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Benchmarking the energy performance of hotel buildings in Hong Kong

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ABSTRACT

Hotel buildings in Hong Kong use significant amount of energy and the potential for energy savings is large. However, the energy performance of hotel buildings is difficult to evaluate and compare because they have different building designs, functional facilities and operational requirements. To promote better and more effective management and design of hotels, benchmarking technique can be used to assess the energy performance and provide useful information to support strategic decision making and planning.

This paper reports the major findings of a research to investigate the energy consumption of hotel buildings in Hong Kong and to develop systematic methods for benchmarking their energy performance. The current knowledge and worldwide experience of energy benchmarking were reviewed critically. The major characteristics of the design and operation of hotel buildings in Hong Kong were studied. Theoretical energy models were established to assess the energy consumption patterns and develop suitable benchmarks. It is hoped that the research findings could provide hints and practical guidelines to reduce hotel energy consumption and carbon emissions.

Keywords: Hotel buildings, energy benchmarking, energy management, Hong Kong.

香港酒店建築物能耗表現的基準分析

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摘要: 香港的酒店建築物使用大量能源，其節能的潛力也很大。但是，酒店建築節能性能是難以評價和比較，因為他們有不同的建築設計、功能設施和業務的要求。為了促進更好和更有效的酒店管理和設計，可以運用基準技術作評估，並提供有用的節能表現資料，以支援戰略決策和規劃。本論文報告一項研究的主要結果，其目標為探討香港酒店建築物的能源消耗情況，以及發展有系統的基準方法來評估能耗的表現。就目前全世界能耗基準的知識和經驗進行了仔細的審查。並且對香港酒店建築的設計和運作的主要特點進行了研究。也建立了能耗的理論模型來評估能源消費模式和發展適當的基準。我們希望研究結果可以提供提示和實際指導方針，以減少酒店的能源消耗和碳排放量。

關鍵詞: 酒店建築物，能耗基準，能量管理，香港。

1. Introduction

Hotels consume significant amounts of energy for daily operations and related activities. In recent years, the management of energy use in hotel buildings has attracted much attention in many countries (Deng and Burnett, 2002; Gao, *et al.*, 2003; Karthik, 2002; Khemiri and Hassairi, 2005; Rajagopalan, Wu and Lee, 2009; Santamouris, *et al.*, 1996; Trung and Kumar, 2005; Wu, 2007; Zmeureanu, Hanna and Fazio, 1994). It is believed that the potential of energy savings in the hotel sector is quite large (Ali, *et al.*, 2008; Bannister, 2008; Beccali, *et al.*, 2009; Deng and Burnett, 2000; ESCWA, 2003).

Managing and controlling energy better will reduce energy costs and help increase competitiveness and profitability of the hotel. Also, using energy more efficiently can reduce greenhouse gases and pollution from electricity generation and heat production, hence contribute to environmental management and sustainable operation of hotels (ITP, 2008; Jones and Lockwood, 2002; Kirk, 1995; Manhas, 2002). This is becoming more and more important for hoteliers since green hotels are a marketing ploy (Pizam, 2009) and sustainable tourism is an emerging trend (Bohdanowicz, Churie-Kallhauge and Martinac, 2001).

However, the energy performance of hotel buildings is difficult to evaluate and compare because they have different building designs, functional facilities and operational requirements (Deng and Burnett, 2000). To promote better and more effective management and design of hotels, benchmarking technique can be used to assess the energy performance and provide useful information to support strategic decision making and planning (Bohdanowicz and Martinac, 2007; Karthik, 2002; IBLF and WWF-UK, 2005).

This paper reports the major findings of a research to investigate the energy consumption of hotel buildings in Hong Kong and to develop systematic methods for benchmarking their energy performance. The current knowledge and worldwide experience of energy benchmarking were reviewed critically. The major characteristics of the design and operation of hotel buildings in Hong Kong were studied. Theoretical energy models were established to assess the energy consumption patterns and develop suitable benchmarks. It is hoped that the research findings could provide hints and practical guidelines to reduce hotel energy consumption and carbon emissions.

2. Energy Benchmarking

Benchmarking is becoming a key methodology for the assessment of energy efficiency opportunity (Field, *et al.*, 2008). A benchmarking tool allows users and operators to compare their energy consumption levels with others in the same group, set future targets and identify measures to reduce energy consumption (CIBSE, 2004, Chps. 19 & 20). Building managers can improve the energy performance of buildings by examining the what, why, when, where and how of the building energy use (Energy Star, 2007). It also provides some guidelines for better energy management based on good practices (ESCWA, 2003).

2.1 Principles of Benchmarking

Benchmarking is a quantitative process for tracking performance and identifying opportunities for improvement (Field, *et al.*, 2008). It can help to compare an organisation’s current performance to past performance and evaluate against both industry and competitor standards (IBLF and WWF-UK, 2005). Benchmarking promotes ongoing assessments of unit operations to determine whether changes are needed to improve process efficiency (Karthik, 2002; Wöber, 2002). This includes identifying specific changes and improvements that should be made to achieve energy and cost savings.

