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Exploring Residents' Attitudes Toward Solar Photovoltaic System Adoption in China

YAQUIN SUN AND STEVEN SPICER

Abstract

As the world's largest energy consuming country, China is facing environmental deterioration, which results from the overuse of non-renewable conventional energy such as coal. Solar photovoltaic (PV) energy, an unlimited and clean energy with minimal impacts on the environment, is considered a good alternative to alleviate this severe issue. A survey was designed and conducted among residents in some major cities in China: Beijing, Shanghai, Nanchang, and Guangdong. Based on the first-hand data, basic statistical methods were utilized to examine Chinese urban residents' knowledge, concerns, and attitudes about solar PV adoption. The research aimed to identify the drivers and dynamics that most encourage customers to install solar PV systems in their residential buildings. The data suggest that the factors that could increase solar PV adoption are (a) reduced costs, (b) practical government incentives, (c) desire to reduce fossil fuel usage, and (d) education to increase awareness of solar PV systems. This research empirically assesses the impacts of the adoption of solar PV systems on various socio-economic groups.

Introduction

China not only has the world's largest population of 1.3 billion people, but is also the fastest growing country. The immense population and economic growth in China has led to an increasing demand for energy. According to Sunpower Corporate Papers (2011), demand is expected to increase by 75 percent by 2035. The conventional energy sources of coal, natural gas, and crude oil generate 69%, 5%, and 18%, respectively, of total energy consumption (Stang, 2014). The overuse of these conventional energies have brought China some adverse environmental impacts such as air and soil pollution, which are hurting public health. According to data released by the Ministry of Environmental Protection, only 9 of 161 Chinese cities (5%) reached the new air quality standards in the first half of 2014 (Xinhua, 2014). The quality of human life in China is threatened without the development of renewable energy sources (Gratzel, 2005). Solar power—sunlight converted directly into energy—is a clean and safe energy source and is regarded as a good alternative to alleviate this serious environmental problem.

In this research study, surveys were randomly distributed among Chinese citizens in June, 2014 in order to learn about public opinion on the value of Solar PV Systems (SPS). The main goal of this research was to analyze the primary data from the survey and to assess which factors are shaping the Chinese solar PV market, especially in terms of Chinese economic, political, and technical development. The survey aimed to understand Chinese citizens' attitudes about installation of solar PV systems (SPS), and when and under what circumstances citizens would consider installing SPS.

Photovoltaic Effect and Solar Photovoltaic Systems

Photovoltaic energy converts sunlight into electricity through solar photovoltaic (PV) cells. Sunlight consists of photons, or particles of solar energy. These photons contain various amounts of energy with different wavelengths in the solar spectrum. When photons hit a PV cell, they may be reflected, pass through, or be absorbed by the cell. Only the absorbed photons provide energy to generate electricity (Bharat Sanchar Nigam Limited, 2011). Today's most common PV device uses a single-junction type of cell to generate electricity (Knier, 2002). This type of PV cell limits the photovoltaic response to the wavelengths of the solar spectrum. PV cells can only absorb the high-energy photons. The current efficiency of this type of PV system (multicrystalline-Si and CIGS modules) is around 15%. By using two or more different cells (monocrystalline-Si modules) with more than one junction, the cells can reach over 20% efficiency (Tao, 2014). The cells in research laboratories have recorded efficiency in excess of 40% (Cotal, et al., 2009). Research indicates that the efficiency of solar PV cells will increase greatly in the future.

A solar PV system (SPS) contains multiple photovoltaic modules, referred to as "solar panels" (Muttaqin, 2013). A module consists of small solar cells. A typical single silicon cell produces 1 or 2 watts of power. Generally, one square meter PV module can generate 150 watts of power (Murmson, 2013). The number of solar modules a household needs depends on the region in which they live. According to Mead (2013), people who live in places such as Arizona, where average solar insolation per year is around 6 kWh/meters squared/day, will need 53 square meters (574 sq ft) of 15% efficient solar panels.

One unit of a solar module made in China costs $800-$900, making the cost of the whole solar PV module (12 units for a typical single-family home) anywhere from $4,500 to $12,000. The power inverter, which converts direct current to alternative current in order to connect to the grid, costs $1,000-$3,000 (Rudge, 2010). There are other factors that determine the final cost for a solar PV system, such as the size of the system, the material of the rooftop, and wiring. The total cost of installing a solar PV system can vary widely within different regions due to different domestic markets, local labor and manufacturing costs, and incentive levels.

