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# Can Tourists' Summer Vacations Save Energy and Reduce $CO_2$ Emissions? Evidence from China

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**Abstract:** This study develops a methodological framework for measuring energy conservation and $CO_2$ emission reductions that considers both origins and destinations. The framework encompasses four key aspects: transportation, accommodation, cooking, and housing rehabilitation. Data were collected through a literature review, questionnaire surveys, and field measurement tracking. Compared to living in the origin, senior tourists from Nanchang visiting Zhongyuan Township in China for summer tourism can save 5.747 MJ of energy and reduce $CO_2$ emissions by 3.303 kg per capita per day. An in-depth analysis indicated that the research site could further enhance energy conservation and reduce $CO_2$ emissions by improving public transportation services, optimizing the energy structure of the destination, and diversifying the available recreational offerings. Depending on the characteristics of the destination and the primary origin, summer or winter tourism in various countries or regions can employ the methodological framework to evaluate energy conservation and $CO_2$ emission reductions after identifying specific parameters. The improved pathways identified through this research can serve as a checklist for other countries or regions aiming to explore energy conservation and $CO_2$-emission-reduction pathways for summer or winter tourism. Enhancing climate-driven tourism development may offer a new avenue for the tourism industry to contribute to carbon reduction targets.

**Keywords:** summer tourism; energy conservation; $CO_2$ emission reduction; rural tourism; climate-driven tourism



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## 1. Introduction

Tourism is a crucial sector for achieving carbon reduction targets [1]. The involvement of the tourism sector can lead to reductions in energy consumption and $CO_2$ emissions during transportation and destination services, while also promoting low-carbon lifestyles among tourists [2]. Scholars have measured energy consumption and $CO_2$ emissions in the service-delivery processes of tourism destinations using various methods. These methods can be categorized into two groups: top-down and bottom-up, each with its own advantages and disadvantages. The top-down method considers the macroeconomic sector of an entire country, region, or industry. However, this method is limited by its reliance on government statistics regarding total tourism consumption and the $CO_2$ intensity of each sector [3]. Commonly used top-down methods include input–output methods and coefficient methods. While the input–output method can comprehensively cover the entire tourism industry [4], it is constrained by the availability of national data and suffers from poor timeliness [3]. Conversely, the coefficient method is freely accessible, regularly updated, and recalibrated annually to reflect advancements in energy and fuel technology. Nonetheless, it fails to address the challenge of measuring $CO_2$ emissions from certain infrastructures [5].

The bottom-up method relies on tourism statistics and data regarding tourists' energy consumption, combined with coefficients or parameters related to tourism energy consumption, to facilitate $CO_2$ emission accounting for transportation, accommodation, and other segments of tourism [6]. The advantages of this method include the following: (1) its ability to conduct an in-depth analysis of the behaviors of different tourists, thereby identifying the tourism choices that contribute most significantly to $CO_2$ emissions, which allows for more targeted emission reduction policies; and (2) its relatively straightforward calculation process. However, a notable disadvantage is that it only accounts for the direct $CO_2$ emissions from a limited number of sectors [7]. For example, the life cycle method provides a comprehensive overview of $CO_2$ emissions from production to consumption and enables comparisons of $CO_2$ emissions across various sectors and products. Nevertheless, this method faces challenges in obtaining research data, and the results may be conservative due to the inability to calculate data for all indicators across all sectors [8].

Existing studies indicate that tourism leads to an increase in energy consumption and $CO_2$ emissions [9–11]. Meanwhile, scholars have generally examined transportation [12], accommodation [13], and tourism activities [14] when assessing energy consumption and $CO_2$ emissions in tourism. For instance, $CO_2$ emissions per tourist per night amount to 232 kg for a vacation farm in northern Italy [15]. In rural areas of the Qingcheng Mountains in China, $CO_2$ emissions from tourism accommodation and services are 30.27 kg per person per day [16]. In addition, $CO_2$ emissions from the round-trip transportation of domestic tourists to the Finnish Lake in Finland amount to 599 kg per tourist per year [17]. However, these studies fail to consider both the origin and destination simultaneously and overlook the energy consumption and $CO_2$ emissions associated with tourists at the origin when they are not engaged in tourism activities.

The number of climate-driven tourists is huge, such as the thousands of Canadian retirees who spend their winters in warmer destinations in the southern United States [18], the approximately 31,300 seniors who leave Florida each July to enjoy milder summer climates elsewhere [19], and the over 600,000 elderly tourists who visit Sanya in Hainan Province, China, to escape the cold from October through May each year [20]. This phenomenon is often studied as seasonal retirement migration [21]. When considering the energy consumption and $CO_2$ emissions of these tourists at both their destinations and origins, their tourism behavior may contribute to energy conservation and $CO_2$ emission reductions. To the best of our knowledge, only Hui et al. [22,23] have attempted to study the effect of $CO_2$ emission reductions associated with residents traveling for summer holidays compared to remaining in their place of origin. However, the methodology employed by Hui et al. [22,23] for measuring $CO_2$ emission reductions primarily focuses on the specific study site and does not systematically establish a universal measurement framework.

As a form of tourism driven by climate factors, rural summer health tourism for urban elderly (RSHTUE) refers to a group of urban seniors who relocate during the summer months, traveling from a high-temperature city to a cooler rural area to escape the heat. This trend is characterized by tourists' longer stays at their destinations, shorter travel distances, and the practice of destination village operators utilizing their own vacant rooms, which have been converted to accommodate tourists and provide lodging and catering services [24]. By the end of 2023, there were 296.7 million people aged 60 and over, accounting for 21.1% of China's total population [25]. As global temperatures continue to rise and the demand for summer vacations among seniors significantly increases, many villages in China are making substantial progress in developing RSHTUE. The first objective of this study is to develop a methodological framework for measuring energy conservation and $CO_2$ emission reductions that can be broadly applied to the energy consumption associated with tourists' travel behavior in RSHTUE.

Food, housing, and transportation are the primary contributors to energy consumption and carbon emissions for residents. This study compares the energy consumption and $CO_2$ emissions of residents living in both the origin and destination for summer tourism. Additionally, it develops a methodological framework for measuring energy conservation and $CO_2$ emission reductions among urban seniors visiting the countryside for summer tourism. In the context of food, energy consumption and $CO_2$ emissions are significantly influenced by the energy structure. On the housing front, disparities in energy consumption and $CO_2$ emissions primarily stem from the use of air conditioning and the rehabilitation of housing. Urban residents who live at home in their original locations often rely on air conditioning to regulate indoor temperatures. In contrast, tourists visiting the destination for summer vacations typically do not require air conditioning due to the comfortable climate of the area. At the same time, the energy consumption and $CO_2$ emissions associated with villagers who remodel existing rooms to accommodate summer vacationers are a result of urban residents traveling to the destination for their summer holidays. In terms of transportation, the energy consumption and $CO_2$ emissions for summer trips encompass both round-trip and local transportation. In contrast, for non-summer trips, only the transportation from the origin is considered. This study develops a methodological framework for measuring the energy conservation and $CO_2$ emission reductions associated with the travel behavior of RSHTUE tourists. This is achieved by subtracting the energy consumption and $CO_2$ emissions incurred during travel to the summer tourism destination from the energy consumption and $CO_2$ emissions associated with living at the origin.

The characteristics of climate-driven tourism destinations and their origins vary from country to country and region to region, which affects the parameters used to measure energy conservation and $CO_2$ emission reductions. For instance, there are differences in energy consumption and $CO_2$ emissions among Chinese RSHTUE tourists [26], Australian "grey nomads" [27,28], and Canadian snowbirds [29] regarding food, housing, transportation, and other factors. See Table 1 for a comparison of energy consumption and $CO_2$ emissions between residents engaged in summer or winter tourism and those who do not participate in different countries and regions.

**Table 1.** Comparison of energy consumption and $CO_2$ emissions between residents engaged in summer or winter tourism and those who do not participate in different countries and regions [a].

| | | Food | Housing | | Transportation | | |
|---|---|---|---|---|---|---|---|
| | | **Cooking Energy Structure** | **Air Conditioning** | **Housing Rehabilitation** | **Destination** | **Origin** | **Round-Trip from the Origin to the Destination** |
| Chinese RSHTUE visitors | Escape the heat at destination | Structure 1 [b] | Unnecessary | Have | On foot | 0 | Coaches, private cars |
| | Living in the origin | Structure 2 [b] | Necessary | 0 | 0 | Buses, private cars | 0 |
| Australian Gray Nomads | Escape the cold at destination | Needs to be investigated | Unnecessary | 0 | Motorhome | 0 | Motorhome |
| | Living in the origin | Needs to be investigated | Necessary | 0 | 0 | Needs to be investigated | 0 |
| Canadian snowbird | Escape the cold at destination | Needs to be investigated | Unnecessary | Have | Needs to be investigated | 0 | Needs to be investigated |
| | Living in the origin | Needs to be investigated | Necessary | 0 | 0 | Needs to be investigated | 0 |

[a] When developing the methodological framework for measurements in this study, only the content differences presented in this table are taken into account. It is assumed that other aspects of energy consumption and $CO_2$ emissions remain consistent between living at the origin and engaging in summer or winter tourism at the destination. [b] Structure 1 represents the cooking energy structure of the destination, while structure 2 represents the cooking energy structure of the origin.