Nowadays, benchmarking has become a commonly used management practice for performance measurement and improvement and is applied by leading companies across all sectors. It is considered a key tool in strategic business development activities. Table 1 shows three general approaches to benchmarking which are commonly used for the evaluation of building energy consumption.

Table 1. Three general approaches to benchmarking

Approach	**Description**
"Tracking" or "baseline" approach	Comparing a building to itself
Target finder approach	Empirical model from a sample of other similar buildings in a population (e.g. EnergyStar)
Simulation model approach	Results of an energy simulation model with certain pre-defined baseline characteristics, such as meeting an energy code or standard

2.2 Benchmarking Methods and Assessment

Liddiard, Wright and Marjanovic-Halburd (2008) have studied and identified five basic types of benchmarking methods for commercial buildings as shown below.

- Ranking systems
- Distribution models, using medians and percentiles
- Regression models
- Regression models using standard regression errors or mean energy use intensity (EUI)
- Prototypical models

The benchmarking methods have different degrees of complexity and their effectiveness is significantly influenced by the quantity and quality of the benchmark's source base data. The criteria for a good benchmarking system usually focus on the following aspects:

- Easy to use and understand
- Accurate and consistent
- Comprehensive for the type of buildings concerned
- Can account for the specific criteria unique to each building

CIBSE (2004, Chps. 19 & 20) describes systematically the benchmarking process and techniques. Three levels of benchmarks were suggested for analysis of building energy use.

- Overall building benchmarks
- Detailed component benchmarks
- Detailed end-use benchmarks

When assessing the energy performance of existing buildings, CIBSE (2006) describes the main procedure based on metered energy use. It is necessary to consider carefully the building types and allow for different use and occupancy.

3. Hotel Energy Performance

CIBSE (2004, Chp. 20) classified three different types of hotels including: Type 1 luxury hotel, Type 2 business or holiday hotel and Type 3 small hotel. The present study focuses mainly on business hotels which are typically multi-storey buildings, generally in city locations, with facilities geared towards business and short-stay recreational travelers.

3.1 Overall Energy Benchmarks

The establishment of a hotel energy benchmark is much more complicated than for offices, because of the diversity in the sector even within notional categories of hotel (Bannister, 2008). Most existing benchmarks have avoided this issue by adopting a highly simplified approach. The Energy Use Intensity (EUI) is often applied for the benchmarking. For hotel buildings, the benchmarks are related to the total hotel gross floor area or the number of guest rooms. The EUI of hotels is typically expressed in units of:

- Building energy consumption per floor area per year (kWh/m^2 per annum)
- Building energy consumption per guest room per year
- Building energy consumption per guest night

The overall performance of a hotel can be roughly expressed by these indicators. Table 2 shows the benchmark values for energy consumption in typical hotels.

Table 2. Benchmark values for energy consumption in typical hotels

		Energy consumption (kWh/m^2 of serviced space)			
		Excellent	Satisfactory	High	Excessive
Luxury Serviced Hotels		Temperate climate			
	Electricity	< 135	135 – 145	145 – 170	> 170
	Other energy	< 150	150 – 200	200 – 240	> 240
	TOTAL	< 285	285 – 345	345 – 410	> 410
		Mediterranean climate			
	Electricity	< 140	140 – 150	150 – 175	> 175
	Other energy	< 120	120 – 140	140 – 170	> 170
	TOTAL	< 260	260 – 290	290 – 345	> 345
		Tropical climate			
	Electricity	< 190	190 – 220	220 – 250	> 250
	Other energy	< 80	80 – 100	100 – 120	> 120
	TOTAL	< 270	270 – 320	320 – 370	> 370
Mid Range Serviced Hotels	Electricity	(*)	70 – 80	80 – 90	> 90
	Other energy	(*)	190 – 200	200 – 230	> 230
	TOTAL	(*)	260 – 280	280 – 320	> 320
Small & Budget Serviced Hotels	Electricity	(*)	60 – 70	70 – 80	> 80
	Other energy	(*)	180 – 200	200 – 210	> 210
	TOTAL	(*)	240 – 270	270 – 290	> 290

[Source: IBLF and WWF-UK (2005)] Note: (*) Insufficient data

The overall performance indicators give only a broad indication of building efficiency and therefore must be treated with caution since they can mask underlying problems with individual end uses of energy (CIBSE, 2004, Chp. 19). Techniques in CIBSE (2006) allow a more detailed analysis in terms of end-use consumption etc. in order to identify more closely where energy problems are occurring within the building. It is also important to understand the functions and facilities of the hotel so that the main factors can be evaluated.

3.2 Major Factors to Consider

A number of physical and operational factors will influence the hotel energy use (Bohdanowicz and Martinac, 2007). To establish and evaluate the hotel energy benchmarks, the major factors to consider are summarised in Table 3.

