs that are commonly used for performing building energy simulations:

Table A1 Commonly used building energy simulation programs

Program	Information Sources
<i>Detailed programs:</i>	
BLAST (Building Load Analysis and System Thermodynamics program)	http://www.uiuc.edu
DOE-2 (simulation program supported by U.S. Department of Energy). Examples of PC version/interface of DOE-2 and DOE-2 derivatives include: <ul style="list-style-type: none"> • ADM-DOE-2.1 • FTI-DOE2 • VisualDOE 	http://doe2.com/ http://gundog.lbl.gov/dirsoft/d2whatis.html http://www.archenergy.com
EnergyPlus (Program supported by U.S. Department of Energy)	http://www.energyplus.gov
ESP-r (Environmental System Performance (research) program)	http://www.esru.strath.ac.uk

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Program	Information Sources
TRNSYS (Transient Systems Simulation program)	http://sel.me.wisc.edu/TRNSYS/ http://www.trnsys.com/
<i>Proprietary programs:</i>	
Carrier HAP (Hourly Analysis Program)	http://www.commercial.carrier.com
TRACE 700/System Analyzer (Trane Air Conditioning Economics)	http://www.trane.com/commercial
<i>Simplified programs:</i>	
e-QUEST (freeware)	http://www.energydesignresources.com/resource/130/
Energy-10	http://www.sbicouncil.org/
ENER-WIN	http://www.eere.energy.gov/buildings/tools_directory/software.cfm/ID=38/pagename=alpha_list

1.3 Requirements of the Building Energy Simulation Program

The building energy simulation program to be used in the modelling evaluation must be able to accurately estimate the energy use of the systems and components. If the modelling of each of the systems and components identified cannot be assessed using one program, more than one program can be proposed and used for the calculation and analysis. Where multiple programs are proposed, the minimum requirement is that the most significant program shall model the building, the lighting, the air conditioning and ventilation systems, with the other programs to model the other energy uses such as for lift and escalator systems, service hot water, daylighting benefits and power systems. The outcomes from each of the modelling programs shall be appropriately grouped to provide an integrated result.

All compliance programs and algorithms used in the energy analysis engine shall be supported by peer-reviewed, referenceable, and published documentation. Documentation of the compliance process shall be sufficient to ensure that all calculations are reproducible and verifiable. Limitations of the compliance software shall also be documented. e.g. cannot model active solar, sloped fenestration etc. A summary of the modelling requirements for the building energy simulation program is provided in the following.

General:

Modelling Requirement	Description
Dynamic modelling	Computer simulation using response function, finite difference or other appropriate techniques.
Accredited	Verified under the test criteria as a means of accreditation (a quality assurance plan or Building Energy Simulation Test procedure (BESTEST) of the International Energy Agency (IEA)).
Uses historical weather data	To use selected year of contiguous weather data (i.e. 8,760 hours) and in particular either TRY or TMY data files.
User functionality	Facility to define the hourly, weekly, monthly and annual profiles for defined spaces, and specifically occupancy density, lighting load, equipment heat load, space temperatures and equipment on/off times.
Metric input and output	Unit consistency.
Capability	To be able to model, at the same time, the interactions among the maximum numbers of spaces and systems required by the reference building.
Plant equipment characteristics	Facility to operate with equipment performance characteristics of equipment specifically available in Hong Kong.
Plant sizing	Equipment sizing either using the modelling program or else by a program that uses the same or similar analysis technique as the dynamic modelling program with a design day capability.

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The Building:

Modelling Requirement	Description
Geometry of the building and adjacent objects	To enable modelling of external shading by adjacent structures.
Geometry of the space for daylighting analysis	To estimate the effects of daylighting (see Lighting below).
Building orientation with reference to North	To enable orientation effects to be analysed with minimal modelling changes.
Material definition	To be able to be user defined.
Glazing / Windows	The program must have a glazing library (or allow user definition of glazing characteristics) that covers the types of glazing required to be modelled. It must also enable window frames to be defined so that their effect can be modelled.
Shading device control	To be able to use conditional control statements to control the operating strategies of internal and external shading devices.
Overhangs, fins and reveals	To enable accurate definition for dynamic modelling.
Air leakage	Must include algorithms to enable modelling of air infiltration based on ambient wind speed.
Interior walls	To enable modelling of imaginary walls between zones to enable zone interaction to be included.
Return air plenums	To enable heat losses and gains from return air plenums to be dynamically evaluated.
Floor on ground	Facility to enable heat transfer to and from a floor on ground.

Lighting:

Modelling Requirement	Description
Distribution of heat output of lights	Be able to distribute the heat output from lights into either return air, the space or some other ventilated space.
Light zoning	To enable different strategies to be introduced to control lighting in separate zones to determine energy savings against lighting performance.
External lighting	To enable energy use to be evaluated with specific lighting levels and control strategies.
Daylighting (optional)	To enable daylighting to be evaluated using luminance weather data and the geometry of the space.

HVAC:

Modelling Requirement	Description
System types	To enable modelling of commonly used HVAC systems, including: <ul style="list-style-type: none"> • Variable air volume (VAV) central station or packaged plant (direct expansion and chilled water) • Multi-zone constant air volume (CAV) with cold deck with either zone heating coils or hot deck (central station or packaged) • Chilled water and hot water fan coils • Air cooled and water cooled heat pump conditioners • Direct expansion cooling only • Evaporative cooling
Economiser cycles	For those systems above where economiser cycles could be used.
Equipment performance	To enable equipment performance variations to be modelled (differing flow rates, temperatures, power, variable speed fans and pumps, VAV and fan powered VAV boxes, etc.), including modifications to standard performance curves for all plant equipment such as chillers, boilers, cooling towers, heat pump conditioners and chillers/heaters, etc., on the basis of ambient conditions.
Controls functions	Temperature control with dead-band, temperature reset on cooling and heating coils by the most demanding zone or outside air temperature or by time clock, optimum start, building flush, and variable space temperatures. Allow modifications to the operating strategies of central plant such as chiller, boiler and cooling tower sequencing.

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Power:

Modelling Requirement	Description
Enclosed versus open plan floor ratios	Have the capability to allocate energy densities from small power equipment according to the extent of occupancy (as determined by the type of space usage / ratio of enclosed to open plan)

Output:

Modelling Requirement	Description
Energy usage	To enable energy use credited to the major components (e.g. lighting, cooling energy, heating energy, fan power, ancillary services energy use) to be output as specific energy use results on a month by month basis and as a summary. Enable energy use to be output as the fuel type by month.
Output statistics	Provide statistics of excursions of space temperatures from the control band. Provide maximum loads on equipment on a space by space basis and on the central plant.

1.4 Definitions

The expressions that appear in the Guidelines are as defined in the Performance-based Building Energy Code and below. Terms that are not defined shall have their ordinarily accepted meanings within the context in which they are used.

“Coefficient of performance (COP) – cooling”: means the ratio of the rate of heat removal to the rate of energy input, in consistent units, for a complete cooling system or factory assembled equipment, as tested under an internationally recognised standard and designated operating conditions.

“Coefficient of performance (COP), heat pump – heating”: means the ratio of the rate of heat delivered to the rate of energy input, in consistent units, for a complete heat pump system, as tested under an internationally recognised standard and designated operating conditions.

“U-value (thermal transmittance)”: heat transmission in unit time through unit area of a material or construction and the boundary air films, induced by unit temperature difference between the environments on each side. Unit of U is $W/m^2\text{°C}$.

ASHRAE :	American Society of Heating, Refrigerating and Air Conditioning Engineers
EMSD :	Electrical and Mechanical Services Department
FCU :	Fan Coil Unit
HKO :	Hong Kong Observatory
HVAC :	Heating, Ventilating and Air Conditioning
KWh :	kilowatt hour
MJ :	Megajoule
MWh :	Megawatt hour
PAU :	Primary Air Unit
PB-BEC :	Performance-based Building Energy Code
OTTV :	Overall Thermal Transfer Value
SWH :	Service Water Heating
SRR :	Sky-light Roof Ratio
TRY/TMY :	Test Reference Year/Typical Meteorological Year
W/m^2 :	Watt per square metre
$W/m^2\text{°C}$:	Watt per square metre per degree Celsius
WWR :	Window-wall Ratio

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2. Input for the Designed building and Reference building

2.1 General

2.1.1 Region & climate data

The climate data adopted should be clearly defined and be representative for Hong Kong. The same set of climate data shall be used for the energy performance analysis of both the *designed building* and the *reference building*.

2.1.2 Calendar

The calendar year in Hong Kong for analysis shall be fixed as 1989 which is the Test Reference Year concluded in a recent study on representative annual weather data for building energy calculations. No inputs for statutory holidays are required.

2.2 Building description

2.2.1 Dividing buildings into zones

Zones are mainly made up of spaces. They could be either “air-conditioned” or “non air-conditioned”. Zones that are “non air-conditioned” shall have the following values set to zero :

- number of occupants;
- service water heating; and
- minimum outdoor air requirement.

Zones will include those areas or spaces in the building that meet the following criteria:

- similar operation and function;
- served by the same HVAC system and thermostat; and
- similar heating/cooling loads.

Perimeter areas should be modeled separately from interior areas. The dividing line between perimeter and interior areas could be set according to the following rules:

- position of full height walls separating perimeter areas from interior areas;
- areas which are conditioned by the perimeter HVAC system will be defined as the perimeter zone; or
- 4m from exterior walls.

2.2.2 Grouping similar zones

From modeling point of view, similar zones could be grouped together so as to reduce data input time. The rules below can be used to group similar zones:

Similar rooms with individual thermostats

These could be grouped together provided they have similar environmental conditions. An example is hotel room. Each room has its own thermostat to handle variations in room use, but each room is just as likely to be full or empty. In this case, all rooms can be treated as one zone.

Same area on different floors

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In many office buildings, the same floor plan is repeated on each storey. The same areas on each floor can be grouped into a zone. Top and bottom floors are modeled separately because of the extra heat transfer through the roof and floor. In Figure 2, the second and third storey can be grouped together.

Areas with similar cooling/heating loads

These areas could be grouped together into one zone. For example, all the west-facing offices in a building could be grouped together provided they have similar space function and envelope characteristics.

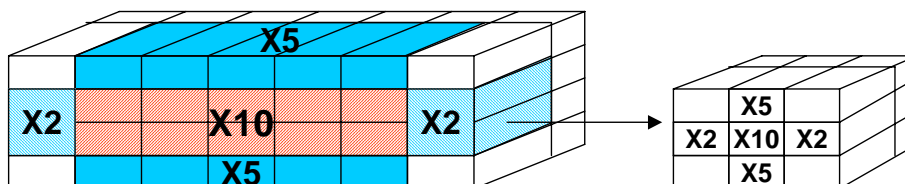


Figure 2.1 Grouping similar zones

2.2.3 Space use classification

All “air-conditioned” thermal blocks could be classified as either *building type* (all spaces having the same function) or *space type* (spaces having different functions)

With the building type approach, a single set of operating parameters is defined for the entire zone. The main advantage of the building type approach is that it reduces the level of effort in describing the building. The building type approach suits:

- speculative commercial buildings where the tenant leaseholds are not known; and
- single-purpose buildings which could be clearly defined as a certain building type such as office, retail, restaurants etc., such that a single set of operating parameters could be applied to the whole building.

The space type approach on the other hand has the flexibility in describing the various building functions.

Characteristics of *Building type* categories and their associated default operating schedules could be selected from Table A2 in the PB-BEC. Characteristics of *Space type* categories and their associated default operating schedules could be selected from Table A3.

Input data for energy analysis should follow Tables A2 to A10 in the PB-BEC. Justifications shall be provided for adopting values different from those in these tables.

Table A2 *Building type categories: default assumptions*

Building Type	Occupant Density (m ² /person)	Minimum Outdoor Air (l/s/person)	Operating Schedule (Tables A4 to A10)	Lighting Power Density (W/m ²)	Equipment Power Density (W/m ²)	Service Water Heating (W/person)
Office	13	8	A	15	10	As design
Restaurant	5	10	B	21	20 W/person *	As design
Retail	10	8	C	18	5-30W/m ²	As design
Mall/Concourse/Atria	10	1 l/s/m ²	C	23	---	As design
Hotel	25	30 l/s per rm	D	17	900 W per rm	500

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Note: * 10W per person for sensible heat and 10W per person for latent heat.

Note 1 : Occupant density is based on local professional practice.

Note 2 : Service water heating is based on CIBSE Guide G (2-hour recovery period). Zero is to be assigned should there be no service water heating.

