The greener the better operating efficiency? A case of green hotels

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ABSTRACT
This study was conducted mainly to analyze the operating efficiency of green hotels during the epidemic, and to explore whether hotels that pay more attention to green and energy-saving would be more economically efficient. The top 20 green hotels as voted on the EU Internet from 2018 to 2022 are the subject of the study. According to the empirical results, all green hotels were affected by COVID-19, and their operating efficiency was getting worse. This study further used Tobit regression to determine the factors that affect the operating efficiency, and also performed a regression analysis on the efficiency value for variables related to the green energy environment. The findings showed that the green energy equipment of the EU green hotel had a negative effect on the operating efficiency, indicating that the investment in green energy equipment cannot be achieved in a short period of time. In addition, the education level of managers and hotel green energy licenses have positive effects on the operating efficiency of green hotels. Especially when the green hotel licenses are the most important, it has the highest coefficient value on the efficiency of green hotels. This means that the higher the education level of green hotel managers and the higher the level of green hotel license, the higher the operating efficiency. These findings suggest that green hotel management should pay attention to its green certificate level and the education knowledge of managers, so as to achieve sustainable energy saving and to improve operating efficiency.

Key words: Green hotel, operating efficiency, COVID-19.

INTRODUCTION
With the World Health Organization declared the end of the global H1N1 influenza pandemic in 2010, the world is gradually moving towards the post-pandemic and all walks of life are thriving as well. The global tourism market has begun to attract the attention of the world due to the successive opening of borders in various countries. World Travel and Tourism Council (2022) found that following a decrease of 69.7% in 2020, international visitor spending increased by 3.8% in 2021. Following a loss of almost US$4.9 trillion in 2020 (-50.4% decline), Travel and Tourism’s contribution to GDP increased by US$1 trillion (+21.7% rise) in 2021. How to tap into the market has emerged as one of the most crucial concerns in operation and management after the tourism industry was severely affected by the epidemic. Moreover, with the rising awareness of energy saving and environmental protection, the hotel industry, which is inseparable from the tourism industry, inevitably has to develop different strategies to cope with environmental issues. Afzar and Umran (2022) pointed out that as people become more concerned about the environment, businesses in the hospitality industry are being forced to implement environmental management plans. It is clear that the global hotel industry should not only meet consumer expectations, but also should take on more corporate responsibility. Nisar et al. (2021) found that hotels have been subjected to critical and different pressures to take responsibility and adopt environmentally friendly practices in their various sectors, such as water and...
energy consumption and waste production. Today, the global hotel industry is gradually showing the results of its environmentally friendly efforts. Greenview (2023) found that virtually all hotels (97.9%) implement at least one initiative that contributes to reducing inequalities. Over 80% of all hotels plan and implement initiatives to reduce energy use. Although the hotel industry has invested in energy saving and environmental protection, it has not brought positive feedback. Robinson et al. (2016) pointed out that eco-labeled hotels experience higher average daily rate but lower occupancy rates. In other words, different types of hotels bring different benefits to energy-saving strategies. Chen (2019) investigated a group of hotel chains and found that they have significantly higher average energy efficiency and branding value than those of a group of independent operators when holistic carbon emissions reduction is considered.

For a long time, there have been diverse researches on the hotel industry and environmental issues. Alyahya et al. (2023) pointed out that even though the number of studies that concentrate on the topic of sustainability in the hospitality industry has recently grown, the findings that have so far been published in the literature are fragmented and concentrate on various aspects of sustainability. It can also be seen from the relevant literature that the issues related to environmental protection hotels and economic benefits are diversified. For example, Teng et al. (2015) explored hotel environmental management decisions issues from a stakeholder perspective. Dodds and Holmes (2016) took North American hotels as example to explain benefits from marketing sustainability. Malcheva (2019) analyzed and assessed the potential marketing and economic advantages for the boutique hotels that provide differentiated and trade recognized tourist product through green oriented ideas. Salama and Mansour (2022) focused on the impact of Covid-19 on green hotel management, highlighting the negative and positive aspects of the pandemic on the green hotel sectors. However, much of the research related to the economic benefits of green hotels up to now has been conducted for a single region or a single country and often leads to different conclusions depending on national conditions and policies. From the relevant literature, it is clear that most of the relevant studies have focused on the issue of green hotel revenue. Chong and Verma (2013) used data provided by Sabre to determine the effect on bookings of widespread advertising of eco-certified hotels to answer the question of whether going green hurts or helps revenues and found that booking revenue neither increased nor decreased for the certified hotels. Although extensive research has been carried out on green hotel revenue, few empirical investigation exist which focus on green hotels’ operating efficiency. The current study aims to investigate eco-friendly hotels in the EU. Network data envelopment analysis is used to study the inputs and outputs of eco-hotels and to analyze the factors that lead to different operating efficiency.

**LITERATURE REVIEW**

**Green hotel and operating efficiency**

As people’s concern for the environment becomes an attitude of life, environmental issues related to self and others are gradually manifested through emotion, behavior and cognition. The travel industry has long been regarded as a smoke-free industry, and as the green trend sweeps the world, the travel industry’s business strategies are often linked to energy-saving and environmental issues. Abdou et al. (2020) pointed out that the tourism industry embodies diversification strategies to sustain and develop its globally acclaimed sectors. At present, the hotel industry is one of the key players in the development of the travel industry, and it has a certain degree of impact on the environment. Saleh and Brem (2023) found that hotel sector around the world is responsible for approximately one percent of global carbon emissions, a number that could rise before long if the business continues to expand. Therefore, incorporating green energy and environmental protection into the management strategy has become one of the focuses of the hotel industry. Teng et al. (2015) pointed out that hotels are implementing eco-friendly programs in their rooms, building eco-friendly buildings, introducing and adopting programs to save water, energy, and reduce waste. This shows that the hotel industry’s practical efforts in green energy and environmental protection have led more hotels to adjust their business direction and gradually move towards the development of eco-friendly hotels.

