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Perception on integrated energy services' design and management among residents in China

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Perception on integrated energy services' design and management among residents in China

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Abstract. Integrated energy services (IES) in China provide the residents with efficient multiple energy supply services through safe and reliable design. The aim of this study is to determine Chinese residents' perception on IES energy planning and design, as well as the operation and maintenance. By distributing questionnaires to 450 Chinese residents, socio-demographic data, and information on IES design and management were collected. Descriptive analysis was used to summarize the data, while the Mann-Whitney U analysis and Kruskal-Wallis analysis were conducted to identify significant differences between different groups. The results of the descriptive analysis show that residents generally agree with the energy services that IES providers should provide. However, in Tianjin, young people and middle-income residents hold neutral perceptions. The Mann-Whitney U and the Kruskal-Wallis analysis results show that there are significant differences in the perception of IES in gender, marital status, ages, occupations, and income salaries. Gender differences are reflected in the emphasis on the importance of residents' opinions in energy design and attention to the diverse needs of energy forms; differences in marital status and residents' differences in family life planning; age differences are reflected in the concern for the innovation and stability of energy services; occupational differences are reflected in concerns about the rationality and practicality of energy services; while income differences are mainly reflected in the need for a balance between affordability and quality of energy services. However, educational background did not significantly influence respondents' perceptions. Analyzing the perception of different residents on IES and the reasons behind differences can help IES providers improve the quality of energy services and provide residents with more efficient and reliable energy services.

1. Introduction

The importance of integrated energy services (IES) has become increasingly prominent in the context of growing global energy demand and increasingly prominent environmental issues [1].

IES achieves efficient, economical, and environmentally friendly energy use by integrating multiple energy services and utilizing intelligent management systems [2-3]. IES mainly includes energy supply, energy management, and energy consulting. Through efficient energy management and energy use optimization measures, IES can significantly improve energy efficiency, ensure safe energy supply, promote the use of renewable energy, and meet users' diverse energy needs [4-6].

IES has received widespread attention in China and developed rapidly as a new energy service model [7]. In 2022, IES was included in China's "14th Five-Year Plan for Renewable Energy Development" for the first time, marking that IES has become one of China's national energy strategies [8]. With China's economy's rapid development and urbanization advancement, energy demand has grown rapidly, and the requirements for the quality of energy services have also increased [9]. IES are important in China's sustainable development by improving energy efficiency, innovating energy management, and upgrading energy systems [10].

The service capability assessment standards for Chinese IES providers include two of the following parts i.e. planning and design as well as operation and maintenance [11]. All key information contained in the standard is shown in Figure 1. Regarding planning and design, IES providers should have strong corporate strength, incorporate residents' opinions into the design system, and ensure the energy supply design plan is reliable and safe. In addition, it is best for the energy providers to offer a variety of energy forms to meet the needs of all users while providing transparent services especially related to the service fees. In terms of operation and maintenance, alongside with the energy supply, the providers should be able to provide detailed operation and maintenance guidelines, apply energy-saving measures in the service management, provide 24-hour energy operation and usage tracking services, being transparent in energy billings, have reliable energy systems for service interruption and update [11]. By assessing these standards, IES providers' abilities in providing more sustainable energy option can be comprehensively determined.