The study conducted by Hui et al. [22,23] presents three additional limitations. (1) The research focused exclusively on the mountainous regions of Sichuan and Chongqing in western China to assess the effects of $CO_2$ emission reductions. It is crucial to include additional case sites to evaluate the effects of $CO_2$ emission reductions from both origins and destinations across various regions. (2) The parameters for $CO_2$ emission reductions were assessed using a questionnaire-based method. However, the data on energy consumption and $CO_2$ emissions collected through this approach may be unreliable, as respondents often struggle to accurately recall their energy usage, particularly when distinguishing air conditioning energy consumption from other sources, such as lighting. To improve the accuracy of the measurement results, it is essential to obtain data on air conditioning energy consumption and $CO_2$ emissions directly from the origin using more precise tracking pathways. (3) There has not been a comprehensive exploration of potential pathways for energy conservation and $CO_2$ emission reductions.

The second objective of this study is to utilize the established methodological framework to evaluate energy conservation and $CO_2$ emission reductions among elderly tourists visiting Zhongyuan Township for summer vacation from Nanchang City, China. Furthermore, the study aims to identify potential pathways for enhanced energy conservation and additional $CO_2$ emission reductions at the research site. We will employ the Xiaomi Air Conditioner Companion Smart Socket for field measurement tracking. Considering the characteristics of RSHTUE and the research site, we will simultaneously employ the coefficient method, the life cycle method, and the questionnaire method to assess the energy conservation and $CO_2$ emission reductions resulting from the tourism behaviors of RSHTUE tourists at the research site. In addition, the study aims to identify potential pathways for further energy conservation and $CO_2$ emission reductions in the region, as well as to simulate the energy conservation and $CO_2$-emission-reduction potential of the research site under various improvement scenarios.

The contributions of this study are as follows. First, this research develops a more generalizable methodological framework for measuring energy conservation and $CO_2$ emission reductions resulting from tourists' behavior related to RSHTUE. This framework can be further applied to assess energy conservation and $CO_2$ emission reductions stemming from climate-driven tourism behavior in other countries or regions. Second, the results of energy conservation and $CO_2$ emission reductions from the tourism behavior of RSHTUE tourists at the research site were measured by employing more precise field measurement tracking methods, such as the Xiaomi Air Conditioning Companion. This enriched the evidence regarding the impact of climate-driven tourism types on energy conservation and $CO_2$ emission reductions. Finally, the identified pathways for energy conservation and $CO_2$ emission reductions at the research site can serve as a reference checklist for other countries or regions.

## 2. Methodological Framework

### *2.1. Research Design and Research Site Introduction*

#### 2.1.1. Research Design

This study was conducted in three steps, as illustrated in Figure 1. The first step involves identifying the indicators, collecting data, and calculating these indicators. The second step explores pathways for enhancing energy conservation and reducing $CO_2$ emissions. The third step simulates the potential for energy conservation and $CO_2$ emission reductions for RSHTUE, based on the tourism capacity of the research site, Zhongyuan Township.

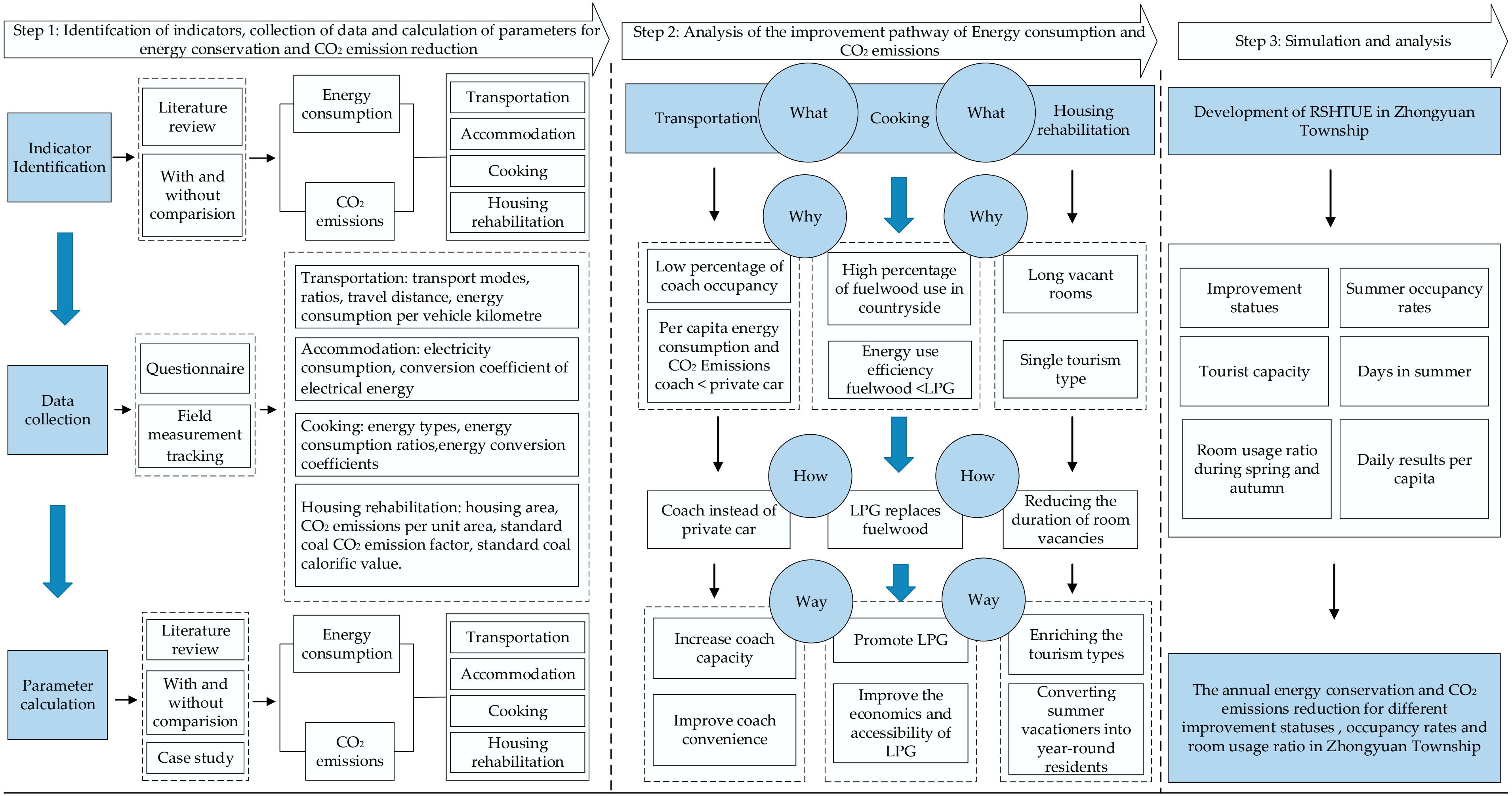


**Figure 1.** Flow chart of the study design.

### 2.1.2. Research Site Introduction

Zhongyuan Township is located in the southwestern region of Jing'an County, Yichun City, Jiangxi Province, China. It is approximately 120 km from Nanchang, the capital of Jiangxi Province. The specific location of the case site is illustrated in Figure 2. The average summer temperature in the area ranges from 20 °C to 22 °C, which is 6 °C to 10 °C lower than that of Nanchang City. With an average annual humidity of 82.5%, forest coverage exceeding 90%, and an anion concentration of up to 100,000 per cubic centimeter, this region represents a summer tourism destination in central China. In 2020, Zhongyuan Township boasted over 640 nongjiales (hotels offering food and accommodation for RSHTUE tourists), providing a total of approximately 30,000 beds and accommodating over 30,000 senior tourists during July to September, primarily from Nanchang [30]. Zhongyuan Township is transitioning from a summer tourism destination to a wellness retreat, with the goal of extending the durations of stays for summer visitors. It serves as a typical site for the development of RSHTUE, offering researchers a convenient location to observe, investigate, and assess energy conservation and $CO_2$ emission reductions among RSHTUE tourists.

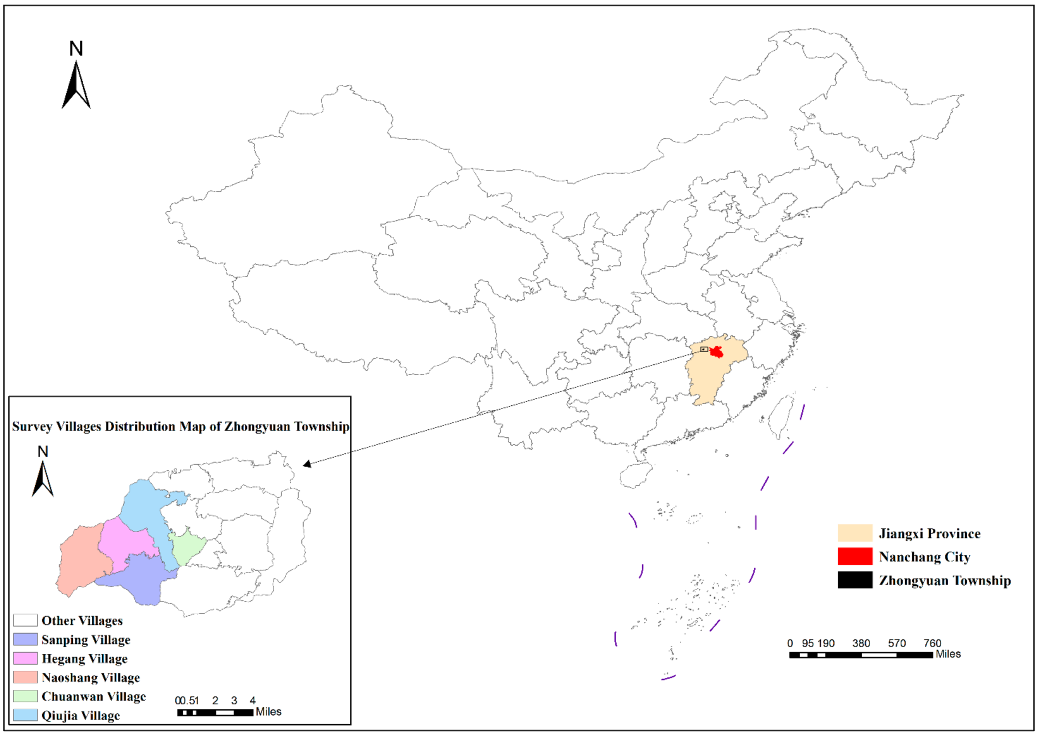


**Figure 2.** Specific location of the research site.

## *2.2. Energy Conservation Calculation Methods*

### 2.2.1. Energy Conservation in Transportation

According to the concept of the with–without comparison, transport energy conservation is defined as the transport energy consumption associated with residing in urban districts, minus the transport energy consumption incurred when traveling to the countryside for summer tourism. The latter includes the transport energy consumption from urban districts to the destination villages, as well as within the destination villages. The daily transport energy conservation ($\triangle E_t$) per urban elderly individual, with or without summer recreation in the countryside, is calculated using Equation (1).