Green hotels are “a natural tourist lodging developed and managed in environmentally sensitive ways to maintain its business environment and provide guests with green products, green services, and healthy, refreshing, and comfortable accommodation that reflect the features of natural ecologies” (Yadegaridehkordi et al., 2021). According to the hotel sustainability basics framework developed by the World Travel and Tourism Council (2022), sustainable hotels are evaluated on 12 indicators across three dimensions:

**Management and efficiency:** (1) Measure and reduce energy use. (2) Measure and reduce water use. (3) Identify and reduce waste. (4) Measure and reduce carbon emissions.

**Planet:** (5) Linen reuse program. (6) No single use plastic straws or stirrers. (7) Replace single use plastic water bottles. (8) Replace single use plastic mini toiletry bottles. (9) Green cleaning products. (10) Vegetarian options.

**People:** (11) Community benefit. (12) Reduce inequalities.

There are currently over 200 eco labels in the hospitality industry worldwide, such as Green Globe, Green Key, Earth Check, Green Tourism, Travel Life, Biosphere Tourism,
European Ecolabel For Tourist, EU Ecolabel for tourist. These certificate authorities are recognized by various third party certification body. Nowakowski (2020) pointed out that both eco-certificates and eco-labels can be of international nature such as e.g. ISO 14001, GSTC (Global Sustainable Tourism Council) or Green Globe Certificate or can be recognized only locally. These certificates improve hotels’ environmental management strategies and social legitimacy and attract environmentally conscious customers (Borella and de Carvalho Borella, 2016). In addition to the above-mentioned benefits of certified eco-hotels, studies have also pointed out the advantages of eco-hotels. Buunk and van der Werf (2019) investigated 68 Green Key labeled firms and had them to respond the question of whether their profits had increased due to adoption of the ecolabel. The results of the study showed that 26% stated that their company had become more profitable after adoption, but only 4% reported that they were able to increase their price. The study of Rashid et al. (2015) also concluded that being environmentally conscious would involve the underlying business culture, policy, and practices through environmental corporate social responsibility, not merely selling environmentally-friendly products. Although Balaji et al. (2019) argued that travelers prefer environmentally responsible hotels, and some are willing to pay more for a hotel’s environmental practices. It is still worth exploring what green hotels can do for operating efficiency. Sharma et al. (2020) pointed out that there is insufficient research to gauge whether they offer a significant competitive advantage. Kramer (2022) found that many travelers say they would prefer to stay at eco-friendly hotels, but lodging facilities do not benefit financially from acquiring certification for green business practices. Yenidogan et al. (2021) pointed out that while some studies support green profitability, others reveal a neutral performance effect of going green in the lodging industry and even highlight some negative effects of environmental stimuli on operating efficiency within a wide spectrum of the sustainability literature. The above related study also echoes the arguments of Chong and Verma (2013) that green is not a “silver bullet” strategy. It is clear that the relationship between environmental hotels and profitability still needs to be further explored, and therefore, the relationship between environmental protection and energy saving on operating efficiency becomes the main focus of this study.

RESEARCH METHODOLOGY

According to the previous research on hotel production efficiency, most of studies were only discussing the relative efficiency of hotel input elements (such as labor, capital and other changes in input, etc.) and converting them into final outputs (such as operating income, etc.) without considering the process of converting inputs into outputs, from the value stage of green energy and environmental protection certification to the final business production activities. The functions of restaurants are different, the input and output processes are different, and the required management skills and resources are also different. For example, in the stage of focusing on environmental protection and green energy, photovoltaic power generation, green plant landscape, room lighting and equipment, etc., affect the operating efficiency of each green hotel; In addition to investing in energy saving in the second stage, it also provides hotel landscape and reduces carbon emission economic value. These are important factors that affect the hotel’s operating efficiency. Therefore, green hotels would have different production efficiencies at different stages of operation, which deserves further measurement and analysis.

RESEARCH DESIGN

This study uses the Dynamic Network SBM DEA model proposed by Tone and Tsutsui (2013) for analysis. The study not only analyzed the production efficiency and market efficiency of the EU green hotels but also analyzed the total operating efficiency generated by the cross-year operating profit created by the two-stage dynamic model.

In this study, the operating efficiency generated by the first stage of green production is used as the basis for the second stage of green hotel management strategy and resource allocation. This paper mainly analyzes the performance of EU green hotels in the green production efficiency stage, market efficiency stage and overall efficiency performance from 2018 to 2022.

Green hotel network DEA model

Assume that EU Green Hotel has three departments, and each department has its own input resources and output. And there are interlinked environmental protection and green energy operations (or intermediate wealth) among the three departments, as shown in the figure, of which among them, Link1→2 refers to using part of the output of department 1 as part of the input of department 2, Link1→3. The meaning of Link2→3 is the same as above.

