Public Response to Installation of Building Integrated Photovoltaic (BIPV) System to Residential Buildings in Wuhan, China

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Abstract

Chinese government has been encouraging the deployment of renewable energy resources such as solar PV for many years. However, up to date building integrated photovoltaic (BIPV) system is still not a common practice in construction industry and encounters many barriers for entry into public realm especially in residential buildings. In this study, a comprehensive survey was conducted in June 2019 to investigate the public responses to and expectations for installing BIPV system to residential buildings in Wuhan, China. A sample size of 206 has been collected from different residential buildings. The results show that agreement is not a real barrier for the installation of BIPV to residential buildings; however, knowledge, technology, economic, social and political barriers are the hurdles for BIPV adoption. Based on the data analysis, some recommendations have been made to address the barriers. The results of this study will assist policymakers and relevant stakeholders of building industry in making informed BIPV-related decisions and in targeting future research and development efforts.

Keywords: Public Response, BIPV, residential buildings; barriers

1. Introduction

Chinese government has been encouraging the deployment of renewable energy resources such as solar PV for many years. As a result, China has become not only the world's largest energy consumer but also a leader in the solar PV industry (Zhang et al. 2016). Based on the statistics of China's National Energy Administration, the total installed capacity of solar PV power generation in China reached 174 GW by the end of 2018, of which the large-scale grid-connected solar PV power plants have a total installed capacity of 123 GW and the distributed solar PV power generation systems have a total capacity of 51 GW, generating 177.5 billion kWh electricity per year (Statistics of China’s National Energy Administration, 2018).

Despite the strong growth in recent years, at present, large-scale ground-based solar PV power plants account for 90% of the total solar power generation in China, while small-scale distributed solar power generation units account for only 10%. To promote the development of distributed solar PV power generation, the central and local governments of China have introduced a series of subsidy and supporting policies to reduce the users' investment pressure and investment risks and, thus, stimulate their enthusiasm for solar energy (Shuai et al., 2019). However, up to date, Building-integrated photovoltaics (BIPV) is still not a common practice in construction industry and encounters many barriers for entry into public realm especially in residential buildings, in spite of huge market capacity of BIPV in residential buildings in China. At present, the total building floor area of China is more than 80 billion square meters, among which residential buildings accounts for 2/3, and industry and commercial buildings accounts for 1/3. More than 7 billion square meters of the rooftop and 3 billion square meters of the facade in residential buildings can be installed with BIPV system, which amounts to 10 billion square meters area with an installation capacity of 1500GW. Despite the huge installation capacity BIPV is rarely recognised as an option for energy saving in residential building design in China. There are only a small number of vendors in the market and BIPV solutions are considered only applicable for very high-end developments for commercial and industry buildings. Consumers are skeptical

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about BIPV especially for home buyers and owners who are difficult to be convinced to invest into BIPV. Therefore, it is important to carry out an investigation to understand the public awareness and perception of this emerging renewable technology for residential buildings in China.

From literature review, it can be seen that there are numerous barriers existing in the utilization of BIPV system in China. A major barrier to promote BIPV system application in buildings is lack of consumer confidence in BIPV systems due to the high capital cost of purchase and installation, and later on-going cost in maintenance (Yang and Zou 2015). Zhao et al. (2013) summarized that in China, the main factors that affect the PV power industry are technologies, industry plan, laws, price and incentive polices. Shuai et al. (2019) also found that the major problems restricting the rapid extension of distributed solar PV power generation are high initial investment (costs), difficulty in financing, and long investment payback periods. These problems are particularly prominent for household distributed solar PV installations. However, Zhang et al. (2015) found that cost is not a significant barrier to distributed-generation PV development in China as the soft costs of distributed-generation PV installation in China appear to be very low compared to those in other countries, suggesting that there must be other important market and policy constraints. Therefore, more studies should be carried out to identify the major barriers to adoption of BIPV applications in residential buildings in China. The identification of these barriers through public response is vital to develop strategies for more rapid entry of BIPV into the residential sector in China.

