Uluslararası İleri Doğa Bilimleri ve Mühendislik Araştırmaları Dergisi
Sayı 8, S. 119-125, 9, 2024

Araştırma Makalesi

International Journal of Advanced Natural Sciences and Engineering Researches
Volume 8, pp. 119-125, 9, 2024

Research Article

https://as-proceeding.com/index.php/ijanser
ISSN:2980-0811

Investigation of the Energy Use Pattern in Hotel Buildings in Tropical Savannah Climate: A Case Study of Minna

Zhiri, Gabriel Hassan *and Bawa, John Agmada [2]

[1] *Department of Architecture/Federal University of Technology Minna, Nigeria*
[2] *Department of Architecture/Baze University, Abuja, Nigeria*

(gabrielzhiri57@gmail.com) Email of the corresponding author

(Received: 27 September 2024, Accepted: 02 October 2024)

(6th International Conference on Applied Engineering and Natural Sciences ICAENS 2024, 25-26 September 2024)

ATIF/REFERENCE: Zhiri, G. H. & Bawa, J. A. (2024). Investigation of the Energy Use Pattern in Hotel Buildings in Tropical Savannah Climate: A Case Study of Minna, *International Journal of Advanced Natural Sciences and Engineering Researches*, 8(9), 119-125.

***Abstract* –** The hospitality industry is crucial for economic development in cities like Minna, Nigeria, providing essential services to a diverse clientele. However, the energy-intensive nature of their operations, exacerbated by the tropical savannah climate's high temperatures and humidity found in Minna, highlighting a critical need for research on energy consumption patterns and factors influencing energy usage in these establishments. There are a lot of questions about the energy consumption patterns of hotel buildings, especially in places like Minna where climatic and ecological factors further shape energy dynamics and the need for sustainable practices. This study aims to investigate the energy use pattern of hotel buildings in Minna. It utilized a qualitative approach through energy audits of ten randomly selected hotel buildings in Minna, analyzing data from energy consumption bills and observations to identify energy usage patterns and inform strategies for enhancing energy efficiency. The analysis of energy consumption revealed that, on average, each room consumes 30.24kWh/day and reflect the operational scale and efficiency of each hotel, with potential for improved energy management particularly in hotels with high differences between full capacity and actual occupancy demands. This also shows possibility for energy efficiency improvements in hotels, particularly by optimizing operational strategies and integrating renewable energy sources to reduce overall environmental impact. It is recommended that hotels adopt energy-efficient technologies and optimize their operational strategies, particularly during low occupancy periods, to enhance energy conservation and reduce environmental impact.

Keywords – Energy Consumption, Hospitality Industry, Hotels, Sustainable Practices, Energy Efficiency

I. INTRODUCTION

The hospitality industry, particularly hotel buildings, plays a vital role in the economic development of many cities worldwide. In Nigeria, hotels provide essential services to tourists, business travellers, and locals alike. However, hotel operations are energy-intensive, contributing significantly to greenhouse gas emissions and environmental degradation [1]. Located in the tropical savannah climate of West Africa, Minna, the capital city of Niger State, Nigeria, experiences high temperatures and humidity levels throughout the year ([2]-[3]). This climatic condition necessitates substantial cooling demands in hotel buildings, leading to increased energy consumption.

Hotel buildings are among the largest energy consumers in the commercial sector, accounting for approximately 46% of total energy usage [4]. In tropical regions like Minna, energy consumption is exacerbated by: High cooling demands due to temperature and humidity [5], increased use of air conditioning, refrigeration, and ventilation systems [6], and limited adoption of energy-efficient technologies and practices [6].

Despite the growing importance of sustainable hospitality practices, there is a scarcity of research focused on energy use patterns in hotel buildings within the tropical savannah climate. Specifically, Minna lacks comprehensive studies on: Energy consumption profiles of hotel buildings, and Factors influencing energy usage in Hotel buildings. Therefore, this study aims to investigate the energy use pattern of hotel buildings in Minna, Niger State, Nigeria.

A. *Energy Use Pattern in Hotel Buildings*

One of the primary metrics used to evaluate energy performance in hotels is Energy Use Intensity (EUI), which quantifies the annual energy consumption relative to the building's gross floor area. Research indicates that hotels typically exhibit the EUI ranging from 200 to 400 kWh/m² annually, with significant portions of this energy allocated to heating, ventilation, and air conditioning (HVAC) systems, which can account for nearly half of total energy usage [7]. For instance, a study on hotels in Lijiang, China, found that the average EUI was approximately 273 kWh/m², highlighting the potential for energy savings through the adoption of more efficient systems [8]. Similarly, a study of 3-star hotels in Sarawak reported an average EUI of 210.8 kWh/m², emphasizing the correlation between building characteristics (such as height and guest room area) and energy consumption [9].