Note 3 : Outdoor air requirement is based on local professional practice and ASHRAE Standard 62-2001.

Note 4 : Operating schedules are based on local practice. Hotel operating schedule is based on published data from Hong Kong Tourist Trade Association.

Note 5 : Lighting Power Density is based on Lighting Code requirements, local professional practice and ASHRAE 90.1-2001.

Note 6 : Equipment Power Density is based on local professional practice.

Table A3 Space type categories: default assumptions

Building Type	Occupant Density (m ² /person)	Minimum Outdoor Air (l/s/person)	Operating Schedule (Tables A4 to A10)	Lighting Power # Density (W/m ²)	Equipment Power Density (W/m ²)	Service Water Heating (W/person)
Office						
General	8	8	A	17	25	As design
Hi-tech	8	8	A	17	50-70	As design
Lift lobby	10	1 l/s/m ²	A	15	---	As design
Reception/Waiting/ Recreation room	8	8	A	14	---	As design
Data centre (server, mainframe computer)	10-15	8	A	16	500-900	As design
Bank business area	10	8	A	As design (max. 25)	30	As design
Bank customer area	1.5	0.25 l/s/m ²	A	As design (max.15)	---	As design
Restaurant						
Chinese restaurant	1	10	B	As design (max. 25)	20W per person *	As design
Western restaurant	1.5	10	B	As design (max. 23)	20W per person *	As design
Coffee shop / Bar / Lounge (smoking allowed)	1.5	15	B	As design (max. 23)	10	As design
Canteen/food plaza	1	10	B	As design (max. 23)	20W per person *	As design
Kitchen	As design	As design	As design	13	As design	As design
Retail						
Retail shop	2.5	8	C	As design (max. 20)	30	As design
Shopping arcade	2.5	8	C	As design (max. 20)	10	As design
Supermarket	12.5	8	C	As design (max. 20)	5-10	As design
Educational activities						
Classroom / Lecture theatre / Laboratory	2, or no. of seats	8	A	17	10	As design
Library	5	8	A	17	10	As design

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Building Type	Occupant Density (m ² /person)	Minimum Outdoor Air (l/s/person)	Operating Schedule (Tables A4 to A10)	Lighting Power # Density (W/m ²)	Equipment Power Density (W/m ²)	Service Water Heating (W/person)
Mass assembly area						
Auditorium	5	8	C	25	5-10	As design
Exhibition hall /gallery	5	8	C	23	5-10	As design
Mass assembly area / Assembly hall	1	8	E	18	5-10	As design
Theatre – Performing arts	2, or no. of seats	8	E	As design (max. 25)	---	As design
Theatre – Motion picture	2, or no. of seats	8	E	As design (max. 25)	---	As design
Indoor sports grounds						
Spectator seating area	1.5	8	F	16	---	As design
Indoor sports ground for amateur players	3	13	F	17	---	As design
Indoor sports ground for tournament	As design	13	F	28	---	As design
Squash courts for amateur players	2 persons	13	F	17	---	As design
Squash courts for tournament	2 persons	13	F	28	---	As design
Indoor swimming pool for amateur players	3	13	F	15	---	As design
Indoor swimming pool for tournament	As design	13	F	28	---	As design
Ice rink for amateur players	3	13	F	15	---	As design
Ice rink for tournament	As design	13	F	28	---	As design
Hotel						
Banquet room	1	10	B	23	20W per person *	90
Back-of-house area	4	8	G	As design (max.13)	20W per person *	60
Main entrance/ large lobby	10	1 l/s/m ²	G	As design (max.15)	---	30
Health club	8-10	13	F	As design (max.17)	---	90
Guest rooms	As design (or 2 per room)	30 l/s/room	D	17	900W per room	500

Note: * 10W per person for sensible heat and 10W per person for latent heat.

Use values in Lighting Code Table (LG4) for spaces not listed in this table.

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Table A4 Operating schedule 'A': offices

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Occupants																								
Mon – Fri	0	0	0	0	0	0	0.1	0.7	0.9	0.9	0.9	0.5	0.5	0.9	0.9	0.9	0.7	0.3	0.1	0.1	0.1	0.1	0	0
Sat	0	0	0	0	0	0	0.1	0.4	0.7	0.7	0.7	0.7	0.7	0	0	0	0	0	0	0	0	0	0	0
Sun	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Equipment																								
Mon – Fri	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.8	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.8	0.5	0.3	0.2	0.2	0.2	0.2
Sat	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.8	0.9	0.9	0.9	0.9	0.9	0.8	0.6	0.5	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Sun	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Lighting																								
Mon – Fri	0.05	0.05	0.05	0.05	0.05	0.05	0.3	0.8	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.8	0.5	0.3	0.1	0.05	0.05	
Sat	0.05	0.05	0.05	0.05	0.05	0.05	0.3	0.8	0.9	0.9	0.9	0.9	0.9	0.8	0.6	0.5	0.3	0.3	0.1	0.1	0.05	0.05	0.05	
Sun	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Fans																								
Mon – Fri	Off	Off	Off	Off	Off	On	On	On	On	On	On	On	On	On	On	On	On	On	On	Off	Off	Off	Off	Off
Sat	Off	Off	Off	Off	Off	On	On	On	On	On	On	On	On	On	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off
Sun	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off
Cooling	(*) = temperature as design																							
Mon – Fri	Off	Off	Off	Off	Off	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	Off	Off	Off	Off	Off
Sat	Off	Off	Off	Off	Off	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	Off	Off	Off	Off	Off	Off	Off	Off	Off
Sun	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off
Heating	(*) = temperature as design																							
Mon – Fri	Off	Off	Off	Off	Off	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	Off	Off	Off	Off	Off
Sat	Off	Off	Off	Off	Off	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	Off	Off	Off	Off	Off	Off	Off	Off	Off
Sun	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off
Hot Water																								
Mon – Fri	0.05	0.05	0.05	0.05	0.05	0.05	0.1	0.5	0.5	0.9	0.9	0.9	0.9	0.9	0.9	0.7	0.5	0.3	0.2	0.2	0.2	0.05	0.05	0.05
Sat	0.05	0.05	0.05	0.05	0.05	0.05	0.1	0.5	0.5	0.9	0.9	0.9	0.9	0.9	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Sun	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05

Table A5-1 Operating schedule 'B-1': western restaurants

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Occupants																								
Mon – Fri	0.1	0	0	0	0	0	0	0	0.1	0.2	0.5	0.9	0.9	0.8	0.2	0.2	0.3	0.6	0.9	0.9	0.9	0.6	0.4	0.3
Sat	0.3	0	0	0	0	0	0	0	0.1	0.2	0.5	0.9	0.9	0.8	0.2	0.2	0.3	0.6	0.9	0.9	0.9	0.6	0.6	0.5
Sun	0.3	0	0	0	0	0	0	0	0.3	0.4	0.7	0.9	0.9	0.9	0.7	0.5	0.4	0.6	0.9	0.9	0.9	0.5	0.4	0.3
Equipment																								
Mon – Fri	0.5	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.5	0.7	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Sat	0.5	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.5	0.7	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Sun	0.5	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.7	0.7	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.5	0.5
Lighting																								
Mon – Fri	0.5	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.5	0.7	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Sat	0.5	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.5	0.7	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Sun	0.5	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.7	0.7	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.5	0.5
Fans																								
Mon – Fri	On	Off	Off	Off	Off	Off	Off	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On
Sat	On	Off	Off	Off	Off	Off	Off	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On
Sun	On	Off	Off	Off	Off	Off	Off	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On
Cooling	(*) = temperature as design																							
Mon – Fri	(*)	Off	Off	Off	Off	Off	Off	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)
Sat	(*)	Off	Off	Off	Off	Off	Off	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)
Sun	(*)	Off	Off	Off	Off	Off	Off	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)
Heating	(*) = temperature as design																							
Mon – Fri	(*)	Off	Off	Off	Off	Off	Off	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)
Sat	(*)	Off	Off	Off	Off	Off	Off	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)
Sun	(*)	Off	Off	Off	Off	Off	Off	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)
Hot Water																								
Mon – Fri	0.5	0.05	0.05	0.05	0.05	0.05	0.05	0.7	0.7	0.7	0.5	0.5	0.6	0.6	0.5	0.3	0.3	0.5	0.5	0.8	0.8	0.9	0.9	0.6
Sat	0.6	0.05	0.05	0.05	0.05	0.05	0.05	0.7	0.7	0.7	0.5	0.5	0.6	0.6	0.5	0.3	0.3	0.5	0.5	0.8	0.8	0.9	0.9	0.7
Sun	0.6	0.05	0.05	0.05	0.05	0.05	0.05	0.7	0.7	0.7	0.5	0.5	0.6	0.6	0.5	0.3	0.3	0.5	0.5	0.8	0.8	0.9	0.9	0.5

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Table A5-2 Operating schedule 'B-2': Chinese restaurants

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Occupants																								
Mon – Fri	0	0	0	0	0	0	0.5	0.7	0.7	0.5	0.5	0.9	0.9	0.8	0.2	0.2	0.3	0.6	0.9	0.9	0.8	0.3	0.1	0
Sat	0	0	0	0	0	0	0.4	0.6	0.7	0.6	0.6	0.8	0.9	0.8	0.2	0.2	0.3	0.6	0.9	0.9	0.8	0.3	0.1	0
Sun	0	0	0	0	0	0	0.4	0.6	0.7	0.8	0.8	0.9	0.9	0.9	0.7	0.5	0.4	0.6	0.9	0.9	0.8	0.3	0.1	0
Equipment																								
Mon – Fri	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.4	0.5	0.7	0.9	0.9	0.9	0.8	0.5	0.5	0.7	0.9	0.9	0.9	0.9	0.7	0.3	0.1
Sat	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.4	0.5	0.7	0.9	0.9	0.9	0.8	0.5	0.5	0.7	0.9	0.9	0.9	0.9	0.7	0.3	0.1
Sun	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.4	0.7	0.7	0.9	0.9	0.9	0.9	0.8	0.8	0.8	0.9	0.9	0.9	0.9	0.7	0.3	0.1
Lighting																								
Mon – Fri	0.1	0.1	0.1	0.1	0.1	0.5	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.7	0.1
Sat	0.1	0.1	0.1	0.1	0.1	0.5	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.7	0.1
Sun	0.1	0.1	0.1	0.1	0.1	0.5	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.7	0.1
Fans																								
Mon – Fri	Off	Off	Off	Off	Off	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On
Sat	Off	Off	Off	Off	Off	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On
Sun	Off	Off	Off	Off	Off	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On
Cooling	(*) = temperature as design																							
Mon – Fri	Off	Off	Off	Off	Off	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)
Sat	Off	Off	Off	Off	Off	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)
Sun	Off	Off	Off	Off	Off	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)
Heating	(*) = temperature as design																							
Mon – Fri	Off	Off	Off	Off	Off	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)
Sat	Off	Off	Off	Off	Off	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)
Sun	Off	Off	Off	Off	Off	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)
Hot Water																								
Mon – Fri	0.05	0.05	0.05	0.05	0.05	0.7	0.7	0.7	0.7	0.7	0.7	0.8	0.9	0.7	0.3	0.3	0.3	0.5	0.6	0.8	0.8	0.5	0.3	0.1
Sat	0.05	0.05	0.05	0.05	0.05	0.7	0.7	0.7	0.7	0.7	0.7	0.8	0.9	0.7	0.3	0.3	0.3	0.5	0.6	0.8	0.8	0.5	0.3	0.1
Sun	0.05	0.05	0.05	0.05	0.05	0.7	0.7	0.7	0.8	0.8	0.9	0.9	0.9	0.9	0.7	0.5	0.5	0.6	0.8	0.8	0.8	0.5	0.3	0.1