$$\triangle E_t = \sum\left[\frac{D_{ci} \times \alpha_{ci} \times p_{ci}}{N_{ci}} - \frac{D_{cri} \times \alpha_{cri} \times p_{cri}}{N_{cri}} - \frac{D_{ri} \times \alpha_{ri} \times p_{ri}}{N_{ri}}\right] \quad (1)$$

where $D_{ci}, D_{cri}, D_{ri}$ denote the daily travel distance (km) per capita; $\alpha_{ci}, \alpha_{cri}, \alpha_{ri}$ denote the energy consumption per vehicle kilometer (KJ/vkm); $N_{ci}, N_{cri}, N_{ri}$ denote the average number of people loaded (person); and $p_{ci}, p_{cri}, p_{ri}$ denote the proportion (%) of the $i$-th mode of transport in three cases: living in urban districts, from the origin to the destination, and in the destination villages.

#### 2.2.2. Energy Conservation in Accommodation

The primary difference between RSHTUE tourists residing in destination villages and those in their origin cities is the energy consumption associated with air conditioning. RSHTUE tourists originate from cities with high summer temperatures, where air conditioning is essential. In contrast, the destination villages do not require air conditioning. The daily accommodation energy conservation ($\triangle E_a$) per urban elderly with or without summer recreation in the countryside is calculated using Equation (2).

$$\triangle E_a = Q \times \beta \tag{2}$$

where $Q$ denotes the per capita daily electricity consumption (kWh) of air conditioners, and $\beta$ denotes the conversion coefficient of electrical energy (KJ/kWh).

#### 2.2.3. Energy Conservation in Cooking

The primary types of energy used for cooking in destination villages and origin cities are also different. The daily cooking energy conservation ($\triangle E_c$) per urban elderly with or without summer recreation in the countryside is calculated using Equation (3).

$$\triangle E_c = \sum Q_{cj} \times \beta_j - \sum Q_{rj} \times \beta_j \tag{3}$$

where $Q_{cj}$, $Q_{rj}$ denote the respective per capita daily energy consumption of the $j$-th energy when living in the urban districts and the destination villages. $\beta_j$ denotes the energy conversion coefficients of the $j$-th energy.

#### 2.2.4. Energy Conservation in Housing Rehabilitation

With regard to measuring energy consumption parameters for housing rehabilitation, the energy consumption in this section is back-calculated based on the results from Section 2.3.4 and is expressed in terms of the calorific value of standard coal, as demonstrated in Equation (4).

$$\triangle Eh = \frac{\Delta C_h}{\lambda} \times \mu \tag{4}$$

where $\triangle E_h$ denotes RSHTUE per capita energy consumption for housing rehabilitation (KJ/person/day), $\triangle C_h$ denotes RSHTUE per capita $CO_2$ emissions from housing rehabilitation (g/person/day), see Equation (8) for details of the calculation, and $\lambda$ denotes the $CO_2$ emissions factor of standard coal (kg/kg), while $\mu$ denotes the calorific value of standard coal (KJ/kg).

### *2.3. $CO_2$ Emission Reduction Calculation Methods*

#### 2.3.1. $CO_2$ Emission Reduction in Transportation

The daily transport $CO_2$ emission reductions ($\triangle C_t$) per urban elderly with or without summer recreation in the countryside is calculated using Equation (5).

$$\triangle C_t = \sum \left[ \frac{D_{ci} \times \gamma_{ci} \times p_{ci}}{N_{ci}} - \frac{D_{cri} \times \gamma_{cri} \times p_{cri}}{N_{cri}} - \frac{D_{ri} \times \gamma_{ri} \times p_{ri}}{N_{ri}} \right] \tag{5}$$

where $D_{ci}, D_{cri}, D_{ri}$ denote the daily travel distance (km) per capita; $N_{ci}, N_{cri}, N_{ri}$ denote the average number of people loaded (person); $p_{ci}, p_{cri}, p_{ri}$ denote the proportion (%) of the $i$-th mode of transport; and $\gamma_{ci}, \gamma_{cri}, \gamma_{ri}$ denote the respective $CO_2$ emissions coefficients per vehicle kilometer (g/vkm) of the *i*-th mode of transport in three cases: living in urban districts, from the source to the destination, and in the destination villages.

### 2.3.2. $CO_2$ Emission Reduction in Accommodation

The daily accommodation $CO_2$ emission reductions ($\triangle C_a$) per urban elderly with or without summer recreation in the countryside is calculated using Equation (6).

$$\triangle C_a = Q \times \delta \tag{6}$$

where $Q$ denotes the per capita daily electricity consumption (kWh) of air conditioners, and $\delta$ denotes the $CO_2$ emissions coefficient of electric energy (g/kWh).

### 2.3.3. $CO_2$ Emission Reduction in Cooking

The daily cooking $CO_2$ emission reductions ($\triangle C_c$) per urban elderly with or without summer recreation in the countryside is calculated using Equation (7).

$$\triangle C_c = \sum Q_{cj} \times \beta_j \times \varepsilon_j - \sum Q_{rj} \times \beta_j \times \varepsilon_j \tag{7}$$

where $Q_{cj}$, $Q_{rj}$ denote the respective per capita daily energy consumption of the *j*-th energy when living in the urban districts and the destination villages. $\beta_j$ denotes the energy conversion coefficients of the *j*-th energy. $\varepsilon_j$ denotes the $CO_2$ emissions coefficients of the *j*-th energy.

### 2.3.4. $CO_2$ Emission Reduction in Housing Rehabilitation

Due to policy constraints, destination villagers primarily focus on rehabilitating their existing rooms to accommodate more RSHTUE tourists. This practice contributes to increased $CO_2$ emissions associated with housing rehabilitation by the operators in the destination. Referring to the study by Hui et al. [23], this research measures the $CO_2$ emissions associated with housing rehabilitation by examining the relationship between the increase in $CO_2$ emissions, the average floor area, and room size. The formula is presented in Equation (8):

$$\triangle C_h = \frac{1}{n_1 \times n_2} Y_e \times S \tag{8}$$

where $\triangle C_\mathrm{h}$ denotes the per capita $CO_2$ emissions from housing rehabilitation in RSHTUE (kg), $n_1$ denotes the number of beds per guest room, $n_2$ denotes the number of days the guest room accommodates tourists in a year, $Y_\mathrm{e}$ denotes the $CO_2$ emissions per unit area of the housing building (kg/$\mathrm{m}^2$), and $S$ denotes the average floor area of the guest room in the farm household ($\mathrm{m}^2$).

## *2.4. Questionnaire*

The questionnaire is primarily designed to gather information about the mode of transport chosen by tourists during their travels, their city of permanent residence, and the duration of their summer tourism trips. A detailed version of the questionnaire can be found in Appendix A.

From 8 to 16 July 2022, six trained graduate students conducted a questionnaire survey at the research site. The survey respondents were urban elderly individuals who stayed at the site for summer recreation and were randomly selected based on the registration information from each nongjiale. The survey was conducted during intervals between the meals and breaks of RSHTUE tourists (i.e., 6:00–7:00, 8:00–10:00, 15:30–17:30, and 18:30–20:30 Beijing time). The questionnaire was administered in a one-on-one format through interviews. A total of 270 questionnaires were distributed, and 226 valid responses were collected, resulting in a valid response rate of 83.6%. The missing data primarily occurred when respondents were unable to complete the survey due to external disturbances. Table 2 presents the demographic characteristics of the respondents.