The operational strategies employed by hotels also significantly impact energy use. An example is [10] which highlighted that the COVID-19 pandemic altered guest behavior and occupancy rates, leading to changes in energy consumption patterns. Hotels have had to adapt their energy management strategies to align with these new dynamics, focusing on optimizing HVAC operations and implementing energy-saving technologies to achieve carbon neutrality ([10]-[11]). Furthermore, energy audits are essential for identifying inefficiencies and establishing benchmarks for energy consumption, allowing hotels to implement targeted interventions to reduce waste ([12]-[13]).

In addition to operational factors, psychological and behavioral aspects of hotel guests play a critical role in energy conservation. Studies have shown that enhancing guests' awareness of energy-saving practices can lead to more sustainable behaviors during their stay ([14]-[15]). For instance, the introduction of energy labels and informational campaigns can encourage guests to engage in energy-saving actions, thereby reducing overall consumption [14].

Moreover, the design and construction of hotel buildings can influence energy use patterns. Passive design strategies, such as optimizing natural ventilation and daylighting, can significantly reduce reliance on mechanical systems, thereby lowering energy consumption [16]. The integration of renewable energy sources, such as solar thermal systems, has also been explored as a means to enhance energy efficiency in hotel operations [17].

It can then be asserted that the energy use patterns in hotel buildings are shaped by a complex interplay of multiple factors and by leveraging energy audits, the hospitality industry can make significant strides toward reducing its environmental impact and promoting sustainability.

B. *Energy Use Patterns in Tropical Savannah Climates*

Tropical savannahs exhibit unique hydrological characteristics that significantly influence energy use. The seasonal flow regimes of rivers in these regions, marked by high inter-annual variability, affect both the availability of water resources and the ecological health of the ecosystems [18]. The interplay between vegetation and landscape features also plays a critical role in determining energy dynamics. Vegetation types such as grasses and scattered trees impact the local microclimate, which in turn influences energy consumption patterns in buildings and other infrastructures ([19]-20]).

Moreover, the integration of renewable energy technologies, such as solar power, is becoming increasingly vital in tropical savannah regions. The high solar irradiance typical of these climates presents opportunities for harnessing solar energy to meet the energy demands of local populations [21]. Studies have shown that building-integrated photovoltaic systems can significantly enhance energy efficiency in tropical climates by reducing reliance on conventional energy sources [22]. This is particularly important in urban areas where energy consumption is high, and the need for sustainable solutions is pressing [23].

The impact of climate change on energy use patterns in tropical savannahs cannot be overlooked. As temperatures rise and precipitation patterns shift, the resilience of these ecosystems is threatened, which may lead to changes in vegetation cover and, consequently, energy dynamics [24]. For example, prolonged dry seasons can increase the demand for energy-intensive cooling systems in buildings, exacerbating energy consumption and greenhouse gas emissions [25]. Therefore, it is essential to adopt energy-efficient building designs and retrofitting strategies that are tailored to the specific climatic conditions of tropical savannahs ([26]-[23]). From the flow of literature, it was seen that energy use patterns in tropical savannah climates could be shaped by climatic, ecological, and anthropogenic factors.

II. Materials and Method

This study employed a qualitative approach by conducting energy audits on a sample of ten randomly selected hotel buildings in the Tunga area of Minna. Data were gathered from energy consumption bills and observations to analyze the energy usage patterns in these hotels. As noted by [27], energy audits are intended to stimulate inquiries regarding energy consumption behaviors. They serve as a critical tool for assessing energy demand, consumption, management, and identifying opportunities for enhancing energy efficiency in hotel operations ([28], [29]-[30]). The audit process included a thorough examination of electricity bills and an analysis of electrical appliances used for lighting and cooling, aligning with the recommendations made by [31]. From this research, a framework for energy conservation design was developed, drawing on insights from the audits. According to [32], information regarding lighting, heating, ventilation, and cooling systems derived from energy audits is essential for accurately evaluating the performance of hotel facilities.