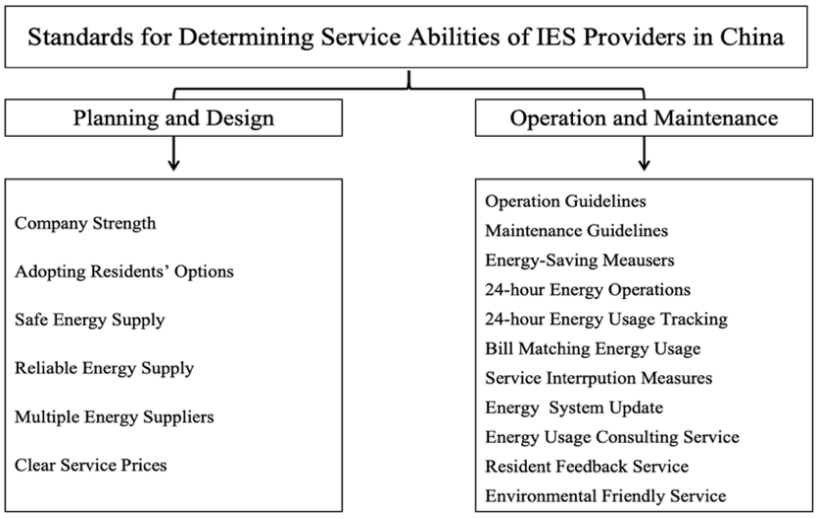

Figure 1. Standards for Determining Service Abilities of IES Providers in China

Therefore, this study is aimed to determine the perceptions of the residents in China on the IES planning and design as well as the operation and maintenance provided by their local energy providers. All elements listed according to the standards for determining service abilities of the IES providers were highlighted for the purpose of the study.

2. Material and Method

2.1 Study Areas

IES pilot tests have been conducted in China in order to improve energy efficiency and reduce carbon emissions by integrating traditional and renewable energy and optimizing energy management models. The pilot tests were conducted at three (3) municipalities of China, i.e., Beijing, Tianjin, and Shanghai (refer to Figure 2), due to the high infrastructure construction, large populations, and huge energy demand. The populations of the tested areas have diverse backgrounds, covering different socio-economic activities [12]. The locations and detailed information on the study areas are shown in Figure 2.

City	Community Name	Longitude Latitude	Size (1000 m²)	Population (Resident)	Type of area	Economic activities
Beijing	Beiren Low Carbon Park	39.894268 116.346101	498	29,392	Urban	Retail, Catering, Service industry
	Zhongsheng Yicheng	40.140335 117.102152	997	41,190	Suburban	Catering, Logistics centre, Manufacturing Base
Tianjin	Jinzhong Street	39.203495 117.272802	30,777	100,536	Urban	Retail, Catering, Education and training
Shanghai	Zhangjiang Town	31.206333 121.614371	8,079	108,597	Urban	Retail, Catering, Financial and Real estate services

Source: https://www.stats.gov.cn/; https://earth.google.com/web/ [13-14].

Figure 2. Location and the details of the study areas

2.2 Data Collection

This study has developed a structured questionnaire to assess the respondents' perceptions of IES providers. The targeted respondents were the residents from the IES pilot tests areas. The pilot tests have been running for more than a year, therefore, the experience gained by the users specifically the residents related to the IES are considered as adequate. The questionnaire consists of the socio-demographic section and the IES abilities on energy design and management section. The socio-demographic section is important to collect the respondents' information related to their gender, age, occupation, marital status, educational backgrounds and income salaries. Meanwhile, the other section focused on collecting information related to the provided IES planning and design as well as the current operation and maintenance. In this section, respondents were required to give feedback by using 5-point Likert scale ranging from 1:"strongly disagree," to 5:"strongly agree" [15].

In this study, the sample size was determined to be 384 using the Cochran formula, and the final size was increased to 450 to reduce the bias [16-17]. Before the actual data collection, the questionnaire has been validated and checked on its reliability. The data was collected by using systematic sampling method. The samples were systematically extracted from widely and randomly distributed households in Tianjin, Shanghai, and Beijing [18]. Systematic sampling ensures a uniform distribution of samples through a transparent and continuous sampling frame, reducing the risk of sample concentration or bias, thereby improving the representativeness of the study and the generalizability of the results [19-20].