Solar Market

China is the largest solar panel manufacturer, and it soon will be the largest consumer as well (International Trade Adminstration, 2014). The solar PV panel market in China has dramatically changed since 2010 (Kaften, 2012). Before 2010, the Chinese government employed massive subsidy programs meant to boost manufacturing and exporting of solar panels (Puttaswamy & Ali, 2013). Furthermore, Chinese production capacity was much larger than its domestic demand for solar panels. Therefore, China has long been a leader in making and exporting solar panels, with 98% of its product was exported (Puttaswamy & Ali, 2013). However, over-exported solar panels significantly hurt the domestic markets of other countries because the Chinese solar PV panel manufacturers sold their products well below the cost of production. This is the practice known as dumping, which makes the international solar panel market competition unfair. America passed anti-dumping legislation against Chinese solar PV panel manufacturing industries and increased the import duties from 24% to nearly 36% on most solar panels imported from China (Cardwell & Bradsher, 2012). After paying the heavy tariff fee, Chinese solar panel suppliers in the markets of some E.U. countries and the U.S. could barely make a profit (EurActiv, 2013). This trade war caused many of the Chinese solar panel companies to go bankrupt, with large amounts of unsold remnants stuck in warehouses, leading to falling revenues and multibillion-dollar deficits. According to the China PV Industry Alliance, orders of Chinese solar panel equipment decreased by 80 percent in just one year in 2012 (Zeng, 2014).

Chinese Policy

With the pressures of economic growth and environmental deterioration, China is now paying much more attention to its own solar power development. The Chinese government has adopted policies to encourage Chinese citizens to buy solar panels. China's energy agency has set a goal of supplying 15% of the country's energy demand with solar power by 2020 and 27.5% by 2050 (Solangi, Aman, Rahim, Fayaz, & Islam, 2012). In order to meet those targets, the Chinese government promulgated a series of laws, policies, and incentives in the last few years (Campbell, 2014). The most significant policies are the following:

a. The National Development and Reform Commission (Zheng, 2013) stipulates a 20-year subsidy standard for distributed generated PV electricity. Self-generated electricity can receive a subsidy of 0.42 yuan ($0.07) per kilowatt-hour. Excess electricity will be purchased by local utility companies at a price between 0.35 and 0.45 yuan/kWh.

b. In some regions with rich solar resources, the price of power generated by PV stations will be lowered to 0.9 yuan or 0.95 yuan/kWh ($0.15) from the previous national standard of 1 yuan/kWh ($0.16) (Zheng, 2013).

c. The National Energy Agency allowed energy generated and distributed by a PV project to receive a 0.9-1.0 yuan/kWh subsidy by selling all power to local grids (McCrone, Usher, Sonntag-O'Brien, Moslener, & Gruning, 2013).

These policies provide significant motivation for the development and use of SPS. The policies of the Chinese government can explain the boost in solar power capacity and increased efficiency. According to the Global Status Report, the capacity of solar PV generation increased rapidly from 0.5 Gigawatts (GW) in 2010 to 2.5 GW in 2011, to 7 GW in 2012, and 16.5 GW in 2013 (Sawin, 2013).

Barriers

Even with significant government support, the adoption of solar PV systems in urban areas in China is limited. One of the possible reasons for the slow adoption could be that policy decisions made by the government vary from the adoption decisions made by householders, who have different concerns, knowledge, and attitudes about this new technology (Islam & Meade, 2013). As the largest population of energy consumers, householders' opinions and attitudes toward SPS adoption could drive the demand and the trend of the market.

Literature Review

Recent studies have indicated two major factors that tend to determine a customer's adoption of solar panel systems: financial incentives and non-financial reasons. Financial incentives include financial supports provided by central and regional governments. Naveen, Prashant, and Yog (2012) provided empirical evidence to show that government initiatives and institutional finance can strongly affect the adoption of solar PV power supply systems in developing countries such as India. Richter (2014) concluded that micro-generation technologies are diffused mainly in countries that provide incentives to support installation. Research shows that government policies' design and implementation influence customers' decisions about the adoption of SPS as well as the SPS market's outlook. Jing et al. (2005) found that the incentive policy played an important role in attracting more social media and enhanced the market competitiveness of grid-connected solar PV systems in China. Chemi et al. (2007) examined the potential effectiveness of the renewable energy policy in China and its regulatory law framework, and identified the types of shortcomings that have interfered with more successful expansions of renewable energy in China, based on primary data collected from interviews with stakeholders. Rogol (2007) reported that the rapid growth of Japan's solar power sector was enabled by the interplay of several factors: (a) the extrinsic setting (including the solar resource, interest rate, and grid price), (b) industrial organization (including the structure of the electric power sector and the structure within the solar power sector), (c) demand-side incentives that drove down the "gap" and provided a "trigger" for supply-side growth, and (d) supply-side expansion that enabled significant reductions in costs, which more than offset the decline in demand-side incentives. REN21 (2010) concluded that the PV manufacturing sector of China flourished due to the availability of low-cost loans. Gallagher (2014) showed how government, through market-formation policy, can unleash global market forces. She pointed out that finances presented an obstacle to the development and deployment of cleaner energy technologies, such as SPS, and argued that the biggest barrier is the failure of government-subsidized traditional technology.