The energy audits facilitated the estimation of daily energy consumption in kilowatt-hours, which was then compared to the average monthly electricity usage recorded in the bills. For this comparison, it was assumed that electricity supply was consistent throughout the 24-hour occupancy period. This approach allowed for the calculation of the estimated energy demand specifically for lighting and space cooling. The results from this analysis were thoroughly examined and compared in relation to the research objective, which focuses on identifying the energy usage patterns within hotel buildings in Minna. This methodical assessment aims to provide a clearer understanding of how energy is consumed in these establishments and to inform strategies for improving energy efficiency.

III. Results

The energy audit was carried out on ten (10) hotels in Tunga area, 60% of them provided valid information required for the audit in the research as the energy bills as well as their capacity were provided. In Table and Figure below, the six (6) hotels whose data was analysed for this audit are the Aloe Vera, Nasfah, Brighter suites, Yayi, nothing pass God (NPG) and Carol deep sleep hotels with an average number of rooms at 43.33 and an average occupancy rate of 40.50%. In these hotel buildings, 50% have over 50 rooms.

It was observed that the energy demand for each room was made up of energy consumption on artificial lighting at 1.26kWh/day, and air conditioning at 28.98kWh/day. Hotel C had an exceptionally high monthly mean energy consumption of 5,330.50 kWh. In contrast, Hotel F had a monthly mean of 909.50 kWh. Also, Hotel B has a full capacity demand of 1,905.12 kWh compared to its occupancy demand of 952.56 kWh, while the average daily energy design demand of 1,310.40 kWh reveals the potential for energy savings in the Hotel.

Hotel C stands out with the highest monthly mean consumption of 5,330.50 kWh, yet its energy design demand at occupancy is relatively low at 362.88 kWh. Hotel A, with a monthly mean consumption of 2,211.42 kWh and the highest design demand at 716.69 kWh, demonstrates a strong correlation between energy usage and the amenities it provides.

Table 1: Energy use and demand by design for lighting and space cooling for rooms

Hotels	Monthly mean Energy consumption (kWh/month)	Estimated daily Energy consumption (kWh/day)	Energy design demand per day in full capacity (kWh)	Energy design demand per day at occupancy rate
Hotel A	2211.42	72.65	2388.96	716.69
Hotel B	1983.13	65.15	1905.12	952.56
Hotel C	5330.50	175.13	1814.4	362.88
Hotel D	3859.57	126.80	786.24	393.12
Hotel E	1589.00	52.21	635.04	209.56
Hotel F	909.50	29.88	332.64	199.58
Average	**2647.19**	**86.97**	**1310.40**	**482.22**