Table A6 Operating schedule 'C': retails

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Occupants																								
Mon – Fri	0	0	0	0	0	0	0	0.1	0.2	0.5	0.5	0.7	0.7	0.7	0.7	0.8	0.7	0.6	0.5	0.4	0.3	0	0	0
Sat	0	0	0	0	0	0	0	0.1	0.2	0.5	0.6	0.7	0.7	0.9	0.9	0.9	0.8	0.8	0.8	0.7	0.6	0	0	0
Sun	0	0	0	0	0	0	0	0	0.1	0.3	0.6	0.8	0.9	0.9	0.9	0.9	0.9	0.9	0.8	0.7	0.6	0	0	0
Equipment																								
Mon – Fri	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.5	0.5	0.7	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.7	0.05	0.05	0.05
Sat	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.5	0.5	0.7	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.7	0.05	0.05	0.05
Sun	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.5	0.5	0.7	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.7	0.05	0.05	0.05
Lighting																								
Mon – Fri	0.05	0.05	0.05	0.05	0.05	0.05	0.5	0.5	0.7	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.7	0.05	0.05	0.05
Sat	0.05	0.05	0.05	0.05	0.05	0.05	0.5	0.5	0.7	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.7	0.05	0.05	0.05
Sun	0.05	0.05	0.05	0.05	0.05	0.05	0.5	0.5	0.7	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.7	0.05	0.05	0.05
Fans																								
Mon – Fri	Off	Off	Off	Off	Off	Off	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	Off	Off	Off
Sat	Off	Off	Off	Off	Off	Off	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	Off	Off	Off
Sun	Off	Off	Off	Off	Off	Off	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	Off	Off	Off
Cooling	(*) = temperature as design																							
Mon – Fri	Off	Off	Off	Off	Off	Off	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	Off	Off	Off
Sat	Off	Off	Off	Off	Off	Off	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	Off	Off	Off
Sun	Off	Off	Off	Off	Off	Off	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	Off	Off	Off
Heating	(*) = temperature as design																							
Mon – Fri	Off	Off	Off	Off	Off	Off	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	Off	Off	Off
Sat	Off	Off	Off	Off	Off	Off	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	Off	Off	Off
Sun	Off	Off	Off	Off	Off	Off	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	Off	Off	Off
Hot Water																								
Mon – Fri	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.1	0.2	0.3	0.4	0.8	0.8	0.8	0.8	0.6	0.4	0.3	0.2	0.2	0.2	0.05	0.05	0.05
Sat	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.1	0.2	0.3	0.5	0.9	0.9	0.9	0.9	0.9	0.7	0.7	0.7	0.5	0.4	0.05	0.05	0.05
Sun	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.1	0.3	0.4	0.9	0.9	0.9	0.9	0.9	0.9	0.7	0.7	0.7	0.5	0.4	0.05	0.05	0.05

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Table A7 Operating schedule 'D': hotels

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Occupants																								
Mon – Fri	0.9	0.9	0.9	0.9	0.9	0.9	0.7	0.4	0.4	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.5	0.5	0.5	0.7	0.7	0.8	0.9	0.9
Sat	0.9	0.9	0.9	0.9	0.9	0.9	0.7	0.5	0.5	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.5	0.6	0.6	0.6	0.7	0.7	0.7
Sun	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.5	0.5	0.5	0.3	0.3	0.2	0.2	0.2	0.3	0.4	0.4	0.6	0.6	0.8	0.8	0.8
Equipment																								
Mon – Fri	0.05	0.05	0.05	0.05	0.05	0.3	0.5	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.4	0.4	0.4	0.5	0.5	0.6	0.5	0.3
Sat	0.05	0.05	0.05	0.05	0.05	0.3	0.5	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.3	0.4	0.4	0.4	0.2	0.2	0.2
Sun	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.3	0.3	0.4	0.4	0.2	0.2	0.2
Lighting																								
Mon – Fri	0.2	0.2	0.1	0.1	0.1	0.2	0.4	0.5	0.4	0.4	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.6	0.8	0.9	0.8	0.6	0.3
Sat	0.2	0.2	0.1	0.1	0.1	0.1	0.3	0.3	0.4	0.4	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.6	0.7	0.7	0.7	0.6	0.3
Sun	0.3	0.3	0.2	0.2	0.2	0.2	0.3	0.4	0.4	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.5	0.7	0.8	0.6	0.5	0.3
Fans																								
Mon – Fri	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On
Sat	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On
Sun	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On
Cooling	(*) = temperature as design																							
Mon – Fri	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)
Sat	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)
Sun	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)
Heating	(*) = temperature as design																							
Mon – Fri	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)
Sat	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)
Sun	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)
Hot Water																								
Mon – Fri	0.3	0.2	0.1	0.1	0.2	0.4	0.6	0.9	0.7	0.5	0.5	0.4	0.5	0.4	0.3	0.3	0.3	0.3	0.5	0.7	0.7	0.7	0.7	0.5
Sat	0.3	0.2	0.1	0.1	0.2	0.4	0.5	0.8	0.6	0.5	0.5	0.5	0.5	0.5	0.4	0.3	0.3	0.3	0.5	0.7	0.7	0.7	0.7	0.5
Sun	0.3	0.2	0.1	0.1	0.2	0.4	0.4	0.6	0.9	0.7	0.5	0.5	0.5	0.4	0.3	0.3	0.3	0.3	0.4	0.6	0.6	0.6	0.6	0.5

Table A8 Operating schedule 'E': theatres

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Occupants																								
Mon – Fri	0	0	0	0	0	0	0	0	0	0.3	0.4	0.5	0.5	0.5	0.5	0.5	0.5	0.6	0.8	0.8	0.8	0.5	0	0
Sat	0	0	0	0	0	0	0	0	0	0.5	0.6	0.7	0.7	0.7	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.5	0	0
Sun	0	0	0	0	0	0	0	0	0	0.5	0.6	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.5	0	0
Equipment																								
Mon – Fri	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.5	0.5	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.7	0.7	0.1	0.1
Sat	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.7	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.7	0.7	0.1	0.1
Sun	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.7	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.7	0.7	0.1	0.1
Lighting																								
Mon – Fri	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.8	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.05	0.05	0.05
Sat	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.8	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.05	0.05	0.05
Sun	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.8	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.05	0.05	0.05
Fans																								
Mon – Fri	Off	Off	Off	Off	Off	Off	Off	Off	On	On	On	On	On	On	On	On	On	On	On	On	On	Off	Off	Off
Sat	Off	Off	Off	Off	Off	Off	Off	Off	On	On	On	On	On	On	On	On	On	On	On	On	On	Off	Off	Off
Sun	Off	Off	Off	Off	Off	Off	Off	Off	On	On	On	On	On	On	On	On	On	On	On	On	On	Off	Off	Off
Cooling	(*) = temperature as design																							
Mon – Fri	Off	Off	Off	Off	Off	Off	Off	Off	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	Off	Off
Sat	Off	Off	Off	Off	Off	Off	Off	Off	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	Off	Off
Sun	Off	Off	Off	Off	Off	Off	Off	Off	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	Off	Off
Heating	(*) = temperature as design																							
Mon – Fri	Off	Off	Off	Off	Off	Off	Off	Off	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	Off	Off
Sat	Off	Off	Off	Off	Off	Off	Off	Off	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	Off	Off
Sun	Off	Off	Off	Off	Off	Off	Off	Off	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	Off	Off
Hot Water																								
Mon – Fri	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.2	0.3	0.4	0.5	0.5	0.5	0.5	0.5	0.5	0.6	0.8	0.8	0.8	0.5	0.05	0.05
Sat	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.3	0.5	0.6	0.7	0.7	0.7	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.5	0.05	0.05
Sun	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.3	0.5	0.6	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.5	0.05	0.05

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Table A9 Operating schedule 'F': sports

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Occupants																								
Mon – Fri	0	0	0	0	0	0	0.3	0.4	0.5	0.5	0.5	0.3	0.3	0.3	0.4	0.5	0.5	0.6	0.8	0.8	0.8	0.5	0	0
Sat	0	0	0	0	0	0	0.3	0.4	0.5	0.7	0.8	0.7	0.7	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.7	0.5	0	0
Sun	0	0	0	0	0	0	0.3	0.4	0.5	0.7	0.8	0.7	0.7	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.7	0.5	0	0
Equipment																								
Mon – Fri	0.1	0.1	0.1	0.1	0.1	0.1	0.5	0.5	0.5	0.9	0.9	0.5	0.5	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.7	0.7	0.1	0.1
Sat	0.1	0.1	0.1	0.1	0.1	0.1	0.7	0.7	0.7	0.9	0.9	0.8	0.8	0.8	0.9	0.9	0.9	0.9	0.9	0.9	0.7	0.7	0.1	0.1
Sun	0.1	0.1	0.1	0.1	0.1	0.1	0.7	0.7	0.9	0.9	0.9	0.8	0.8	0.8	0.9	0.9	0.9	0.9	0.9	0.9	0.7	0.7	0.1	0.1
Lighting																								
Mon – Fri	0.05	0.05	0.05	0.05	0.05	0.05	0.8	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.05	0.05
Sat	0.05	0.05	0.05	0.05	0.05	0.05	0.8	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.05	0.05
Sun	0.05	0.05	0.05	0.05	0.05	0.05	0.8	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.05	0.05
Fans																								
Mon – Fri	Off	Off	Off	Off	Off	Off	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	Off	Off	
Sat	Off	Off	Off	Off	Off	Off	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	Off	Off	
Sun	Off	Off	Off	Off	Off	Off	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	Off	Off	
Cooling	(*) = temperature as design																							
Mon – Fri	Off	Off	Off	Off	Off	Off	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	Off	Off
Sat	Off	Off	Off	Off	Off	Off	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	Off	Off
Sun	Off	Off	Off	Off	Off	Off	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	Off	Off
Heating	(*) = temperature as design																							
Mon – Fri	Off	Off	Off	Off	Off	Off	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	Off	Off
Sat	Off	Off	Off	Off	Off	Off	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	Off	Off
Sun	Off	Off	Off	Off	Off	Off	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	Off	Off
Hot Water																								
Mon – Fri	0.05	0.05	0.05	0.05	0.05	0.05	0.2	0.3	0.4	0.5	0.5	0.3	0.3	0.3	0.5	0.5	0.5	0.6	0.8	0.8	0.8	0.5	0.05	0.05
Sat	0.05	0.05	0.05	0.05	0.05	0.05	0.3	0.5	0.6	0.7	0.7	0.5	0.5	0.5	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.5	0.05	0.05
Sun	0.05	0.05	0.05	0.05	0.05	0.05	0.3	0.5	0.6	0.8	0.8	0.5	0.5	0.5	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.5	0.05	0.05

Table A10 Operating schedule 'G': common activities areas

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Occupants																								
Mon – Fri	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Sat	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Sun	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Equipment																								
Mon – Fri	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Sat	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Sun	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Lighting																								
Mon – Fri	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Sat	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Sun	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Fans																								
Mon – Fri	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On
Sat	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On
Sun	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On
Cooling	(*) = temperature as design																							
Mon – Fri	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)
Sat	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)
Sun	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)
Heating	(*) = temperature as design																							
Mon – Fri	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)
Sat	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)
Sun	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)
Hot Water																								
Mon – Fri	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Sat	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Sun	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9

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2.2.4 Lighting

Heat from lighting fixtures that goes to the space could be assumed as follows:

- for lights suspended in the space, or recessed into a ceiling not used as a return air plenum - 100% to the space;
- for lights recessed into a ceiling used as a return air plenum - 85% to the space, 15% to return air; or
- for lights recessed into return air ducted directly through the fixture - the proportion of heat from lights going to return air, a minimum of 15%.

2.2.5 Envelope components

Envelope components will consist of the following:

- exterior walls;
- roofs;
- doors;
- windows;
- skylights;
- walls in contact with the ground; and
- floors in contact with the ground.

2.2.5.1 Exterior walls, roofs and doors

Input is required for:

- orientation, surface area and thermal transmittance (U-value);
- for exterior wall, the tilt must be greater than 60° from horizontal while for roof, the tilt must be between 0 and 45° from horizontal; and
- absorptivity to be between 0.2 and 0.9, default value could be set to 0.7.

2.2.5.2 Windows and skylights

Input is required for:

- orientation, area, U-value, shading coefficient (SC);
- shading by exterior shading devices such as overhangs and side fins;
- sloping window, which falls in the vertical category if it has a slope equal to or more than 60 degrees from the horizontal, and falls in the skylight category if it slopes less than 60 degrees from the horizontal; and
- window-wall ratio in each orientation, which should be equal for both the reference and designed building (e.g. if the designed building has 40% of window area facing north, the reference building shall also have 40% of window area facing north).

2.2.5.3 Walls and floors in contact with the ground

Input for conditioned floor areas is required to define area and depth with respect to ground level.

2.2.6 Infiltration

Each thermal block of the designed building that contains exterior walls should allow for an infiltration rate as follows:

- a maximum of 5.0 l/s m² for glazed entrance doors and for revolving doors; and
- 2.0 l/s m² for operable windows.

2.2.7 Thermal Mass

Input for the thermal mass or thermal response characteristics for each thermal block is required for energy analysis. The default could be set to "medium weight" construction (around 340 kg/m²).

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2.3 System Description

The building's cooling and heating systems are divided into *Primary system* and *Secondary system*.