It can be seen from Figure 1 that the network DEA model solves the problem that the traditional DEA model cannot handle, such as intermediate wealth issues, and transform the production within the eco-friendly hotel into sub-production activities that are interconnected and influenced by each other.

Let \( m_k \) and \( r_k \) represent the input and output of each department \( K \), and use \( (h,k)i \) to represent departments \( k \) to \( h \); \( L_{hk} \) represents the set of departments \( k \) and \( h \), and the input-output, connection and existence period are defined as follows:
(1) Inputs and outputs
\[ X_{itk}^{j} \in R, (i = 1, \ldots, m; j = 1, \ldots, n; k = 1, \ldots, k; t = 1, \ldots, T) \]
Represents the input item i of k division of DMUj in period t
\[ Y_{rkt}^{j} \in R, (r = 1, \ldots, r; j = 1, \ldots, n; k = 1, \ldots, k; t = 1, \ldots, T) \]
It represents the output item r of the k division of DMUj in period t

(2) Intermediate Goods (Links)
\[ Z_{kh}^{ijkl} \in R, (j = 1, \ldots, n; l = 1, \ldots, l_k; t = 1, \ldots, T) \]
Represents the intermediate wealth linking from k division to h division in DMUj in period t, where \( L_{kh} \) is the number of items linked from k to h.

(3) Carry-overs
\[ Z_{kh}^{ijkl+1} \in R, (j = 1, \ldots, n; l = 1, \ldots, l_k; k = 1, \ldots, k; t = 1, \ldots, T-1) \]
Represents the cross-period of DMUj k division to h division in period t to t+1, where \( l_k \) is the number of items spanning the k division.

Mathematical model of this study

(1) Definition of production possible:
\[ x_{itk}^{j} \geq \sum_{j=1}^{n} x_{itkj}^{j} \chi_{itkj}^{j} (\forall k, \forall t) \]
\[ y_{rkt}^{j} \leq \sum_{j=1}^{n} y_{rktj}^{j} \chi_{rktj}^{j} (\forall k, \forall t) \]
\[ z_{kh}^{ijkl} \geq \sum_{j=1}^{n} z_{kh}^{ijkl+1} \chi_{kh}^{ijkl+1} (\forall k, \forall h, \forall t) \]
\[ z_{kh}^{ijkl+1} \geq \sum_{j=1}^{n} z_{kh}^{ijkl+1} \chi_{kh}^{ijkl+1} (\forall k, \forall h, \forall t, 1 - 1) \]
\[ \chi_{itkj}^{j} \geq 0 (\forall j, \forall k, \forall t) \]

(2) Mathematical objective formula of this study:
The objective formula of the overall efficiency model of input and output in this research is as follows:
\[ \theta_{0} = \min \frac{\sum_{i=1}^{m} w^{i} \left[ \frac{1}{\sum_{m} (\sum_{k} t_{ik}}^{i} \sum_{j} \alpha_{j}^{ik} \sum_{l} \beta_{l}^{ikj}}^{i} \right] + \sum_{j=1}^{n} \alpha_{j}^{ikj} \sum_{l} \beta_{l}^{ijk} + \sum_{k=1}^{k} \alpha_{k}^{ijkl} \sum_{l} \beta_{l}^{kijkl}}{\sum_{i=1}^{m} w^{i} \left[ \frac{1}{\sum_{m} (\sum_{k} t_{ik}}^{i} \sum_{j} \alpha_{j}^{ik} \sum_{l} \beta_{l}^{ikj}}^{i} \right] + \sum_{j=1}^{n} \alpha_{j}^{ikj} \sum_{l} \beta_{l}^{ijk} + \sum_{k=1}^{k} \alpha_{k}^{ijkl} \sum_{l} \beta_{l}^{kijkl}} + \sum_{i=1}^{m} w^{i} \left[ \frac{1}{\sum_{m} (\sum_{k} t_{ik}}^{i} \sum_{j} \alpha_{j}^{ik} \sum_{l} \beta_{l}^{ikj}}^{i} \right] + \sum_{j=1}^{n} \alpha_{j}^{ikj} \sum_{l} \beta_{l}^{ijk} + \sum_{k=1}^{k} \alpha_{k}^{ijkl} \sum_{l} \beta_{l}^{kijkl}}{\sum_{i=1}^{m} w^{i} \left[ \frac{1}{\sum_{m} (\sum_{k} t_{ik}}^{i} \sum_{j} \alpha_{j}^{ik} \sum_{l} \beta_{l}^{ikj}}^{i} \right] + \sum_{j=1}^{n} \alpha_{j}^{ikj} \sum_{l} \beta_{l}^{ijk} + \sum_{k=1}^{k} \alpha_{k}^{ijkl} \sum_{l} \beta_{l}^{kijkl}} \]
\[ \theta_{0} \geq 0 \]

(3) The restrictions are as follows:
Table 1: EU green hotels and characteristics.