Table 3. Major factors to consider for hotel energy benchmarks

Factor	**Description**
Service level or hotel star rating	This approach is pragmatic but does carry some risks, as there is still some diversity within star bands and not all hotels are rated.
Number of rooms	This is a preferred variable for benchmarking, as it is relatively well defined.
Floor area	This factor is strongly correlated to the number of rooms but is not measured to any consistent metric by the industry and as such is not a preferred index for hotel size.
Scale of meeting/ conference facilities	This varies independently of other factors and can be a significant contributor to the overall energy use of an individual site.
Scale of restaurant facilities	While this is to some extent correlated to hotel quality, other independent factors also play a strong role.
Swimming pools	The scale of swimming pools offered varies widely, again with a marginal correlation to the hotel star rating.
Laundries	While most hotels have some form of house laundry, this may range from a small facility for washing a few select items to a large facility washing sheets, towels and other linen for more than one hotel.
Retail operations	Many hotels also house some limited independent retail operations. These are typically but not always sub-metered.
Level of occupancy	In principle, the level of occupancy should have a large influence on hotel energy and water consumption, although in practice for energy at least this is not as significant as might otherwise be the case due to the propensity of hotels to provide service to empty rooms in preparation for unexpected arrivals.
Other facilities	Such as health club, casino, theatre and retail

Note: The information in this table is adapted from Bannister (2008).

It should be noted that hotel operations are largely equipment-based rather than wholly people-based services (Jones and Lockwood, 2002). The specific operation mode of hotels leads to the difficulties in energy management. In order to study the energy performance effectively, a hotel can be seen as a combination of three distinct zones:

- Guest room area (bedrooms, bathrooms/showers, toilets)
- Public area (reception hall, lobby, bars, restaurants, meeting rooms, swimming pool)
- Service area (kitchens, offices, store rooms, laundry, staff facilities, machines rooms)

Different benchmarking and evaluation methods can be used to assess the zones and the specific areas or components. For designing new hotel buildings, the general guidelines for energy design and planning will be useful (CIBSE, 2004; ITP and CELB, 2008). For existing hotels, the operation, management and upgrading should be carried out with energy efficiency and environmental objectives in mind all the time.

When developing an energy and environment benchmarking model for Indian hotels, Karthik (2002) has identified the performance indicators for major hotel departments as shown in Table 4. This department-wise benchmarking will facilitate an efficient management process and clear responsibility.

Table 4. Hotel departments and performance indicators [adapted from Karthik (2002)]

Hotel department	**Performance indicators**
Engineering	Energy, water/wastewater, greenhouse gas (GHG) emission, finance
Laundry	Energy, water/wastewater, chemicals, packaging material, finance
Housekeeping	Soiled linen, solid waste
Food and beverage	Energy, water/wastewater, detergents, food waste, finance
Purchase	Solid waste, finance

3.3 Experience in Hong Kong

In Hong Kong, some research studies have been done to investigate the energy performance and operation of hotels (Chan, Lee and Burnett, 2003; Chow and Chan, 1993; Deng, 2003; Deng and Burnett, 2002; Deng, and Burnett, 2000; Lai and Yik, 2008). They provide useful data and information for assessing hotel energy use. However, most of them do not have information on detailed component and end-use benchmarks.

Electricity, gas and diesel fuel are the three types of energy used in hotels in Hong Kong (Deng, 2003; Deng and Burnett, 2002). Electricity is usually the most important one for the hotel's building services systems including mechanical ventilation and air-conditioning (MVAC), lighting and vertical transportation. Town gas and diesel are used for cooking, hot water heating and laundries. Figure 1 shows the component breakdown of total energy use for hotels in Hong Kong (based on a survey of 16 hotels).

	MJ/sq.m	kWh/sq.m	(%)
Air conditioning	670	186.1	32
Lighting	250	69.4	12
Lifts and escalators	106	29.4	5
Miscellaneous	468	130.0	23
Non-electrical	586	162.8	28
TOTAL	2080	577.8	100.0

[Data source: Deng and Burnett (2000)]

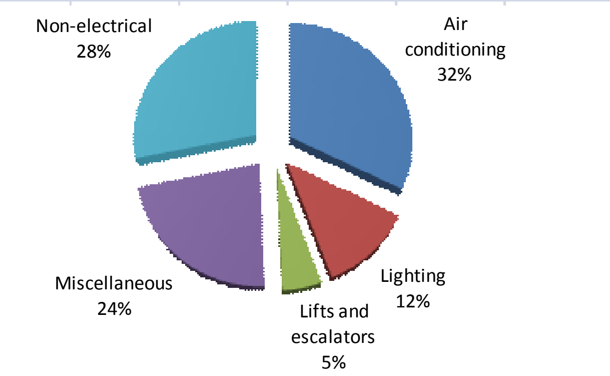

Figure 1. Average component breakdown of total energy use for hotels in Hong Kong

The Electrical and Mechanical Services Department (EMSD) of Hong Kong Government has developed some data for energy consumption indicators and benchmarks (CDM, 2002). The details can be found on the website “www.emsd.gov.hk/emsd/eng/pee/ecib.shtml”. The energy benchmarks were setup using distribution models and the one for hotels is shown in Figure 2. The average EUI is 1575 MJ/m^2/annum (or 438 kWh/m^2/annum).