Primary system (plant) is the system which consists of equipment such as chillers, boilers, cooling towers, etc. that convert electricity or fuel to cooling or heating effect and distribute it to one or more secondary systems. Secondary system is the system that provides air for distribution of cooling and heating to the thermal blocks (i.e. fan system). Secondary systems may be 'single zone' (serving only a single thermal block), or multiple zone (serving one or more thermal blocks).

The primary and secondary systems are connected by circulation loops which bring cold/hot water from the chillers/boilers to the cooling/heating coils.

2.3.1 Air systems

All air-conditioned zones in a thermal block have to be assigned to an air side system. In general, air side systems can be split into six distinct categories:

(1) *Variable Air Temperature Systems (Constant-volume)*

As heat gain increases, the temperature of the supply air decreases proportionately, and vice-versa. The single-zone AHU system is a representative of this type of system

Another example is the Primary Air Fan Coil System. Fan coil units are either 4-pipe or 2-pipe. Outside air is usually pre-treated in primary air units before introducing to fan coil units. Refer to Figure 2.2 for the typical configuration of a Primary Air Fan Coil System.

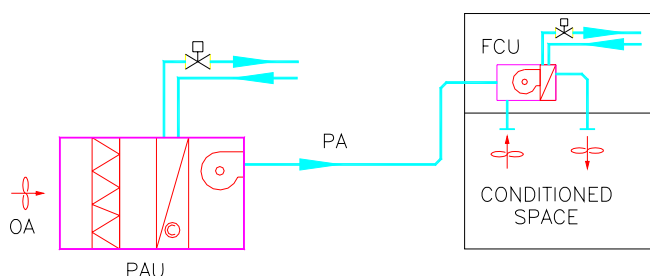


Figure 2.2 Primary air fan coil system

(2) *Reheat Systems (Constant-volume)*

The reheating coil is located downstream of the cooling coil so that all supply air is cooled as well as dehumidified (the supply air is maintained at a constant temperature)

(3) *Air Mixing Systems (Constant-volume)*

These systems are commonly referred to as Dual-Duct and Multizone Systems. They control space temperatures by the mixing of two air streams.

(4) *Variable Air Volume Systems (Constant temperature)*

With a decreasing heat gain in the space, the system responds directly with a corresponding decrease in (cold) air supply to the space. Most systems have a minimum stop beyond which the supply air is no longer decreased. The ratio of this minimum air flow rate to the design air flow rate is the minimum flow ratio. Refer to Figure 2.3 for the typical configuration of a variable air volume system.

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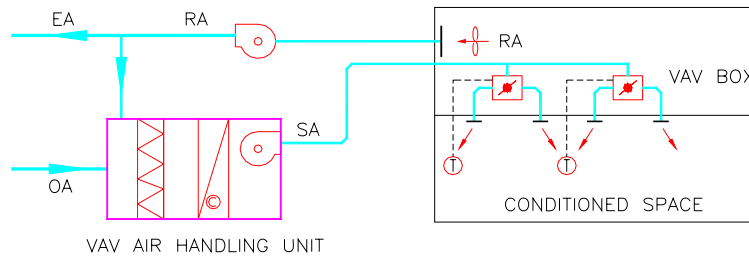


Figure 2.3 Variable air volume system

(5) Hybrid Systems (mixture of 1 through 4)

Hybrid systems are defined here as a combination of any of the above systems. Examples are VAV-Reheat System (Fig. 2.4) and VAV-Dual-Duct System (Fig.2.5).

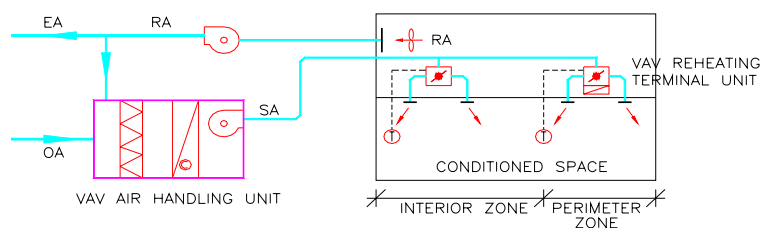


Figure 2.4 VAV reheat system

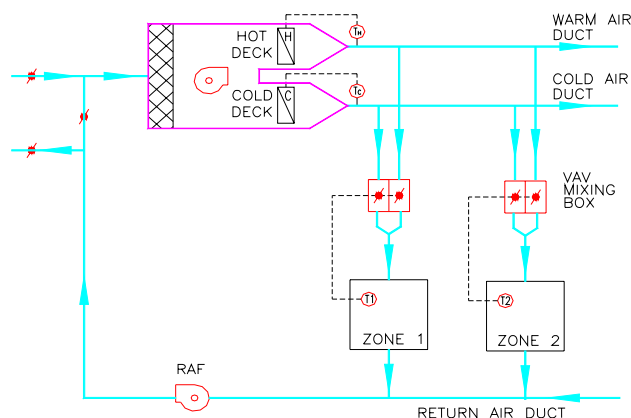


Figure 2.5 VAV dual-duct system

(6) Packaged Units

These are unitary system (fans, compressors and condensers are encased in a single unit). They perform cooling with direct expansion coils and there is no primary equipment.

Depending upon the system type chosen, systems are then “built-up” in the simulation program by specifying the following components:

- cooling coils;
- pre-cool/heat coils;
- heating coils;
- zone (reheat) coils;
- fans (supply ,return, and exhaust);
- thermostats;
- dehumidifiers / Humidifiers;

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- economizers;
- outside air dampers;
- mixing dampers; and
- variable air volume terminal device (VAV box).

2.3.2 System Controls

2.3.2.1 Supply air flow rates

The design air flow rate for each thermal block of the designed building is normally automatically calculated by the simulation program based on the following assumptions:

- a supply-air-to-room temperature difference of 11°C (cooling); and
- a heating supply air temperature of 38°C (heating).

2.3.2.2 Supply air temperature control

The control of supply air temperature of the secondary system should be one of the following:

- a constant setpoint temperature;
- scheduled reset of supply temperature depending on outdoor air temperature; or
- reset of supply temperature from zone requiring maximum cooling or heating.

2.3.2.3 Thermostat throttling range (dead band)

The room throttling range should be set to no greater than 1°C.

2.3.3 Fans

Input is required for the following:

- design static pressure;
- combined fan, drive and motor efficiency;
- position of the fan with respect to the coils (i.e draw through or blow through);
- whether or not the motor is located in the airstream; and
- operation of fan (off, or cycled with cooling/heating to maintain setback temperature) during shutoff/setback period

2.4 Plant description

The following equipment are included as central plant equipment:

- chillers;
- boilers;
- heat rejection equipment (e.g. cooling towers);
- domestic water heaters; and
- circulation loops and water pumps.

2.4.1 Chillers

The following information are required to be specified:

- number of chillers;
- type of chillers;
- design capacity of each chiller;
- COP;
- sequencing of chillers;

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- chilled water supply temperature;
- chilled water supply and return temperature difference; and
- part load performance characteristics.

2.4.2 Boilers

The following information are required to be specified:

- number of boilers;
- type of fuel used;
- design capacity of each boiler;
- boiler full load efficiency;
- sequencing of boilers;
- heating water supply temperature;
- heating water supply and return temperature difference; and
- part load efficiency characteristics.

2.4.3 Pumps

The cooling/heating circulation pumping system should be described with the following:

- pump head;
- water flow rate; and
- pumping power determined with a combined motor/impeller efficiency, a default of 60% be adopted should actual figures not be available.

2.4.4 Cooling towers

If the primary cooling system consists of cooling towers, the following input is required to describe the cooling tower:

- design capacity;
- number of cells;
- design fan power;
- design pump power;
- design entering and leaving water temperature;
- method of temperature control; and
- part load performance characteristics.

2.4.5 Service water heating

If service water heating is of electric resistance type, the input of the heater capacity is required. Efficiency of the electric boiler could be taken as 100%.

If service water heating is by a non-electric boiler, the input for the following is required:

- the fuel used;
- design capacity;
- full load efficiency; and
- part load efficiency characteristics.

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3. Assumptions for reference building

The following shows the minimum input requirements. Designers may choose to input values better than the minimum requirements. Trade-offs are allowed between building aspects with good performances and those with less desired performances. The trade-off is such that the overall good performance effects shall outweigh the less desirable performance effects, as given by the rule that the designed energy must not exceed the energy budget.

3.1 Input for reference building – office, retail and hotel

Table 3.1 Input for reference building

Input parameter			Reference building			Remark	Trade-off items
			Office	Retail shops	Hotel guest rooms		
1. Building description							
<i>1.1 Building envelope (Note 1)</i>							
A	Absorptance of roof	-	As design			Same for both reference and designed building (Note 2)	
B	Absorptance of wall	-	As design				
C	External shading device	-	Nil			Note 3	√
D	Shading coefficient (window)	-	Min. 0.25			Note 4	√
E	U-value of fenestration	W/m ² °C	Max. 6.93 (fixed) Max. 7.21 (operable)			Note 5	√
F	Window-wall ratio	-	As design			Same for both reference and designed building	
G	Shading coefficient (skylight)	-	Min. 0.25			Note 4	√
H	U-value of skylight	W/m ² °C	Max. 7.72			Note 5	√
I	Skylight-roof ratio	-	As design			Same for both reference and designed building	
J	U-value of roof	W/m ² °C	As design (Max. 0.39)			Same for both reference and designed building if value is less than 0.39 (Note 6)	
K	U-value of opaque wall	W/m ² °C	As design (Max. 3.3)			Same for both reference and designed building if value is less than 3.3 (Note 7)	
L	U-value of internal partitions	W/m ² °C	As design			Same for both reference and designed building	
M	U-value of wall below grade	W/m ² °C	As design (Max. 1.99)			Same for both reference and designed building if value less than 1.99 (Note 8)	
N	Thermal mass	kg/m ²	Medium weight			Note 9	
<i>1.2 Building configuration</i>							
A	Floor-to-floor height	m	As design			Same for both reference and designed building	
B	Number of storeys	-	As design				
C	Orientation	-	As design				
D	Perimeter zone depth	-	As design/4 m				
E	Floor area	m ²	As design				
<i>1.3 Space load and space conditions</i>							
A	Space air temperature	°C	As design				
B	Equipment load	W/m ²	Refer to Tables A2 & A3			Same for both reference & designed building	
C	Occupant density	m ² /person					
D	Lighting type		As design				

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Input parameter			Reference building			Remark	Trade-off items
			Office	Retail shops	Hotel guest rooms		
E	Lighting load	W/m ²	Refer to Tables A2 & A3				√
F	Infiltration rate	-	5 l/s m ² (doors) 2 l/s m ² (operable windows)				
G	Thermal block		As design			Same for both reference & designed building (Note 10)	
2. System description							
<i>2.1 System operation</i>							
A	Type of air side system	-	FCU			Note 11	√
B	Outdoor air flow rate	L/s/person	Refer Tables A2 & A3			Same for both reference & designed building	
C	Operation hours		Refer Tables A4 to A10				
D	HVAC system zoning		As design				
<i>2.2 System controls</i>							
A	Minimum supply air ratio		1			Note 12	
B	Thermostat set point	°C	As design				
C	Throttling range	°C	1			Note 13	
D	Supply air flow rates	L/s	As design or based on a supply-air-to-room temperature difference of 11°C for cooling / supply air temp. of 38 °C for heating			Common professional practice	
E	Oversizing ratio		As design			Note 14	
<i>2.3 Fan</i>							
A	Fan speed control		Constant speed			Note 15	√
B	Combined fan-motor-drive efficiency		40%			Note 16	√
C	Fan motor placement		As design			Common professional practice	√
D	Fan static pressure		50 Pa for individual FCU				
3. Plant description							
<i>3.1 Chilled water circuit</i>							
A	Chilled water supply temperature	°C	As design			Typical 7°C	
B	Chilled water design temperature difference	°C	As design			Typical 5.5°C	
<i>3.2 Chilled water pump</i>							
A	Pump motor efficiency		Combined motor/impeller efficiency of 60%			Note 17	√
B	Pump impeller efficiency						
C	Pump head	m	As design			Same for both reference & designed building	
D	Pump sizing		System peak				
E	Pump speed control		As design			Same for both reference & designed building	

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Input parameter	Reference building			Remark	Trade-off items
	Office	Retail shops	Hotel guest rooms		
<i>3.3 Refrigeration and heat rejection</i>					
A	Chiller COP		Meet Air Conditioning Code	Based on suppliers' information	√
B	Heat rejection method		As design	Same for both reference & designed building	
C	Number of chillers		As design	Same for both reference & designed building (Note 18)	
D	Type of compressor		As design	Same for both reference & designed building	
E	Minimum part-load ratio		As design	Same for both reference & designed building	
4. Heating plant					
A	Fuel		Section 3.2		
B	Equipment efficiency		Section 3.2		√
5. Service water heating system					
A	Fuel		As design	Note 19	
B	Water heating equipment efficiency		Section 3.2		√

Explanatory Notes to Table 3.1

Note 1: Building Envelope

Basically, parameters for all of the opaque elements are required to be the same for both the reference and designed building. However, the U-values for the opaque elements should not exceed the maximum/minimum allowable figures as stipulated in notes 2, 5, 6, 7 & 8.