<table>
<thead>
<tr>
<th>DMU</th>
<th>Hotel name</th>
<th>Located in the country</th>
<th>Hotel Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>D1</td>
<td>Jetpak Eco Lodge</td>
<td>Berlin, Germany</td>
<td>100% of the energy this hostel uses comes from renewable sources.</td>
</tr>
<tr>
<td>D2</td>
<td>Hostel Trastevere</td>
<td>Rome, Italy</td>
<td>All electricity is generated by solar panels, so the air conditioning and heating are 100% green</td>
</tr>
<tr>
<td>D3</td>
<td>Reykjavik City HI Hostel and Downtown HI Hostel</td>
<td>Reykjavik, Iceland</td>
<td>Facilities for recycling including different disposal containers and information available to guests</td>
</tr>
<tr>
<td>D4</td>
<td>City Backpackers Hostel</td>
<td>Stockholm, Sweden</td>
<td>Electricity from renewable sources</td>
</tr>
<tr>
<td>D5</td>
<td>Alter Hostel</td>
<td>Lyon, France</td>
<td>Energy is supplied by Enercoop, a French company that works with small producers of renewable energy</td>
</tr>
<tr>
<td>D6</td>
<td>Sleep Well Youth Hostel</td>
<td>Brussels, Belgium</td>
<td>Use of sustainable supplies. Electricity is 100% green!</td>
</tr>
<tr>
<td>D7</td>
<td>Ecomama</td>
<td>Amsterdam, Netherlands</td>
<td>They use cradle-to-cradle (C2C) furniture, a production system that minimises waste Use of fair-trade materials</td>
</tr>
<tr>
<td>D8</td>
<td>Eco Hostel Republik</td>
<td>Uzice, Serbia</td>
<td>They pay close attention to waste, recycling and reselling</td>
</tr>
<tr>
<td>D9</td>
<td>Urban Garden Hostel</td>
<td>Lisbon, Portugal</td>
<td>Use of recycled materials in construction projects</td>
</tr>
<tr>
<td>D10</td>
<td>Twentytu Hi-Tech Hostel</td>
<td>Barcelona, Spain</td>
<td>Lighting on each floor has presence and timing detectors to save energy</td>
</tr>
<tr>
<td>D11</td>
<td>High Street Hostel</td>
<td>Edinburgh, United Kingdom</td>
<td>There is a waste recycling system that is completely green</td>
</tr>
<tr>
<td>D12</td>
<td>The Circus Hostel</td>
<td>Berlin, Germany</td>
<td>The energy is green and energy saving gadgets are used here.</td>
</tr>
<tr>
<td>D13</td>
<td>Sleep Green</td>
<td>Spain</td>
<td>The energy is 100% generated from renewable sources</td>
</tr>
<tr>
<td>D14</td>
<td>Saas-Fee</td>
<td>Switzerland</td>
<td>Hot water is boiled with solar panels here, and the building is green.</td>
</tr>
<tr>
<td>D15</td>
<td>Hostel Strowis Utrecht</td>
<td>Netherlands</td>
<td>The atmosphere is warm and ecological, and social innovations are imbibed.</td>
</tr>
<tr>
<td>D16</td>
<td>Green Solution House</td>
<td>Denmark</td>
<td>Have built a carbon-negative extension entirely from wood.</td>
</tr>
<tr>
<td>D17</td>
<td>Parcel Tiny House</td>
<td>France</td>
<td>Each house is built with wood from responsibly managed forests in France and is equipped with solar panels</td>
</tr>
<tr>
<td>D18</td>
<td>Apipura Hotel Rinner</td>
<td>South Tyrol, Italy</td>
<td>Electricity comes from a new district heating station that generates power from waste wood products</td>
</tr>
</tbody>
</table>
Table 1 conts

<table>
<thead>
<tr>
<th>D19</th>
<th>Explorer Hotels</th>
<th>Germany and Austria</th>
<th>Each property is carbon neutral, uses ecologically safe cleaning products</th>
</tr>
</thead>
<tbody>
<tr>
<td>D20</td>
<td>Dene Cottage</td>
<td>Orkney Islands</td>
<td>Solar panels and a small wind turbine provide the electricity</td>
</tr>
</tbody>
</table>

\[ x^t_{ok} = x^t_{ok} + s^t_{ko}(\forall k, \forall t) \]

\[ y^t_{ok} = Y^t_{k} - s^t_{ko}(\forall k, \forall t) \]

\[ e^t_{k} = \begin{cases} 1 & (\forall k, \forall t) \\ 0 & (\forall k, \forall t) \end{cases} \]

\[ x^t_{(hk)}^{free} = x^t_{(hk)}^{free} + \frac{s^t_{(hk)}^{free} (\forall (k,h) \text{ free}, \forall t)}{R^{(n)\text{free}n}} \]

\[ x^t_{(hk)}^{fix} = x^t_{(hk)}^{fix} + \frac{s^t_{(hk)}^{fix} (\forall (k,h) \text{ fix}, \forall t)}{R^{(n)\text{fix}n}} \]

\[ x^t_{(kh)}^{in} = x^t_{(kh)}^{in} + \frac{s^t_{(kh)}^{in} ((k,h) \text{ in} = 1, \ldots, \text{linkin}_k) (\forall (k,h) \text{ out} = 1, \ldots, \text{linkout}_k)}{R^{(n)\text{in}n}} \]

\[ s^t_{(kh)}^{good} = s^t_{(kh)}^{good} + \frac{s^t_{(kh)}^{good} (\forall k; \forall t)}{R^{(n)\text{good}n}} \]

\[ s^t_{(kh)}^{bad} = s^t_{(kh)}^{bad} + \frac{s^t_{(kh)}^{bad} (\forall k; \forall t)}{R^{(n)\text{bad}n}} \]

\[ s^t_{(kh)}^{free} = s^t_{(kh)}^{free} + \frac{s^t_{(kh)}^{free} (\forall k; \forall t)}{R^{(n)\text{free}n}} \]