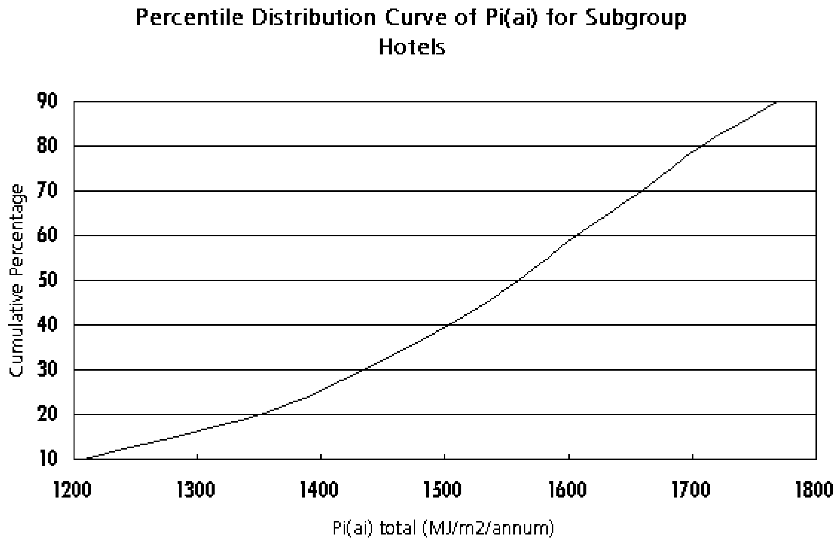

Figure 2. Percentage distribution curve of energy benchmark for hotels in Hong Kong
[Source: http://www.emsd.gov.hk/emsd/eng/pee/ecib.shtml]

The energy consumption of commercial buildings in Hong Kong can also be studied in the Hong Kong Energy End-use Database (EMSD, 2009). However, at present, hotels are included under “Other Commercials” and suitable data and breakdown cannot be identified for further evaluation.

4. Building Energy Model and Analysis

It is found that guest rooms usually consume the largest portion of total energy use in business hotels. Therefore, the present study focuses on the design factors for the guest rooms. Building energy simulation technique with a prototypical model is used to investigate the energy performance and develop energy equations for the benchmarking.

4.1 Based Case Model

A base case model was developed using a building energy simulation program TRACE 700 (Trane, 2005). The model is a 20-storey building with total gross floor area of 28,600 m^2 and each floor has 23 guest rooms. For each guest room, a fan coil unit is provided and typical electrical appliances are present. The simulation input assumptions were taken from EMSD (2007) and the practical hotel projects in Hong Kong. The EUI of the base case model is calculated as 1447 MJ/m^2/annum (or 402 kWh/m^2/annum).

The important parameters affecting the energy consumption were studied by sensitivity tests and parametric analysis. More than 80 simulations were done. About six to seven parameters were identified. They represent the common energy design factors for hotel guest rooms and can be used to assess the energy performance of hotel buildings.

4.2 Regression Analysis

A statistical software Minitab (www.minitab.com) was used to analyse the simulation results using multiple regression method with ANOVA (analysis of variance) procedures. Figure 3 shows the scatter plots of the selected parameters generated from Minitab. The best-fit lines or curves were identified for developing the energy prediction equation.