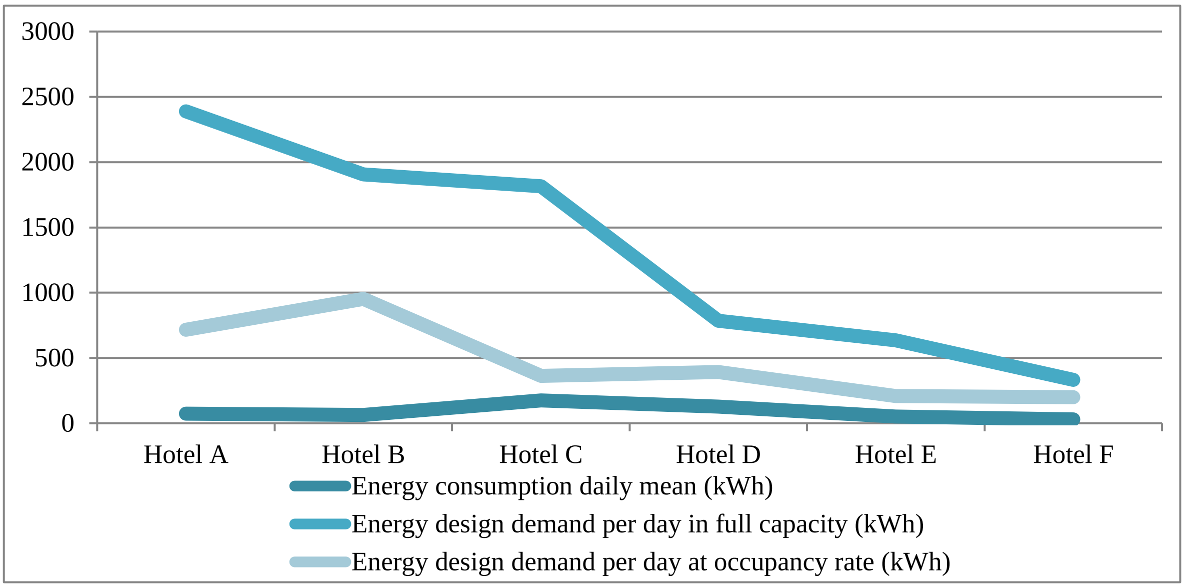

Figure 1: Energy consumption and demand

IV. DISCUSSION

The energy consumption data highlights distinct patterns across the hotels, revealing both the operational scale and energy efficiency measures in place. Examining the energy design demands in relation to occupancy rates illustrates potential areas for improvement by design. Hotels like A and B exhibit a notable difference between their full capacity demands and actual occupancy consumption, suggesting they could enhance energy efficiency by optimizing operations during lower occupancy periods. The full capacity demand of Hotel B compared to its occupancy demand indicates that energy savings could be realized by adjusting energy use in line with real-time occupancy.

The energy demand metrics observed in the study, particularly the consumption values for air conditioning per room, align with established energy performance benchmarks in the hospitality sector. Research indicates that hotels generally exhibit that the annual Energy Use Intensity (EUI) has HVAC systems accounting for a substantial portion of total energy usage [7]. The total daily energy demand indicates that hotels could benefit from implementing more energy-efficient technologies to bring their energy use in line with optimal performance metrics.

Examining the broader patterns of energy consumption across various hotels reveals a stark contrast in energy usage and operational efficiency. The high monthly energy consumption of Hotel C could be indicative of its extensive amenities and larger guest capacity. However, its energy design demand at occupancy of only 362.88 kWh suggests a potential for energy conservation that could be optimized further [8].

Conversely, the monthly mean consumption of Hotel A and its highest design demand at 716.69 kWh, demonstrates a strong correlation between energy usage and the amenities it provides; possibly reflecting a maintained higher energy needs even when occupancy fluctuates.

On the other hand, Hotels E and F exhibit significantly lower energy consumption and design demands, with monthly means of 1,589.00 kWh and 909.50 kWh, respectively. Their design demands at occupancy (209.56 kWh and 199.58 kWh) further highlight their efficiency in maintaining lower energy needs. The average energy design demand across all hotels is 482.22 kWh, and the significant variation in demand indicates diverse operational strategies and levels of energy efficiency. Hotels with higher consumption relative to their design demand may benefit from evaluating their energy practices to enhance efficiency, while those with lower consumption levels exemplify potential models for sustainable operation in the hospitality sector.

This should explore the significance of the results of the work, not repeat them. The results should be drawn together, compared with prior work and/or theory and interpreted to present a clear step forward in scientific understanding. Combined Results and Discussion sections comprising a list of results and individual interpretations in isolation are particularly discouraged.

Conversely, Hotels E and F, with much lower monthly mean consumptions of 1,589.00 kWh and 909.50 kWh, demonstrate efficient energy management practices. This variation in energy consumption points to the influence of operational strategies, as noted in the literature, where adjusting energy use based on occupancy can yield significant savings [10]. This aligns with findings from [9], which highlighted that building characteristics and operational efficiencies are closely correlated with energy consumption levels.

Moreover, the potential for energy savings is highlighted in the analysis of energy design demands relative to occupancy rates. This is because of significant discrepancies seen between full capacity and actual occupancy energy demands of Hotels A and B, suggesting that they could enhance energy efficiency by optimizing their operations during periods of lower occupancy [11]. The results suggest that while some hotels are operating well within their energy limits, others could adopt smarter resource management strategies to achieve better efficiency. This is particularly relevant in light of the unique climatic influences noted in tropical savannahs, where factors such as high solar irradiance provide opportunities for integrating renewable energy sources [21].

V. CONCLUSION

Given that air conditioning is one of the most energy-intensive components, the per-room consumption observed suggests that operational strategies and the efficiency of HVAC systems significantly impact overall energy consumption patterns. Ultimately, by adopting energy audits and improving operational strategies, the hospitality sector can make significant strides in reducing its environmental impact while promoting sustainability, thereby addressing the complex interplay of operational, ecological, and behavioural factors influencing energy consumption.