(4) Period efficiency is as follows:

\[
\begin{align*}
    t^t_{ok}^{*} = & \sum_{k=1}^{k} w^k \left[ \frac{1}{m_k + \text{linkin}_k + \text{nbad}_k} \left( \sum_{i=1}^{t} s^t_{(ih)}^{fix} \right) + \sum_{k=1}^{k} \left( \frac{\text{globals}}{\text{okgood}} \right) \right] \\
    t^t_{ok}^{*} = & \sum_{k=1}^{k} w^k \left[ \frac{1}{m_k + \text{linkin}_k + \text{nbad}_k} \left( \sum_{i=1}^{t} s^t_{(ih)}^{fix} \right) + \sum_{k=1}^{k} \left( \frac{\text{globals}}{\text{okgood}} \right) \right]
\end{align*}
\]

(5) Division efficiency is as follows:

\[
\begin{align*}
    t^t_{ok}^{*} = & \sum_{k=1}^{k} \left[ \frac{1}{m_k + \text{linkin}_k + \text{nbad}_k} \left( \sum_{i=1}^{t} s^t_{(ih)}^{fix} \right) + \sum_{k=1}^{k} \left( \frac{\text{globals}}{\text{okgood}} \right) \right] \\
    t^t_{ok}^{*} = & \sum_{k=1}^{k} \left[ \frac{1}{m_k + \text{linkin}_k + \text{nbad}_k} \left( \sum_{i=1}^{t} s^t_{(ih)}^{fix} \right) + \sum_{k=1}^{k} \left( \frac{\text{globals}}{\text{okgood}} \right) \right]
\end{align*}
\]

(6) The period efficiency of the division is as follows:

\[
\begin{align*}
    \gamma^t_{ok} = & \sum_{i=1}^{t} \left[ \frac{1}{m_k + \text{linkin}_k + \text{nbad}_k} \left( \sum_{i=1}^{t} s^t_{(ih)}^{fix} \right) + \sum_{k=1}^{k} \left( \frac{\text{globals}}{\text{okgood}} \right) \right] \\
    \gamma^t_{ok} = & \sum_{i=1}^{t} \left[ \frac{1}{m_k + \text{linkin}_k + \text{nbad}_k} \left( \sum_{i=1}^{t} s^t_{(ih)}^{fix} \right) + \sum_{k=1}^{k} \left( \frac{\text{globals}}{\text{okgood}} \right) \right]
\end{align*}
\]

Questionnaires/Sample

The object of this research is the 20 most popular green hotels voted online in the European Union in 2022. The characteristics of the hotels are different and the operating conditions are different, resulting in different economic benefits. The information is in Table 1.

This study adopts the dynamic network data envelopment analysis model. The input items are tree planting area, environmental protection equipment investment and solar photovoltaic input cost; Take energy saving and carbon reduction benefits as the output item of the first stage. The second-stage input items include the first-stage output (intermediate wealth), the number of employees, the number of guest rooms, and operating expenses. The output item of the second stage is EPS, and the net profit is used as the multi-year carry over to measure the efficiency change in each period (Table 2).

**EMPIRICAL FINDINGS AND DISCUSSION**

**Dynamic network DEA empirical results**

This study mainly uses DEA-SOLVER Professional 16.0 application software, sets the production process as
Table 2: Definition of input and output variables.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Variable definition description</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Environmental protection and green energy input item</td>
<td>Tree Planting and Green Area</td>
<td>Planting area of trees and flowers</td>
</tr>
<tr>
<td></td>
<td>Investment in green energy and environmental protection equipment</td>
<td>Environmental protection material input and lighting cost</td>
</tr>
<tr>
<td></td>
<td>Solar photovoltaic input cost</td>
<td>Solar power equipment cost</td>
</tr>
<tr>
<td>Intermediate output</td>
<td>Energy saving</td>
<td>Save electricity and water costs every year</td>
</tr>
<tr>
<td></td>
<td>Reduce the amount of plastic waste</td>
<td>Reduce waste by using environmentally friendly materials</td>
</tr>
<tr>
<td></td>
<td>Reduce carbon emissions</td>
<td>Plants and solar photovoltaics lead to carbon reduction</td>
</tr>
<tr>
<td>The second stage input item</td>
<td>Number of employees</td>
<td>Number of employees</td>
</tr>
<tr>
<td></td>
<td>Operating expenses</td>
<td>Including water and electricity charges</td>
</tr>
<tr>
<td></td>
<td>Number of rooms</td>
<td>Number of rooms</td>
</tr>
<tr>
<td>Interdepartmental Link</td>
<td>Operating income</td>
<td>Net revenue after deducting sales returns and discounts</td>
</tr>
<tr>
<td>Final output</td>
<td>EPS</td>
<td>Net profit after tax ÷ number of common shares outstanding</td>
</tr>
<tr>
<td>Inter-period carry over</td>
<td>Profit</td>
<td>Presented in the financial statements net profit after tax</td>
</tr>
</tbody>
</table>

variable returns to scale, and uses the Dynamic Network DEA model to explore the operating performance of green hotels in the European Union and help relatively inefficient departments find improvement strategies. The empirical results of the overall efficiency and ranking, departmental efficiency and ranking of the 20 most popular green hotels in the EU from 2018 to 2022 are shown in Table 3.