Note 2: Absorptance of wall and roof

The absorptance for the opaque elements are required to be the same as the designed building. Absorptivity for common wall and roof surfaces could be found in Table 4 of the OTTV Code. In case information is not available at the time of submission, a default value of 0.7 could be adopted.

Note 3: External shading device

The reference building is assumed to have glazing that is flushed with its wall or roof surface. This means that the PB-BEC method gives shading credit for window recesses, overhangs, side fins, or other permanent shading devices that reduce solar gains on the glazing.

Interior shading may be included in the PB-BEC method but must be modeled identically for both the reference and designed building so that they are energy neutral for trade-off purposes. Interior shading devices are not considered as permanent features.

Note 4: Shading coefficient (SC) – minimum value of 0.25

The 1998 Working Party on Review of OTTV control was concerned about the unnecessary use of glass with low SC, which is generally accompanied with high reflective glazing and hence glare pollution problems. Besides, low SC also means low visible light transmittance which will penalize the use of daylight, and will bring along psychologically poor indoor visual environment.

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As a result, the Working Party has agreed in early 2000 to limit the SC of glass to be not less than 0.25 as the most simple and appropriate approach.

The Shading coefficient, U-value of fenestration and skylights are allowed to be adjusted so that the reference building could satisfy the OTTV requirements and are therefore not required to be the same as the designed building.

Note 5: U-value of fenestration and skylight

The combination U-value and SC are allowed to be adjusted in order to satisfy the OTTV requirements. However, it is recommended that the maximum U-value should not exceed the following figures:

	Maximum allowed U-value (W/m ² /K)	Typical products
Fenestration	6.93 (fixed)	Single glazing, 10 mm thick glass
	7.21 (operable)	
Skylight	7.72	Single glazing, 10 mm thick glass

Note 6: U-value of roof

The roof U-value shall be the same as the designed building. Again, the recommended maximum U-value should not exceed 0.39 W/m² °C. A typical roof construction in Hong Kong is shown as follows:

Layer material	Thermal conductivity, k (W/m °C)	Resistance (m ² °C/W)
Outside air film	-	0.055
25 mm Concrete tiles	1.1	0.025/1.1 = 0.023
20 mm asphalt	1.15	0.02/1.15 = 0.017
50 mm cement/sand screed	0.72	0.05/0.72 = 0.069
50 mm polystyrene insulation	0.034	0.05/0.034 = 1.471
150 mm concrete	2.16	0.15/2.16 = 0.069
10 mm gypsum plaster c/w white semi gloss paint	0.38	0.01/0.38 = 0.026
Inside air film	-	0.801
Total		2.531

Overall U-value = 1/ 2.531 = 0.39 W/m² °C

Note 7: U-value of opaque wall

The wall U-value shall be the same as the designed building. The recommended maximum U-value should not exceed 3.3 W/m² °C. A typical wall construction in Hong Kong is shown as follows:

Layer material	Thermal conductivity, k (W/m °C)	Resistance (m ² °C/W)
Outside air film	-	0.044
10 mm cement/sand render	0.72	0.01/0.72 = 0.014
150 mm concrete	2.16	0.15/2.16 = 0.069
20 mm gypsum plaster	0.38	0.02/0.38 = 0.053
Inside air film	-	0.12
Total		0.3

Overall U-value = 1/ 0.3 = 3.3 W/m² °C

Note 8: U-value of wall below grade and slab on grade

The U-value shall be the same as the designed building. Although internal design

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temperature is given by the basement air temperature, none of the usual external design air temperatures could apply because of the heat capacity of the soil. In order to simplify the simulation/compliance procedures, the resistance of the interior air film, exterior air film or the effect of earth could be excluded in the calculation of the U-value.

Besides, the designer is also advised to note the assumptions for performing simulations for wall below grade and slab on grade. For example, in DOE-2, it is required to specify an "effective (lower) area" which is defined as one-foot-wide band around the perimeter of the surface for slab-on-grade and a one-foot-high band at the top of the wall for wall below grade.

A typical wall below grade construction in Hong Kong is shown as follows:

Layer material	Thermal conductivity, k (W/m °C)	Resistance (m ² °C/W)
30mm asphalt	1.15	0.03/1.15 = 0.026
400 mm concrete	2.16	0.4/2.16 = 0.185
100 mm air space	-	0.16
100 mm face brick	0.95	0.1/0.95 = 0.105
10 mm gypsum plaster	0.38	0.01/0.38 = 0.026
Total (excluding inside and outside film resistance)		0.502

Overall U-value = $1/0.502 = 1.99 \text{ W/m}^2\text{°C}$

Note 9: Thermal mass

The reference building shall be assigned as "medium weight" construction of which the density is around 340 kg/m³. Besides, such construction is also considered as an average construction adopted in Hong Kong.

Note 10: Thermal block

A thermal block could be a space, or group of spaces, that is considered as one homogeneous space for modeling purposes. A thermal block should be:

- (a) one temperature controlled zone; or
- (b) a group of temperature controlled zones that:
 - are served by the same air handling system, or by systems that can be considered to be identical;
 - are operated and controlled in the same way; and
 - have space use and envelope characteristics that are sufficiently similar that the cooling and heating energy consumption obtained by modeling the group of zones as a thermal block is not significantly different than would be obtained by summing the results for the individual zones modeled separately.

Note 11: Type of air side system

Fan coil unit system is chosen for the reference building as this type of system is commonly employed in Hong Kong.

Note 12 Minimum supply air ratio

As FCU system is employed for the reference building, it is assumed that fresh air intake will be constant and no ventilation control strategy is applied to control the outdoor air supply during part load condition.

For variable air volume systems this is the minimum allowed flow rate specified as a fraction

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of the maximum flow rate. It is required that the minimum air ratio should not be less than 0.3. This means that if a zone needs 1000 l/s at peak design conditions, at least 300 l/s will be delivered at any other time.

Note 13: Throttling range (dead band)

The throttling range is required to be at least 1°C within which the supply of cooling and heating energy to the zone is shut off or reduced to a minimum.

Note 14: Oversizing ratio

The sizing of equipment can have a significant impact on system efficiency, depending on how efficient the equipment is at part load and how often it operates at part load. Sizing differences between the designed building and reference building should be prevented as it could influence trade-offs. It is therefore required that both the designed and reference building should be oversized or undersized to the same degree. The procedures should be as follows:

- (a) calculate the sizing factor for the designed building:

$$\text{sizing factor} = \frac{\text{designed equipment capacity}}{\text{calculated design load}}$$

- (b) calculate the design (peak) load for the reference building;
(c) determine the reference building equipment capacities:

$$\text{equipment capacity of reference building} = \text{calculated design load for reference building} \times \text{sizing factor}$$

Note 15: Fan

The same operating strategy needs to be used for both the designed and reference building. For example, constant volume fan systems can be cycled on and off. For variable volume systems, they should be modeled as operating whenever the spaces they serve are occupied.

Note 16: Fan efficiency

As shown in Table 3.1, a typical value of 50 Pa is chosen for the fan static which is an average value for FCU fan static. The combined fan-motor-drive efficiency is calculated from the following:

$$\text{Average fan efficiency} = 60\%$$

$$\text{Average drive efficiency} = 80\%$$

$$\text{Average motor efficiency} = 86\%$$

$$\text{Combined fan-motor-drive efficiency} = 0.6 \times 0.8 \times 0.86 = 0.4$$

Note 17: Pump and motor efficiency

The required combined motor/impeller efficiency is obtained as follows:

$$\text{Average pump impeller efficiency (include all losses)} = 70\%$$

$$\text{Average motor efficiency} = 86\%$$

$$\text{Combined motor/impeller efficiency} = 0.7 \times 0.86 = 0.6$$

Note 18: District cooling system

If the secondary system is connected to a district cooling supply, it will be assumed that no trade-off could be applied for the primary system. Both the reference and designed buildings

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will be modeled based on a water-cooled plant.

As an alternative for water-cooled plant, the designer may also choose to adopt the "exceptional calculation methods" as stated in the PB BEC Clause 6.4 to model the effects of district cooling using other scientific and reasonable methods .

Note 19: Service water heating system

The only characteristic that may contribute to trade-off credits is the water heater equipment efficiency.

In case where the service water heater is also used for space heating (or vice versa), the reference building is assumed to have a separate boiler for space heating and a separate water heater for service hot-water heating.

3.2 Heating equipment

3.2.1 Heat pumps

If the designed building employs electric heat pump, then the reference building shall also employ electric heat pump with a COP meeting the Air Conditioning Code.

3.2.2 Hydronic heating

The fuel for the reference building heating plant shall be the same as the designed building.

- The reference building heating plant shall be defined as one with efficiency at full load of not less than 80% (other than electrical fuel).

If the reference building contains heating circulation pumps, the power for the pumps could be calculated based on constant speed pump having:

- combined motor/impeller efficiency of 60%; and
- design water flow rate based on designed water temperature drop.

3.3 Cooling equipment

Cooling tower

- If the designed building employs water cooled chillers, the reference building shall also employ water cooled chillers.
- The program shall calculate the cooling tower capacity required based on water temperature rise of 5.5°C.
- Cooling tower fan shall be defined as a constant fan speed with cycling control (in steps according to load).
- Cooling tower pump shall be defined as follows:
 - a constant speed pump with a flow rate determined from tower capacity and water temperature rise of 5.5°C; and
 - combined motor/impeller efficiency of 60%.

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4. Illustrations and examples

4.1 Example for an office building

The input for both the reference building and the designed building (Trade-off Case 7) of a typical 20-storey office building shown in Figures 4.1 & 4.2 are as follows:

Table 4.1 *Input for office reference building and designed building*

Input parameter			Office	
			Reference building	Designed building
1. Building description				
<i>1.1 Building envelope</i>				
A	Absorptance of roof	-	0.7	0.7
B	Absorptance of wall	-	0.7	0.7
C	External shading device	-	Nil	Nil
D	Shading coefficient (window)	-	0.29	0.29
E	U-value of fenestration	W/m ² °C	6.93	4.99
F	Window-wall ratio	-	0.6	0.6
G	Shading coefficient (skylight)	-	Nil	Nil
H	U-value of skylight	W/m ² °C	Nil	Nil
I	Skylight-roof ratio	-	Nil	Nil
J	U-value of roof	W/m ² °C	0.38	0.38
K	U-value of opaque wall	W/m ² °C	2.43	2.43
L	U-value of internal partitions	W/m ² °C	4.02	4.02
M	U-value of wall below grade	W/m ² °C	Nil	Nil
N	Thermal mass	kg/m ²	Medium	Medium
<i>1.2 Building configuration</i>				
A	Floor-to-floor height	m	3.6	3.6
B	Number of storeys	-	30	30
C	Orientation	-	As design	As design
D	Perimeter zone depth	-	4	4
E	Floor area	m ²	47,386 m ²	47,386 m ²
<i>1.3 Space load and space conditions</i>				
A	Space air temperature	°C	24 (summer) 21 (winter)	24 (summer) 21 (winter)
B	Equipment load	W/m ²	10	10
C	Lighting load	W/m ²	20	25
D	Occupant density	m ² /person	13	13
E	Lighting type	-	--	As design
F	Infiltration rate	-	2 l/s m ² for operable window	2 l/s m ² for operable window
G	Thermal block		As design	As design

