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Original Article

ENERGY PERFORMANCE ASSESSMENT OF HOTEL BUILDINGS IN VARADERO, CUBA

EVALUACIÓN DEL DESEMPEÑO ENERGÉTICO DE EDIFICIOS HOTELEROS EN VARADERO, CUBA

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ABSTRACT

Introduction:
Hotels are among the most energy-intensive building types; improving their efficiency offers both economic and environmental benefits. Reliable assessment of energy performance requires statistically validated baselines and performance indicators.
Objective:
To evaluate the energy performance of hotel buildings in Varadero, Cuba, using statistically derived baselines and performance metrics.
Materials and Methods:
Baseline energy consumption (EnB) was established for 15 hotels using the IDELIN_Hotel software tool, which integrates occupancy and cooling degree days (CDD) into a combined variable (Room Degree Days, RDD). Statistical validity was verified using the correlation coefficient (R^2), the mean squared error coefficient of variation (CV-RMSE), and the normalized mean error coefficient (NMBE). Performance in the subsequent year was evaluated using specific energy consumption (Cee), non-service energy (Eo), energy variance (Ev), and cumulative sum of deviations (CUSUM).

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Results and Discussion:
Twelve hotels achieved energy savings relative to their baselines, while three operated inefficiently. The best performance was observed in Hotel K, which saved 1300 MWh/year. Indicators highlighted the influence of occupancy and outdoor temperature on consumption patterns.
Conclusions:
The study confirms the statistical robustness of the baselines and demonstrates the utility of IDELIN_Hotel software tool for energy performance assessment. Comparative analysis of indicators provides actionable insights for energy management systems in the hotel sector.

Keywords: energy baseline; energy management; energy performance; hotel industry.

RESUMEN

Introducción:
Los hoteles se encuentran entre los tipos de edificios de elevado consumo energético; mejorar su eficiencia ofrece beneficios económicos y ambientales. Una evaluación confiable de su rendimiento energético requiere líneas base e indicadores de desempeño estadísticamente validados.
Objetivo:
Evaluar el rendimiento energético de edificios hoteleros en Varadero, Cuba, utilizando líneas base y métricas de rendimiento estadísticamente validadas.
Materiales y Métodos:
Líneas base energéticas fueron establecidas para 15 hoteles usando la herramienta de software IDELIN_Hotel, que integra ocupación y grado días de enfriamiento (CDD) en una variable combinada (Habitación-Grado Días, RDD). Su validez estadística fue verificada a través del coeficiente de correlación (R^2), el coeficiente de variación del error cuadrático medio (CV-RMSE) y el coeficiente de error medio normalizado (NMBE). El rendimiento en el año posterior fue evaluado calculando el consumo específico de energía (Cee), la energía no asociada al servicio (Eo), la varianza del consumo de energía (Ev) y la suma acumulativa de desviaciones del consumo energético (CUSUM).
Resultados y Discusión:
Doce hoteles lograron ahorros de energía en relación con sus líneas de base, mientras que tres operaron ineficientemente. El mejor rendimiento fue observado en el Hotel K, que ahorró 1300 MWh/año. Los indicadores calculados resaltaron la influencia de la ocupación y la temperatura exterior en los patrones de consumo.
Conclusiones:
El estudio confirma la robustez estadística de las líneas base obtenidas y demuestra la utilidad del software IDELIN_Hotel para la evaluación de su rendimiento energético. El análisis comparativo de indicadores proporciona información útil para la toma de decisiones en los sistemas de gestión energética del sector hotelero.

Palabras clave: línea base energética; gestión energética; desempeño energético; industria hotelera.