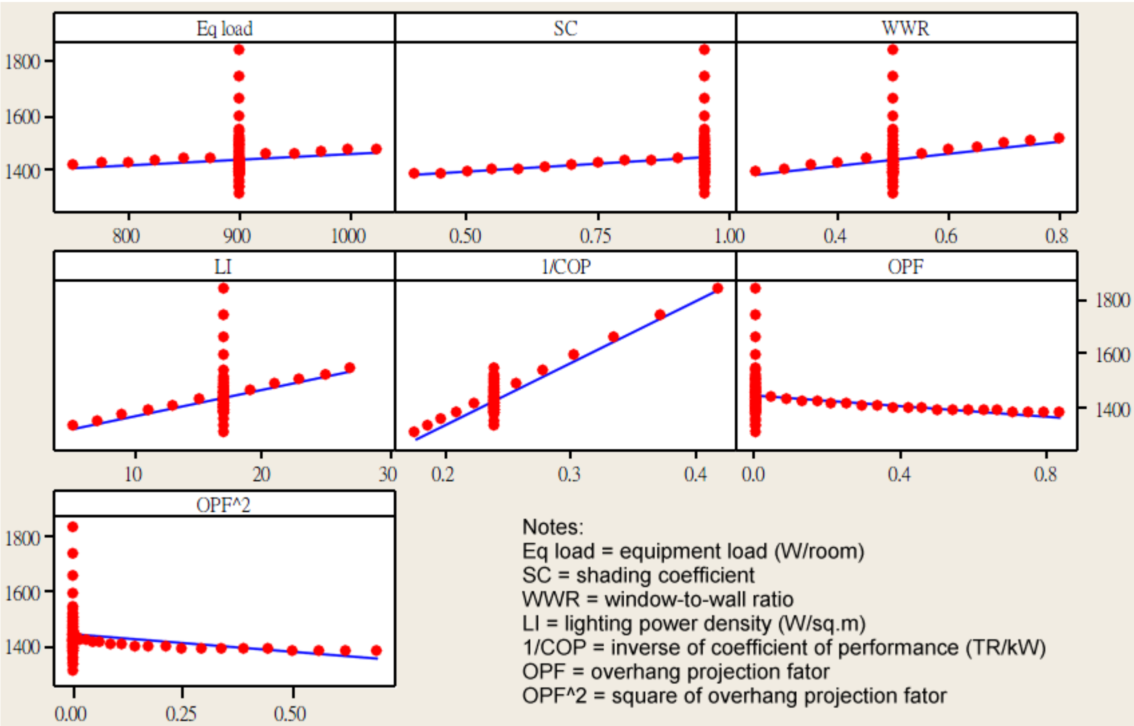

Figure 3. Scatter plots of the selected parameters generated from Minitab

After considering suitable control factors for hotel energy management, the proposed energy equation is determined. This equation includes seven parameters which are essential for the design assessment of business hotels (for guest room area only).

$$\text{Energy consumption (MJ/m}^2\text{/annum)} = 210 + 9.53\,L + 0.21\,EQ + 2199\,(1/COP) + 4.25\,OA + 127\,SC + 226\,WWR - 162\,OPF + 105\,OPF^2$$

where L = Lighting power density (W/m^2)
EQ = Equipment load (W/room)
COP = Coefficient of performance of the chiller (kW/TR)
OA = outdoor ventilation air flow rate (l/s/room)
SC = Shading coefficient of fenestration
WWR = Window-to-wall ratio
OPF = Overhang projection factor

4.3 Development of Benchmarks

The analysis results of the prototypical model provide useful information for developing detailed component and end-use benchmarks. In order to assess the individual parameters and establish the overall benchmark values, efforts have been made to evaluate and determine suitable ratings for each of the seven parameters. The main considerations here include hotel design requirements, building energy codes, appliance energy labels and common design practices. To ensure the benchmarks are easy to use and understand, only three grades (A, B and C) are employed for the energy rating.

Table 5 shows the proposed benchmark values for individual parameters and Table 6 indicates the overall hotel building energy benchmarks. It should be noted that the prototypical model only represent a certain type of business hotels (guest rooms only). For other types of hotels and building designs, the benchmarks should be applied with caution.

Table 5. Proposed benchmark values for individual parameters

Parameter	**Benchmark rating**		
	A	**B**	**C**
Lighting power density (W/m^2)	< 9	9-12	> 12
Equipment load (W/room)	< 852	852-948	> 948
Coefficient of performance of the air-cooled chiller (kW/TR)	> 3.06	2.71-3.06	< 2.71
Coefficient of performance of the water-cooled chiller (kW/TR)	> 4.53	3.86-4.53	< 3.86
Outdoor ventilation air flow rate (l/s/room)	< 10	10-16	> 16
Shading coefficient of fenestration	< 0.3	0.3-0.6	> 0.6
Window-to-wall ratio	< 40%	40%-70%	> 70%
Overhang projection factor	> 0.52	0.22-0.52	< 0.22

Table 6. Overall hotel building benchmark indicators

Overall benchmark	**Benchmark value (MJ/m^2/annum)**		
	A	**B**	**C**
For hotels with air-cooled chillers	< 1091	1091-1340	> 1340
For hotels with water-cooled chillers	< 813	813-1098	> 1098

5. Discussions

As of December 2009, Hong Kong has 167 hotels and 591 tourist guesthouses with a total of 65,386 rooms (HKTB, 2010). The number of hotels is expected to grow in the coming years. It is the right time to promote better energy efficiency in the hotel sector and foster the concepts of environmental management and sustainable tourism in new and existing hotels. The experience and knowledge on hotel energy management are not only essential to Hong Kong, but also useful to other cities in the world.

In mainland China, Wu (2007) pointed out that the best opportunities for improving energy efficiency in hotels are at new hotels and retrofitting of existing hotels. Huang (2009) indicated from the analysis of chain economic hotels that management of energy audit and control of energy consumption are crucial to enhancing economic benefits. Gao, *et al.* (2003) presented the survey and research findings on large hotels in some major cities. They have also further investigated the energy consumption of the air conditioning system (Gao, *et al.*, 2005) as well as the food and beverage (F&B) service (Gao, *et al.*, 2007). With the fast economic and tourist development in mainland China, it is believed that the need for controlling energy consumption in hotels will continue to increase and the skills for hotel energy management have to be improved drastically.