2.3 Data Analysis

There are three analysis that have been conducted in this study which involved the descriptive analysis, Mann-Whitney U analysis and Kruskal-Wallis analysis. Descriptive analysis was conducted to summarize the data collected for this study [21]. The study analyzed each item in the questionnaire, including the total N, missing values, median, minimum, maximum values, distribution of residents. Mann-Whitney U analysis is a non-parametric test that compares differences between two independent samples [22]. In this study, the Mann-Whitney U analysis was used to analyze the impact of dichotomous variables of gender and marital status on perception of IES design and management [23]. Meanwhile, Kruskal-Wallis analysis was conducted to analyze data that consist of more than two groups of categorical variables, i.e., ages, occupations, educational backgrounds, and income salaries [24]. From both analyses, the significant differences related to different age groups, occupations, educational backgrounds, and income salaries regarding IES providers' abilities on energy design and management were determined among residents. If the significant value (p-value) is less than or equal to 0.050, it will indicate that there is significant difference between the tested groups or variables [25].

3. Results and Discussion

3.1 Descriptive analysis

Descriptive analysis results showed that the number of valid samples for all questions was 450, and there were no missing values. The median of all questions was 4, indicating that respondents agreed to the items stated in the questionnaire related to the IES abilities on energy design and management. All items also recorded minimum and maximum values of 1 and 5, respectively. Detailed of the overall residents' perception on IES design and management in China is shown in Table 1.

Further descriptive analysis was also conducted based on the socio-demographic background of the respondents as shown in Table 2. The data showed that the median values of gender, age, occupation, marital status, high education level, and income salaries related to the IES providers' abilities on energy design and management are mostly 4, indicating that these specific groups agreed that IES providers have good service abilities with regard to the planning and design as well as the operation and maintenance. Different perspectives were recorded in Tianjin, where young and middle-income residents have neutral agreement towards services that IES providers should provide. Young people lack social experience, which leads to a low understanding of the importance of energy services and, as a result, a low perception of IES [26]. Meanwhile, non-income groups were observed to have no or less expectations regarding IES providers' abilities on energy design and management compared to other income salary groups

due to economic pressure. They would like to consider basic survival needs first, i.e., food and daily expenses [27].

Table 1. Descriptive statistics of overall residents' perception on IES design and management in China

Items (I)	N total	Missing value	Median	Min	Max
I1: Strong IES abilities	450	0	4	1	5
I2: IES design include residents' input	450	0	4	1	5
I3: IES provide reliable energy supply	450	0	4	1	5
I4: IES provide secure energy supply	450	0	4	1	5
I5: IES provide variety of energy forms	450	0	4	1	5
I6: Price list for IES	450	0	4	1	5
I7: IES operation guidelines	450	0	4	1	5
I8: IES maintenance guidelines	450	0	4	1	5
I9: IES energy-saving measures	450	0	4	1	5
I10: IES 24-hour energy operation	450	0	4	1	5
I11: IES 24-hour energy usage tracking	450	0	4	1	5
I12: IES energy usage billings	450	0	4	1	5
I13: IES notification on maintenance service interruptions	450	0	4	1	5
I14: IES system update	450	0	4	1	5
I15: IES consultation on energy usage	450	0	4	1	5
I16: IES customer feedback channels	450	0	4	1	5
I17: IES environmentally friendly practices	450	0	4	1	5

Table 2. Descriptive statistics of residents' perception on IES design and management by regions based on the socio-demographic background