1. INTRODUCTION

The tourism sector is one of the fastest-growing industries worldwide, with an estimated annual growth rate of 3.3 % through 2030. However, it is also a significant contributor to greenhouse gas emissions. Early global assessments suggested that transportation, accommodation, and related activities accounted for approximately 5 % of direct global energy use and emissions. More recent analyses attribute nearly 8 % of global warming to tourism-related CO_2 and other long-lived greenhouse gases (Gössling et al., 2023).
Hotels are among the most energy-intensive building types. Improving their efficiency therefore represents a dual opportunity: enhancing economic performance while reducing environmental impact (Borowski, 2022; Karvounidi et al., 2024; Menegaki, 2025; Martínez et al, 2025). To balance economic interests with environmental concerns, the tourism sector has adopted strategies such as energy efficiency programs, waste reduction measures, and the implementation of energy management systems aligned with ISO 50000 standards (Alhawamdeh et al., 2023; ISO, 2023).
Accurate assessment of hotel energy consumption is essential to verify whether usage remains within expected limits and to identify inefficiencies that compromise performance. As the maxim states: “If it cannot be measured, it cannot be managed” (Alghanmi et al., 2022). Energy baselines are critical for reporting realistic savings, identifying operational failures, and understanding consumption patterns (Afroz et al., 2021; Singh, et al., 2024).
In hotel buildings, energy consumption is strongly influenced by occupancy and climatic conditions (Van Thillo et al., 2022). Indicators such as total energy per room, per bed, or per occupied room have been widely studied (Dasandara et al., 2022; Prakash et al., 2023; Arenhart et al., 2024). However, these occupancy-based metrics alone cannot detect poor practices or account for external parameters such as outdoor temperature (Dibene et al., 2021; Permana et al., 2023). Cooling degree days (CDD) and heating degree days (HDD) are practical indicators for estimating the energy required to maintain thermal comfort (Bezerra et al., 2021; Cao et al., 2021; Salem et al., 2022; García et al., 2023; Triana et. al, 2023).
Based on these considerations, this study evaluates the energy performance of 15 hotel buildings in Varadero, Cuba. The sample comprises nine 5-star hotels (named A, B, C, G, I, J, K, L, and M) and six 4-star hotels (named D, E, F, H, N, and Ñ). All facilities have centralized air conditioning systems with chillers and domestic hot water production via heat recovery from the chillers, supplemented by electric or liquefied gas water heaters. Hotels A, B, I, L, and M also have solar water heaters. Baseline energy values were determined for a two-year reference period and validated statistically (Iturralde et al., 2023). Subsequent performance was analyzed through specific energy consumption (Cee), non-service energy (Eo), energy variation (Ev), and cumulative sum of deviations (CUSUM).
The goal of this study is to evaluate the energy performance of hotel buildings in Varadero, Cuba, using statistically derived baselines and performance metrics.

2. MATERIALS AND METHODS

The Room Degree Day (RDD) is introduced as an explanatory variable, which considers the effects of occupancy (occupied room for day, ORD) and climatic conditions (CDD).

$$RDD = ORD * CDD \qquad (1)$$

Cooling Degree Days (CDD) were defined as the cumulative positive differences between ambient temperature and a reference base temperature. The base temperature (Tb) was determined using the Performance Line Method (PLM), which establishes correlations between electrical consumption and calculated CDDs for different base temperatures.
Five established procedures were applied to calculate CDDs: ASHRAE (Erbs et al., 1983; Hitchin, 1983; Schoenau & Kehrig, 1990; Krese et al., 2012; Rodríguez et al., 2021). These were implemented in the IDELIN_Hotel software tool (Vázquez et al., 2023).
Once the appropriate base temperature was selected (Mehregan et al, 2022), the tool generated energy consumption lines as a function of RDD and calculated the coefficient of determination (R^2). CV-RMSE and NMBE were also used to evaluate model accuracy (Meng & Mourshed, 2017).
If the regression line satisfied the goodness-of-fit criteria, it was adopted as the energy baseline (EnB):

$$E_t = E_o + m * RDD \qquad (2)$$

From this baseline, the following indicators were derived:

- Specific energy consumption (C_{ee}):

$$C_{ee} = \frac{E_o}{RDD} + m \qquad (3)$$

- Energy variance (Ev):

$$E_v = \frac{E_t}{E_a} * 100 \qquad (4)$$

- CUSUM: cumulative difference between actual consumption and baseline predictions:

$$CUSUM = \sum_{i=1}^{n} (E_r - E_T)_i \qquad (5)$$

3. RESULTS AND DISCUSSION

Table 1 shows the baseline energy consumption equations established using the combined variable RDD. Except for hotel M, all facilities satisfied the statistical requirements for R2 (>0.7), CV-RMSE (<15 %) and NMBE (<5 %), confirming the validity of the regression models. In some cases (Hotels I, L, M, Ñ) data filtering was required to remove outliers. The hotel M model was accepted because, despite the coefficient of determination is less than 0.7, the correlation can be considered strong and the errors CV-RMSE and NMBE met the requirement.

