ENGINEER - Vol. LII, No. 04, pp. [51-61], 2019
© The Institution of Engineers, Sri Lanka
DOI: http://doi.org/10.4038/engineer.v52i4.7393

in Existing Hotel Buildings – A Review

H.A.H. Amanda and C. Sanjei

Abstract: Tourism is one of the main sources of income in some of the countries around the world. The hotel industry has thus become one of the main industries. Hotels are one of the most energy intensive building categories and the hospitality industry contributes to 2% of the world's CO_2 emissions. At present, new buildings can be made energy efficient even from the design stage but existing buildings consume more energy than the new ones. Building energy efficiency retrofitting techniques should be applied, based on economics, to existing buildings to reduce the high energy consumption. This paper presents a review on energy performance and energy intensive areas of some existing hotel buildings at different tourist destinations in the world. Energy retrofitting technologies should be mainly focused on these energy intensive areas. It also provides a review of common retrofitting technologies and past studies on hotel building retrofits. Finally, it discusses the barriers for retrofit projects and a market mechanism to carry out successful retrofit projects. After seeing more than 50% of energy saving in retrofitted hotels, this paper concludes that all possible retrofitting technologies should be implemented from now on and measure the energy performance both before and after retrofitting.

Keywords: Energy Performance, Energy Retrofit, Hotel Buildings, Tourism

1. Introduction

Building sector has been identified as one of the highest energy consumers in the world because buildings consume more than 40% of primary energy in most countries [1]. According to the latest published assessment report of the Intergovernmental Panel on Climate Change (IPCC) [2], the building sector accounted for approximately 117 Exajoules (EJ) or 32% of global final energy consumption, 19% of energy related CO_2 emissions and 51% of global electricity consumption in 2010.

Today, there are building energy codes and standards in each country, to be followed from the design stage of new buildings. Green buildings and low or nearly zero energy buildings are outcomes of that. Among the buildings anywhere, existing buildings consume more energy than the new ones [3]. As buildings have very long lives, and a large portion of the total building stock existing today will exist in 2050 in developed countries, retrofitting the existing stock is a key to a low emission building sector [2].

Existing buildings are of different types. Ma et al. [4] have performed a review of past studies on energy retrofits of commercial office buildings, educational buildings and residential buildings. Many retrofit studies in literature are based on these types of buildings. However, according to Priyadarsini et al. [5], past studies and research reveal that hotels are among the most energy intensive of all building categories.

The tourism sector is one of the faster growing sectors of the global economy with an estimated yearly increase of 3.3% up to 2030 [6]. Hotels are among the most energy intensive tourism facilities and energy accounts for an important part of their operational costs [6]. Substantial quantities of energy are consumed in providing comfort and services to guests, many of whom are accustomed to, and willing to pay for exclusive amenities, treatment and entertainment [7].

Thus, this study focuses on the tourism sector, and presents a review of past studies on energy performance and energy retrofits of hotel buildings. When reviewing it was identified that only a limited number of publications were available. One possible reason is most of those publications had considered a sample of hotel buildings of different star ratings for their studies instead of individual publications for

Eng. H.A.H. Amanda, BSc Eng (Hons) (Moratuwa), MSc (Moratuwa), AMIE(SL), AM(SLEMA), Electrical Engineer, Lanka Energy Conservation (Pvt) Ltd.
Email: hrshnamanda08@gmail.com
https://orcid.org/0000-0002-3993-4957
Eng. C. Sanjei, BSc Eng (Hons) (Moratuwa), MSc (Moratuwa), AMIE(SL), Design Engineer, Central Engineering Consultancy Bureau.
Email: sanjeic@gmail.com
https://orcid.org/0000-0002-0778-2645

each hotel. The other reason is, even at present, only few Energy Service Companies (ESCos) in the world are engaged in providing successful building energy retrofit projects overcoming barriers as discussed under Sections 3.3 and 3.4. As tourism is one of the main sources of income in some of the countries around the word, this paper will be important to them.

2. Energy Performance of Hotel Buildings

Hotel buildings can be somewhat categorized as commercial buildings [9]. The difference of hotels from other types of commercial buildings such as office buildings is that, hotels operate 24 hours and there are usually functional areas other than guest rooms [9]. Results of past studies on energy performance of hotel buildings from 1991 are reviewed below to understand the energy intensive areas in hotels in international tourist destinations.

2.1. Energy Use Intensity of Hotels

Energy Use Intensity (EUI) is defined as the site energy consumption per unit of gross floor area [8]. The average EUI of 19 hotels in Ottawa, Canada was 688.7 kWh/m^2/year in 1991. There, the breakdown of different energy types was, electricity, gas and steam 28.9%, 26.4% and 44.7% of total energy consumption respectively [8].

Deng and Burnett [8] conducted a study on energy performance of 16 hotels in Hong Kong (three three-star, four four-star and nine five-star) using energy consumption data in 1995. On average, 72% of total energy consumed in Hong Kong's hotels was electricity, and 28% for gas and diesel [8]. The average EUI was calculated as 564 kWh/m^2/year. In the same year, the average EUI of lodging buildings in the United States was 401 kWh/m^2/year, while electricity and gas accounted for 40.9% and 51.9%, respectively [8].