	BEJING		TIANJIN		SHANGHAI		OVERALL	
Items	**N**	**Median**	**N**	**Median**	**N**	**Median**	**N**	**Median**
Gender								
Male	50	4	74	4	91	4	215	4
Female	55	4	82	4	98	4	235	4
Ages								
18 to 24 years old	8	4	9	**3**	16	4	33	4
25 to 34 years old	22	4	26	4	28	4	76	4
35 to 44 years old	20	4	30	4	40	4	90	4
45 to 54 years old	20	4	40	4	52	4	112	4
55 to 64 years old	25	4	38	4	44	4	107	4
65 years old and above	10	4	13	4	9	4	32	4
Occupations								
Government sector	5	4	10	4	11	4	26	4
State-owned enterprise Sector	19	4	24	4	31	4	74	4
Private sector	57	4	78	4	102	4	237	4
Self-employee	12	4	27	4	17	4	56	4
Unemployed	7	4	11	4	17	4	35	4
Others	5	4	6	4	11	4	22	4
Marital Status								
Single	22	4	24	4	37	4	83	4
Married	83	4	132	4	152	4	367	4
Highest Educational Level								
No formal education	2	4	0	-	0	-	2	4
Primary school	8	4	13	4	15	4	36	4
Secondary school	20	4	39	4	44	4	103	4
Academy	38	4	59	4	68	4	165	4
Bachelor's degree	32	4	33	4	51	4	116	4
Master's degree	0	-	9	4	6	4	15	4
Doctor of Philosophy	5	4	3	4	5	4	13	4
Income Salary (Monthly)								
No Monthly Salary	7	4	6	**3**	10	4	23	4
Less than 3000 yuan	18	4	42	4	43	4	103	4
3001~5000 yuan	33	4	58	4	70	4	161	4
5001~10000 yuan	34	4	33	4	50	4	117	4
10001~15000 yuan	5	4	10	4	6	4	21	4
15001~20000 yuan	4	4	5	4	7	4	16	4
More than 20001 yuan	4	4	2	4	3	4	93	4

3.2 Mann-Whitney U and Kruskal-Wallis Analyzes

The results of the Mann-Whitney U test showed that there are significant differences (p-value <0.050) between different gender groups in terms of I2 (p= 0.050) and I5 (p= 0.047) which associated to the consideration of residents' input in IES design and the ability of IES provider to

provide variety of energy forms, respectively, while others recorded no significant difference. Females and males prioritize different aspects of energy services based on their unique perspectives and needs. One group emphasizes the practicality and efficiency of energy forms, meanwhile the other focuses on inclusivity and ensuring that their specific needs and preferences are considered in the design process [28]. Detailed data is shown in Table 3.

There were also significant differences recorded between groups of marital status for I1 (p= 0.050), I4 (p = 0.003), I5 (p = 0.031), I7 (p = 0.005), I8 (p = 0.017), I9 (p = 0.018), I14 (p = 0.014), I17 (p = 0.006). There are significant differences between married and unmarried residents related to the abilities of IES providers to provide integrated energy to the users, secure energy supply, variety of energy forms, operation and maintenance guidelines, energy-saving measures, system update services, and IES prioritization on environmentally friendly practices. Married residents tend to take on family responsibilities and tend to make longer-term plans for their families. They expect the stability and reliability of energy services to create a stable family environment. Single residents tend to have a flexible and simple lifestyle, so they pay more attention to the convenience of services [29].

The results of the Kruskal-Wallis test revealed that there were significant differences (p-value <0.050) between groups of age, type of occupation and income salaries, whereas there was no significant difference was recorded between level of education related to the items. It is worth noting that different educational backgrounds did not significantly influence the respondents' energy service expectations.

For variable age, significant differences were recorded for I3 (p=0.015) and I17 (p=0.022), which related to IES providers' abilities to provide reliable energy supply and prioritize environmentally friendly practices in their IES system. Young residents are more receptive to new things and will prioritize innovation and flexibility in energy services. Middle-aged residents focus on the stability and reliability of energy services because of their stable jobs and families. Older residents prefer tried-and-tested energy services because this involves energy services security [30].

For variable occupation, there were significant for I2 (p=0.030), I5 (p=0.006), I7 (p=0.006), I8 (p=0.013), I15 (p=0.000), I16(p=0.036), I17(p=0.003) which related to IES design includes their inputs, providing multiple energy forms, operating and maintenance guidelines, providing energy use consultation, and environmentally friendly services. The reason for the difference is due to the environmental impacts that respondents receive in different types of occupation. Residents working in the public sector and state-owned enterprises are accustomed to considering the rationality of service design, safe and stable operation, and compliance with environmental protection requirements. Private and self-employed residents are more inclined to the practicality of services. For residents who are unemployed, they will pay attention to the service that meets their basic needs based on their current situation [31].