**Table 2.** Demographic characteristics of respondents.

| Index and Option | N | % | Index and Option | N | % |
|---|---|---|---|---|---|
| **Sex** | | | **Cohabitants** | | |
| Male | 98 | 43.40% | Solitary | 35 | 15.50% |
| Female | 128 | 56.60% | Couple | 118 | 52.20% |
| **Age** | | | Parents and children | 54 | 23.90% |
| <61 | 11 | 4.80% | Three generations | 17 | 7.50% |
| 61–70 | 56 | 24.80% | Others | 2 | 0.90% |
| 71–80 | 95 | 42.00% | **Length of rural stay (day)** | | |
| >80 | 64 | 28.30% | <15 | 10 | 4.40% |
| **Marriage situation** | | | 15–29 | 20 | 8.80% |
| Single | 0 | 0.00% | 30–44 | 10 | 4.40% |
| Married | 183 | 81.00% | 45–59 | 157 | 69.50% |
| Divorced | 2 | 0.90% | 60–120 | 29 | 12.80% |
| Widowed | 41 | 18.10% | **Education level** | | |
| **Monthly income** (¥) | | | Primary School and below | 51 | 22.6 |
| 1000–2999 | 48 | 21.20% | Senior High School | 79 | 35.00 |
| 3000–4999 | 132 | 58.40% | High School and Technical Secondary School | 62 | 27.40 |
| 5000–6999 | 34 | 15.00% | Bachelor and Junior College | 34 | 15.00 |
| 7000–9999 | 9 | 4.00% | **Permanent residence city** | | |
| ≥10,000 | 3 | 1.30% | Nanchang | 218 | 96.50 |
| **Career before retirement** | | | Fuzhou | 5 | 2.20 |
| Government or public institution | 66 | 29.20% | Yingtan | 2 | 0.90 |
| Enterprise worker | 139 | 61.50% | Jiujiang | 1 | 0.40 |
| Farmer | 9 | 4.00% | **Transport mode** | | |
| Liberal profession | 39 | 4.00% | Private car | 213 | 94.20 |
| Unemployed | 3 | 1.30% | Coach | 13 | 5.80 |

### *2.5. Field Measurement Tracking*

We employ the field measurement tracking method to isolate the actual electricity consumption of air conditioners from the total household electricity consumption. The specific steps of the field measurement tracking process are as follows. (1) Select representative elderly households using purposive sampling. (2) Install the Xiaomi Smart Socket Air Conditioning Companion 2, a wireless smart socket equipped with an integrated power measurement module that uploads air conditioner power statistics and real-time power records to the cloud, and follow the following steps: 1) plug the Xiaomi Air Conditioning Mate Smart Socket into a power outlet, and then connect your air conditioner to the Xiaomi Smart Socket. 2) Use the Mijia app (https://home.mi.com/wap.html?eqid=faf3341400001c2b00000006644e0db2, accessed on 20 November 2024) to connect the Xiaomi Air Conditioning Mate Smart Socket to your network. 3) Open the Mi Home app and select the brand of your air conditioner to establish a connection. 4) Access real-time data and download the power-usage records. (3) Exclude days when the average daily temperature exceeds 30 °C and the air conditioner registers zero electricity usage. In this study, such occurrence is considered an instance when no household members are at home. (4) Calculate the daily per capita electricity consumption of air conditioners based on the total daily electricity consumption, the number of days the air conditioner is used, and the number of people in the household. The detailed calculation is shown in Equation (9).

$$Q = \frac{\sum_n \left( \sum_d \frac{q_{nd}}{D_n} \right)}{N} \tag{9}$$

where $q_{nd}$ denotes the electricity consumption (kWh) of air conditioning on the $d$-th day of the $n$-th household, $D_n$ denotes the number of days that the $n$-th household has members at home, and $N$ denotes the total population of all tracked households. Data on daily per capita energy consumption for air conditioning across 40 households, utilizing the field measurement tracking methodology, are presented in Supplementary Material S1.

## 3. Results Measured at the Research Site

The sources of the parameters mentioned Equation (1) to Equation (9) and the calculation principle are illustrated in Figure 3. The results of the questionnaire survey, energy conservation, and $CO_2$ emission reductions at the research site are as follows.

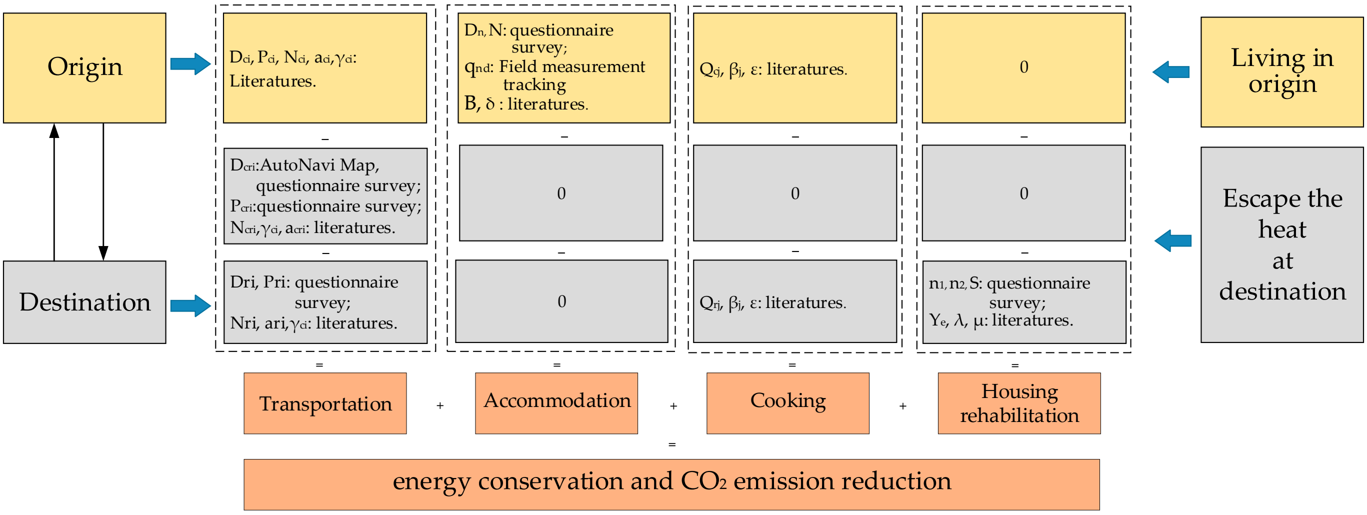


**Figure 3.** The sources of parameters and the calculation principles.

### *3.1. Results of Energy Conservation*

#### 3.1.1. Results of Energy Conservation in Transportation

The parameters of Equation (1) are determined as follows. First, according to Feng and Yang [31], the elderly's mode of transport when living in the urban districts are coach ($i$ = 1) and car ($i$ = 2), $D_{c1} = D_{c2}$ = 3.5 km, $p_{c1}$ = 0.25, and $p_{c2}$ = 0.02. According to Becken et al. [32], $\alpha_{c1}$ = 23,140 KJ/vkm and $\alpha_{c2}$ = 3180 KJ/vkm. According to Xiao et al. [33], $N_{c1}$ = 22.8 and $N_{c2}$ = 2.6. Second, according to the results of the questionnaire survey, 96.5% of the tourists at the research site are from Nanchang. The tourists' average number of summer holiday days at the research site is 58 days. The modes of transport from Nanchang to the research site are coach ($i$ = 1) and car ($i$ = 2), $p_{cr1}$ = 0.06 and $p_{cr2}$ = 0.94. Based on the average of the farthest distance (153.67 km) and nearest distance (116 km) (obtained from AutoNavi Map) from Nanchang to Zhongyuan Township and the tourists' average number of summer holiday days at the research site (58 days), $D_{cr1} = D_{cr2}$ = 4.649 km is calculated. Other parameter sources are the same as above: $\alpha_{cr1} = \alpha_{c1}$ = 23,140 KJ/vkm, $\alpha_{cr2} = \alpha_{c1}$ = 3180 KJ/vkm, $N_{cr1} = N_{c1}$ = 22.8, $N_{cr2} = N_{c2}$= 2.6. Finally, since the transport mode of tourists in the destination villages is walking, $\alpha_{r1}$ = 0. Based on the above parameters, $\triangle E_t = -4654.36$ KJ/person/day. This result indicates the additional energy consumption per person per day for transportation that would be incurred by tourists visiting a destination compared to living in their place of origin.

From the survey, the percentage of elderly tourists taking the coach is only 6%. The reliability and convenience of coaches still need to be improved, which are the key factors [34]. There are fewer coaches from the source city to the destination villages, and they do not pick up and drop off the elderly in the community, which is inconvenient. If the number of coaches from the source city to the destination village is increased in the summer and the proportion of tourists who take the coach will increase, then energy consumption and $CO_2$ emissions will be reduced accordingly. The energy conservation across various traffic mode proportion scenarios is simulated according to Equation (1), as detailed in Table A1 of Appendix B. If the proportion of tourists using coaches increases from the current 6% to 80%, an additional 716.14 KJ/person/day in energy consumption would be saved.

#### 3.1.2. Results of Energy Conservation in Accommodation

According to the steps of the field measurement tracking, forty elderly households in Nanchang were tracked to obtain the daily electricity consumption of their air conditioners during July and August 2022. The careers of the heads of these households prior to retirement, the number of individuals in each household, the number of days spent at home, and the total electricity consumption (in kWh) of the air conditioners for these households during July and August 2022 are presented in Table A2 of Appendix B.

According to Equation (9), the daily per capita electricity consumption of air conditioners $Q$ = 5.44 kWh/person/day was obtained. $\beta$ = 3600 KJ/kWh comes from the Department of Energy Statistics of the National Bureau of Statistics [35]. Based on the above parameters, $\triangle E_a$ = 19,576.72 KJ/person/day. This result shows the amount of reduced energy consumption per person per day for the accommodation by visitors to the destination compared to those living in the origin.