Deng's study [9] of 36 quality hotels in Hong Kong in 1996/1997 period showed EUI as 542 kWh/m^2/year.

Trung and Kumar [10] selected 50 hotels in Vietnam in 2000. The average EUI values of electricity for four-star, three-star, two-star and resort hotels were calculated as 141, 143, 101, 78 kWh/m^2/year, respectively. In four-star hotels, 76% of total energy consumption was for electricity, 21% for LPG, and 3% for diesel and other fuels. In three-star hotels it was 90%, 6% and 4%, in two-star hotels it was 91%, 6%, and 3% and in resort hotels it was 66%, 28% and 6%, respectively.

Using data during the 2001/2003 period, Batle et al. [11] studied operational phase energy use of 31 hotels (20 three-star and 11 four-star) in Balearic Islands, Spain. The average EUI values of annual hotels were 179.6 kWh/m^2/year of nine three-star and 199.8 kWh/m^2/year of eight four-star hotels. Their electricity consumption was 57.3% and 55.9%, and gas/diesel consumption was 42.7% and 44.1%, respectively.

Bohdanowicz and Martinac [12] studied 73 upscale hotels (Hilton International) and 111 mid - market hotels (Scandic) in Europe in 2004. The average EUI values were given as 364.3 kWh/m^2/year for Hilton and 285 kWh/m^2/year for Scandic hotels. The energy mix for Hilton hotels was electricity 49.3%, town gas 32.3%, district heating 10.9%, heavy fuel oil 2.8%, gas/diesel oil 2.7% LPG 1.3% and district cooling 0.6%. For Scandic hotels, it was electricity 48.3%, district heating 42.3%, town gas 4.5%, heavy fuel oil 1.9%, district cooling 1.8%, gas/diesel oil 1% and LPG 0.3%.

Priyadarsini et al. [5] conducted a study on energy performance of 29 hotels in Singapore (five three-star, 13 four-star and 11 five-star) based on a national survey conducted in 2005/2006. The study results showed that, in hotels where only electricity and gas were consumed, 91% was for electricity and 9% for gas. In hotels where electricity, gas and diesel were used, 77% of total energy was consumed for electricity. The average total EUI of these 29 hotels was 427 kWh/m^2/year [5]. Onut and Soner [13] conducted an energy efficiency assessment for 32 five-star hotels located in Antalya region, Turkey in 2005. The results showed an average EUI of electricity as 388.8 kWh/m^2/year.

Farrou et al. [14] selected 90 hotels in Greece for their study. Out of the 90 hotels, annual operation was in 49 hotels. Based on energy data in 2007, the average EUI of these annual operation hotels was calculated as 290 kWh/m^2/year.

In 2010, Wang [15] conducted a study on energy performance of 200 hotels in Taiwan. The hotels comprised 45 international tourist hotels, 19 standard tourist hotels, 116 hotel enterprises, and 20 bed and breakfast facilities and the average EUI values were 280.1, 237.7, 186.3 and 143.6 kWh/m²/year, respectively. Electricity, on average, accounted for 84% of the total energy consumption.

In 2012, Tulsyan et al. [16] studied a five - star hotel in Jaipur city, India, which showed its EUI as 239 kWh/m²/year.

A study was conducted by Chedwal et al. [17] for 79 hotels in Jaipur city, India, in 2014/2015. It showed average EUI values as 203 kWh/m²/year for 47 hotels (non-star and one-star), 208 kWh/m²/year for 16 hotels (two- star and three-star) and 222 kWh/m²/year for 16 hotels (four-star and five-star). In 2015, Yao et al. [18] conducted a study on 45 hotels in Shanghai (15 three-star, 15 four-star and 15 five-star), and the average EUI was 215.7, 234.8 and 279.8 kWh/m²/year, respectively. On average, breakdown of energy use of these hotels was electricity 75%, natural gas 11%, diesel oil 9%, gas 3%, steam 0.8% and LPG 0.15%.

Tang et al. [19] conducted a study on energy performance of 24 hotels in Lijiang, China (one, two, three and four-star) in 2016. On average, electricity accounted for 81% of total energy consumption. Of the sampled hotels, electricity was the 100% dominant energy of 29% of the hotels; 50% of sampled hotels used both electricity 73% and diesel 27%; and 175% of hotels used electricity 67%, diesel 25% and gas. The average EUI of four, three, two and one-star rated hotels were 180.8, 113.3, 74.2 and 70.2 kWh/m²/year, respectively.

Based on the past studies discussed, the average total EUI values were plotted as shown in Figure 1 for the period from 1991 to 2016. It shows a reduction of EUI over time due to the gradual increase on the world's focus on energy conservation. As the energy crisis and impacts of global warming have become increasingly serious problems, more energy efficient improvements can also be seen in hotel buildings in the recent past.