In the study, the barriers to BIPV development in residential buildings are investigated using Trudgill's AKTESP framework (1990), which focuses on agreement, knowledge, technological, economic, social, and political aspects of BIPV development. A case study with a comprehensive survey has been carried out in Wuhan, China to identify the major barriers affecting the installation of BIPV system to residential buildings in Wuhan, China. The results of this study will assist policymakers and other relevant stakeholders in making informed BIPV-related decisions and in targeting future research and development efforts.

2. Research Methodology

2.1 Survey Design and Data Collection Procedure

The survey region, Wuhan, is one of the major economic centres of China and the most populous city in Central China, with a population of over 10 million (National Bureau of Statistics of China, 2014).

The survey was conducted in June 2019 and a total of 206 valid questionnaires were collected from different residential buildings in Wuhan. The city of Wuhan is divided into 3 districts, which are Wuchang, Hankou, and Hanyang. The data collection ensured an equal number of samples from these 3 districts. In addition, it is important to note that all the respondents surveyed should be the residents who have not installed any solar PV generation equipment. A small gift was provided to compensate the participants after the survey.

The questionnaire design was based on Trudgill’s framework which consists of six major groups of barriers: agreement, knowledge, technology, economic, social and political (AKTESP) (as shown in Fig.1). The ‘AKTESP’ Framework has proven its versatility in helping to explain a diverse array of environmental challenges, including Amazonian deforestation (Trudgill, 1990), cumulative effects assessment (Piper, 2001), cultural landscape conservation (Selman, 2004), public resistance to solar energy (Haw et al., 2009), implementing renewable energy policy (Sulaiman et al., 2014) and barriers to wind energy development (Mercer et al., 2017).

2.2 Statistical Analyses

For the purpose of identifying the barriers for the BIPV installation, descriptive analysis and independent Chi-Square test were applied using SPSS 20.0 software to interpret and analyse some of the survey results. The Chi-Square Test is a nonparametric test and determines whether there is an association between categorical variables (i.e., whether the variables are independent or related) (Dowdy et al., 2004). Thus, this test can reveal whether there is a significant relationship between the residents’ responses and the six groups of barriers.

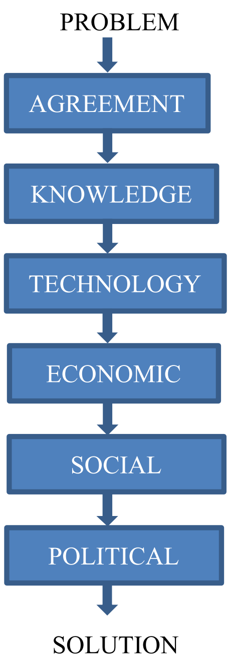

Fig. 1: The AKTESP groups of barriers (Source: Trudgill, S., 1990)

3. Results and Discussion

3.1 Respondents Characteristics

As shown in Table 1, for the demographic factor of gender, approximately 55% of the respondents are male and 45% are female. For the age factor, the majority (73.3%) of the respondents are within the 20 to 40 years old range. For the education factor, more than 70% of the respondents are well educated with at least a bachelor's degree. For the income factor, nearly 70% of the respondents earn more than 5000 RMB per month. This is consistent with the average monthly income (5883 RMB) of Wuhan residents in 2018 according to Wuhan Statistical Bureau (Wuhan Statistical Bureau, 2018).

Tab. 1: The distribution of respondent characteristics

Factors		Frequency	Percentage
Gender	Male	113	54.9%
	Female	93	45.1%
Age	Under 20	17	8.3%
	20-29	67	32.5%
	30-39	84	40.8%
	40-49	29	14.1%
	Above 50	9	4.4%
Education	Secondary school	14	6.8%
	High school	13	6.3%
	Vocational school	22	10.7%
	Bachelor Degree	87	42.2%
	Master Degree	57	27.7%
	PhD	13	6.3%
Monthly income	Below 1500 RMB	4	1.9%
	1500-2999 RMB	23	11.2%
	2999-4999 RMB	37	18.0%
	5000-6999 RMB	37	18.0%
	7000-10000 RMB	38	18.4%
	Above 10000 RMB	67	32.5%

3.2 Agreement barrier

In assessing the agreement barrier from the respondents, the following two questions were asked:

(1) Do you know that using solar energy is helpful for the environmental protection?