#### 3.1.3. Results of Energy Conservation in Cooking

According to Zheng [36], the cooking energy types are coal ($j$ = 1), fuelwood ($j$ = 2), electricity ($j$ = 3), natural gas ($j$ = 4), LPG ($j$ = 5), $Q_{c1} = 7.504 \times 10^{-3}$ kg, $Q_{c2} = 5.320 \times 10^{-2}$ kg, $Q_{c3} = 4.846 \times 10^{-1}$ kWh, $Q_{c4} = 1.478 \times 10^{-1}$ m$^3$, $Q_{c5} = 3.144 \times 10^{-2}$ kg, $Q_{r1} = 9.359 \times 10^{-2}$ kg, $Q_{r2} = 4.664 \times 10^{-1}$ kg, $Q_{r3} = 4.993 \times 10^{-1}$ kWh, $Q_{r4} = 1.360 \times 10^{-2}$ m$^3$, and $Q_{r5} = 6.201 \times 10^{-2}$ kg. According to the Department of Energy Statistics of the National Bureau of Statistics [35], $\beta_1$ = 20,908 KJ/kg, $\beta_2$ = 16,726 KJ/kg, $\beta_3$ = 3600 KJ/kWh, $\beta_4$ = 38,931 KJ/m$^3$, and $\beta_5$ = 50,179 KJ/kg. Substituting the above parameters into Equation (3), $\triangle E_c = -5073.42$ KJ/person/day. This result indicates the additional energy consumption per person per day for cooking that would be incurred by tourists visiting a destination compared to living in their place of origin.

The per capita energy consumption in the countryside is higher compared to those in cities. The primary reason for this discrepancy is that cooking in the countryside predominantly relies on fuelwood, which has a low energy-use efficiency due to the traditional wood-fired stoves employed. The research site advocates for the use of LPG instead of fuelwood. If LPG is eventually used instead of fuelwood, then cooking energy consumption per capita in the rural and urban areas will be nearly equal. Table A3 of Appendix B illustrates the changes in energy conservation during cooking for urban elderly individuals who travel to the countryside for summer recreation, corresponding to each 20% increase in the replacement ratio when LPG is used to replace fuelwood beyond the urban area. If the replacement ratio achieves 100%, it would save another 5073.42 KJ/person/day in energy consumption.

#### 3.1.4. Results of Energy Conservation in Housing Rehabilitation

Referring to the study by Hou et al. [37], it is noted that the calorific value ($\mu$) of standard coal is 29,400 KJ/kg, and the carbon emission factor of standard coal is 0.68 kg/kg. From the molecular weight of carbon dioxide, which is 44 (with a carbon atomic weight of 12 and an oxygen atomic weight of 16), the $CO_2$ emission factor $\lambda$ for standard coal is calculated as follows: $0.68 \times (44/12) = 2.493$ kg/kg. From Equation (8), $\triangle C_h$ is $-347.83$ g/person/day. By substituting the values of $\triangle C_h$, $\mu$, and $\lambda$ into Equation (4), we find that $\triangle Eh = -4101.97$ KJ/person/day. This result indicates the additional energy consumption per person per day for housing rehabilitation that would be incurred by tourists visiting a destination compared to living in their place of origin.

In the context of housing rehabilitation, rooms in RSHTUE destinations are typically occupied for a maximum of three months in summer. This limited usage is primarily due to the monotonous nature of the local tourism industry, which currently relies solely on summer resources. As a result, these rooms are utilized only during the summer months and remain unoccupied for the remainder of the year. If additional tourism resources, such as health tourism, can be developed to extend the duration of room occupancy, the per capita energy consumption associated with housing rehabilitation will be further reduced. Table A4 in Appendix B shows the changes in average energy consumption for housing rehabilitation across various usage ratios over a period of 183 days in both spring and autumn for guest room beds, assuming that destination guest rooms maintain the same occupancy rate during the summer. If the room usage rate reaches 25% during the spring and autumn seasons, per capita energy conservation can increase by an additional 1362.39 KJ/person/day.

### *3.2. Results of $CO_2$ Emission Reductions*

#### 3.2.1. Results of $CO_2$ Emission Reductions in Transportation

According to Xiao et al. [33], $\gamma_{c1}$ = 1616.52 g/vkm, $\gamma_{c2}$ = 256.1 g/vkm, and other parameters in Equation (5) are the same as Section 3.2.1. Based on the above parameters, $\triangle C_t = -381.30$ g/person/day. Consistent with the reasons outlined in Section 3.1.1, variations in the proportions of coach and private car usage have distinct impacts on $CO_2$ emissions. The $CO_2$ emission reductions for different traffic mode proportion scenarios are simulated according to Equation (4), as presented in Table A1 of Appendix B. If the proportion of tourists taking the coach increases from the current 6% to 80%, it would reduce another 94.96 g/person/day in $CO_2$ emissions. This result indicates the additional $CO_2$ emissions per person per day for transportation that would be incurred by tourists visiting a destination, compared to those living in the origin.

#### 3.2.2. Results of $CO_2$ Emission Reductions in Accommodation

According to the Ministry of Ecology and Environment of the People's Republic of China [38], $\delta$ = 858.7 g/kWh. According to Section 3.2.2, $Q$ = 5.43 kWh/person/day. Substituting the above parameters into Equation (6) results in $\triangle C_a$ = 4669.59 g/person/day. This result indicates the amount of reduced $CO_2$ emissions per person per day for accommodation by visitors to the destination compared to those living in the origin.

#### 3.2.3. Results of $CO_2$ Emission Reductions in Cooking

According to the Guidelines for National Greenhouse Gas Inventories [39], $\varepsilon_1 = 8.73 \times 10^{-2}$ g/KJ, $\varepsilon_2 = 9.5 \times 10^{-2}$ g/KJ, $\varepsilon_4 = 5.43 \times 10^{-2}$ g/KJ, and $\varepsilon_5 = 6.16 \times 10^{-2}$ g/KJ. According to the Ministry of Ecology and Environment of the People's Republic of China [38], $\varepsilon_3 = 2.385 \times 10^{-1}$ g/KJ. Substituting the above parameters into Equation (7) derives $\triangle C_c = -637.11$ g/person/day. This result indicates the additional $CO_2$ emissions per person per day for cooking that would be incurred by tourists visiting a destination, compared to those living in the origin.

For the same reasons outlined in Section 3.1.3, fuelwood is currently utilized more frequently at RSHTUE destinations. This practice is less energy-efficient and results in higher $CO_2$ emissions. Substituting fuelwood with more energy-efficient and environmentally friendly energy sources would contribute to a reduction in $CO_2$ emissions. Table A3 in Appendix B illustrates the corresponding changes in $CO_2$ emission reductions from cooking for urban elderly individuals who travel to the countryside for summer recreation, with each 20% increase in the replacement ratio of LPG for fuelwood beyond the urban portion. If the replacement ratio reaches 100%, it would reduce another 543.35 g/person/day in $CO_2$ emissions.

#### 3.2.4. Results of $CO_2$ Emission Reductions in Housing Rehabilitation

According to the studies conducted by Hui et al. [23] and Xiong [40], it is established that $Y_e$ is 4 kg/m$^2$. From the survey data, it is determined that the number of beds per guest room is $n_1$ = 2, the length of guest room use is $n_2$ = 92 days, and the average size of each guest room is $S$ = 16 m$^2$. By substituting the aforementioned data into Equation (8), it can be concluded that $\triangle C_h = -347.83$ g/person/day. This result indicates the additional $CO_2$ emissions per person per day for housing rehabilitation that would be incurred by tourists visiting a destination, compared to those living in the origin.

Consistent with the reasons outlined in Section 3.1.4, retrofitting self-built houses results in higher $CO_2$ emissions. However, enhancing the frequency and duration of room usage through the development of tourism resources can reduce $CO_2$ emissions associated with housing rehabilitation on a per capita basis. Table A4 in Appendix B illustrates the changes in average $CO_2$ emissions for housing rehabilitation across various usage ratios over a period of 183 days in both spring and autumn for guest room beds, assuming that destination guest rooms maintain the same occupancy rate during the summer. If the room usage rate reaches 25% during the spring and autumn seasons, per capita $CO_2$ emissions can be reduced by an additional 115.53 g/person/day.

### *3.3. Energy Conservation and $CO_2$ Emission Reductions of Research Site*

Based on the results presented in Sections 3.1 and 3.2, further calculations indicate a per capita daily energy conservation of 5.747 MJ and a per capita daily reduction in $CO_2$ emissions of 3.303 kg for this research site. Figures 4 and 5 illustrate the per capita daily energy conservation and $CO_2$ emission reductions, respectively, during summer holidays at the destination compared to residing at the origin.

Zhongyuan Township has 30,000 beds [30], with an occupancy rate exceeding 98% during the summer season [41]. Assuming an 80% occupancy rate and considering the current levels of actual energy consumption and $CO_2$ emissions, the annual energy conservation resulting from the development of RSHTUE in Zhongyuan Township is estimated at 12.66 TJ, with a corresponding reduction in $CO_2$ emissions of 7.29 kilotons. If the occupancy rate reaches 100% and all three improvement pathways are fully optimized, the annual energy conservation achieved through the development of RSHTUE in Zhongyuan Township would increase to 36.14 TJ, while the reduction in $CO_2$ emissions would amount to 11.27 kilotons. Detailed calculations refer to Table A5 in Appendix B.

Table A6 in Appendix B illustrates the energy conservation and $CO_2$ emission reductions associated with an increase in the proportion of tourists traveling by coach, the replacement ratio of LPG, and room usage. This analysis corresponds to different statuses of urban elderly individuals, both with and without summer recreation in the countryside. Status 1 represents the current actual state, while Status 6 denotes the potential optimal state for energy conservation and $CO_2$ emission reductions in transportation, cooking, and housing rehabilitation. Transitioning from the current state to the optimal state could result in an additional savings of 7345.51 KJ/person/day in energy consumption and a reduction of 779.5 g/person/day in $CO_2$ emissions.