Enhancing energy efficiency in hotel buildings while reducing costs and environmental impact, it is suggested that hotels adopt comprehensive energy audits to identify inefficiencies and implement targeted interventions such as upgrading HVAC systems and integrating renewable energy sources like solar panels. Policymakers in Nigeria should promote sustainable hospitality practices by developing regulations and incentives that encourage energy efficiency, including grants for retrofitting existing buildings and guidelines for new constructions. Additionally, valuable insights should be provided to hotel owners, operators, and architects to design and manage energy-efficient structures that are tailored to the unique climatic conditions of tropical savannahs, such as incorporating passive design strategies for natural ventilation and daylighting, thereby fostering a more sustainable hospitality sector in Nigeria.

ACKNOWLEDGMENT

All that supported the research are acknowledged.

REFERENCES

[1] Bohdanowicz, P., Churie-Kallhauge, A., Martinac, I., & Rezachek, D. (2001, April). Energy-efficiency and conservation in hotels–towards sustainable tourism. In 4th International Symposium on Asia Pacific Architecture (Vol. 21).

[2] Sankaran, M. (2019). Droughts and the ecological future of tropical savanna vegetation. Journal of Ecology, 107(4), 1531-1549.

[3] Alonge, D. O., Oyetola, S. A., Adebisi, G. O., Onuwe, J. O., Tauheed, I. A., & Attah, A. U. (2016). Assessment of bioclimatic principles in the design of public spaces in Minna.

[4] U.S. Energy Information Administration (EIA). (2018). 2018 Commercial Buildings Energy Consumption Survey (CBECS): Principal Building Activities Lodging. U.S. Energy Information Administration (EIA). Retrieved September 25, 2024, from https://www.eia.gov/consumption/commercial/pba/lodging.php

[5] Kolo, Y., & Olagunju, R. (2018). Assessment of Passive Cooling Techniques in All Lecture Theatres of Federal University of Technology Minna, Niger State. International Journal of Innovative Research and Advanced Studies, 5, 346-354.

[6] Zhiri, G. H., & Akande, O. K. (2018). Passive Techniques for Energy Conservation in Hotel, Buildings in Minna, Nigeria. In Contemporary Issues and Sustainable Practices in the Built Environment. In School of Environmental Technology Conference, SETIC (pp. 95-104).

[7] Vujošević, M. and Krstić-Furundžić, A. (2017). The influence of atrium on energy performance of hotel building. Energy and Buildings, 156, 140-150. https://doi.org/10.1016/j.enbuild.2017.09.068

[8] Tang, M., Xiao, F., Cao, H., Yuan, S., Deng, H., & Wu, G. (2016). Energy performance of hotel buildings in Lijiang, China. Sustainability, 8(8), 780. https://doi.org/10.3390/su8080780

[9] Jing, W. J., Gapor, S. B. A., & Sze, W. L. (2021). A Study on Energy Performance of 3-Star Hotel Buildings in the Capital City of Sarawak. Borneo Journal of Social Sciences and Humanities. https://doi.org/10.35370/bjssh.2021.3.1-03

[10] Wu, Y., Xin, B., Zhu, H., & Ye, Z. (2022). Energy-saving operation strategy for hotels considering the impact of covid-19 in the context of carbon neutrality. Sustainability, 14(22), 14919. https://doi.org/10.3390/su142214919

[11] Wang, Y., Dong, L., & Li, H. (2022). Economic evaluation of energy-saving retrofit of existing hotels. Energies, 15(3), 757. https://doi.org/10.3390/en15030757

[12] Okpala, C. (2023). A data envelopment analysis to benchmark hotel energy consumption in an urban locality. https://doi.org/10.20944/preprints202309.1476.v1

[13] Dibene-Arriola, L., Carrillo-González, F., Quijas, S., & Rodríguez-Uribe, M. (2021). Energy efficiency indicators for hotel buildings. Sustainability, 13(4), 1754. https://doi.org/10.3390/su13041754

[14] Wang, Q., Xie, K., Li, X., Shen, G., Wei, H., & Liu, T. (2021). Psychological drivers of hotel guests' energy-saving behaviours—empirical research based on the extended theory of planned behaviour. Buildings, 11(9), 401. https://doi.org/10.3390/buildings11090401

[15] Sam-Amobi, C., Ekechukwu, O., & Chukwuali, C. (2019). A preliminary assessment of the energy related carbon emissions associated with hotels in Enugu metropolis Nigeria. Afrrev Stech an International Journal of Science and Technology, 8(2), 19-30. https://doi.org/10.4314/stech.v8i2.2

[16] Yu, C., Guo, H., Wang, Q., & Chang, R. (2020). Revealing the impacts of passive cooling techniques on building energy performance: a residential case in Hong Kong. Applied Sciences, 10(12), 4188. https://doi.org/10.3390/app10124188