The overall ranking of the efficiency of green hotels in the EU from 2018 to 2022 is shown in the Table 3, the overall efficiency average is 0.833, the maximum is 1, the minimum is 0.712, and the standard deviation is 0.20. The top 3 rankings are: D3, D14, D11. According to the efficiency of each year, the maximum average is 0.916 in 2020, and the minimum average is 0.753 in 2018. The data shows that when the green hotel was first start of operations in 2018, the operating efficiency could not reach the target. The green hotel achieved the best operating efficiency in the third year of operation. However, after the impact of the COVID-19 epidemic in 2020, operating efficiency will decline in 2021 and 2022, respectively.

Among the annual operating efficiency values, the average efficiency in 2018 is 0.753, the maximum value is 1 for D3 and D14, the minimum value is 0.514 for D18, and the standard deviation is 0.12. The average efficiency in 2019 is 0.822, the maximum efficiency value of D3, D6, D11, D14 and D16 is 1, the minimum value is D12, its efficiency value is 0.539, and the standard deviation is 0.26. The average efficiency in 2020 is 0.916, the maximum value is D3, D4, D7, D11, D14, their efficiency value is 1, the minimum value is D20, its efficiency value is 0.683, and the standard deviation is 0.08. The average efficiency in 2021 is 0.803, the maximum value is D3 and D5, their efficiency value is 1, the minimum value is D16, its efficiency is 0.627, and the standard deviation is 0.18. The average efficiency in 2022 is 0.873, the maximum is D2, D3, D5, their efficiency value is 1, the minimum is 0.660 of D16, and the standard deviation is 0.31.

According to the analysis of individual DMUs, the input-output efficiency D3 is maintained at 1 and the performance is relatively good from 2018 to 2022. The operating efficiency values of D11 and D14 also remained above 0.8. All belong to the advantage green hotel. However, the operating efficiency of D10 and D18 is relatively low, and the management problems of these two green hotels need to be reviewed and improved.

Green production efficiency stage and market efficiency stage discussion

This part discusses the sectoral efficiency of green hotels in the EU from 2018 to 2022. The first stage is the green efficiency stage. The input cost of solar power, the number of trees planted, and the equipment cost of environmental friendly building materials are the input variables, and the energy saving and carbon reduction benefits are the output.
We took the operating profit as the cross-divisional link with the market efficiency stage as well. The average performance and ranking of the green production efficiency stage are shown in Table 4. The EU green hotel input costs and output technologies are used to maintain the competitiveness of the hotel. Therefore, the performance of both input and output shows high scores. The average green production efficiency is 0.862, the maximum green production efficiency is 1, which is D2, D3, D11, and D14 respectively, and the minimum green production efficiency is D20, which is 0.647.

In the second stage of the market efficiency stage of this research model, the output item of the first stage is the energy saving and carbon reduction benefit as a cross-departmental link to the market efficiency stage. The output item of this stage is earnings per share, and then the net profit is used as the multi-year Carry Over, the average value of the overall market efficiency in the market efficiency stage from 2018 to 2022 is 0.902, the maximum value is 1, and the minimum value is 0.623.

Among them, the market efficiency of D3, D4, D6, D7, and D14 is the best, with an efficiency score of 1 from 2018 to 2022.

**Tobit regression analysis**

After estimating the efficiency value with DEA, further use the regression method to find out the factors that affect the efficiency, and then regress the efficiency value on the operating environment variable, and then judge whether the environmental variable has a positive or negative effect on the manufacturer’s efficiency value based on the sign and significance of the regression coefficient have a significant impact on it. Because the explained variable (that is, the efficiency value) is limited to not be greater than 1, the general least squares (Ordinary Least Squares) evaluation method is not applicable, and the Tobit regression method must be used. This study uses SHAZAM for analysis.

This study uses hotel green energy equipment capital, manager education level, hotel green license (gold, silver, copper level, dummy variables) as explanatory variables, and the value of manufacturer efficiency as explained variables. Since the efficiency value of DEA is greater than 0 and less than or equal to 1, Tobit regression can only limit yi on one side, and the reciprocal of the efficiency value can be converted into a natural logarithm to convert the lower