(2) Do you think PV power generation have a promising future?

As shown in Figure 2, 96% of the respondents agree that solar energy is helpful for the environmental protection. Most of the respondents (70.9%) vote for “very bright” and “bright”, which suggests that they consider that the solar energy power generation industry has a bright future.

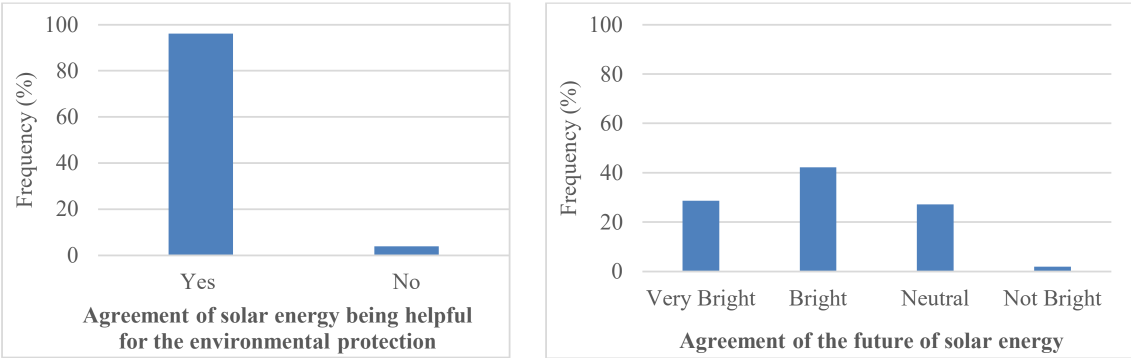

Fig. 2: Agreement barrier

The above results indicate that agreement is not a real barrier for the development of BIPV for residential buildings in Wuhan. Most of the respondents acknowledge the benefits of solar energy for reducing environmental problem and the bright future of solar power generation industry.

3.3 Knowledge Barrier

In assessing the knowledge barrier among the respondents, the following two questions were asked:

(1) Do you know about PV power generation?

(2) Have you seen any type of solar energy system or product? Four options were provided (No, Solar hot water heater, BIPV, Solar lighting product) and respondents can choose more than one answer for this question).

For the first question, 7.8% of the respondents are professionals in this area and they fully understand PV power generation. 55.3% of the respondents understand it to a certain extent from books, TV and other social media. 31.5% the respondents do not understand the PV power generation very well, and 5.3% understand nothing about it (as shown in Figure 3).