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Input parameter		Office		
		Reference building		Designed building
2. System description				
<i>2.1 System operation</i>				
A	Type of air side system	-	FCU	VAV
B	Outdoor air flow rate	L/s/person	8 l/s	8 l/s
C	Operation hours		Schedule 'A'	Schedule 'A'
D	HVAC system zoning		As design	As design
<i>2.2 System controls</i>				
A	Minimum supply air ratio		1	0.3
B	Thermostat set point	°C	24 (summer) 21 (winter)	24 (summer) 21 (winter)
C	Throttling range	°C	1	1
D	Supply air flow rates	L/s	S.A. temp 13°C cooling 11°C differential; SA temp 38 °C heating	S.A 13°C cooling; SA temp 38 °C heating
E	Oversizing ratio		1 for cooling 1.2 for heating	1 for cooling 1.2 for heating
F	Preheat coil		Nil	Nil
G	Outdoor air control	-	Constant	Constant
<i>2.3 Fan</i>				
A	Fan control method		-	Variable frequency drive
B	Fan efficiency		Fan-motor-drive efficiency of 40%	Fan-motor-drive efficiency of 50%
C	Fan motor efficiency			
D	Fan motor placement		Inside air stream	Inside air stream
E	Fan placement		Blow-through	Blow-through
F	Fan static pressure		50 Pa	500 Pa
3. Plant description				
<i>3.1 Chilled water circuit</i>				
A	Chilled water supply temperature		7°C	7°C
B	Chilled water design temperature difference		5.5°C	5.5°C
<i>3.2 Chilled water pump</i>				
A	Primary chilled water pump		√	√
B	Secondary chilled water pump		√	√
C	Pump motor efficiency		Combined motor/impeller efficiency of 60%	Combined motor/impeller efficiency of 65%
D	Pump impeller efficiency			
E	Pump head	m	30 m	30 m
F	Pump sizing		System peak	System peak
G	Speed		Constant	Constant

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Input parameter		Office		
		Reference building	Designed building	
<i>3.3 Refrigeration and heat rejection</i>				
A	Chiller COP		2.9	3.0
B	Heat rejection		Air cooled	Air cooled
C	Number of chillers		5	5
D	Type of chiller		Air-cooled Screw	Air-cooled Screw
4. Heating plant				
A	Fuel		Electric resistance	Electric resistance
5. Service water heating system				
	Equipment		Nil	Nil

4.2 Illustration on Trade-off alternatives for office building

The following table shows the trade-off procedures for the said office building. The designed energy initially exceeds the energy budget by 11.5%. 5 trade-off options are implemented to reduce the design energy consumption until it is lower than the energy budget, and 2 more options are implemented for enhanced energy efficiency design:

- Case 1 - improve chiller COP
- Case 2 - improve combined pump-motor efficiency of the chilled water pumps
- Case 3 - use building integrated photovoltaic panel
- Case 4 - improve combined fan-drive-motor efficiency of the FCU
- Case 5 - change air side system to VAV
- Case 6 - use economizer cycle for free cooling
- Case 7 - utilize daylight control

Table 4.2 Trade-off alternatives for office building

Items	Reference building	Designed building							
		Design Base	Trade-off Case 1	Trade-off Case 2	Trade-off Case 3	Trade-off Case 4	Trade-off Case 5	Trade-off Case 6	Trade-off Case 7
OTTV = 30 W/m ² , SC = 0.29, Window/wall ratio = 0.6									
Chiller COP	2.9	2.9	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Combined pump-motor efficiency	60%	60%	60%	65%	65%	65%	65%	65%	65%
BIPV	No	No	No	No	Yes (80W/m ² x 200m ²)	Yes (80W/m ² x 200m ²)	Yes (80W/m ² x 200m ²)	Yes (80W/m ² x 200m ²)	Yes (80W/m ² x 200m ²)
Combined fan-drive-motor efficiency	40%	40%	40%	40%	40%	50%	50%	50%	50%
HVAC System	FCU	FCU	FCU	FCU	FCU	FCU	VAV	VAV	VAV
Economizer	No	No	No	No	No	No	No	Yes	Yes
Daylight Control	No	No	No	No	No	No	No	No	Yes (500 lux, 0.5)
Lighting power density	15 W/m ²	20 W/m ²	20 W/m ²	20 W/m ²	20 W/m ²	20 W/m ²	20 W/m ²	20 W/m ²	20 W/m ²
Overall consumption (kWh)	9,608,685	10,732,623	10,629,620	10,593,039	10,572,823	10,245,521	9,598,618	9,516,792	9,434,004
	100%	111.5%	110.4%	110.0%	109.8%	106.4%	99.7%	98.9%	98.00%

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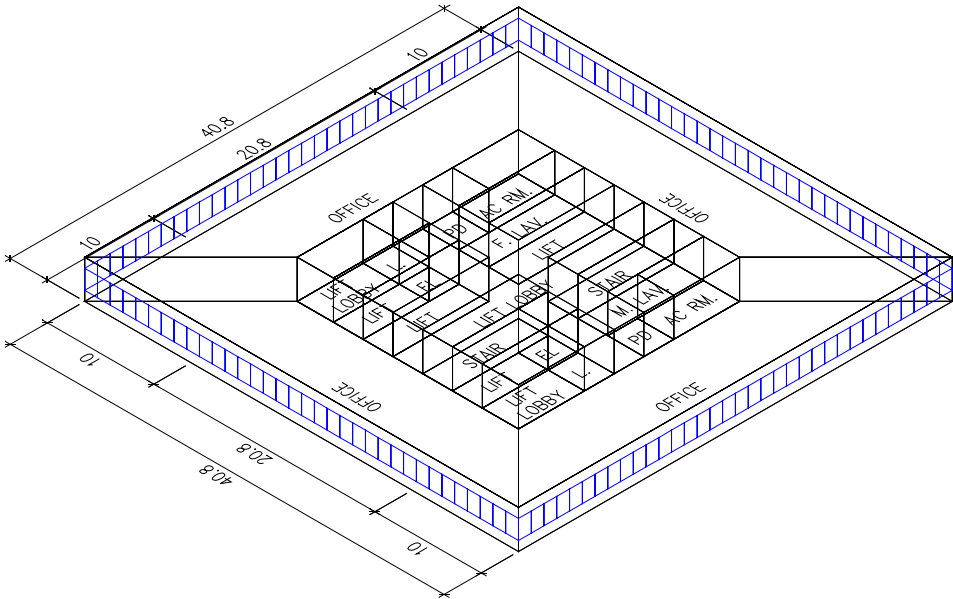


Figure 4.1 Typical floor for office building (isometric view)

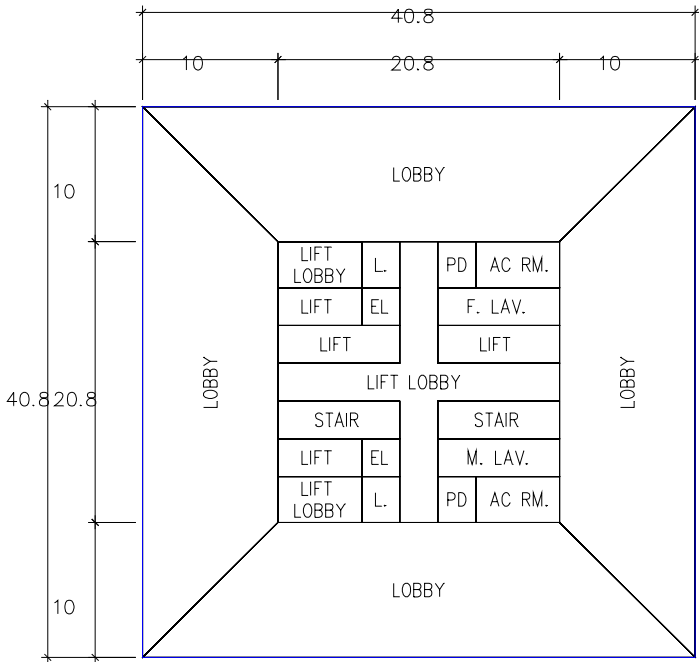


Figure 4.2 Typical floor plan for office building

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4.3 Submission forms for office building

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Job Ref. No. _____ Office _____

Compliance Summary	Form PB-1
--------------------	-----------

A. Applicant Information

Name of organisation:	XXXX	
Address:		
Telephone no.:		
Fax no.:		
E-mail:		
Registered Professional Engineer (RPE) responsible for the compliance:	Name: XXXX RPE no.: XXXX Discipline: XXXX	Telephone no.: Fax no.: E-mail:
Signature:		
Date:		

B. Project Information

Project/Building name:	XXXX Office
Project/Building address:	XXXX Road, Hong Kong
Primary building type:	Office
Other building usage(s):	-
No. of storeys:	30
Building height (m):	108
Gross floor area (m ²):	49,939
Floor area (m ²):	47,386
Air-conditioned floor area (m ²):	42,996
Construction starting date:	Jan 2008
Expected completion date:	Dec 2009

C. Summary of Building Energy Performance

Design energy consumption (MWh)	9,434	
Total energy budget (MWh)	9,609	
Breakdown of energy usage (MWh):	<u>Designed Building</u>	<u>Reference Building</u>
- Area lights	3641	2784
- Miscellaneous equipment	2059	2059
- Space cooling	2898	3002
- Space heating	2	49
- Ventilation fans	451	1290
- Pumps	405	424
- Other energy uses (pls. specify)	-ive 22 (recovered energy from D. below)	Nil
Energy use intensity (kWh/m ² /year) (based on gross floor area)	190	192

D. Site-renewable or Site-recovered Energy

Have you considered "site-renewable energy" or "site-recovered energy" and excluded it in the design energy consumption? Yes / ~~No~~
If yes, please provide detailed information and calculation for the "site-renewable energy" or "site-recovered energy". Use additional sheets if necessary.

*Total energy = Area of photo-voltaic panel x Power generated by photo-voltaic panel per area x Duration of Sunshine
Total energy = 200 m² x 80W/m² x 1376.8hrs (simplified calculation method)
Total energy = 22029kWh*

Guidelines on Performance-based Building Energy Code

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Basic Requirements Checklist	Form PB-2
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1. Building Envelope

Building (Energy Efficiency) Regulation Cap. 123 Sub. Leg. M	Yes
Shading coefficient of window glasses shall be not less than 0.25.	0.29

2. Lighting

<ul style="list-style-type: none"> • Minimum allowable luminous efficacy [Lighting Code 4.1] • Maximum allowable lamp controlgear loss [Lighting Code 4.2] • Interior lighting control [Lighting Code 4.4] 	Yes Yes Yes
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3. HVAC

Air Side System <ul style="list-style-type: none"> • System load design [Air Conditioning Code 4] • Separate distribution system [Air Conditioning Code 5.1.1] • Air leakage limit on ductwork [Air Conditioning Code 5.1.2] 	Yes Yes Yes
Water Side System <ul style="list-style-type: none"> • Pumping system [Air Conditioning Code 6.1] • Friction loss [Air Conditioning Code 6.2] 	Yes Yes
Control <ul style="list-style-type: none"> • Temperature control [Air Conditioning Code 7.1] • Humidity control [Air Conditioning Code 7.2] • Zone control [Air Conditioning Code 7.3] • Off hours control [Air Conditioning Code 7.4] 	Yes N/A Yes Yes
Insulation <ul style="list-style-type: none"> • Piping insulation [Air Conditioning Code 8] • Ductwork and AHU casing insulation [Air Conditioning Code 8] 	Yes Yes

4. Electrical

Power Distribution in Buildings <ul style="list-style-type: none"> • High voltage distribution [Electrical Code 4.1] • Minimum transformer efficiency [Electrical Code 4.2] • Locations of distribution transformers and main LV switchboards [Electrical Code 4.3] • Main circuits [Electrical Code 4.4] • Feeder circuits [Electrical Code 4.5] • Sub-main circuits [Electrical Code 4.6] • Final circuits [Electrical Code 4.7] 	N/A N/A Yes Yes Yes Yes Yes
<ul style="list-style-type: none"> • Efficient Utilisation of Power • Motors and drives [Electrical Code 5.4] • Power factor improvement [Electrical Code 5.5] 	Yes Yes
Power Quality <ul style="list-style-type: none"> • Maximum total harmonic distortion [Electrical Code 6.1] • Balancing of single-phase loads [Electrical Code 6.2] 	Yes Yes
Metering and Monitoring Facilities <ul style="list-style-type: none"> • Main circuits [Electrical Code 7.1] • Sub-main and feeder circuits [Electrical Code 7.2] 	Yes Yes

5. Lift & Escalator

Lift <ul style="list-style-type: none"> • Maximum allowable electrical power [Lift/Escalator Code 4.1] • Energy management of lift systems [Lift/Escalator Code 4.2] • Total harmonic distortion of motor drive systems [Lift/Escalator Code 4.3] • Total power factor of motor drive systems [Lift/Escalator Code 4.4] 	Yes Yes Yes Yes
Escalators & Passenger Conveyors <ul style="list-style-type: none"> • Energy management of escalators & passenger conveyors [Lift/Escalator Code 5.1] • Max allowable electrical power of escalators & passenger conveyors [Lift/Escalator Code 5.2] • Total harmonic distortion of motor drive systems [Lift/Escalator Code 5.3] • Total power factor of motor drive systems [Lift/Escalator Code 5.4] 	Yes Yes Yes Yes