Non-financial reasons affecting adoption of PV include social or peer influences (Beiley, et al., 2011), attitudes about innovation (Chen, 2013), and environmental preferences (Bollinger & Gillingham, 2014). Kaplan (1999) first identified the importance of customers' technical knowledge, motivation, experiences, and familiarity influencing their interest in PV. Faiers and Neame (2006) explained that environmental concerns affect household PV system installation, along with other adoption factors such as financial status, economic concerns, and aesthetic characteristics. Islam and Meade (2013) discussed how the lack of information about the new technology slows the adoption of micro-generation technology using renewable energy. Solangi, Aman and Rahim (2012) suggested that the government should increase use of solar energy, while colleges and graduate schools should promote research in solar energy. Li, Li, and Wang (2013) used surveys to test farmers' purchasing desire as related to certain factors. They showed that concerns about quality of life, government incentives, and word of mouth (favorable comments from friends and neighbors) have significant positive impacts on farmers' willingness to convert traditional houses to solar houses in rural areas. Additional monthly out-of-pocket expenses and switching costs have significant negative impacts. Durability of the system, popularity of PV, timing, and the local solar market's maturity had no significant impacts. Richter (2014) explained that the local environment could influence the social effects on the household PV installation.

There are few papers discussing the adoption of solar energy in urban areas in China by examining primary data. This paper reports on surveys and analysis of the attitudes of Chinese citizens toward purchasing decisions regarding residential solar PV systems.

Method

A total of 222 Chinese citizens took the survey. They were chosen randomly in the major cities of Shenzhen, Shanghai, Nanchang, Fuzhou, and Beijing. Participants anonymously completed a 12-item questionnaire aimed at understanding the most crucial drivers for customers to consider installing solar panels. The participant group consisted of 50.4% males and 48.1% females. The largest age group was 18-26 years old (64%); 25% were 27-40 years old. There were 43.3% of the respondents who had a monthly income between \$351 and \$850, which would be considered middle class. About 15% of the respondents reported monthly incomes below \$350. A large percentage of the participants, 47.6%, held a bachelor's degree, and 40.6% had graduate degrees. (Please see Table 1 for details of the demographic information)

In this research we used a one-way ANOVA test to compare the means between the different salary groups to determine whether any of those means are statistically significantly different from each other. Specifically, the ANOVA tests the null hypothesis:

where μ = group mean and k = number of groups. If the one-way ANOVA shows a significant result, we accept the alternative hypothesis (HA), which is that there are at least two group means that are significantly different from each other. In this research, we wanted to know whether different salaries would correlate with participants' social concerns, their knowledge about solar panels, and their willingness to adopt solar PV systems. P value determines whether there is a statistically significant difference between different income groups. We assumed that the results would show significantly different results among different income groups, where the p value is less than 0.05.

$$H_O: \mu_1 = \mu_2 = \mu_3 = \cdots = \mu_k$$

Some limitations in the population sample may have affected results. Our population sample included mostly residents from the eastern and southern parts of China; a larger sample, taken across the whole country, would be more representative of overall public opinion. In addition, the age of most of our participants was between 18 and 40 years. Sampling from a wider range of age groups might provide different results.

Results and Discussion

The purpose of this paper is to identify Chinese citizens' concerns and attitudes about purchasing a solar PV system (SPS) and under what circumstances households would adopt SPS. We sampled participants' opinions about SPS in three major areas: (a) knowledge and awareness of SPS, (b) factors driving further development of the SPS market, and (c) barriers preventing the growth of the SPS market.

In the survey, we first asked participants to rank the importance of five social issues in China (Employment, Energy, Safety, Quality of Life, and Education) on a scale of 1-5, where 1 is least important and 5 is most important. Participants ranked Quality of Life and Safety as the top two social issues in China with scores of 3.61 and 3.37, respectively. Energy was considered the least important social issue, with a score of 2.44. These results imply that participants do not consider energy, which could bring pollution, shortages, and climate change, one of the most important social issues in China.