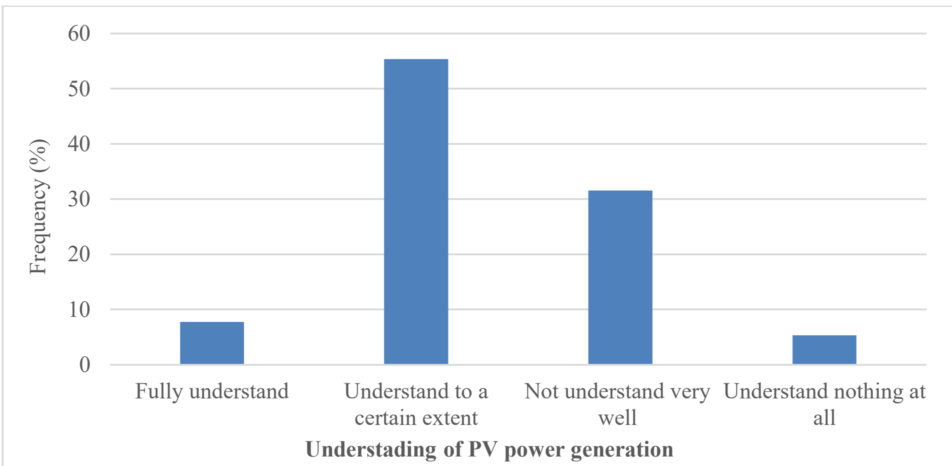

Fig. 3: Knowledge barrier

For the second question, it can be seen from Table 2 that solar water heater has been chosen for 168 times, solar lighting product has been selected for 81 times, but BIPV has been chosen only for 23 times. The exposure of BIPV is much less compared to solar hot water system. Since 2013, it is compulsory for new buildings to install solar hot water system in order to comply with the Design Standard for Residential Buildings of Low Energy Consumption (DB 42/T 559-2013) in Wuhan, which to some extent increases the people's knowledge on solar hot water system. It should be noted here that solar lighting product refers to the solar lights and Building-integrated photovoltaics (BIPV) refers to the photovoltaic materials that are used to replace conventional building materials in parts of the building envelope such as the roof, skylights, or facades.

Tab. 2: Responses on solar energy system or product

Solar Energy Product	Responses		Percent of Cases
	Number	Percent	
No	33	10.8%	16.0%
Solar hot water heater	168	55.1%	81.6%
BIPV	23	7.5%	11.2%
Solar lighting product	81	26.6%	39.3%
Total	306	100.0%	148.1%

a. Dichotomy group tabulated at value 1.

It has been also found that the knowledge of PV power generation has significant relationship with education level as shown in Table 3. People with higher education understand PV power generation better than people with lower education. The Chi-square test shown in Table 4 indicates that this correlation is statistically significant.

Tab. 3: Knowledge and Education Crosstabulation

Understanding of PV power generation		Education						Total
		Secondary school	High school	Vocational school	Bachelor degree	Master degree	PhD	
Fully understand	Count	0	0	0	8	6	2	16
	% within Education	.0%	.0%	.0%	9.2%	10.5%	15.4%	7.8%
Understand to a certain extent	Count	4	8	8	48	36	10	114
	% within Education	28.6%	61.5%	36.4%	55.2%	63.2%	76.9%	55.3%
Understand not very well	Count	8	5	11	26	14	1	65
	% within Education	57.1%	38.5%	50.0%	29.9%	24.6%	7.7%	31.6%
Understand nothing at all	Count	2	0	3	5	1	0	11
	% within Education	14.3%	.0%	13.6%	5.7%	1.8%	.0%	5.3%
Total	Count	14	13	22	87	57	13	206
	% within Education	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Tab. 4: Chi-Square Tests for Knowledge and Education

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	27.125[a]	15	.028
Likelihood Ratio	31.602	15	.007
Linear-by-Linear Association	18.264	1	.000
N of Valid Cases	206		
Pearson Chi-Square	27.125a	15	.028

a. 14 cells (58.3%) have expected count less than 5. The minimum expected count is 0.69.

The above results suggest that BIPV has not yet entered into public realm in the city of Wuhan. There is a lack of promotion of BIPV technology to the public. This can be addressed by introducing more BIPV education programs through more effective communication means or channels like TV and internet. In addition, more educational programs regarding the awareness of renewable energy in particular solar energy and benefits of BIPV system such as make buildings more thermally comfortable and energy efficient (Yang et al. 2014), need to be channelled and introduced into secondary schools, high schools and vocational schools.

3.4 Technology barrier

In assessing the technology barrier from the respondents, the following question was asked:

What do you care most about the installation of BIPV system? Three options were provided (Cost, System Stability, System Maintenance) and respondents can choose more than one answer for this question.

As shown in Table 5, cost has been selected for 110 times, system stability has been selected for 176 times, and maintenance has been selected for 114 times. Among the 206 respondents, 85.4% considered system stability as the most important factor for the installation of BIPV.

It is known that BIPV modules are integrated with the building surface and might not permit airflow between module and supporting structure which may experience higher operating temperatures and cause early failure of the system. Beside this, there are other technical barriers such as fire safety, structural capacity needed to be considered in order to promote the adoption of BIPV system.