2.2. Hotel Energy Consumption Distribution

Energy consumption in hotels varies with latitude and geographical location because of climate and weather, and depends on the characteristics of the facilities and their operation [6].

Except the cases in Ottawa, Canada (1991) and United States (1995), electrical energy is the dominant type of energy in rest of the discussed hotels under Section 2.1. As mentioned by Deng et al. [8], non-electrical energy (gas, oil, LPG, coal, etc.) dominates the total energy consumption of hotel buildings in North America and United Kingdom. Onut and Soner [13] did not mention such a difference and said that electricity is the primary form of energy used within hotel facilities. As hotels are located within different climate zones in the world, it is important look at their energy usage for hotel operations and equipment.

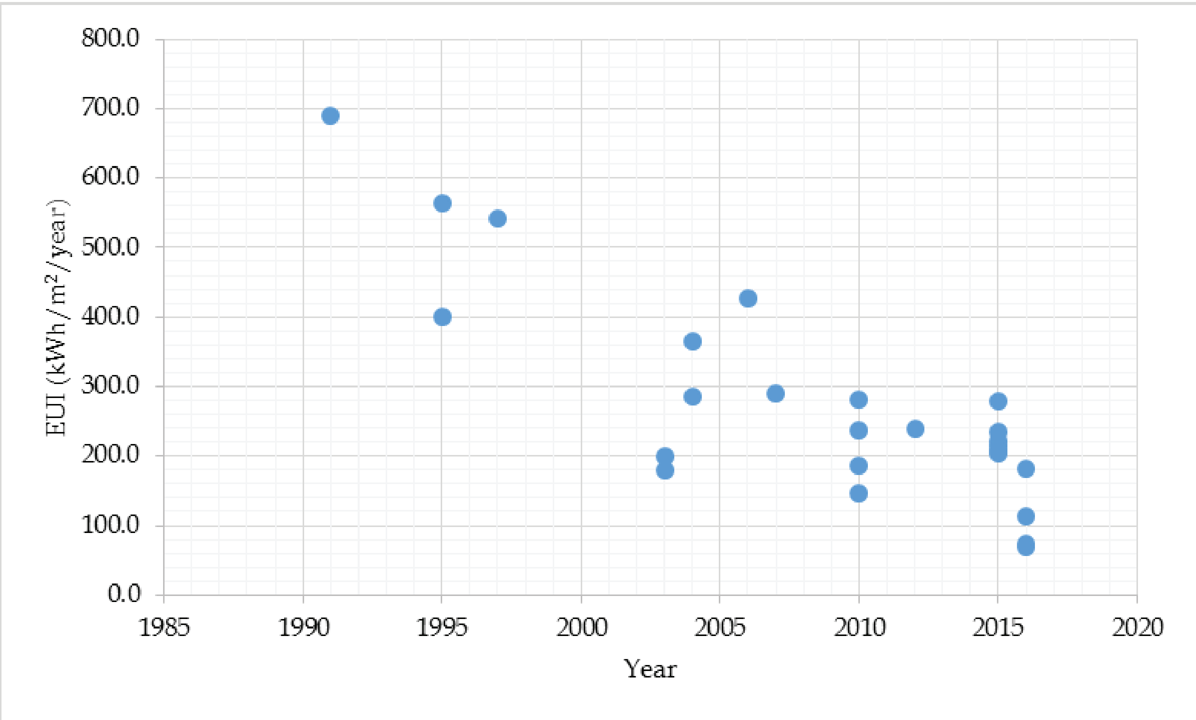

Figure 1 - Variation of average total EUI of hotels in the world

Table 1 - Climate conditions and tourism status of hotel locations

Hotel Location	Climate Condition	Tourism/Hotel Status
United States	Mostly temperate [20]	• Out of the hotels world-wide, 70% are in Europe and North America [14]
Hong Kong	Subtropical [9] (Long hot and humid summers)	• Within the country tourism sector, hotels are the major energy end user [21]
Vietnam	Tropical [20]	• Growth of foreign and local tourists • Hotels and resorts rated from two- star to five-star have been built with a total of 63,500 rooms in 1999 [10]
Balearic Islands, Spain	Warm summers and soft winters [11]	• Economic system based fundamentally on tourism [11]
Europe	Mediterranean [12] (Hot dry summers and cool wet winters [22])	• European segment of Hilton International and Scandic hotels hosted about, 3% of all visitors in Europe or 8% of all international hotel guests [12]
Antalya Region, Turkey	Mediterranean [13]	• Major tourist centre in Turkey [13]
Singapore	Tropical [5] (Hot and humid)	• Hotels play a very important role in Singapore's tourism industry [5]
Greece	Mediterranean [14]	• By 2000, hotels accounted for 22,830 buildings [14]
Taiwan	Subtropical [15]	• As of 2011, total number of International tourist hotels 70; Standard tourist hotels 37; Hotel enterprises 3169; and Bread and breakfast facilities 5582 [15]
Jaipur City, India	Composite [16] (Extreme temperatures in summers and winters, low humidity in summers and high humidity in monsoons)	• Hotel industry is growing at faster rate [16] • One of the most visited cities by Indian and foreign tourists [16]
Lijiang, China	Plateau monsoon climate - four seasons tend to be indistinct, clear wet and dry seasons [19]	• China was the world's third most visited tourist destination in 2010 [19] • Tourism is a boom industry in Lijiang [19] • Number of star rating hotels in China increased from 7358 in 2001 to 11,779 in 2010 [19]
Sri Lanka	Tropical	• Three categories – tourist hotels, supplementary establishments and other establishments [27] • At the end of 2018, there were 457 tourist hotels and 1855 supplementary establishments, with a total of 38,214 rooms [27] • Compared to 2017, tourist hotels increased by 13.97% and supplementary establishments by 9.56% in 2018 [27]