Table 1

Demographic Characteristics

Gender	
Male	50.4%
Female	48.1%
Prefer not to answer	1.5%
Education Level Completed	
Below undergraduate	6.5%
Undergraduate	47.6%
Above undergraduate	40.6%
Age	
18-26	64%
27-40	25%
41-60	7%
Over 60	0.9%
Monthly Salary	
Below $350	14.9%
$351-$550	21.4%
$551-$850	21.9%
$851-$1150	10.2%
$1151 or more	4.2%
Prefer not to answer	23.3%

However, participants identified Pollution as the most important subcategory under the issue of Energy, indicating they might not be aware of the strong relationships among energy, pollution, safety, and quality of life. Clean air is crucial to quality of life and good health (Pope, Majid, & Dockery, 2009). Once people realize the links among energy, safety, and quality of life, the solar panel market could be much more promising. According to Roberts (1996), customers want to adopt a "green" product if they have knowledge of the product's positive contribution to the health of the environment or individuals.

The Cost of Conventional Energy was listed as the least important subcategory under the issue of Energy, as compared with Pollution, Energy Shortages, and Waste of Energy (see Table 3). This suggests that the potential for switching from inexpensive conventional energy to comparatively expensive renewable energy is low; most participants appreciate inexpensive conventional energy. This result is different from the conclusion that one research study, by Somasundaram, Souhib, and Armando (2010) suggested. They explained that competition with the strong conventional energy industry would not be a major concern for participants to adopt SPS. However, the means from Table 3 are not that different from one another, so the interpretation based on the rank ordering is not incredibly meaningful.

The null hypothesis in Table 2 shows that social concerns are independent of the salary groups of the participants. The p values in Table 2 and Table 3 indicate that concerns about Employment, Energy, and Education and the subcategory Waste of Energy are different for participants in different salary groups. The survey suggested that wealthier people are more concerned about Education and Employment and have less awareness of the subcategories Sustainability and Waste of Energy.

In the second part of the survey, we tested participants' awareness of solar power products, their knowledge of government incentives, and their attitudes toward SPS markets. As indicated in Table 4, most participants were familiar with solar water heaters and solar batteries since they have used these technologies for a long time, but few had used or researched SPS. As Table 5 shows, most participants said they intended to buy solar water heaters and solar batteries in the next five years. Meanwhile, fewer participants showed interest in purchasing SPS within 5 years. This result suggests that awareness of solar products contributes to the solar product market, as participants' knowledge of solar products was correlated with their intention to buy the products. Foxall and Neame (2006) explained that lack of knowledge brought uncertainty and confusion to consumers and therefore decreased consumer interest in purchasing, thereby limiting future market growth. Table 5, with P value as 0.02, indicates that people with different income levels have different histories with and purchasing intentions toward solar PV system.

Participants were asked to note the locations where they had observed solar energy products. They chose the rooftops of residential buildings (83%), commercial buildings (36%), and government buildings (36%) as the most common places they had seen the solar power products. The results reported in Tables 4 and 5 suggest that participants may have observed solar water heaters on the roofs of buildings.

According to Ansar (2013), consumers have been learning about climatic change and environmental issues through the mass media and advertisements. The most common media through which this study's participants have heard or seen news or advertisements about solar PV systems are television (70%) and the internet (49%). Participants believed that advertisements on television (60%) or advertisements from utility companies (50.7%) are the most reliable. Most participants knew that the government has provided incentives to improve the market for solar PV systems (77.1%) and held a positive attitude toward Chinese solar panel market trends (66.8%). However, 16.8% of participants were not certain about the outlook for the future SPS market.

In the third part of the survey, participants were asked to identify (a) factors that would positively influence their purchasing decisions, (b) barriers affecting the development of SPS markets, and (c) government incentives or policies they would prefer. In

Table 2

Means of Public Opinion on Importance of Five Social Issues

	Employment	Energy	Safety	Quality of Life	Education
Mean	3.01	2.44	3.37	3.61	3.08
P value	0.01*	0.02*	0.06	0.07	0.03*

Table 3

Means of Public Opinion on Importance of Energy Subcategories

	Pollution from Conventional Energy	Energy Shortages	Cost of Energy	Waste of Energy
Mean	2.80	2.50	2.39	2.40
P value	0.07	0.58	0.41	0.02*

order of importance, the participants listed the following reasons for them to adopt SPS: environmental protection, energy savings, government incentives, generating electricity and reducing electricity bills, public opinion, and recommendations from close friends or relatives (see Table 6). Participants considered the lack of suitable government support and high initial investment cost as two main barriers preventing the growth of the SPS market (see Table 7). Most of those choices appeared to be influenced by the varying needs of people from different income levels. In terms of government incentives, participants most preferred that the central government would provide discounts on the purchase of Solar PV Systems (see Table 8). The results from this section indicated that cost saving is the major motivation for participants to consider the installation of SPS.