Tab. 5: Responses on cost, system stability and system maintenance

	Responses		**Percent of Cases**
	Number	**Percent**	
Cost	110	27.5%	53.4%
System Stability	176	44.0%	85.4%
System Maintenance	114	28.5%	55.3%
Total	400	100.0%	194.2%

a. Dichotomy group tabulated at value 1.

3.5 Economic barrier

The economic barrier in this study is analysed by the expectation of payback period of the BIPV system. As shown in Figure 4, 68.4% of the respondents hope that the payback period is below 5 years and 14.1% of the respondents hope within 6 to 10 years. Only 4.9% of the respondents indicate more than 10 years. In addition, 12.6% of the respondents reveal that they do not care about the payback period because environment protection is of paramount importance.

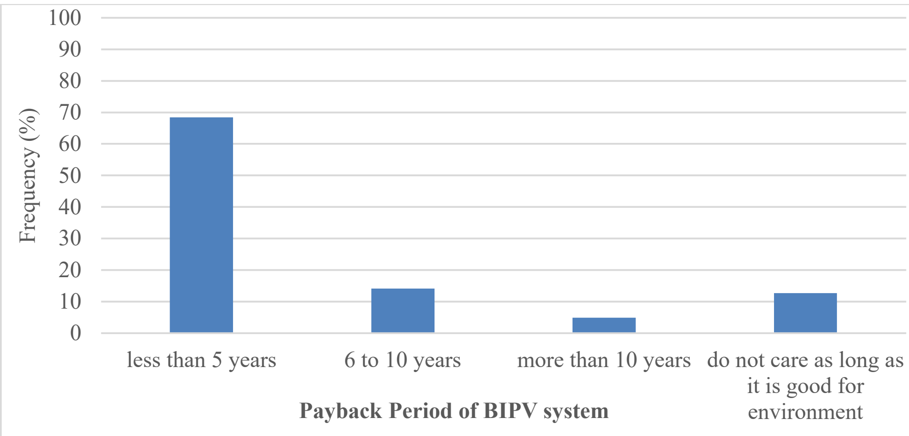

Fig. 4: Expected payback period

A further analysis into the payback period and income level is shown in Table 6 which suggests that there is no significant relationship between the expected payback period and income. Even for people with high monthly income (more RMB 10,000 per family per head, which can be characterized as high income in China), 74.6% of those respondents still hope that the payback period is less than 5 years.

The above result indicates that payback period could be a barrier for the development BIPV system in Wuhan. Therefore, reducing BIPV cost in short term is still the major challenge for its development in residential sectors.

Tab. 6: Monthly income and payback period Crosstabulation

Monthly income		**Payback period**				**Total**
		Less than 5 years	6 to 10 years	More than 10 years	Do not care	
Below 1500 RMB	Count	2	0	1	1	4
	% within income	50.0%	.0%	25.0%	25.0%	100.0%
1500-2999 RMB	Count	17	2	0	4	23
	% within income	73.9%	8.7%	.0%	17.4%	100.0%
2999-4999 RMB	Count	20	8	3	6	37
	% within income	54.1%	21.6%	8.1%	16.2%	100.0%
5000-6999 RMB	Count	25	8	1	3	37
	% within income	67.6%	21.6%	2.7%	8.1%	100.0%
7000-10000 RMB	Count	27	3	3	5	38
	% within income	71.1%	7.9%	7.9%	13.2%	100.0%
Above 10000 RMB	Count	50	8	2	7	67
	% within income	74.6%	11.9%	3.0%	10.4%	100.0%
Total	Count	141	29	10	26	206
	% within income	68.4%	14.1%	4.9%	12.6%	100.0%

3.6 Social Barrier

In assessing the social barrier from the respondents, the following question was asked:

Will you support the installation of BIPV system for your building?