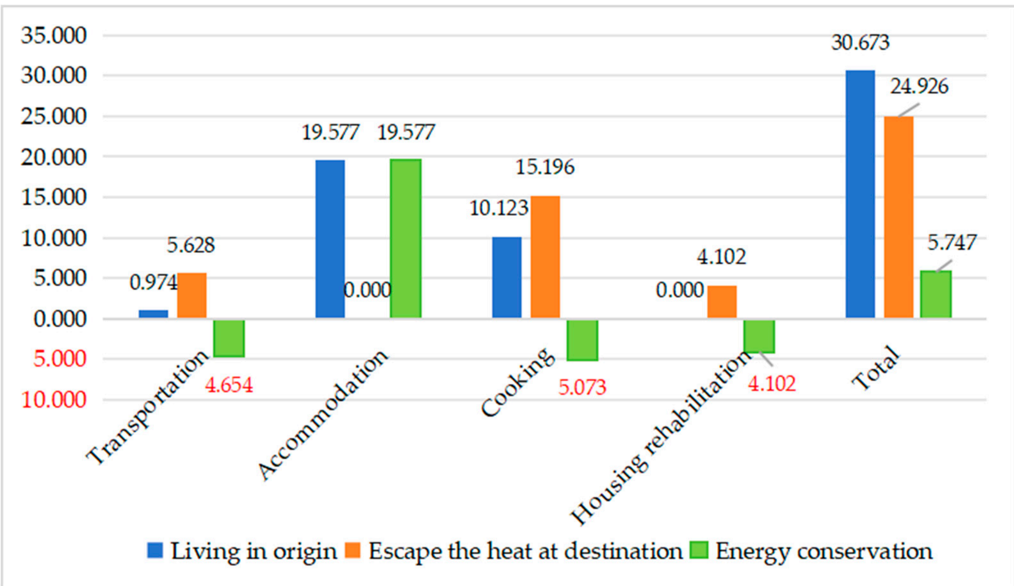


**Figure 4.** Daily per capita energy conservation at the research sites (MJ).

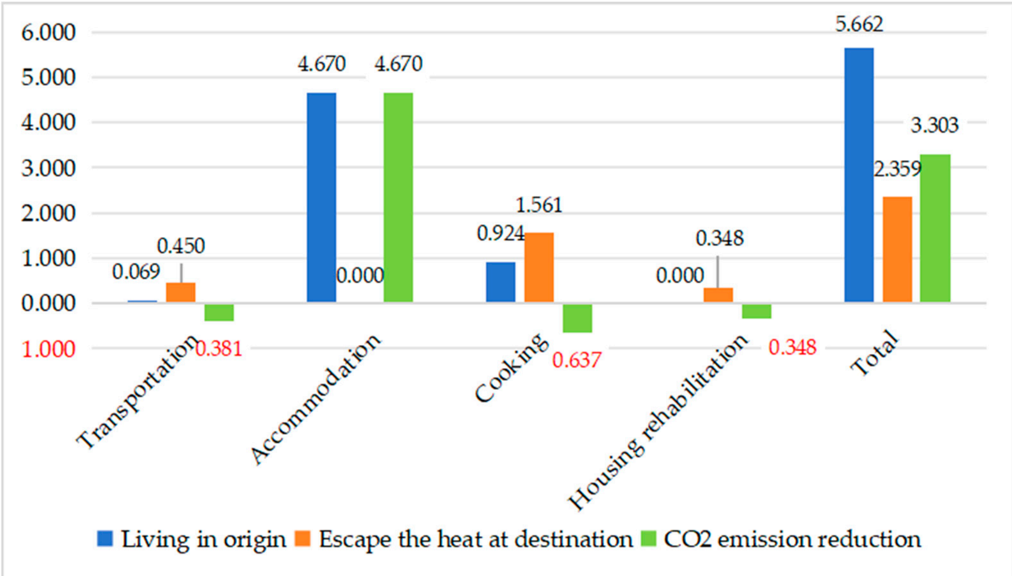


**Figure 5.** Daily per capita $CO_2$ emission reductions at the research sites (kg).

## 4. Discussion

### *4.1. Theoretical Implications*

The methodological framework developed in this study can be utilized to assess the effects of energy conservation and $CO_2$ emission reductions in climate-driven tourism destinations and their origins in other countries or regions. Climate-driven tourism refers to the phenomenon in which travelers leave their home regions, characterized by uncomfortable climatic conditions, to visit destinations with more favorable climates for leisure and vacation purposes. This type of tourism can be further classified into two categories: summer tourism, which occurs when tourists seek cooler climates during hot months, and winter tourism, where individuals travel to warmer locations to escape cold weather. Considering the origin and destination as a cohesive system, air conditioning is typically required to regulate indoor temperatures when tourists are in regions with extreme heat or cold. However, if they are in a destination with a comfortable climate, air conditioning is generally unnecessary. Vacation and leisure trips taken by tourists from areas with uncomfortable climates to destinations with more pleasant weather contribute to increased energy consumption and $CO_2$ emissions associated with transportation from the origin to the destination. Additionally, these trips lead to higher energy consumption and $CO_2$ emissions for destination operators, who must retrofit hospitality facilities to accommodate visitors. The methodological framework for energy conservation and $CO_2$ emission reductions developed in this study, which compares the impacts of traveling versus not traveling, can be directly applied to assess energy conservation and $CO_2$ emission reductions resulting from climate-driven tourism behaviors. Currently, there is very limited empirical evidence available to study the impact of climate-driven tourism on energy conservation and $CO_2$ emission reductions. Furthermore, climate-driven tourism behaviors in other countries or regions can be evaluated by applying the methodological framework established in this study, thereby enriching the existing body of evidence.

Considering the origin and destination as a holistic system, the climate-driven travel behavior of tourists can yield benefits in energy conservation and reductions in $CO_2$ emissions. In this study, we measured the energy conservation and $CO_2$ emission reductions associated with a typical RSHTUE destination in central China by tracking air-conditioning energy consumption through field measurements. The results indicate that the combined $CO_2$ emission reductions of summer tourism for elderly residents in Zhongyuan Township, Nanchang, China, are 3.3 kg/person/day. This finding aligns with research conducted by Hui et al. [22,23], which indicated that the combined benefits of $CO_2$ reductions from summer tourism in the Wuling Mountains for urban elderly residents in Chongqing, China, ranged from 2.367 to 3.807 kg/person/day [22]. From the findings of this study, it is evident that RSHTUE tourists who visit summer destinations during the high-temperature months play a significant role in energy conservation and the reduction in $CO_2$ emissions. The primary reason for this is the extreme climate of their home regions. When tourists choose to stay in their home areas during the sweltering summer months, they are forced to rely on air conditioning to maintain comfortable indoor temperatures, resulting in substantial energy consumption. In contrast, RSHTUE destinations provide comfortable climatic conditions, thereby eliminating the need for air conditioning or other devices to regulate indoor temperatures. If the total energy consumption and $CO_2$ emissions from transportation, accommodation, cooking, and housing rehabilitation to accommodate tourists during the summer vacation at the destination are lower than those associated with living in their place of origin, then tourism behavior demonstrates a significant impact on energy conservation and $CO_2$ emission reductions. The types of tourism that exhibit similar conditions include not only summer tourism but also winter tourism. Tourists from colder climates often require heating and other equipment to regulate indoor temperatures, which can lead to substantial energy consumption. If winter tourists choose to stay in a destination with a milder climate, they may not need heating systems to maintain comfortable indoor temperatures. Consequently, the energy consumption and $CO_2$ emissions generated from traveling to that destination may be lower than those produced while living in their place of origin. Therefore, winter tourism can positively contribute to energy conservation and $CO_2$ emission reductions.

The potential demand for developing a climate-driven tourism niche is substantial. With global warming, socio-economic development, and an aging population, there is a significant increase in the number of tourists seeking summer tourism opportunities. Research indicates that in China alone, there are 179 cities at the prefecture level and above that experience high temperatures during the summer. Additionally, more than 100 million potential summer visitors aged 60 and older reside in these cities [42]. Globally, winter tourists also represent a large demographic, including "grey nomads" who travel from the southern regions of mainland Australia in motorhomes to rural bush campgrounds in northern Australia to escape the cold [27,28]. Similarly, "snowbirds" from Northern Europe, such as those from France, travel to Southern Europe, including the Atlantic coast of Morocco [29]. Likewise, individuals from North America, particularly Canadians, often relocate to warmer regions like Florida [43] and Arizona [44] to avoid the cold. Notably, "Houniao" traveled from northeastern China to the city of Sanya in Hainan Province to escape the winter chill [45].

Depending on the characteristics of the destination and the primary origin, the summer or winter tourism industry in various countries or regions can utilize the methodological framework of this study to evaluate energy conservation and $CO_2$ emission reductions, once specific parameters have been established. For instance, the energy conservation and $CO_2$ emission reductions of "grey nomads" in Australia can be assessed using four dimensions: transportation, accommodation, cooking, and housing rehabilitation, utilizing the measurement methodological framework developed in this study. Taking transportation as an example, energy conservation and $CO_2$ emission reductions for the transportation of "grey nomads" can still be achieved by utilizing Equations (1) and (5), respectively. However, the values of the parameters in these equations must be determined based on the specific circumstances of the origin and destination of the "grey nomads". (1) If "grey nomads" continue to reside in their place of origin, measuring energy consumption and $CO_2$ emissions from transportation will necessitate determining the average daily distance $D_{ci}$ traveled by the $i$-th mode of transport, the energy consumption factor $\alpha_{ci}$ and $CO_2$ emission factor $\gamma_{ci}$ of the $i$-th mode of transport, the average number of passengers $N_{ci}$, and the proportion (%) of the $i$-th mode of transport. (2) Between the origin and the destination, "grey nomads" usually choose the mode of transportation that involves driving a motorhome. It is needed to determine the average daily travel distance $D_{cri}$

for the $i$-th model of motorhome, the energy consumption coefficient $\alpha_{cri}$ for the $i$-th mode of motorhome, the carbon emission coefficient $\gamma_{cri}$ of the $i$-th mode of motorhome, and the average number of passengers permitted $N_{cri}$ in the $i$-th mode of motorhome. (3) At the destination, "grey nomads" are also transported in motorhomes. It is needed to determine the average daily travel distance $D_{ri}$ for the $i$-th mode of motorhome, the energy consumption coefficient $\alpha_{ri}$ for the $i$-th mode of motorhomes, the carbon emission coefficient $\gamma_{ri}$ of the $i$-th mode of motorhomes, and the average number of passengers permitted $N_{ri}$ in the $i$-th mode of motorhomes. Taking housing rehabilitation as an example, the energy conservation and $CO_2$ emission reductions of "grey nomads" can still be measured using Equations (4) and (8), respectively. However, at the camps located at their destination, the carbon emission factor for housing rehabilitation, denoted as $\Upsilon_e$, is zero. Although the formulas employed are the same, the values of these parameters differ from those in the present study.