[17] Mouneer, T. and Aly, M. (2021). Hybrid chiller plant optimization strategies for hotel building on nile river of egypt. Journal of Power and Energy Engineering, 09(04), 61-88. https://doi.org/10.4236/jpee.2021.94005

[18] King, A., Townsend, S., Douglas, M., & Kennard, M. (2015). Implications of water extraction on the low-flow hydrology and ecology of tropical savannah rivers: an appraisal for northern Australia. Freshwater Science, 34(2), 741-758. https://doi.org/10.1086/681302

[19] Gao, H., Hrachowitz, M., Sriwongsitanon, N., Fenicia, F., Gharari, S., & Savenije, H. (2016). Accounting for the influence of vegetation and landscape improves model transferability in a tropical savannah region. Water Resources Research, 52(10), 7999-8022. https://doi.org/10.1002/2016wr019574

[20] Alkali, A. (2024). Benefits of integrating green architecture in public buildings within the savannah region of Nigeria. AJESRE, 15(1), 104-112. https://doi.org/10.62154/4bzbq615

[21] Kibtiah, T. (2024). Solar energy in Indonesia: the implementation of sustainable development goals for net zero emissions. Iop Conference Series Earth and Environmental Science, 1324(1), 012093. https://doi.org/10.1088/1755-1315/1324/1/012093

[22] Joseph, B., Kichonge, B., & Pogrebnaya, T. (2019). Semi-transparent building integrated photovoltaic solar glazing: investigations of electrical and optical performances for window applications in tropical region. Journal of Energy, 2019, 1-10. https://doi.org/10.1155/2019/6096481

[23] Chung-Camargo, K. (2024). Advances in retrofitting strategies for energy efficiency in tropical climates: a systematic review and analysis. Buildings, 14(6), 1633. https://doi.org/10.3390/buildings14061633

[24] Levine, N., Zhang, K., Longo, M., Baccini, A., Phillips, O., Lewis, S., Alvarez-Dávila, E., Segalin de Andrade, A.C., Brienen, R.J., Erwin, T.L. and Feldpausch, T.R. & Moorcroft, P. (2015). Ecosystem heterogeneity determines the ecological resilience of the amazon to climate change. Proceedings of the National Academy of Sciences, 113(3), 793-797. https://doi.org/10.1073/pnas.1511344112

[25] Esfandiari, M., Zaid, S., Ismail, M., Hafezi, M., Asadi, I., & Mohammadi, S. (2021). A field study on thermal comfort and cooling load demand optimization in a tropical climate. Sustainability, 13(22), 12425. https://doi.org/10.3390/su132212425

[26] Chung-Camargo, K. (2023). Energy-efficiency measures to achieve zero energy buildings in tropical and humid climates.. https://doi.org/10.5772/intechopen.1002801

[27] Green Impact Universities. (n.d.). Save Energy, Recycle More, Less Flying, Sustainable Local Food. Energy Audit Checklist retrieved from . https://www2.le.ac.uk/offices/estates/environment/getinvolved/archive/green-impact/resoucre-for-teams/energy-saving-resources/Green%20Impact%20audit%20checklist%20UoL.docx.

[28] International Institute for Energy Conservation (IIEC). (2015). Energy Efficiency Guidelines for Hotels in the Pacific: Promoting Energy Efficiency in the Pacific. Wattana,Bangkok: Asian Development Bank (ADB)
[29] Module 18,. (2009). Energy Efficiency in Buildings: Sustainable Energy Regulation and Policymaking for Africa. Sustainable Energy Regulation and Policymaking Training Manual, https://www.Unido.org>default>files.
[30] Hong, W., Chaing, M. S., Shapiro, R. A., & Clifford, M. L. (2007). Building Energy Efficiency: Why Green Buildings Are Keys To Asia's Future (Vol. An Asia Bussines Council Book). (M. P. Laurenzi, Ed.) Hong Kong: Pearl River Tower in Guangzhou, courtesy of Skidmore, Owings & Merrill LLP
[31] Goodwin, D. (2003). Home Energy Audit: Electricity Use. Teacher LAB Template . College Entrance Examination Board, Advanced Placement Program.
[32] Hotel Energy Solutions. (2011). Analysis on Energy Use by European Hotels: Online Survey and Desk Research. Hotel Energy Solutions project publications.