---

**Table 3:** Overall Efficiency of Green Hotels in the European Union 2018-2022.

<table>
<thead>
<tr>
<th>DMU</th>
<th>2018</th>
<th>2019</th>
<th>2020</th>
<th>2021</th>
<th>2022</th>
<th>Efficiency value</th>
<th>Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>D1</td>
<td>0.571</td>
<td>0.632</td>
<td>0.903</td>
<td>0.680</td>
<td>0.911</td>
<td>0.739</td>
<td>18</td>
</tr>
<tr>
<td>D2</td>
<td>0.600</td>
<td>0.623</td>
<td>0.963</td>
<td>0.957</td>
<td>1.000</td>
<td>0.829</td>
<td>10</td>
</tr>
<tr>
<td>D3</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>D4</td>
<td>0.566</td>
<td>0.566</td>
<td>1.000</td>
<td>0.766</td>
<td>0.917</td>
<td>0.763</td>
<td>16</td>
</tr>
<tr>
<td>D5</td>
<td>0.531</td>
<td>0.651</td>
<td>0.815</td>
<td>1.000</td>
<td>1.000</td>
<td>0.799</td>
<td>13</td>
</tr>
<tr>
<td>D6</td>
<td>0.852</td>
<td>1.000</td>
<td>0.852</td>
<td>0.781</td>
<td>0.806</td>
<td>0.858</td>
<td>8</td>
</tr>
<tr>
<td>D7</td>
<td>0.877</td>
<td>0.867</td>
<td>1.000</td>
<td>0.846</td>
<td>0.868</td>
<td>0.891</td>
<td>5</td>
</tr>
<tr>
<td>D8</td>
<td>0.698</td>
<td>0.713</td>
<td>0.971</td>
<td>0.765</td>
<td>0.866</td>
<td>0.802</td>
<td>12</td>
</tr>
<tr>
<td>D9</td>
<td>0.728</td>
<td>0.918</td>
<td>0.855</td>
<td>0.793</td>
<td>0.809</td>
<td>0.821</td>
<td>11</td>
</tr>
<tr>
<td>D10</td>
<td>0.656</td>
<td>0.772</td>
<td>0.720</td>
<td>0.675</td>
<td>0.861</td>
<td>0.737</td>
<td>19</td>
</tr>
<tr>
<td>D11</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
<td>0.844</td>
<td>0.945</td>
<td>0.958</td>
<td>3</td>
</tr>
<tr>
<td>D12</td>
<td>0.529</td>
<td>0.539</td>
<td>0.982</td>
<td>0.886</td>
<td>0.887</td>
<td>0.765</td>
<td>15</td>
</tr>
<tr>
<td>D13</td>
<td>0.842</td>
<td>0.930</td>
<td>0.905</td>
<td>0.687</td>
<td>0.788</td>
<td>0.830</td>
<td>9</td>
</tr>
<tr>
<td>D14</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
<td>0.857</td>
<td>0.960</td>
<td>0.963</td>
<td>2</td>
</tr>
<tr>
<td>D15</td>
<td>0.956</td>
<td>0.962</td>
<td>0.994</td>
<td>0.805</td>
<td>0.843</td>
<td>0.912</td>
<td>4</td>
</tr>
<tr>
<td>D16</td>
<td>0.851</td>
<td>1.000</td>
<td>0.851</td>
<td>0.627</td>
<td>0.660</td>
<td>0.798</td>
<td>14</td>
</tr>
<tr>
<td>D17</td>
<td>0.936</td>
<td>0.952</td>
<td>0.983</td>
<td>0.662</td>
<td>0.762</td>
<td>0.859</td>
<td>7</td>
</tr>
<tr>
<td>D18</td>
<td>0.514</td>
<td>0.651</td>
<td>0.896</td>
<td>0.750</td>
<td>0.751</td>
<td>0.712</td>
<td>20</td>
</tr>
<tr>
<td>D19</td>
<td>0.705</td>
<td>0.812</td>
<td>0.941</td>
<td>0.952</td>
<td>0.983</td>
<td>0.878</td>
<td>6</td>
</tr>
<tr>
<td>D20</td>
<td>0.647</td>
<td>0.861</td>
<td>0.683</td>
<td>0.736</td>
<td>0.852</td>
<td>0.756</td>
<td>17</td>
</tr>
<tr>
<td>Average value</td>
<td>0.753</td>
<td>0.822</td>
<td>0.916</td>
<td>0.803</td>
<td>0.873</td>
<td>0.833</td>
<td>NA</td>
</tr>
<tr>
<td>Maximum value</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
<td>NA</td>
</tr>
<tr>
<td>Minimum value</td>
<td>0.514</td>
<td>0.539</td>
<td>0.683</td>
<td>0.627</td>
<td>0.660</td>
<td>0.712</td>
<td>NA</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>0.12</td>
<td>0.26</td>
<td>0.08</td>
<td>0.18</td>
<td>0.31</td>
<td>0.20</td>
<td>NA</td>
</tr>
</tbody>
</table>
Table 4: Comparison of green production efficiency and market efficiency.

<table>
<thead>
<tr>
<th>DMU</th>
<th>Green production efficiency average</th>
<th>Average market efficiency</th>
<th>Overall efficiency average</th>
</tr>
</thead>
<tbody>
<tr>
<td>D1</td>
<td>0.871</td>
<td>0.932</td>
<td>0.903</td>
</tr>
<tr>
<td>D2</td>
<td>1.000</td>
<td>0.623</td>
<td>0.963</td>
</tr>
<tr>
<td>D3</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
</tr>
<tr>
<td>D4</td>
<td>0.987</td>
<td>1.000</td>
<td>1.000</td>
</tr>
<tr>
<td>D5</td>
<td>0.931</td>
<td>0.851</td>
<td>0.815</td>
</tr>
<tr>
<td>D6</td>
<td>0.852</td>
<td>1.000</td>
<td>0.852</td>
</tr>
<tr>
<td>D7</td>
<td>0.977</td>
<td>1.000</td>
<td>1.000</td>
</tr>
<tr>
<td>D8</td>
<td>0.986</td>
<td>0.913</td>
<td>0.971</td>
</tr>
<tr>
<td>D9</td>
<td>0.728</td>
<td>0.918</td>
<td>0.855</td>
</tr>
<tr>
<td>D10</td>
<td>0.656</td>
<td>0.772</td>
<td>0.720</td>
</tr>
<tr>
<td>D11</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
</tr>
<tr>
<td>D12</td>
<td>0.929</td>
<td>0.939</td>
<td>0.982</td>
</tr>
<tr>
<td>D13</td>
<td>0.842</td>
<td>0.930</td>
<td>0.905</td>
</tr>
<tr>
<td>D14</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
</tr>
<tr>
<td>D15</td>
<td>0.956</td>
<td>0.962</td>
<td>0.994</td>
</tr>
<tr>
<td>D16</td>
<td>0.851</td>
<td>1.000</td>
<td>0.851</td>
</tr>
<tr>
<td>D17</td>
<td>0.936</td>
<td>0.952</td>
<td>0.983</td>
</tr>
<tr>
<td>D18</td>
<td>0.814</td>
<td>0.851</td>
<td>0.896</td>
</tr>
<tr>
<td>D19</td>
<td>0.905</td>
<td>0.812</td>
<td>0.941</td>
</tr>
<tr>
<td>D20</td>
<td>0.647</td>
<td>0.861</td>
<td>0.683</td>
</tr>
<tr>
<td>Average value</td>
<td>0.862</td>
<td>0.902</td>
<td>0.916</td>
</tr>
<tr>
<td>Maximum value</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
</tr>
<tr>
<td>Minimum value</td>
<td>0.647</td>
<td>0.623</td>
<td>0.683</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>0.22</td>
<td>0.15</td>
<td>0.08</td>
</tr>
</tbody>
</table>