Table 1 shows the climate conditions in the hotel locations mentioned under Section 2.1 and in Sri Lanka. In the countries with tropical/subtropical climate or long warm /summer periods, majority of the electricity consumption was for air conditioning (space cooling).

In temperate and Mediterranean countries, space and water heating are dominant, hence either electrical or non- electrical energy can be the dominant energy source.

When presenting the energy consumption distribution of hotels, some studies presented it as a percentage while some only mentioned the high energy consumption areas. Of the studies presented on the energy consumption percentages, some presented it as a percentage from the total energy consumption while some presented as a percentage from total electricity consumption. These are described below.

In Hong Kong, air conditioning accounted for 32% of total energy consumption [8]. On average, it represented about one-third of the total energy [8]. In Vietnam, air conditioning consumed 53% (in four-star hotels), 47% (in three-star hotels), 46% (in two-star hotels) and 48% (in resort hotels) of the total electricity consumption [10].

In a five-star hotel in Singapore, central chiller plant consumed the largest portion of electrical energy of 39% which was followed by Air Handling Units /Fan Coil Units using 24% of electricity [5]. In three hotels in Singapore where district cooling systems were used, the proportion of chiller plant (inclusive of cooling tower and condensing water pumps) energy consumption were given as 40%, 44% and 35% of the total electricity use [5].

In Greece, 72% of total energy was used for heating, 9% for artificial lighting, 4% for cooling and 15% for other electrical appliances [14]. Of the total energy used for space heating and cooling, 18% was used by electricity for central heating. For the same, 36% was used by natural gas, oil and LPG. Of the energy used for space cooling, 74% was used by electricity for central cooling [14].

In Jaipur City, India, Category 1 hotels (non-star and one-star) used 54% of total energy for space cooling, 25% for area lighting and 16% for miscellaneous equipment. Similarly, Category 2 hotels (two-star and three-star) used 32%, 23% and 24%, and Category 3 hotels (four- star and five-star) used 41%, 21% and 18%, respectively [17].

2.3. Climate Conditions and Tourism Status of Hotel Destinations

In addition to the type of climate conditions mentioned in Table 1, there are ASHRAE defined climate zones for selected locations in each country of the world, to define energy standards for buildings. These climate zones are classified into eight main zones ranging from extremely hot humid to subarctic/arctic. As an example, in Sri Lanka, Katunayake city location has been selected and categorized under zone 0A (extremely hot humid). As shown in world climate zone map, the whole of Sri Lanka has only two ASHRAE climate zones. They are 0A and 1A (very hot humid) [28]. In addition to climate conditions, Table 1 shows significant facts related to tourism industry in each selected hotel location and country.

3. Building Energy Efficiency Retrofit

Building energy efficiency retrofit (BEER) provides excellent opportunities to reduce energy consumption in buildings as well as encouraging implementation of other sustainability measures such as environment protection, rational resource use, and occupant healthcare [23]. As mentioned by Xu et al. [23], BEER has significant benefits to the society, owners and occupants of buildings including:

(i) Improving environment by reduction of CO_2 emission
By implementing BEER techniques, energy wastage can be minimized causing for a reduction in the demand for energy in buildings. Accordingly, there will be a supply side reduction in energy generation. As a result, burning of fossil fuel for energy, which releases CO_2 to the environment, will be reduced. Therefore, BEER implementations help to improve the environment by reducing global warming.

(ii) Saving money on utility bills and reducing maintenance costs
Energy cost, especially for electricity, is increasing day by day with the increase of energy crisis in the world. Therefore, commercial buildings have to allocate money from their profits to pay utility bills. BEER implementations save energy and hence energy bills. Most of the BEER methods come with new technology

implementations. These reduce maintenance requirements than conventional technologies. Although the initial or capital cost of BEER projects is high, they are more profitable when the life cycle cost is considered.

(iii) Creating jobs and career opportunities
BEER opportunities create jobs and career opportunities because nowadays there are Energy Service Companies (ESCos) engaged in this industry.

(iv) Enhancing comfort, safety and productivity in workplace and community spaces
BEER technologies replace the conventional systems in buildings with new systems considering the improvement of comfort and safety, and productivity as well. Therefore, these value additions can be gained in the buildings in addition to energy efficiency improvement.