Support Documentation

<i>Description of document</i>	<i>No. of pages</i>

Guidelines on Performance-based Building Energy Code

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Numerical Method for Building Energy Analysis	Form PB-3
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1. General Information

Name of software/method:	VisualDOE 4
Software version number:	
Software release number (if any):	
Name of software license owner:	XXXX

2. Software Developer/Supplier

Organisation that developed the software:	Eley Associates
Organisation that supplied the software:	Eley Associates

3. Climatic Data

Climatic data used for the analysis:	TRY 1989 for Hong Kong
Format and nature of the climatic data:	

4. Systems or Equipment Not Yet Determined But Assumed

<i>Items</i>	<i>Description</i>

5. Other Modelling Assumptions

<i>Items</i>	<i>Description</i>

6. Limitations of the Software/Method

<i>Items</i>	<i>Description</i>

Support Documentation

<i>Description of document</i>	<i>No. of pages</i>
Input building description file (printed and electronic format)	
Output reports file (printed and electronic format)	

Guidelines on Performance-based Building Energy Code

Performance-based Building Energy Code

Job Ref. No. _____ Office _____

Key Building Data Summary		Form PB-4
	Designed Building	Reference Building
1. General Information		
Total gross floor area (m ²)	49,939	49,939
Average occupant density (m ² /person)	13	13
Minimum outdoor air (l/s per person)	8	8
2. Building Envelope		
Gross wall area (m ²)	17,625.6	17,625.6
Window-to-wall ratio	0.6	0.6
Shading coefficient of windows	0.29	0.29
Gross roof area (m ²)	1,664.64	1,664.64
Skylight- roof ratio	NA	NA
Shading coefficient of skylights	NA	NA
OTTV of exterior walls (W/m ²)	Combined OTTV value of 30	Combined OTTV value of 30
OTTV of roof (W/m ²)		
External shading device provided?	Nil	Nil
3. Lighting		
Average lighting power density (W/m ²)	20	15
Daylighting design provided? How?	Yes (Off/0.33/0.66/On)	No
4. HVAC		
Number of chiller	5	5
Total cooling capacity (kW)	5750	4800
Total heating capacity (kW)	N/A	N/A
Type of air side system	VAV	FCU
Total design supply air flow rate (m ³ /s)	252	234
Type of chiller plant	Air cooled/screw	Air cooled/screw
Chiller coefficient of performance (kW/kW)	3.0	2.9
5. Electrical		
Total installed equipment capacity (kW)	499	499
Average equipment power density (W/m ²)	10 W/m ²	10 W/m ²
6. Service Hot Water		
Service hot water provided? Fuel?	No	No
Total heating capacity (kW)	N/A	N/A

List of Energy-related Features for Trade-off		Form PB-5
Features	Description	
Chiller COP	Select chiller with COP of 3.0	
Improve pump-motor efficiency	Adopt combined pump-motor efficiency of 65%	
Use renewable energy	Use PV panel	
Improve fan-drive-motor efficiency	Adopt combined FCU fan-drive-motor efficiency of 50%	
Change air side system	Adopt VAV	
Economizer cycle	Add economizer cycle to reduce energy consumption	
Daylight	Utilize daylight controls	

Guidelines on Performance-based Building Energy Code

4.4 Example for a hotel building

- A hotel building consisting of 20 storeys of typical guest room floors as shown in Figure 4.3 will be used as an example for illustrations. Each guest room floor will consist of air-conditioned space (guest rooms, corridor and housekeeping) and non air-conditioned space (bath room, stair and lift well).

The input for both the reference building and the designed building (Base Case) are as follows:

Table 4.3 *Input for hotel reference building and designed building*

Input parameter		Hotel guest rooms		
		Reference building	Designed building	
1. Building description				
<i>1.1 Building envelope</i>				
A	Absorptance of roof	-	0.7	0.7
B	Absorptance of wall	-	0.7	0.7
C	External shading device	-	Nil	Nil
D	Shading coefficient (window)	-	0.32	0.32
E	U-value of fenestration	W/m ² °C	7.21	5.7
F	Window- wall ratio	-	0.5	0.5
G	Shading coefficient (skylight)	-	Nil	Nil
H	U-value of skylight	W/m ² °C	Nil	Nil
I	Skylight-roof ratio	-	Nil	Nil
J	U-value of roof	W/m ² °C	0.39	0.39
K	U-value of opaque wall	W/m ² °C	2.32	2.32
L	U-value of internal partitions	W/m ² °C	2.76	2.76
M	U-value of wall below grade	W/m ² °C	Nil	Nil
N	Thermal mass	kg/m ²	medium	medium
<i>1.2 Building configuration</i>				
A	Floor-to-floor height	m	3.6	3.6
B	Number of storeys	-	20	20
C	Orientation	-	As design	As design
D	Perimeter zone depth	-	-	-
E	Floor area	m ²	23,768 m ²	23,768 m ²
<i>1.3 Space load and space conditions</i>				
A	Space air temperature	°C	24 (summer) 21 (winter)	24 (summer) 21 (winter)
B	Equipment load		900W/room	900W/room
C	Lighting load	W/m ²	18	18
D	Occupant density		2 persons/room	2 persons/room
E	Lighting type	-	--	As design
F	Infiltration rate	-	2 l/s m ² for operable window	2 l/s m ² for operable window
G	Thermal block	-	As design	As design
2. System description				
<i>2.1 System operation</i>				
A	Type of air side system	-	FCU	FCU
B	Outdoor air flow rate		30 l/s per room	30 l/s per room
C	Operation hours		Schedule 'D'	Schedule 'D'
D	HVAC system zoning		As design	As design
<i>2.2 System controls</i>				
A	Minimum supply air ratio		1	1

Guidelines on Performance-based Building Energy Code

Input parameter			Hotel guest rooms	
			Reference building	Designed building
B	Thermostat set point	°C	24 (summer) 21 (winter)	24 (summer) 21 (winter)
C	Throttling range	°C	1	1
D	Supply air flow rates	L/s	SA temp. 13°C cooling at 11°C differential; SA temp. 38 °C heating	SA temp. 13°C cooling at 11°C differential; SA temp. 38 °C heating
E	Oversizing ratio		1 for cooling 1.2 for heating	1 for cooling 1.2 for heating
F	Type of heat recovery		Nil	Heat recovery wheel applied to guest rooms
G	Heat recovery wheel effectiveness		Nil	0.7
<i>2.3 Fan</i>				
A	Fan speed control		constant	constant
B	Combined fan-motor-drive efficiency		40%	50%
C	Fan motor placement		Inside air stream	Inside air stream
D	Fan static pressure		50 Pa	50 Pa
3. Plant description				
<i>3.1 Chilled water circuit</i>				
A	Chilled water supply temperature		7	7
B	Chilled water design temperature difference	°C	5.5	5.5
<i>3.2 Chilled water pump</i>				
A	Primary chilled water pump		√	√
B	Secondary chilled water pump		x	x
C	Pump motor efficiency		Combined motor/impeller efficiency of 60%	Combined motor/impeller efficiency of 65%
D	Pump impeller efficiency			
E	Pump head	m	30 m	30 m
F	Pump sizing		System peak	System peak
G	Pump speed		Constant	Constant
<i>3.3 Refrigeration and heat rejection</i>				
A	Chiller COP		4.6	4.2
B	Heat rejection method		Water cooled	Water cooled
C	Number of chillers		3	3
D	Type of chiller		Screw	Screw
E	Minimum part load ratio		10%	10%
F	Cooling tower		One-speed fan	One-speed fan
<i>3.4 Condenser water pump</i>				
A	Pump motor efficiency		Combined motor/impeller efficiency of 60%	Combined motor/impeller efficiency of 65%
B	Pump impeller efficiency			
C	Pump sizing		System peak	System peak
4. Heating plant				
A	Fuel		Electric resistance	Electric resistance
5. Service water heating system				
A	Fuel		Electric	Electric
B	Equipment		Electric boiler	Heat pump
C	COP		1	3

Guidelines on Performance-based Building Energy Code

4.5 Illustration on Trade-off alternatives for hotel building

The following table shows the trade-off procedures for the said hotel building. The designed energy initially exceeds the energy budget by 1.2%. It is mainly due to the use of older model chillers with slightly lower COP to meet budget constraint. To off-set the COP effect, 3 trade-off options are reduce the design energy consumption until it is lower than the energy budget, and 1 more option is implemented for enhanced energy efficiency design:

- Case 1 - improve combined pump-motor efficiency of the chilled water pumps
- Case 2 - improve combined fan-drive-motor efficiency of the FCUs
- Case 3 - use air-to-air heat recovery
- Case 4 - utilize heat pump as the services water heating plant

Table 4.4 Trade-off alternatives for hotel building

Items	Reference building	Designed building				
		Base case	Trade-off Case 1	Trade-off Case 2	Trade-off Case 3	Trade-off Case 4
OTTV = 29 W/m ² , SC = 0.32, Window/wall ratio = 0.5						
Chiller COP	4.6	4.2	4.2	4.2	4.2	4.2
Combined pump-motor efficiency	60%	60%	65%	65%	65%	65%
Combined fan-drive-motor efficiency	40%	40%	40%	50%	50%	50%
Heat recovery	No	No	No	No	Yes	Yes
Services water heating plant	Electric boiler	Electric boiler	Electric boiler	Electric boiler	Electric boiler	Heat pump
Lighting power density	17 W/m ²	17 W/m ²	17 W/m ²	17 W/m ²	17 W/m ²	17 W/m ²
Overall consumption	3,714,362 kWh	3,760,435 kWh	3,756,018 kWh	3,738,369 kWh	3,605,399 kWh	3,589,543 kWh
	100%	101.2%	101.1%	100.6%	97.1%	96.6%

Guidelines on Performance-based Building Energy Code

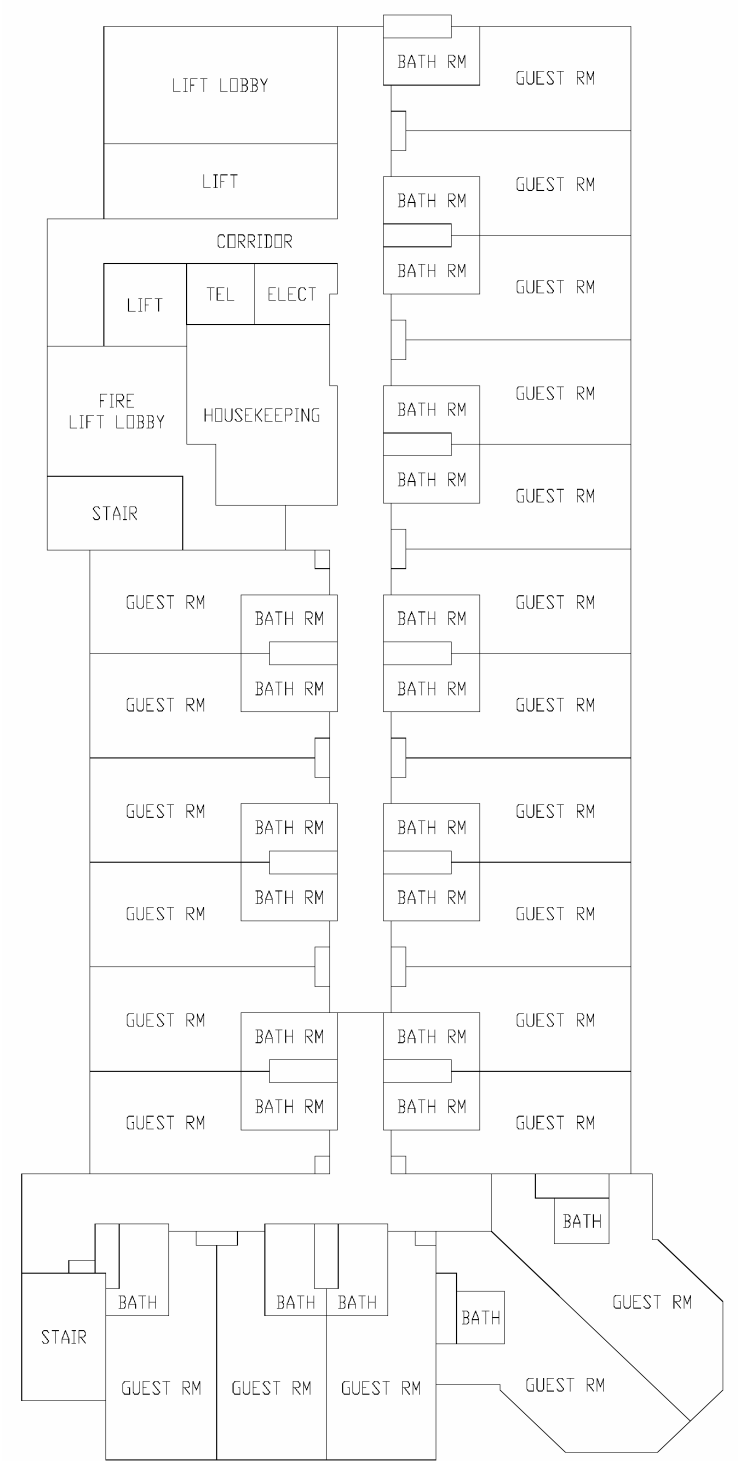


Figure 4.3 Typical floor plan for hotel building

Guidelines on Performance-based Building Energy Code

4.6 Example for a retail building

The input for both the reference building and the designed building (Trade-off Case 5) of the retail building shown in Figures 4.4 & 4.5 are as follows:

Table 4.5 *Input for retails reference building and designed building*

Input parameter			Retail	
			Reference building	Designed building
1. Building description				
<i>1.1 Building envelope</i>				
A	Absorptance of roof	-	0.7	0.7
B	Absorptance of wall	-	0.7	0.7
C	External shading device	-	Nil	Nil
D	Shading coefficient (window)	-	0.95	0.95
E	U-value of fenestration	W/m ² °C	6.172	6.172
F	Window-wall ratio	-	0.75	0.75
G	Shading coefficient (skylight)	-	Nil	Nil
H	U-value of skylight	W/m ² °C	Nil	Nil
I	Skylight-roof ratio	-	Nil	Nil
J	U-value of roof	W/m ² °C	0.38	0.38
K	U-value of opaque wall	W/m ² °C	2.43	2.43
L	U-value of internal partitions	W/m ² °C	4.02	4.02
M	U-value of wall below grade	W/m ² °C	Nil	Nil
<i>1.2 Building configuration</i>				
A	Floor-to-floor height	M	5	5
B	Number of storeys	-	3	3
C	Orientation	-	As design	As design
D	Perimeter zone depth	-	-	-
E	Floor area	m ²	6,480 m ²	6,480 m ²
<i>1.3 Space load and space conditions</i>				
A	Space air temperature	°C	24 (summer) 21 (winter)	24 (summer) 21 (winter)
B	Equipment load	W/m ²	30	30
C	Lighting load	W/m ²	18	23
D	Occupant density	m ² /person	10	10
E	Lighting type	-		As design
F	Infiltration rate	-	2 l/s m ² for operable window	2 l/s m ² for operable window
G	Thermal mass	kg/m ²	Medium	Medium
2. System description				
<i>2.1 System operation</i>				
A	Type of air side system	-	FCU	VAV
B	Outdoor air flow rate	L/s/person	8 l/s	8 l/s
C	Operation hours		Schedule 'C'	Schedule 'C'
D	HVAC system zoning		As design	As design

Guidelines on Performance-based Building Energy Code

Input parameter			Retail	
			Reference building	Designed building
<i>2.2 System controls</i>				
A	Minimum supply air ratio		1	1
B	Thermostat set point	°C	24 (summer) 21 (winter)	24 (summer) 21 (winter)
C	Throttling range	°C	1	1
D	Supply air flow rates	L/s	S.A. temp. 13°C cooling 11°C differential; SA temp. 38 °C heating	S.A. 13°C cooling; SA temp. 38 °C heating
E	Oversizing ratio		1 for cooling 1.2 for heating	1 for cooling 1.2 for heating
<i>2.3 Fan</i>				
A	Fan control method		-	
B	Fan efficiency		Fan-motor-drive efficiency of 40%	Fan-motor-drive efficiency of 50%
C	Fan motor efficiency			
D	Fan motor placement		Inside air stream	Inside air stream
E	Fan placement		Blow-through	Draw-through
F	Fan static pressure		50 Pa	500 Pa
3. Plant description				
<i>3.1 Chilled water circuit</i>				
A	Chilled water supply temperature		7	7
B	Chilled water design temperature difference		5.5	5.5
<i>3.2 Chilled water pump</i>				
A	Primary chilled water pump		√	√
B	Secondary chilled water pump		x	x
C	Pump motor efficiency		Combined motor/impeller efficiency of 60%	Combined motor/impeller efficiency of 65%
D	Pump impeller efficiency			
E	Pump head	m	30 m	30 m
F	Pump sizing		System peak	System peak
G	Pump speed control		Constant	Constant
<i>3.3 Refrigeration and heat rejection</i>				
A	Chiller COP		2.9	3.2
B	Heat rejection method		Air cooled	Air cooled
C	Number of chillers		2	2
D	Type of refrigerant plant		Screw	Screw
4. Heating plant				
A	Fuel		Electric resistance	Electric resistance
5. Service water heating system				
A	Fuel		Nil	Nil
B	Equipment efficiency		Nil	Nil

Guidelines on Performance-based Building Energy Code

4.7 Illustration on Trade-off alternatives for retail building

The following table shows the trade-off procedures for the said retail building. The designed energy initially exceeds the energy budget by 12%. 4 trade-off options are implemented to reduce the design energy consumption until it is lower than the energy budget, and a further option is implemented for enhanced energy efficiency in design:

- Case 1 - improve chiller COP
- Case 2 - improve combined pump-motor efficiency of the chilled water pumps
- Case 3 - improve combined fan-drive-motor efficiency of the FCU
- Case 4 - change air side system to VAV
- Case 5 - adopt economizer cycle

Table 4.6 Trade-off alternatives for retails building

Items	Reference building	Designed building					
		Base case	Trade-off Case 1	Trade-off Case 2	Trade-off Case 3	Trade-off Case 4	Trade-off Case 5
OTTV = 67.52 W/m ² , SC = 0.95, Window/wall ratio = 0.75							
Chiller COP	2.9	2.9	3.2	3.2	3.2	3.2	3.2
Combined pump-motor efficiency	60%	60%	60%	65%	65%	65%	65%
Combined fan-drive-motor efficiency	40%	40%	40%	40%	50%	50%	50%
System	FCU	FCU	FCU	FCU	FCU	VAV	VAV
Economizer	No	No	No	No	No	No	Yes
Lighting power density	18 W/m ²	23 W/m ²	23 W/m ²	23 W/m ²	23 W/m ²	23 W/m ²	23 W/m ²
Overall consumption	2,521,117 kWh	2,818,532k Wh	2,669,546 kWh	2,660,858k Wh	2,556,189 kWh	2,294,660 kWh	2,264,789 kWh
	100%	112%	106%	106%	101%	91%	90%

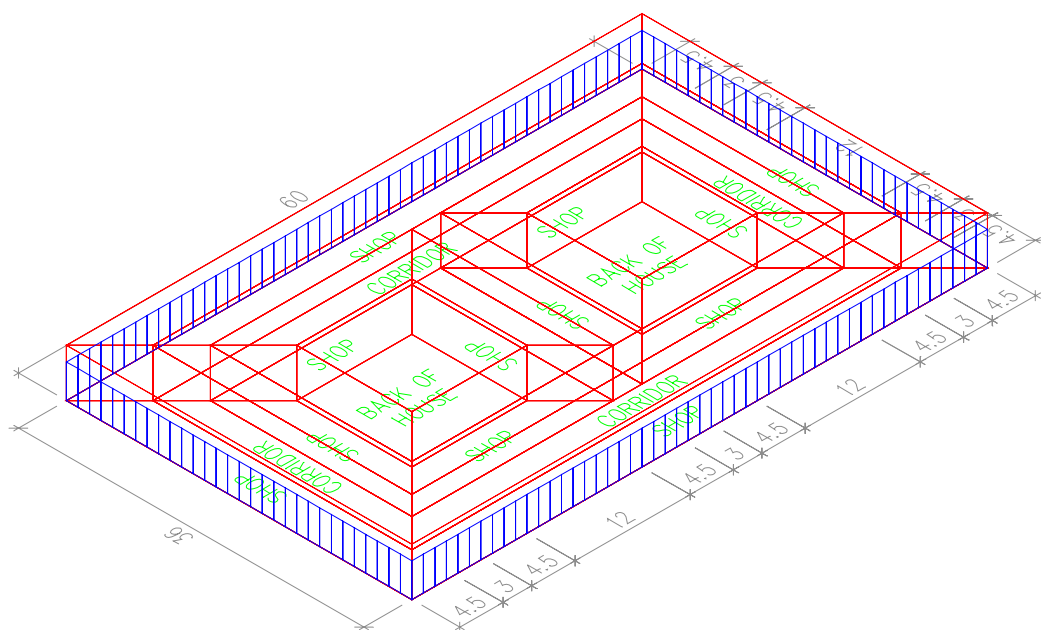


Figure 4.4 Typical floor for retail building (isometric view)

Guidelines on Performance-based Building Energy Code

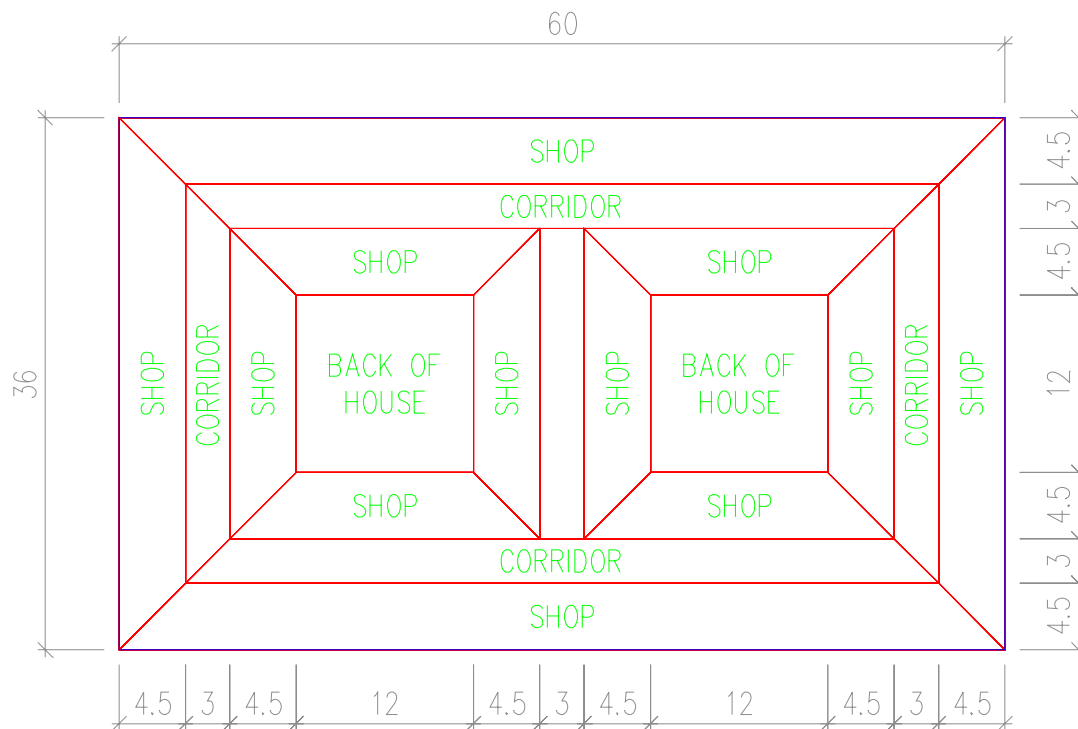


Figure 4.5 Typical floor plan for retail building

5. References

Reference has been made to the following documents in determining some of the input parameters and methods in the Guidelines:

- ASHRAE, 2001. *ANSI (American National Standards Institute) / ASHRAE / IESNA (Illuminating Engineering Society of North America) Standard 90.1-2001, Energy Standard for Buildings Except Low-rise Residential Buildings*, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Atlanta, Georgia.
- ASHRAE, 2000. *Standard 90.1-1999 - Energy Standard for Buildings Except Low-Rise Residential Buildings, User's Manual*, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Atlanta, Georgia.
- Canadian Commission on Building and Fire Codes, 1999. *Performance Compliance for Buildings – Specifications for Calculation Procedures for Demonstrating compliance to the Model National energy Code for Buildings Using Whole Building Performance*, National research Council, Canada.
- *DOE-2 Basics (2.1E)*, Lawrence Berkeley Laboratory
- *VisualDOE 3.0 Program Documentation, 2001*, Eley Associates

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