Developing incentive support policies focused on energy conservation and $CO_2$ emission reductions is a promising approach for guiding the growth of climate-driven tourism segments, ultimately aiding the tourism sector in meeting global $CO_2$ reduction targets. Previous research has explored energy conservation and $CO_2$ emissions within the tourism sector, particularly during the production of tourism services [46–48]. The findings of this study reveal that the travel behaviors of tourists in climate-driven tourism segments, such as summer and winter tourism, significantly affect energy conservation and $CO_2$-emission-reduction efforts. Government agencies and relevant management departments can formulate appropriate incentive policies to promote the development of both summer and winter tourism segments. When designing these incentives or support policies, the benefits derived from energy conservation and $CO_2$ emission reductions should be allocated to the operators or tourists involved. This allocation can stimulate the growth of climate-driven tourism, thereby contributing to global carbon emission reduction goals.

### *4.2. Management Implications*

Emphasizing the benefits of energy conservation and the reduction in $CO_2$ emissions resulting from climate-driven tourism is essential. Managers of potential tourism destinations aiming to develop climate-driven tourism should conduct a thorough evaluation of the benefits associated with energy conservation and $CO_2$ emission reductions. This analysis can serve as a valuable reference when applying for public sector funding support. In formulating policies to promote the development of low-carbon industries, government authorities should consider the role of climate-driven tourism segments in energy conservation and $CO_2$ emission reductions. They can design incentive policies that include both supply-side funding and demand-side subsidies to strategically guide the growth of this industry.

Enhancing the layout of public transportation systems from origin to destination can increase the percentage of tourists utilizing public transport. Findings from the case research sites indicate that the majority of RSHTUE tourists travel by private car, while the use of public transportation remains low. This trend results in high energy consumption and elevated $CO_2$ emissions associated with transportation. The government can facilitate the transformation of transportation modes through various policies. These may include improving public transportation options, such as increasing the frequency of coaches between key destinations during peak tourist seasons, establishing more public transportation stops at convenient locations for tourists, and enhancing the load factor to accommodate more passengers. These measures aim to achieve greater energy conservation and reduce $CO_2$ emissions related to transportation and travel. The proportion of tourists utilizing public transportation, such as coaches, can be gradually increased to 20% in the first year, 40% in the second year, and 60% in the third year.

Enhancing the structure of energy consumption across various destinations and improving the efficiency of energy utilization within these areas, the RSHTUE destinations examined in this study primarily rely on traditional fuelwood stoves, which are less efficient in their energy consumption. Government tourism authorities can assist tourism operators in modifying their energy-usage practices and optimizing their energy structures. For instance, they can promote the adoption of LPG as a substitute for fuelwood, thereby further reducing energy consumption and $CO_2$ emissions. The proportion of LPG replacing fuel wood could be increased in phases: 20% in the first year, 40% in the second year, and 60% in the third year.

It is essential to diversify the types of tourism and the tourism industry within the area, as well as to extend the operational days of accommodation facilities. Research conducted at the research sites indicates that RSHTUE is highly seasonal, with the majority of operators currently operating for only three months during the summer. Managers in the area are striving to transform the destination from a summer vacation spot into a health-focused retreat. This initiative aims to convert summer visitors into long-term health and wellness residents, thereby extending the duration of stay for older visitors. Such a shift would further reduce per capita energy consumption and $CO_2$ emissions associated with housing rehabilitation.

The energy conservation and $CO_2$-emission-reduction-improvement pathways identified in this study can serve as a comparative checklist for other countries or regions seeking to explore energy conservation and $CO_2$-emission-reduction pathways in summer or winter tourism. Existing research has not thoroughly examined potential pathways for energy conservation and $CO_2$ emission reductions in tourism destinations. This study proposes specific pathways for enhancing energy conservation and reducing $CO_2$ emissions in summer tourism destinations. Additionally, it simulates the potential for energy conservation and $CO_2$ emission reductions at the research site. The results indicate a significant potential for energy conservation and $CO_2$ emission reductions in RSHTUE. The managers of similar tourism destinations can utilize the improvement pathways identified in this study as a checklist. They can identify development pathways for energy conservation and $CO_2$ emission reductions in the tourism industry that align with local conditions by comparing their circumstances to the checklist identified in this study. Subsequently, they can implement the identified pathways to achieve enhanced energy conservation and further reductions in $CO_2$ emissions.

## 5. Conclusions and Limitations

The emphasis on energy conservation and $CO_2$ emission reductions resulting from climate-driven tourism is crucial. It highlights the potential for tourism to contribute positively to energy conservation and $CO_2$-emission-reduction efforts. While tourism is often perceived as an industry characterized by high energy consumption and significant $CO_2$ emissions, this study reveals that tourists participating in summer tourism can save 5.747 MJ of energy and reduce $CO_2$ emissions by 3.303 kg per capita per day compared to living in the origin. The findings indicate that the development of summer tourism contributes to energy conservation and $CO_2$ emission reductions. Furthermore, when we expanded our analysis to encompass the entire research site over a one-year period, the calculations indicated that the research site could save up to 15.86 TJ of energy and reduce $CO_2$ emissions by 9.12 kt annually. This suggests that the development of summer tourism in the research site has significant potential for energy conservation and $CO_2$ emission reductions. Consequently, the tourism sector should prioritize and support the advancement of climate-driven tourism, enabling the industry to make a more substantial contribution to global $CO_2$-emission-reduction targets.

In this study, we developed a methodological framework for measuring energy conservation and $CO_2$ emission reductions across four areas: transportation, accommodation, cooking, and housing rehabilitation at the destination. This framework integrates both the origin and destination by comparing residents of the origin who visit the destination with those who do not. Using Nanchang City and Zhongyuan Township in central China as research sites, we collected the necessary parameters to calculate energy conservation and $CO_2$ emission reductions resulting from the summer vacation behaviors of elderly tourists visiting Zhongyuan Township. These data were gathered through a combination of literature reviews, questionnaire surveys, and field measurement tracking. The per capita daily energy conservation and $CO_2$ emission reductions for elderly tourists in Nanchang were 5.747 MJ and 3.303 kg, respectively. Increasing the proportion of tourists utilizing public transportation, substituting LPG for fuel wood, and enhancing the use of hospitality facilities at the destination are effective strategies for further energy conservation and $CO_2$ emission reductions at the research site.

The methodological framework for measurements developed in this study can be applied to assess the effects of energy conservation and $CO_2$ emission reductions in climate-driven tourism destinations and origins in other countries or regions. This application aims to enhance the evidence regarding the impact of various types of climate-driven tourism on energy conservation and $CO_2$ emission reductions. Measurements taken at the research site indicate that the development of RSHTUE, a climate-driven tourism model, significantly impacts energy conservation and $CO_2$ emission reductions, achieving a per capita daily $CO_2$ reduction of up to 3.3 kg. Existing studies have primarily concentrated on energy conservation and $CO_2$ emission reductions within the tourism sector, particularly during the service provision process. These studies emphasize energy conservation and $CO_2$ emission reductions in the production and service aspects of tourism, often neglecting a holistic view of both the origin and destination. Furthermore, they do not adequately address specific tourism segments, such as RSHTUE, where tourists' behaviors significantly contribute to energy conservation and $CO_2$ emission reductions, embodying a sustainable lifestyle. The development of incentive support policies aimed at guiding the growth of climate-driven tourism segments, with a focus on energy conservation and $CO_2$ emission reductions, represents a new approach for the tourism sector to meet global carbon reduction targets.

The energy conservation and $CO_2$-emission-reduction pathways initially explored in this study, based on the research site, can serve as a valuable reference for managers in other countries or regions. Managers can further explore potential for energy conservation and $CO_2$ emission reductions in several ways: by enhancing public transportation facilities from origin to destination, which can significantly decrease per capita energy consumption and $CO_2$ emissions associated with tourist transportation; by optimizing the energy structure of destinations to reduce energy consumption and $CO_2$ emissions resulting from cooking by tourists; and by diversifying the range of tourism products available at destinations to improve the utilization efficiency of hospitality facilities. This strategy can lead to a reduction in the average daily energy consumption and $CO_2$ emissions associated with the renovation of hospitality facilities by tourists.

The present study has successfully met its research objectives; however, this study still has some limitations; firstly, it was validated only in a specific destination and origin in China. In the future, it will be necessary to measure energy conservation and $CO_2$ emission reductions in various RSHTUE destinations and origins across additional countries and regions. Second, this study focused solely on measuring the energy conservation and $CO_2$-emission-reduction effects of summer tourism. Future research should expand its scope to include winter tourism in order to further assess the energy conservation and $CO_2$-emission-reduction impacts of climate-driven tourism.