In Section 2 above, energy intensive areas in existing hotel buildings in the world were discussed. Accordingly, energy efficiency retrofit technologies should be mainly implemented focusing them.

3.1. Key Phases in Energy Retrofitting

To implement successful energy retrofit projects, it is important to follow a proper procedure by the building owners as well as the service providing ESCos. Because of the high capital cost of these projects, achieving an attractive payback period and a guarantee for the predicted energy savings are key factors to be considered. Ma et al. [4] divided the overall process of a building retrofit into five major phases, mentioned as key phases in a sustainable building retrofit program. These can be described as follows.

- Phase 1: Project setup and pre-retrofit survey
  As categorized by Ma et al. [4] in Table 2, there are different types of building energy retrofit technologies. To initially prioritize and select the immediately required retrofit actions according to the financial capability of the building owners, a pre-retrofit survey is important. Project scope can be defined accordingly. Energy bill data over a period in the past (generally for 12 months) of the building can be gathered and observed by the selected ESCo in this Phase. Hence, significant bill variations and reasons for such variations can be initially investigated.
- Phase 2: Energy auditing and performance assessment
  Based on the findings in Phase 1, a comprehensive or focused energy audit can be conducted in the building. In a comprehensive energy audit scope, both electrical and thermal energy systems are considered. In a focused energy audit, the

Table 2 - Main categories of building retrofit technologies [4]

Category	Area of Energy Retrofit	Building Energy Retrofit Technologies
Demand Side Management	Heating and cooling demand reduction	• Building fabric insulation • Window retrofits • Cool roof and cool coatings • Air tightness, etc.
	Energy efficient equipment and low energy technologies	• Control upgrade • Natural ventilation • Lighting upgrade • Thermal storage • Energy efficient equipment and appliances • Heat recovery, etc.
Supply Side Management	Renewable energy technologies and electrical system retrofits	• Solar thermal systems • Solar PV/PVT systems • Wind power systems • Biomass systems • Geothermal power systems • Electric system retrofits, etc.
Human Factors	Energy Consumption Patterns	• Comfort requirements • Occupancy regimes • Management and maintenance • Occupant activities • Access to controls, etc.

scope can be limited only to a part of either electrical or thermal system (e.g. Heating, Ventilation and Air Conditioning (HVAC) system of the building). Energy audit findings can be used to assess the current energy performance of the building and hence to establish benchmarks prior to retrofitting.

- Phase 3: Identification of retrofit options
  Initially, prioritized retrofit options under Phase 1 can be now ensued and finalized based on the detailed analysis obtained under Phase 2. Based on the building situation, there can be no/low cost, medium cost and high cost/investment grade retrofit options to be considered. An estimate of energy savings which can be obtained after implementing the energy retrofit actions is required to be given by the ESCo in its energy retrofit proposal to the building owner. There are some ESCos who give a bank guarantee for these estimated saving amounts which makes the building owner more confident to invest.
- Phase 4: Site implementation and commissioning
  Energy retrofit project is implemented during an agreed period and commissioned at the end.
- Phase 5: Validation and verification
  After commissioning, savings are measured and verified to check whether the estimated savings are achieved. This can be done until the payback period is achieved.

3.2. Hotel Building Energy Retrofits

The following examples show the practical aspects of some of the energy retrofit technologies mentioned in Table 4.

The selected sample of 29 hotels in Singapore by Priyadarsini et al. [5] consisted of hotels constructed during 1920 – 2004 period. Of these, 15 hotels had gone through major energy retrofits, including upgrading façade, replacing chillers, installing energy efficient lamps and installing Building Management Systems (BMSs), during 1993 to 2003 period. Priyadarsini et al [5] further described that replacement of old chiller units with new and more efficient ones often resulted in great savings in cooling energy demand. Chow et al. [24] also mentioned two ways to replace chillers under energy retrofitting. These are, replacing air cooled chillers with water cooled chillers and replacing conventional chillers with oil free magnetic bearing chillers. At present, these magnetic bearing chillers are the most energy efficient chillers with about 30% energy savings than conventional chillers. BMS installations are also important to monitor and control building facilities while minimizing wastages and human errors. Building Energy Management System (BEMS) is a new version of BMS.

The study published by Yao et al. [18] in 2015 mentioned that, out of the selected 45 hotels in Shanghai, 30 hotels had been retrofitted in the past ten years. Of that, 15 hotels installed energy-efficient lights. Chow et al. [24] also mentioned lighting related retrofit actions such as replacement with T8 fluorescent lamps and LED lamps, adding motion/occupancy sensor controls and daylight sensors for lighting. Six of the hotels installed variable frequency pumps. Yao et al. [18] mentioned about installation of variable speed primary chilled water pumps, fan coil units with variable speed drive fans and lift motors with variable voltage variable frequency drives. Five of the hotels implemented condenser heat recovery technologies and four hotels replaced coal boilers by heat pumps or gas. Implementing renewable energy technologies, three hotels used solar collectors for hot water generation. As a retrofit action, Chow et al. [24] also mentioned installing solar collectors: thermal or photovoltaic.