5.1 Effective Energy Management

From an institutional perspective, the hotel sector has a number of factors that work against efficient practice, such as the ownership and operational structures with large chain hotels (Bannister, 2008). Moreover, hotel operations often focus on guest service, leading to a tendency towards over-servicing being used as a first response, while the resultant energy consumption impacts are given a low priority. This results in little investment in back-of-house infrastructure, poor plant maintenance and capital upgrade practices in the hotels, and the widespread use of inefficient practices (e.g. incandescent lamps).

Effective management of energy use in hotels must consider proper efficiency measures without compromising service levels. Successful hotel energy management programmes are often initiated by management staff through a detailed cost-benefit analysis highlighting the energy and cost savings potential of the energy conservation measures. To ensure good implementation, it is important to promote efficiency and behavioural change amongst hotel staff, suppliers, guests and clients. People's attitudes are critical for the decision-making process (Han, Hsu and Lee, 2009). As hotel guests and management groups are increasingly tuned in to environmental thinking, hopefully, the efficiency measures can save money, reduce avoidable waste, add to guest comfort and encourage their return, and get valuable recognition from customers and the community at large.

5.2 Energy Saving Measures in Hotels

Energy benchmarking can provide useful information to support decision making and planning, however, it is the practical energy saving measures that really count. Table 7 shows a summary of the common energy savings opportunities in hotels. It is hoped that they could give hints and practical guidelines to hotel managers and investors.

Table 7. Energy savings opportunities in hotels [adapted from Bannister (2008)]

System/Issue	Description
Lighting (power density)	Upgrade of lights by simple lamp replacements and fitting refurbishments. Refurbishment of fluorescent light fittings using delamping, reflectors, electronic transformers and/or autotransformers.
Lighting (time of use)	Upgrade of lighting control systems to achieve turn-off out of hours. For example, installing occupancy sensors in toilets, car parks and back of house areas and the use of timer controls in some locations.
MVAC (control)	Upgrade and optimizing of air-conditioning systems and their maintenance through improvement of control and the use of building automation systems
MVAC (plant)	Upgrade and/or replacement of air-conditioning plant. Revisions to or deletion of steam generation and distribution systems and modification of boiler systems.
Hot water supply	Upgrade of hot water generation, distribution and end-use. For example, reduction of water flow in shower heads.
Swimming pool	Upgrade of pool efficiency. For heated pools, use pool covers and replace gas heating by heat pump heating.
Laundry	Upgrade of laundry efficiency, such as by heat recovery and/or replacement of existing inefficient equipment.

The importance of energy audits and reporting is obvious (CIBSE, 2006; Huang, 2009) and in some cities such as Hong Kong (Environment Bureau, 2009) and Singapore (Lee and Rajagopalan, 2008) there are already proposals to implement mandatory requirements on building energy audits and building energy labels. The benchmarking tool and information are essential to these initiatives and other "green" building rating systems. In order to overcome financial and institutional barriers, the use of energy performance contracting might also be considered in hotel and other commercial buildings (Hui, 2002).

5.3 Recommendations for Future Works

Although the present study is limited by the time and resources, it has investigated the key issues and problems for hotel energy benchmarks and energy management. The following works are recommended so as to develop useful knowledge and skills to improve hotel energy efficiency and achieve sustainable tourism.

- To develop energy benchmarks and information for the public and service areas of business hotels, as well as other types of hotels.
- To analyse and generate the hotel sector and breakdown data (now under "Other Commercials") in the Hong Kong Energy End-use Database (EMSD, 2009).
- To study and establish energy benchmarks and skills for tourist guesthouses and serviced apartments.
- To compare and evaluate the hotel energy benchmarks in Hong Kong with those in the major cities in mainland China and other countries.
- To investigate the normalization techniques for climate effect and level of occupancy.

6. Conclusions

Benchmarking is becoming more and more important in the hotel industry, not only for energy issue but also for other business aspects (Wöber, 2002). The nature of benchmarking is about learning how to improve business activity, processes and management. It is an integral tool within the management process that assesses performance and helps to identify and prioritise areas to manage.

The energy management programme for the hotel sector should be targeted at the key areas of inefficiency and the key institutional drivers or financial barriers underlying the lack of activity. It is possible to benchmark the operational energy use of hotels and obtain a meaningful relationship with the level of energy efficiency opportunity from such benchmarks. This also complements the fact that the hotel industry is already quite common in using key performance indicators for assessing its business operations. However energy benchmarking will only become a major force in the supply chain when it becomes a selection criterion for travellers, either through travel policy changes for major corporates and governments or through inclusion in the hotel quality star rating system. Education and information is the key to achieve this.

It is concluded that the hotels sector is a unique sub-sector of the commercial buildings sector and that it has significant opportunity for improved energy efficiency. Benchmarking and target setting can help to facilitate the energy and environmental programmes that will eventually reduce hotel energy consumption and carbon emissions. Both Hong Kong and mainland China have an urgent need to tackle these.