As shown in Figure 5, only 48% of the respondents choose “yes”, 35% are “not sure”, 5.4% choose “No” and 11.6% indicate that they do not care about it. One reason for the low social acceptance of BIPV may be due to the fact that only 11.2% of the respondents have seen BIPV or photovoltaic system in their life as discussed in Section 3.4 knowledge barrier. BIPV is still a relatively new concept for residents in Wuhan, which impedes a broader penetration of BIPV into residential buildings in Wuhan. Therefore, more demonstration residential buildings with BIPV system should be built and residents should be invited to visit these demonstration buildings more frequently so that residents can appreciate more benefits of BIPV system and then perhaps change their view on the installation of BIPV system.

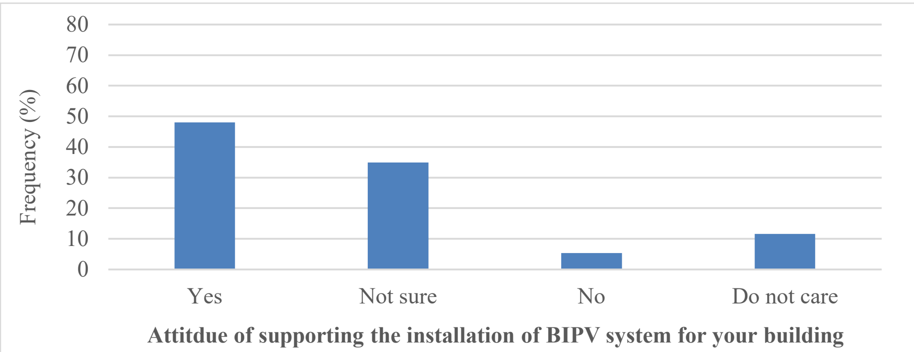

Fig. 5: Social barrier

3.7 Political Barrier

The Chinese government subsidies for the PV industry have brought a booming time for the substantial development of solar PV companies in China. In the long-term, nevertheless, governmental subsidies for solar PV companies should be maintained and strengthened (Xiong and Yang 2016). Apart from the government subsidies, there are some other political barriers.

This survey asked whether the respondent has ownership of the roof top. Only 41.3% of the respondents have ownership of rooftop. Most of the respondents (58.7%) live in high-rise apartment buildings for which the rooftop is shared by all the residents in the building. For existing buildings, the installation of BIPV system requires all the residents to sign on, which needs effective communication and coordination. There is an apparent lack of policy or regulations to govern the installation of BIPV system for existing buildings and to resolve the disputes among residents regarding the different opinions on the installation of BIPV system. Therefore, it is necessary to have some polices in place for the property management company to install BIPV for existing buildings. Regulations to resolve the disputes among the residents for the installation of BIPV are also needed.

4. Conclusions

Results of a comprehensive survey on public responses to and expectations for installing building integrated photovoltaic (BIPV) to residential buildings in a Chinese city Wuhan has been presented in this paper. Based on 'AKTESP' Framework, six barriers in terms of agreement, knowledge, technology, economic, social and political in installing BIPV to residential have been discussed. SPSS 20.0 software has been employed to interpret and analyse the survey results from which some recommendations have been proposed to address these barriers.

From the analysis of the survey results, it has been found that agreement is not a real barrier for the installation of BIPV to residential buildings; instead, knowledge, technology, economic, social and political barriers are the hurdles for BIPV adoption. It has also been found that knowledge barrier in terms of understanding of BIPV system and technology barrier in terms of BIPV system stability are of most concerns to residents. There is an apparent lack of policy or regulations to govern the installation of BIPV system for existing buildings and to resolve the disputes among residents regarding the different opinions on the installation of BIPV system. It is recommended that more demonstration residential buildings with BIPV system should be built and residents should be invited to visit these demonstration buildings more frequently so that residents can appreciate more benefits of BIPV system. It is also necessary to have some polices in place for the property management company to install BIPV for existing buildings. Regulations to resolve the disputes among the residents for the installation of BIPV are also needed.

It can be concluded that the results of this study can assist policymakers and relevant stakeholders in making informed decisions relating to installation of BIPV to residential buildings and in setting future research and development directions in this area.

5. Acknowledgments

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