**Supplementary Materials:** The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/atmos15121414/s1, Table S1: Air conditioning energy consumption data.

**Author Contributions:** Conceptualization, P.Z. and X.G.; methodology, P.Z. and X.L.; software, X.L. and M.R.; validation, P.Z. and X.G.; formal analysis, P.Z. and X.L.; investigation, X.L., M.R., and R.L.; resources, P.Z. and R.L.; data curation, X.L. and M.R.; writing—original draft preparation, P.Z., M.R., and X.L.; writing—review and editing, P.Z., R.L., and X.G.; visualization, M.R. and X.L.; supervision, X.G.; project administration, P.Z. and X.G.; funding acquisition, P.Z. and R.L. All authors have read and agreed to the published version of the manuscript.

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**Institutional Review Board Statement:** The study was conducted in accordance with the ethics protocol approved by the College of City Construction, Jiangxi Normal University Ethics Committee (IRB No. 2021004).

**Informed Consent Statement:** Not applicable.

**Data Availability Statement:** The data that support the findings of this study are available from the corresponding author upon reasonable request.

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**Conflicts of Interest:** Author Xin Gao was employed by the Yunnan Ecological and Environmental Cooperation Office. The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

## Appendix A

### Questionnaire

Questionnaire number

We are conducting a study on energy conservation and the reduction of $CO_2$ emissions associated with summer tourism. Completing the questionnaire will take approximately five minutes. The information collected will be used exclusively for academic research purposes. Your responses will remain anonymous, and we will ensure that your information is kept confidential. There are no right or wrong answers to the questions; please respond based on your actual situation. As a token of our appreciation for your participation, we will provide you with a gift.

Sex: Age: Permanent residence city:

**Q1-1** What is your education level?

☐Primary School and below ☐Senior High School
☐High School and Technical Secondary School ☐Bachelor and Junior College

**Q1-2** How is your marriage situation?

☐Single ☐Married ☐Divorced ☐Widowed

**Q1-3** How many children do you have?

☐None ☐One ☐Two ☐Three ☐Four and above

**Q1-4** Who are you currently living with?

☐Solitary ☐Couple ☐Parents and children
☐Three generations ☐Others

**Q1-5** What is your source of income? (Multiple options)

☐Retirement Benefits ☐Pension ☐Maintenance from children
☐Second Career ☐Others

**Q1-6** How much is your monthly income?

☐Less than RMB 3000 yuan ☐RMB 3000–5000 yuan ☐RMB 5000–7000 yuan
☐RMB 7000–9000 yuan ☐RMB 10,000 yuan and above

**Q1-7** What was your career before you retired?

☐Government or public institution ☐Enterprise worker ☐Farmer
☐Liberal profession ☐Unemployed

**Q1-8** How long do you plan to stay for the trip?

☐<15 ☐15–29 ☐30–44 ☐45–59 ☐60–120

**Q1-9** What is your mode of transport to Zhongyuan Township?

☐Private car ☐Coach

## Appendix B

**Table A1.** Energy conservation and $CO_2$ emission reductions for different traffic mode proportions.

| Proportion of Private Car (%) | Proportion of Coach (%) | Energy Conservation (KJ/Person/Day) | $CO_2$ Emission Reduction (g/Person/Day) |
|---|---|---|---|
| 94 | 6 | −4654.36 | −381.30 |
| 80 | 20 | −4518.87 | −363.33 |
| 60 | 40 | −4325.32 | −337.67 |
| 40 | 60 | −4131.77 | −312.01 |
| 20 | 80 | −3938.22 | −286.34 |
| 0 | 100 | −3744.66 | −260.68 |

**Table A2.** Profile of the tracked elderly households.

| No. | Career | People | Days | Usage (kWh) | No. | Career | People | Days | Usage (kWh) |
|---|---|---|---|---|---|---|---|---|---|
| 1# | Public institution | 2 | 60 | 994.8 | 21# | Enterprise worker | 2 | 60 | 1094.28 |
| 2# | Enterprise worker | 2 | 46 | 301.4 | 22# | Government | 1 | 60 | 252.63 |
| 3# | Enterprise worker | 2 | 55 | 572.5 | 23# | Government | 1 | 54 | 373.56 |
| 4# | Enterprise worker | 1 | 54 | 339.6 | 24# | Public institution | 2 | 46 | 271.26 |
| 5# | Public institution | 2 | 60 | 990.9 | 25# | Enterprise worker | 2 | 60 | 1193.76 |
| 6# | Government | 1 | 60 | 280.7 | 26# | Public institution | 2 | 60 | 1189.08 |
| 7# | Public institution | 2 | 57 | 203.5 | 27# | Government | 2 | 55 | 687 |
| 8# | Enterprise worker | 2 | 62 | 709.7 | 28# | Public institution | 1 | 54 | 407.52 |
| 9# | Public institution | 2 | 60 | 895.32 | 29# | Public institution | 2 | 62 | 851.64 |
| 10# | Enterprise worker | 2 | 60 | 1089.99 | 30# | Public institution | 1 | 60 | 336.84 |
| 11# | Public institution | 2 | 55 | 629.75 | 31# | Public institution | 2 | 57 | 244.2 |
| 12# | Enterprise worker | 1 | 54 | 305.64 | 32# | Enterprise worker | 2 | 46 | 361.68 |
| 13# | Public institution | 2 | 62 | 638.73 | 33# | Government | 2 | 60 | 792.72 |
| 14# | Public institution | 1 | 60 | 308.77 | 34# | Public institution | 2 | 62 | 567.76 |
| 15# | Enterprise worker | 2 | 57 | 183.15 | 35# | Public institution | 2 | 55 | 458 |
| 16# | Enterprise worker | 2 | 62 | 780.67 | 36# | Enterprise worker | 2 | 57 | 162.8 |
| 17# | Public institution | 2 | 60 | 891.81 | 37# | Enterprise worker | 2 | 60 | 795.84 |
| 18# | Government | 2 | 46 | 331.54 | 38# | Public institution | 1 | 60 | 224.56 |
| 19# | Government | 2 | 55 | 515.25 | 39# | Enterprise worker | 1 | 54 | 271.68 |
| 20# | Enterprise worker | 2 | 57 | 223.85 | 40# | Enterprise worker | 2 | 46 | 241.12 |

**Table A3.** Cooking energy conservation and $CO_2$ emission reductions with different replacements.

| Statues | Ratio (%) | Fuelwood Usage (kg) | LPG Usage (kg) | Energy Conservation (KJ/Person/Day) | $CO_2$ Emission Reduction (g/Person/Day) |
|---|---|---|---|---|---|
| 1 | 0 | 0.47 | 0.06 | −5073.42 | −637.11 |
| 2 | 20 | 0.38 | 0.07 | −4058.73 | −528.44 |
| 3 | 40 | 0.30 | 0.08 | −3044.05 | −419.77 |
| 4 | 60 | 0.22 | 0.08 | −2029.37 | −311.10 |
| 5 | 80 | 0.14 | 0.09 | −1014.68 | −202.43 |
| 6 | 100 | 0.05 | 0.10 | 0.00 | −93.76 |

**Table A4.** Changes in average energy consumption and $CO_2$ emissions of housing rehabilitation at varying usage rates of guest room beds during the spring and autumn seasons.

| Statues | Ratio (%) | Energy Conservation (KJ/Person/Day) | $CO_2$ Emission Reduction (g/Person/Day) |
|---|---|---|---|
| 1 | 0 | −4101.97 | −347.83 |
| 2 | 5 | −3730.86 | −316.36 |
| 3 | 10 | −3421.37 | −290.12 |
| 4 | 15 | −3159.29 | −267.89 |
| 5 | 20 | −2934.50 | −248.83 |
| 6 | 25 | −2739.58 | −232.30 |

**Table A5.** Energy conservation and $CO_2$ emission reductions of developing RSHTUE under different improvement statuses.

| Status | Occupancy Rate (80%) | | Occupancy Rate (90%) | | Occupancy Rate (100%) | |
|---|---|---|---|---|---|---|
| | E (TJ) | C (kt) | E (TJ) | C (kt) | E (TJ) | C (kt) |
| 1 | 12.66 | 7.29 | 14.28 | 8.21 | 15.86 | 9.12 |
| 2 | 16.05 | 7.64 | 18.05 | 8.60 | 20.06 | 9.55 |
| 3 | 19.40 | 8.00 | 21.82 | 9.00 | 24.25 | 10.00 |
| 4 | 22.65 | 8.34 | 25.48 | 9.39 | 28.31 | 10.43 |
| 5 | 25.81 | 8.68 | 29.04 | 9.77 | 32.26 | 10.85 |
| 6 | 28.91 | 9.01 | 32.52 | 10.14 | 36.14 | 11.27 |

**Table A6.** Energy conservation and $CO_2$ emission reductions with different improvement statuses.

| Status | Proportion of Coach (%) | LPG Replacement Ratio (%) | Different Room Beds Usage Rates (%) | Energy Conservation (KJ/Person/Day) | $CO_2$ Emission Reduction (g/Person/Day) |
|---|---|---|---|---|---|
| 1 | 6 | 0 | 0 | 5746.97 | 3303.35 |
| 2 | 20 | 20 | 5 | 7268.26 | 3461.46 |
| 3 | 40 | 40 | 10 | 8785.98 | 3622.03 |
| 4 | 60 | 60 | 15 | 10,256.29 | 3778.59 |
| 5 | 80 | 80 | 20 | 11,689.32 | 3931.99 |
| 6 | 100 | 100 | 25 | 13,092.48 | 4082.85 |

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