Table 1. EnB equations and their adjustment values per hotels

Hotel	*Energy Baseline Equation*	*Tb, ⁰C*	*R^2*	*CV-RMSE*	*NMBE*
A	$E_t = 0.1163 * RDD + 214718$	20.0	0.71	13.86	0.0094
B	$E_t = 0.1656 * RDD + 185882$	20.5	0.93	7.63	0.0115
C	$E_t = 0.0852 * RDD + 357396$	18.5	0.72	10.00	3.0299
D	$E_t = 0.1366 * RDD + 223262$	22.0	0.92	4.64	0.0060
E	$E_t = 0.1283 * RDD + 221122$	21.5	0.80	7.68	0.0255
F	$E_t = 0.1410 * RDD + 274802$	22.0	0.86	5.40	0.0021
G	$E_t = 0.0837 * RDD + 271472$	20.5	0.92	3.09	0.0191
H	$E_t = 0.1486 * RDD + 326504$	20.5	0.83	5.81	0.0052
I	$E_t = 0.0966 * RDD + 485260$	20.0	0.95	4.76	0.0021
J	$E_t = 0.1225 * RDD + 661927$	22.0	0.89	4.15	0.0005
K	$E_t = 0.1065 * RDD + 383207$	20.0	0.88	5.42	1.2650
L	$E_t = 0.1068 * RDD + 175732$	21.5	0.82	8.96	0.0175
M	$E_t = 0.1166 * RDD + 240595$	21.5	0.66	7.44	0.0126
N	$E_t = 0.1454 * RDD + 306675$	20.0	0.92	5.64	0.0059
Ñ	$E_t = 0.0981 * RDD + 393670$	20.0	0.71	4.63	0.0016

Performance in the subsequent year was evaluated using specific energy consumption, non-service energy, energy variance, and cumulative sum of deviations (table 2).

Table 2. Energy performance indicators for the subsequent year

Hotels	*Rooms Number*	*Specific energy consumption (kWh/RDD)*	*Non-service energy (%)*	*Energy variation (%)*	*CUSUM of the energy variation (MWh)*
A	633	0.15-1.25	97.3	92.7-162	Decreasing /-546.5
B	1032	0.39-1.46	78.7	82.9-126.2	Decreasing until June and then increasing by -65
C	814	0.13-0.38	61.9	89.2-117.1	Decreasing until June, then decreasing until October and then decreasing until December/-302.3
D	272	0.24-0.67	70.7	100.3-122.4	Decreasing / -471
E	350	0.22-0.51	56.8	89.1-109.3	Decreasing until June, after increasing/ -1.3
F	385	0.32-0.76	73.8	96.4-116.8	Decreasing /-251.3
G	470	0.25-2.0	66.9	83.5-98.2	Increasing /461
H	630	0.24-0.52	56.6	83.8-145	Decreasing until July, then increasing until October, and then decreasing/-543.7
I	421	0.21-0.50	57.2	77.7-96	Increase /1107

J	883	0.25-0.74	65.4	70.8-126.3	Decreasing /-1016
K	340	0.16-0.38	59.3	103.9-145.9	Decreasing /-1300
L	420	0.18-0.27	65.7	82.8-104.2	Increasing /400
M	391	0.24-0.72	91.8	94-117.8	Decreasing until May, then increasing until September, and then decreasing until December /-130
N	600	0.27-0.38	51.7	88.6-112.3	Decreasing until May, then increasing until December/12
Ñ	408	0.27-0.46	74.9	95.6-127.6	Decreasing / -343

Performance in the subsequent year revealed heterogeneous outcomes.

- High-performing hotels: Twelve facilities achieved energy savings relative to their baselines. Hotel K achieved the highest savings (1300 MWh/year), followed by Hotel J (1016 MWh), Hotel H (543.7 MWh), and Hotel D (471 MWh). Hotel C maintained low specific energy consumption (0.13–0.30 kWh/RDD) and saved 302.3 MWh (figure 1).