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References

Ali, Y., *et al.*, 2008. Potential of energy savings in the hotel sector in Jordan, *Energy Conversion and Management*, 49 (2008): 3391-3397.

Bannister, P., 2008. Business hotel utility consumption and saving opportunities, In *Proceedings of the IEECB Focus 2008 Improving Energy Efficiency in Commercial Buildings Conference*, 10-11 April 2008, Congress Center Messe Frankfurt (CMF), Frankfurt am Main, Germany, 12 pp. (http://re.jrc.ec.europa.eu/energyefficiency/html/Proceedings_IEECB2008.htm)

Beccali, M., *et al.*, 2009. An empirical approach for ranking environmental and energy saving measures in the hotel sector, *Renewable Energy*, 34 (2009): 82-90.

Bohdanowicz, P. and Martinac, I., 2007. Determinants and benchmarking of resource consumption in hotels -- case study of Hilton International and Scandic in Europe, *Energy and Buildings*, 39 (2007): 82–95.

Bohdanowicz, P., Churie-Kallhauge, A. and Martinac, I., 2001. Energy-efficiency and conservation in hotels -- towards sustainable tourism, In *Proceedings of the Fourth International Symposium on Asia-Pacific Architecture*, April 5-7, 2001, University of Hawaii School of Architecture, Honolulu, Hawaii, 12 pages.

CDM, 2002. *Consultancy Study on the Development of Energy Consumption Indicators and Benchmarks for Selected Energy-consuming Groups in Hong Kong: Executive Summary for Principal Groups A & B (Final)*, prepared by Camp Dresser & McKee International Inc. (CDM), Electrical and Mechanical Services Dept., Hong Kong.

Chan, K. T., Lee, R. H. K. and Burnett, J., 2003. Maintenance practices and energy performance of hotel buildings, *Strategic Planning for Energy and the Environment*, 23 (1): 6-28.

Chow, W. K. and Chan, K. T., 1993. A survey of the electricity energy requirement of hotels in Hong Kong, *Energy Engineering*, 90 (6): 33-42.

CIBSE, 2006. *Energy Assessment and Reporting Methodology*, CIBSE TM 22: 2006, 2nd edition, Chartered Institution of Building Services Engineers (CIBSE), London.

CIBSE, 2004. *Energy Efficiency in Buildings*, CIBSE Guide F, 2nd edition, Chartered Institution of Building Services Engineers (CIBSE), London.

Deng, S., 2003. Energy and water uses and their performance explanatory indicators in hotels in Hong Kong, *Energy and Buildings*, 35 (2003): 775-784.

Deng, S. and Burnett, J., 2002. Energy use and management in hotels in Hong Kong, *International Journal of Hospitality Management*, 21 (2002): 371-380.

Deng, S.-M. and Burnett, J., 2000. A study of energy performance of hotel buildings in Hong Kong, *Energy and Buildings*, 31 (2000): 7-12.

EMSD, 2009. *Hong Kong Energy End-use Data 2009*, Energy Efficiency Office, Electrical & Mechanical Services Department (EMSD), Hong Kong.

EMSD, 2007. *Guidelines on Performance-based Building Energy Code*, Electrical and Mechanical Services Department (EMSD), Hong Kong.

Energy Star, 2007. *Benchmarking to Save Energy: Protect Our Environment Through Energy Efficiency*, U.S. Environmental Protection Agency, Washington, DC. (available at www.energystar.gov)

Environment Bureau, 2009. *Legislative Council Brief: Building Energy Efficiency Bill*, ENB 24/26/22, Legislative Council, Hong Kong SAR. (available at www.legco.gov.hk)

ESCWA, 2003. *A Guide to Efficient Energy Management in the Tourism Sector*, Economic and Social Commission for Western Asia, United Nations, New York. (available at www.escwa.un.org)

Field, J., *et al.*, 2008. *Energy Benchmarks*, CIBSE Technical Memoranda TM46, Chartered Institution of Building Services Engineers, London.

Gao, X., *et al.*, 2007. The energy consumption analysis of hotel F&B service process in China, *Building Science*, 23 (4): 40-44+69. 高興, 張殿光, 袁杰, 李文霞, 鄧文濤, 張興文, 楊鳳林, 2007. 我國酒店業餐飲服務全過程能耗現狀分析, 建筑科學, 23 (4): 40-44+69.

Gao, X., *et al.*, 2005. Evaluation on energy consumption of building and air conditioning system for hotels, *HV & AC*, 35 (4): 34-38. 高興, 楊鳳林, 張興文, 徐曉晨, 2005. 酒店建筑能耗及空調系統能耗合理性評價, 暖通空調, 35 (4): 34-38.

Gao, X., *et al.*, 2003. Evaluation on reasonable energy consumption and budget control for large-scale all-around hotel, *Energy Engineering*, 2003 (2): 58-62. 高興, 楊鳳林, 張興文, 徐曉晨, 2003. 大型酒店能源消耗合理性評價及預算控制,能源工程, 2003 (2): 58-62.