Table 5: Tobit regression results (numbers in brackets are t values).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Constant</th>
<th>Green energy equipment</th>
<th>Manager Education</th>
<th>Green license</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coefficient value</td>
<td>0.347 (1.708°)</td>
<td>0.362 (1.812°)</td>
<td>-0.379 (-1.681°)</td>
<td>-0.484 (-2.460&quot;)</td>
</tr>
</tbody>
</table>

* express p<0.05,  **express p<0.01.

The coefficient of any variable that has a positive impact on the efficiency value should be negative. The impact of environmental variables on the efficiency value was investigated by Tobit regression, and the results are shown in Table 5.

Table 5 shows that the green energy equipment of green hotels in the European Union has a negative effect on the operating efficiency. It not only indicated that the investment of green energy equipment cannot bring positive operating efficiency to green hotels in a short period of time, but also indicated that the cost of green energy equipment is higher than that of general equipment. However, the education level of managers and hotel green energy licenses have positive effects on the operating efficiency of green hotels, especially the t-value of hotel green licenses is the most significant, and the coefficient value for green hotels is as high as -0.484. It means that the higher the education level of green hotel managers and the higher the level of green hotel license, the higher the operating efficiency.

CONCLUSIONS AND IMPLICATIONS

How to balance the protection of the earth's environment with the efficiency of green hotel operation is a very important issue. The empirical results of this study show that green hotels will have different green energy efficiency, market efficiency and total efficiency with different energy
conservation and environmental protection inputs and outputs. According to the operating efficiency of 20 EU green hotels from 2018 to 2022, it was observed that the COVID-19 epidemic occurred in 2020, which obviously had a negative effect on the operating efficiency of each green hotel. It can be seen that the COVID-19 epidemic has seriously affected the operating efficiency of green hotels.

That is to say that the future business strategy of green hotels must be adjusted. Specifically, it is suggested that green hotels can grasp the demand for health care in the post-epidemic era and can create new value through humanized experiences in line with the global trend of “Wellness Travel”. For example, the green hotel recommends the use of local and seasonal ingredients in the food and beverage section in order to reduce carbon footprint by reducing transportation consumption and air pollution; in addition, sourcing local ingredients to reduce the consumption of ingredients and transportation costs. By doing this, it helps companies reduce the cost of raw materials for their products. The green purchasing concept not only helps to enhance the corporate social responsibility image of green hotels, but also improves the operating efficiency by focusing on the niche market of health tourism and establishing a unique market niche.

According to the analysis of this study, the more the investment in green energy equipment, the worse the operating efficiency of green hotels. The reason may be that the investment in green energy equipment increases the cost of green hotels, which leads to the inability to have a positive effect on short-term operating efficiency. In other words, the energy-saving and environment-related facilities of the green hotels do not easily translate into revenue in a short period of time. In terms of customer, we suggested that green hotels could clearly explain green prices so that consumers could understand that they could get reduced prices through less toiletries, less linen changes, etc., thus reducing operating costs. On the other hand, through price increases, consumers could choose to use green buildings, organic ingredients, or environmentally friendly products in green hotels to raise their fees. In terms of management, the construction of vertical farms is also one of the strategies that can be adopted for green hotels. Building vertical farms in green hotels may help meet hotel food demands in an environmentally responsible and sustainable way by focusing on the niche market of health tourism and establishing a unique market niche.

The education level of green hotel managers and the green license level of green hotels have positive effects on their operating efficiency, especially the green hotel license level is more significant. It indicated that customers pay more attention to the license level of green hotels. It's clear that leaders could create an environment for sustainable development in the workplace to make it easier for managers to set specific environmental goals and maintain meaningful policies. Furthermore, providing educational opportunities could improve managers' understanding of the contributions they can make to an environmentally workplace. In other words, creating a motivating environment for managers to know more about workplace is crucial for green hotel leaders. By doing it, the managers not only have a more comprehensive understanding of energy saving policies and environmental practices but is also familiar with the knowledge required for the green hotel certification process. Therefore, in the future, green hotels should pay attention to the application of their green certificate level and operate efficiently and sustainably.

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World Travel and Tourism Council (2022). Economic Impact Reports.

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