Kilic and Altun [3] conducted a case study on achieving sustainable buildings via energy efficiency retrofit for a hotel building in Turkey. The case study hotel consisted of 252 rooms. An energy audit was conducted before the retrofit which showed an annual total electricity and coal consumption as 1,140,685 kWh and 669,210 kg, respectively. During energy retrofit implementations, a significant attention was paid to the air conditioning system. Instead of using coal as the heat source in the central heating system of this hotel building, water source heat pumps with higher Coefficient of Performance (COP) was proposed. In addition to the water sourced pump, a condensing fuel fired boiler was proposed. Energy audit results after implementation of those retrofit actions showed an increase in energy efficiency and decrease of annual energy cost by 50%. Chow et al. [24] also mentioned the retrofitting technology of installing heat pumps to domestic hot water supply.

Xing et al. [25] selected a four-star hotel in Tianjin, China as a case study to analyse the implemented energy efficiency retrofit scheme in that hotel. Consumption of monthly electrical energy, and electrical & thermal energy, before and after retrofits were plotted as shown in Figure 2 and Figure 3, respectively.

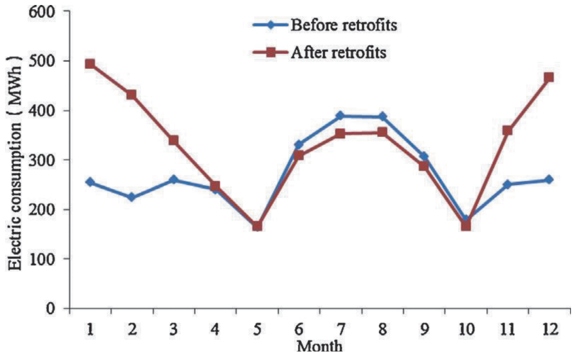

Figure 2 - Comparison of electrical energy before and after retrofits [25]

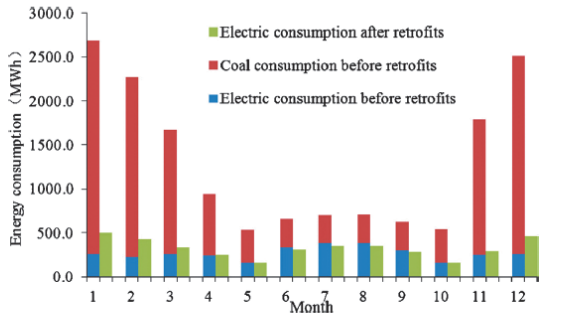

Figure 3 - Comparison of electrical & thermal energy consumption [25]

From the study, Figures 2 and 3 were selected for this paper to show that energy retrofits do not always cause reduction of electrical energy consumption. This is evident with proven records which can be used to remove misunderstanding among some people that BEER projects are only for electrical systems.

In that case study, energy retrofit actions were taken for both heating in winter and cooling in summer. Previously coal was used as the energy source for the boiler but at the retrofit, electric heat pumps were installed. Although it increased the electricity consumption in winter months of the year as shown in Figure 2, it eliminated the coal-based energy consumption. Coal was the largest energy source in this hotel compared to electricity as shown in Figure 3 and therefore the retrofit actions were mainly focused to eliminate coal consumption. To reduce electricity consumption for cooling in summer, energy efficient chillers were installed, and constant speed pumps were replaced with variable speed pumps. Annual energy saving was 74.6%.

All the above discussed energy retrofit technologies can be identified under demand side management category. Tsoutsos et al. [26] studied Nearly Zero Energy Buildings (NZEB) in Mediterranean hotels. As mentioned in that study, to reach a NZEB hotel level, the hotels have to reduce their energy consumption to 100 kWh/m^2/year. These hotels are required to produce 80% of their needs by renewable energy systems (50% for heating, 50% for electricity). As shown in Table 2, renewable energy technologies are categorized as supply side management energy retrofitting technologies. Tsoutsos et al. [26] also stated that Near Zero Energy Hotels (NZEHs) will link the supply side and demand side. The European Union (EU) has set an ambitious target to reduce the domestic greenhouse gas emissions by 80%-95% by 2050 compared to 1990 levels. To achieve that with NZEB, EU focused on the hospitality industry which is responsible for 2% of the world's CO_2 emissions. Therefore, NZEB can be considered as the latest trend in energy retrofit implementations.

3.3. Barriers for Energy Retrofit Projects

High capital investment has become the most common barrier to implement energy retrofit projects in buildings. Tsoutsos et al. [26] mentioned some other barriers to improve energy efficiency in new buildings and further mentioned them as common for energy efficiency retrofitting in existing buildings [26]. These can be explained as follows:

(i) Major focus on incremental cost instead of running cost
Most of the energy retrofit solutions come with latest energy saving technologies, with higher incremental costs but lower operational costs during their lifetime than conventional technologies. Therefore, during an economic comparison of two technologies or equipment, it is important to conduct a life cycle cost analysis before decision making.