Han, H., Hsu, L.-T. and Lee, J.-S., 2009. Empirical investigation of the roles of attitudes toward green behaviors, overall image, gender, and age in hotel customers' eco-friendly decision-making process, *International Journal of Hospitality Management*, 28 (2009): 519-528.

HKTB, 2010. *Hotel Supply Situation - as at Dec 2009*, Research, Hong Kong Tourism Board, Hong Kong. (available at http://partnernet.hktb.com)

Huang, H., 2009. Analysis on the energy audit of the chain economic hotels, *Energy Engineering*, 2009 (4): 58-61. 黃河, 2009. 淺析經濟型連鎖酒店的能耗評估管理, 能源工程, 2009 (4): 58-61.

Hui, S. C. M., 2002. Opportunities and challenges of energy performance contracting to improve existing buildings in Hong Kong, In *Proceedings of the Joint Symposium 2002: Achieving Sustainable Performance in Built Environment*, 19 November 2002, Shangri-la Hotel, Kowloon, Hong Kong, pp. 8-1 to 8-10.

IBLF and WWF-UK, 2005. *Why Environmental Benchmarking Will Help Your Hotel*, The International Business Leaders Forum (IBLF) Tourism Partnership and World Wildlife Fund (WWF) UK, London. (available at www.iblf.org)

ITP, 2008. *Environmental Management for Hotels - The Industry Guide to Sustainable Operation*, Third Edition, International Tourism Partnership (ITP), London.

ITP and CELB, 2008. *Sustainable Hotel Siting, Design and Construction*, International Tourism Partnership (ITP), London and Center for Environmental Leadership in Business (CELB), Arlington, VA.

Jones, P. and Lockwood, A., 2002. *The Management of Hotel Operations*, Continuum, London and New York.

Karthik, S., 2002. Energy and environment (E2) benchmarking -- performance evaluation tool for Indian hotel sector, *Development Alternatives Newsletter*, Vol. 12, No. 3, March 2002. (available at www.devalt.org)

Khemiri, A. and Hassairi, M., 2005. Development of energy efficiency improvement in the Tunisian hotel sector: a case study, *Renewable Energy*, 30 (2005): 903–911.

Kirk, D., 1995. Environmental management in hotels. *International Journal of Contemporary Hospitality Management*, 7 (6): 3-8.

Lai, J. H. K. and Yik, F. W. H., 2008. Benchmarking operation and maintenance costs of luxury hotels, *Journal of Facilities Management*, 6 (4): 279-289.

Lee, S. E. and Rajagopalan, P., 2008. Building energy efficiency labeling programme in Singapore, *Energy Policy*, 36 (2008): 3982-3992.

Liddiard, R., Wright, A. and Marjanovic-Halburd, L., 2008. A review of non-domestic energy benchmarks and benchmarking methodologies, In *Proceedings of the IEECB Focus 2008 Improving Energy Efficiency in Commercial Buildings Conference*, 10-11 April 2008, Congress Center Messe Frankfurt (CMF), Frankfurt am Main, Germany, 11 pp. (http://re.jrc.ec.europa.eu/energyefficiency/html/Proceedings_IEECB2008.htm)

Manhas, D., 2002. Environmental management systems - a tool for greening the hotel industry, *Development Alternatives Newsletter*, Vol. 12, No. 3, March 2002. (available at www.devalt.org)

Pizam, A., 2009. Green hotels: A fad, ploy or fact of life?, *International Journal of Hospitality Management*, 28 (2009): 1.

Rajagopalan, P., Wu, X. and Lee, S. E., 2009. A study on energy performance of hotel buildings in Singapore, *Energy and Buildings*, 41 (12): 1319-1324.

Santamouris, M., *et al.*, 1996. Energy conservation and retrofitting potential in Hellenic hotels, *Energy and Buildings*, 24 (1996): 65–75.

Trane, 2005. *TRACE 700 Building Energy and Economic Analysis version 6: User's Manual*, American Standard Companies, La Crosse, Wisconsin.

Trung, D. N. and Kumar, S., 2005. Resource use and waste management in Vietnam hotel industry, *Journal of Cleaner Production*, 13 (2): 109-116.

Wöber, K. W., 2002. *Benchmarking in Tourism and Hospitality Industries: the Selection of Benchmarking Partners*, CABI Publishing, Wallingford, Oxon and New York, N.Y.

Wu, W., 2007. A few key questions about improving energy efficiency in hotels -- concepts, mechanism and techniques, *Hotel Modernization*, 2007 (12): 58-61. 吳懷祥, 2007. 酒店節能增效的幾個關鍵問題——觀念、機制、技術, 飯店現代化, 2007 (12): 58-61.

Zmeureanu, R. G., Hanna, Z. A. and Fazio, P., 1994. Energy performance of hotels in Ottawa, *ASHRAE Transactions*, 100 (Part 1): 314–322.