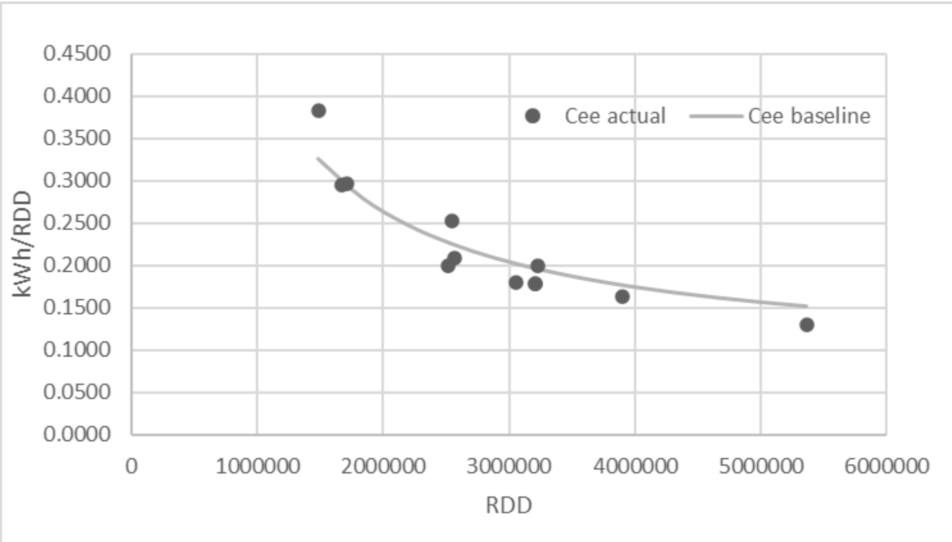

Figure 1. Specific energy consumption for hotel C

- Inefficient hotels: Three facilities showed excess consumption. Hotel G exceeded its baseline throughout the year (+461 MWh), Hotel I consumed consistently above baseline (+1107 MWh), and Hotel L recorded a cumulative excess of +400 MWh (figure 2).
- Hotels A and M show an unusual non-service energy value. This can be explained by the fact that they offered high-standard services, and the occupancy rate was very low (below 40%) in the years analyzed.

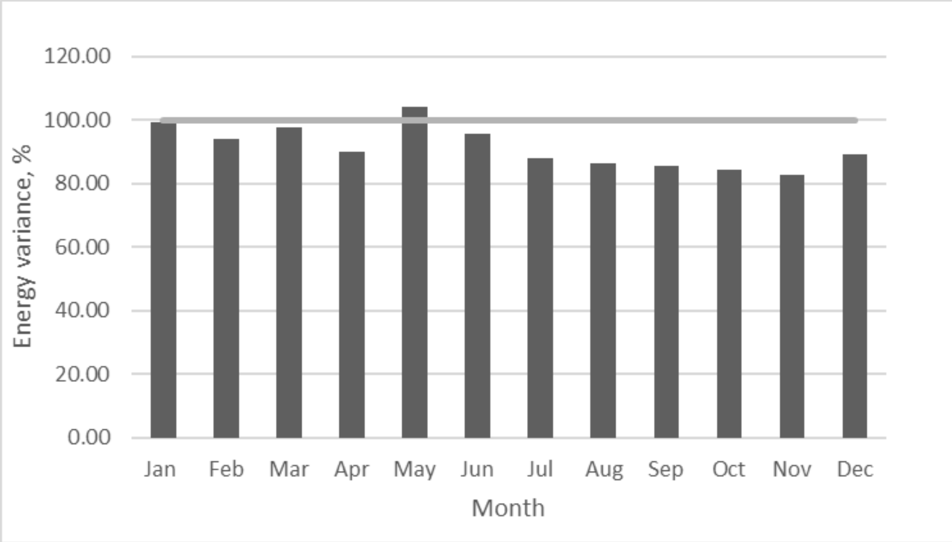

Figure 2. Energy variance for hotel L

- Indicators highlighted the influence of occupancy and outdoor temperature (Martínez et al., 2025). Low occupancy often resulted in elevated specific energy consumption, even when total consumption remained near baseline levels. The CUSUM method effectively distinguished facilities with sustained savings from those with recurrent inefficiencies.

4. CONCLUSIONS

1. This study validated statistically robust energy baselines for 15 hotels in Varadero, Cuba, using RDD as the explanatory variable. The IDELIN_Hotel software proved effective in determining base temperatures, calculating cooling degree days, and generating reliable regression models.
2. Twelve hotels achieved measurable savings relative to their baselines, confirming the effectiveness of energy management actions. Hotel K demonstrated the highest efficiency, saving 1300 MWh/year. Three hotels (G, I, L) exhibited inefficient performance, underscoring the need for further investigation into operational practices and auxiliary system management.
3. Overall, the comparative evaluation demonstrates the effectiveness of energy management actions in most hotels. The results confirm that statistically validated baselines, combined with performance indicators such as Cee, Eo, Ev, and CUSUM, provide a robust framework for monitoring and improving energy efficiency in the hotel sector.

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CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest.

AUTHOR'S CONTRIBUTIONS

- Ph.D. Osvaldo Fidel García Morales. Project management, conceptualization, writing (first draft), supervision.
- Ph.D. Gabriel Roque Villalonga. Conceptualization, research, data curation.
- M.Sc. José Antonio Deán Bacelo. Research, data curation, software.
- Ph.D. Mario Antonio Álvarez-Guerra Plasencia. Methodology, writing - revision and editing.