(ii) Low updated knowledge on the present best practices for energy efficiency issues and potential savings
Most of the decision makers/consultants are familiar with conventional energy saving technologies than latest most energy efficient technologies. Therefore, they provide consultancy to their clients based on that.

(iii) Some markets require specific equipment or expertise to implement energy efficiency improvements which are not commonly available.

In these cases, incremental cost of equipment can be much higher compared to other energy retrofit technologies because special designs are required. The required technical expertise also can be limited.

(iv) Traditional belief as to provide guest comfort, high energy consumption rates are required.

It was a popular belief in the past that to achieve one condition, it is required to sacrifice another condition. In this case, to provide comfort indoor conditions to people it is considered necessary to sacrifice energy conservation. This attitude, which has been proven wrong in the past, is still in some people's mind.

(v) Reluctance to increase the energy efficiency of the building more than the minimum standards as mentioned in the national building codes.

The reason for this is the budgetary constraints to invest on further energy efficiency improvement projects once the minimum requirements are fulfilled. Energy saving should not be terminated after obtaining either national or global standards. It is important to continue with latest energy saving technologies thinking as a contributor to reduce global energy crisis and global warming.

After understanding these barriers, it is important to consider the paths to implement successful energy retrofit projects by overcoming these barriers.

3.4. Energy Performance Contracting for Successful Retrofit Projects

Energy Performance Contracting (EPC) is a methodology used by ESCos to implement (design, install and deliver) building energy retrofit projects while overcoming above barriers. The speciality of EPC is, ESCos give bank guarantees to their clients for the monetary value of the estimated annual energy saving amount during the project payback period. Mostly, EPC comes with the latest and proven energy efficiency improvement technologies, and therefore it is possible to guarantee the estimated savings. After project implementation, it is required to measure and verify the monthly achieved energy savings. This is mostly done by an independent measure and verification consultant. Actually, building owners get motivated to invest on energy retrofit projects via EPC because of this guarantee. Although there are many ESCos in the world engaged in energy saving, only few of them provide EPC service.

4. Conclusions and Recommendations

It is concluded that existing hotel building energy retrofitting is important for countries with tourism industry as a major source of income. It will help the industry to reduce their overhead costs and be competitive with newly constructed energy efficient hotels. There is a possibility that future tourists will search for energy efficiency certified hotels.

As majority of energy consumption of a hotel building is for the HVAC system, it is recommended to give priority to improve the efficiency of that. Energy efficient magnetic bearing chiller technology and pressure independent balancing control valves are present energy saving technologies related to HVAC system. It is always recommended to follow ASHRAE HVAC standards based on the location climate zone. It is recommended to install a BMS/BEMS to monitor, operate and control all critical equipment of the hotel such as chiller, air handling units, pumps, cooling towers, lighting, cold rooms, exhaust air fans, supply air fans, boilers, generators, solar power systems, etc.

As these are high cost technologies to get substantial energy savings, it is important for hotels to plan for the investment through early budget allocations or loans. To implement above technologies under a turnkey energy retrofit project, it is strongly recommended to get the service from an experienced ESCo who provides EPC service. Support of the hotel engineering team to ESCo engineers is very important to deliver a successful project.

Acknowledgement

The authors would like to acknowledge the assistance given by Prof. J.R. Lucas of Department of Electrical Engineering, University of Moratuwa, for editing this paper.

References

1. IEA webstore. (2017, December 4). *Policy Pathways Brief: Modernizing Building Energy Codes 2017* [Online]. Available: https://webstore.iea.org/policy-pathways-brief-modernising-building-energy-codes-2017.

2. Lucon O., D. Ürge-Vorsatz, A. Zain Ahmed, H. Akbari, P. Bertoldi, L.F. Cabeza, N. Eyre, A. Gadgil, L.D.D. Harvey, Y. Jiang, E. Liphoto, S. Mirasgedis, S. Murakami, J. Parikh, C. Pyke, and M.V. Vilariño, 2014: Buildings. In*: Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J.C. Minx (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

3. Kilic, M. and Altun, A. F., "Achieving Sustainable Buildings via Energy Efficiency Retrofit: Case Study of a Hotel Building," in *Proceedings of 3rd International Sustainable Buildings Symposium,* 2018, pp. 97-107.

4. Ma, Z., Cooper, P., Daly D., and Ledo, L., "Existing Building Retrofits: Methodology and State-of-the-Art," *Energy and Buildings*, vol. 55, pp.889-902, Dec. 2012.

5. Priyadarsini, R., Xuchao, W., and Eang, L. S., "A Study on Energy Performance of Hotel Buildings in Singapore," *Energy and Buildings*, vol. 41, no.12, pp.1319-1324, Dec. 2009.

6. Eras, J. J. C., Santos, V. S., Gutiérrez, A. S., Plasenica, M. A. G., Haeseldonckx D. and Vandecasteele, C., "Tools to Improve Forecasting and Control of the Electricity Consumption in Hotels," *Journal of Cleaner Production*, vol. 137, pp.803-812, Nov. 2016.