As for the income salary variable, I1, I5, I8, and I13 were reported to have significant differences with the p-values of 0.020, 0.046, 0.029, and 0.006, respectively. The differences were related to the IES provider's strength, variety of energy forms supplements, maintenance guidelines, and notification on maintenance service interruptions. Residents with no income or low income tend to focus on basic energy services due to their low basic affordability. Middle-income residents pay more attention to budgeting household expenses and seek a good balance between cost-effectiveness and quality; high-income residents pay more attention to energy service quality and innovation and hope to obtain energy services that meet their higher

standards and lifestyle expectations [32]. Table 4 summarizes the results by integrating the three dimensions of groups, significant differences, and perception.

Table 3. The results of the Mann-Whitney U analysis and Kruskal-Wallis Analysis

Items (I)	Mann-Whitney U analysis				Kruskal-Wallis							
	Gender		Marital Status		Ages		Occupations		Education		Income Salaries	
	U	p-value	U	p-value	K	p-value	K	p-value	K	p-value	K	p-value
I1	23469	.178	13201	**.050**	6.95	.224	9.24	.100	1.79	.938	15.00	**.020**
I2	22644	**.050**	14824	.695	5.06	.409	12.34	**.030**	1.47	.962	12.01	.062
I3	23253	.133	14082	.269	14.08	**.015**	9.68	.085	6.48	.371	8.02	.236
I4	23216	.127	12112	**.003**	4.59	.468	8.00	.156	0.94	.988	11.33	.079
I5	22607	**.047**	12993	**.031**	4.50	.481	16.30	**.006**	7.45	.282	12.82	**.046**
I6	24784	.722	15012	.834	5.78	.328	4.43	.489	3.62	.728	7.88	.247
I7	24075	376	12306	**.005**	10.36	.066	16.17	**.006**	4.73	.578	10.98	.089
I8	24864	.765	12756	**.017**	3.32	.651	14.37	**.013**	8.39	.211	14.06	**.029**
I9	25085	.895	12773	**.018**	10.74	.057	4.62	.464	2.47	.872	7.94	.243
I10	22951	.085	13543	.106	7.26	.202	3.22	.667	9.97	.126	9.86	.131
I11	23805	.276	15136	.927	7.25	.202	5.52	.356	1.21	.976	7.38	.287
I12	22643	.051	14253	.348	6.29	.280	9.52	.090	3.71	.715	2.37	.883
I13	24251	.448	14399	.422	4.62	.464	6.47	.263	3.09	.798	18.27	**.006**
I14	23509	.189	12675	**.014**	7.72	.172	3.56	614	1.71	.944	8.28	.218
I15	24529	.582	13377	.073	6.65	.248	29.36	**.000**	1.52	.958	9.91	.129
I16	24427	.532	13895	.199	8.81	.117	11.93	**.036**	3.54	.738	11.26	.081
I17	22925	.080	12368	**.006**	13.12	**.022**	18.29	**.003**	5.27	.510	6.81	.339

Table 4. The summary of analysis

Analysis	**Groups**	**Significant Differences**	**Perception**
Mann-Whitney U	Gender	Yes	Males: Practicality and efficiency of energy forms. Female: Inputs considered into the energy design.
	Marital Status	Yes	Married: Make longer-term plans for their families. Single: Prefer flexible and simple lifestyle.
Kruskal-Wallis	Ages	Yes	Young: Innovation and flexibility in energy services. Middle-aged: Stability and reliability of energy services. Older: Tried-and-tested energy services.
	Occupations	Yes	Public sector / State-owned enterprises: Safe, stable operation and compliance of services. Private and self-employed: The practicality of services. Unemployed: Basic needs of services.
	Education	No	Educational background did not affect residents' perception
	Income Salaries	Yes	No-income / low-income: Basic energy services. Middle-income: Balance between cost-effectiveness and quality of services. High-income: Energy service quality and innovation.

4. Conclusion

This study aims to determine residents' perceptions on IES providers' abilities related to the planning and design as well as the operation and maintenance in China. The results can help understand the diverse perspectives of different groups on IES and the underlying reasons that can enable IES providers to enhance service quality, ultimately delivering more efficient and reliable energy services to residents.

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