Table 6 shows significantly different levels of influence of family and friends' recommendations on the adoption of SPS in different income groups (p value of 0.036). Table 7 shows that participants from different income groups had significantly different

Table 4

Knowledge of Solar Products (%)

Product Name	I have used this	I have researched but not used this	I do not know what this is	P value
Solar water heater	75.70	19.15	3.27	0.69
Solar PV system	4.43	35.04	54.67	0.35
Solar power Battery	46.72	36.91	14.48	0.47

Table 5

Purchasing History and Intentions (%)

Product Name	I have purchased this	I plan to purchase this within 5 years	I do not plan to purchase this within 5 years	I do not know this product	P value
Solar water heater	48.59	25.23	21.02	2.3	0.47
Solar power battery	32.71	22.64	34.11	8.87	0.61
Solar PV system	5.60	17.28	39.71	34.11	0.02*

ideas about whether the size of their building structure would limit the required space for SPS (p value of 0.02).

Implications and Conclusion

This research study indicates that solar PV systems have a bright future in the domestic market in China. Chinese citizens are

Table 6

Reasons to Adopt SPS

Reasons	Average score	P value
Environmental protection	4.58	0.27
Self-generated electricity to reduce expenses	3.97	0.08
Public opinion	3.69	0.23
Incentives and programs sponsored by government	4.19	0.055
An increased effort for sustainable energy production	4.26	0.64
Recommendations from family and friends	3.25	0.036*

Table 7

Barriers Preventing the Growth of SPS

Barriers	Yes (%)	No (%)	P value
Some people's attitude that clean and renewable energy is not needed and conventional energy is cheaper	16.8	83.1	0.30
The technology for solar power production is behind the technology possessed by other global markets	38.3	61.6	0.35
The building structure limits the required space for PV panels and solar power production	29.0	71.0	0.02*
There is not enough sunshine for solar power production due to weather and pollution	25.7	74.2	0.07
Local governmental policies do not support PV or solar power energy production	46.2	53.7	0.66
Initial investment costs are too high and the return on investment takes too long	40.6	59.3	0.06

Table 8

Preferred Government Incentives

Type of Government Incentives	Average score (scale of 1-5)	P value
Government offers cash discount on original investment (on purchase of PV panel by consumers)	1.93	0.63
Government offers discounted electricity rates for system owners with connectivity to the grid	2.44	0.38
Government provides low-interest loan to assist in initial investment costs	2.56	0.07
Restriction on companies' use of conventional fuel sources (e.g. 20% of electricity consumed must be from green sources)	2.96	0.47

the direct consumer group for SPS; understanding their concerns and preferences could largely improve the market and increase profits. This research focused on collecting and analyzing Chinese citizens' opinions, concerns, and attitudes about the adoption of SPS. The survey results indicated two major barriers to the adoption of SPS: high initial cost and lack of knowledge of SPS.

To address cost concerns,

- Low-interest loans could improve the adoption of SPS. Even with preferable loan policies, solar energy may not be cost competitive with conventional electricity, but loans could reduce the pressure of the initial investment. If there is not sufficient financial support for the adoption of SPS, it will not be a high priority, since most customers care most about their electricity bill (Rundle, Paladino, & Apostoal, 2008).
- Limiting the electrical output of fossil fuel and increasing the cost of conventional energy could make SPS more competitive with the current strong conventional energy industries.

To promote consumer education:

- Increase public awareness of environmental values and ecological lifestyles in order to motivate the public to seek and try green products such as SPS.
- Augment consumer knowledge of solar PV systems. Rowlands and Parker (2002) found that perception of a renewable electricity source determined the premium that a green consumer was willing to pay.
- Place trustworthy environmental advertisements on television and the internet. Akehurst, Afonso, and Goncalves (2012) explained that environmental advertisements are an effective way to educate consumers about green products and to help them make informed decisions. According to Chen & Chang (2012), building trust with customers enhanced their intentions to buy green products.

The results of this study could help government policymakers and industry leaders plan and implement strategies to encourage more customers to participate in SPS installation. However, as a pilot study in this field, our findings can be potentially extended to research on the adoption of other new technologies.

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