7. Bohdanowicz, P., Churie-Kallhauge A. and Martinac, I., "Energy-Efficiency and Conservation in Hotels - Towards Sustainable Tourism," *4th International Symposium on Asia Pacific Architecture*, Apr. 2001.

8. Deng, S. and Burnett, J., "A Study of Energy Performance of Hotel Buildings in Hong Kong," *Energy and Buildings*, vol. 31, no.1, pp.7-12, Jan. 2000.

9. Deng, S., "Energy and Water Uses and Their Performance Explanatory Indicators in Hotels in Hong Kong," *Energy and Buildings*, vol. 35, no.8, pp.775-784, Sep. 2003.

10. Trung, D., and Kumar, S. "Resource use and Waste Management in Vietnam Hotel Industry," *Journal of Cleaner Production,* vol. 13, no. 2, pp.109-116, Jan. 2005.

11. Batle, B. R., Moià, A., Cladera, A., and Martínez, V., "Energy Use, CO_2 Emissions and Waste Throughout the Life Cycle of a Sample Hotels in the Balearic Islands," *Energy and Buildings*, vol. 42, no. 4, pp.547-558, Apr. 2010.

12. Bohdanowicz, P., and Martinac, I., "Determinants and Benchmarking of Resource Consumption in Hotels – Case Study of Hilton International and Scandic in Europe," *Energy and Buildings*, vol. 39, no.1, pp.82-95, Jan. 2007.

13. Onut, S., and Soner, S., "Energy Efficiency Assessment for the Antalya Region Hotels in Turkey," *Energy and Buildings*, vol. 38, no. 8, pp.964-971, Aug. 2006.

14. Farrou, I., Kolokotroni M., and Santamouris, M. "A Method for Energy Classification of Hotels: A Case-Study of Greece," *Energy and Buildings*, vol. 55, pp.553-562, Dec. 2012.

15. Wang, J. C. "A Study on the Energy Performance of Hotel Buildings in Taiwan," *Energy and Buildings*, vol. 49, pp.268-275, Jun. 2012.

16. Tulsyan, A., "Potential of Energy Savings Through Implementation of Energy Conservation Building Code in Jaipur City, India," *Energy and Buildings*, vol. 58, pp.123-130, Mar. 2013.

17. Chedwal, R., "Energy Saving Potential Through Energy Conservation Building Code and Advance Energy Efficiency Measures in Hotel Buildings of Jaipur City, India," *Energy and Buildings*, vol. 92, pp.282-295, Apr. 2015.

18. Yao, Z., Zhuang, Z., and Gu, W., "Study on Energy Use Characteristics of Hotel Buildings in Shanghai," *Procedia Engineering*, vol. 121, pp.1977-1982, 2015.

19. Tang, M., Fu, X., Cao, H., Shen, Y., Deng H., and Wu, G., " Energy Performance of Hotel Buildings in Lijiang, China," *Sustainability*, vol. 8, no. 8, Aug. 2016.

20. NationMaster. *Geography* > *Climate: Countries Compared* [Online]. Available: https://www.nationmaster.com/country-info/stats/Geography/Climate.

21. Chan, W. W., and Lam, J. C., "Prediction of Pollutant Emission Through Electricity Consumption by the Hotel Industry in Hong Kong," *International Journal of Hospitality Management*, vol. 21, no. 4, PP.381-391, Dec. 2002.

22. Encyclopaedia Britannica. *Mediterranean Climate* [Online]. Available: https://www.britannica.com/science/Mediterranean-climate.

23. Xu, P., Chan, E. H. W., and Qian, Q. K., "Success Factors of Energy Performance Contracting (EPC) for Sustainable Building Energy Efficiency Retrofit (BEER) of Hotel Buildings in China," *Energy Policy*, vol.39, no. 11, pp.7389-7398, Nov. 2011.

24. Chow, T. T., Lee, C. K., Fong, A. M. L., Leung, C. F., Hung, A., Wan, M., Wong, W., Chung, C., Sat, P., and Tsang, I. "Retrofitting Existing Buildings: a Quantitative Approach to Energy Project Evaluation," in *The 7th Greater Pearl River Delta Conference on Building Operation and Maintenance.*

25. Xing, J., Ren, P., and Ling, J., "Analysis of Energy Efficiency Retrofit Scheme for Hotel Buildings Using eQuest Software: A Case Study From Tianjin, China," *Energy and Buildings*, vol. 87, pp.14-24, Jan. 2015.

26. Tsoutsos, T., Tournaki, S., Santos, C. A. D., and Vercellotti, R., "Nearly Zero Energy Buildings Application in Mediterranean Hotels," *Energy Procedia*, vol. 42, pp.230-328, 2013.

27. "Annual Statistical Report 2018", Research and International Relation Division, Sri Lanka Tourism Development Authority, Colombo 03.

28. ASHRAE Manager of Standards, "Addenda b to ANSI/ASHRAE Standard 169-2006 Climate Change Data for Building Design Standards" 1791 Tullie Circle, NE, Atlanta GA, 30329.