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Attitude of Chinese Students towards Solar PV Rooftop System Adoption

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Examining College Students' Knowledge of and Attitudes Toward PV Power Systems in Major Cities in China

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Introduction

Photovoltaic (PV) power generation is a rapidly expanding source of electricity. PV generation, originally invented to fuel space-bound aircrafts (Knier, 2002), is now a viable alternative to traditional fossil fuels. With rising environmental concerns and the increasing cost of conventional fuel sources, countries are more invested than ever in PV generation (Renewable Energy Policy Network for the 21st Century, 2014).

Background of Photovoltaics

In 1922 Albert Einstein was awarded the Nobel Prize for his work and papers exploring the photoelectric effect. The photoelectric effect refers to the electric current produced when certain materials, called photons, are exposed to light (Knier, 2002). Solar PV panels use the photoelectric effect to directly convert the sun's light energy into usable electricity. Panels or modules consist of an array of cells, each of which generates an electric current when exposed to light. Panels are rated by output stated in watts. In cell manufacturing, the wattage of a system is dependent on the number of solar cells present (size of panel), the semiconductor material used (primarily silicone) and the quality of said material. The geographic location of installation, weather, as well as installation parameters also affect the output of the solar module.

Global Photovoltaic Market

In 2013, following a record addition of 36.9GW, the installed capacity for PV power generation was 136GW globally. Germany, the world's largest producer with 35.5GW installed PV capacity, nearly doubled China's 18.3GW, which represented the second largest contribution. Italy, Japan and the United States rounded out the top five with 17.6GW, 13.6GW, and 12.0GW respectively (International Energy Agency, 2014).

The Trade War

In 2012, Chinese firms manufactured roughly 2/3rds of the global PV modules that reached market (Renewable Energy Policy Network for the 21st Century, 2014). After struggling to compete with low Chinese prices, PV panel manufacturers in the US and Europe claimed foul play, stating Chinese firms were unfairly selling panels below costs, or dumping products internationally. EU Prosun, an industry association for European solar PV manufacturers, filed a suit with the World Trade Organization in July of 2012 (Clean Technica, 2012). Dumping allegations are explained below.

The European Commission, on behalf of the European Union and the World Trade Organization, conducted an anti-dumping investigation of Chinese manufactured panels exported to the European Union from 2011-2012. Case AD590 concluded with the EC imposing anti-dumping taxes on Chinese imports to Europe (European Commission, 2013). The US International Trade Commission published similar findings in 2011, stating that Chinese module manufacturers were exporting panels at less than fair value (LTFV). The US ITC penalized the Chinese manufacturers and imposed increased tariffs on Chinese imported panels (U.S. International Trade Commission, 2011). Australia also launched an investigation into the 'dumping' of Chinese panels in 2013 (Hannam, 2014). As a result, all Chinese made PV modules and components imported into the European Union are subject to an average anti-dumping duty of 47.6%. The tariff is in effect until at least 2018 (European Commission, 2013). Chinese and Taiwanese solar modules and components exported to the US are also subject to sanctioned duties, ranging from 26% to 165% (Roselund, 2014)

Following dumping investigations and repercussions, China observed an 18% decrease in PV panel exports, including a 62% decrease to European markets (Clover, 2014). Additional sanctions from trade organizations limit exporting potential for Chinese PV panel manufacturers. China's manufacturing levels, dependent on foreign markets, were far greater than the domestic need. In 2013 China observed a 20% decline in the export value of PV modules and components (Fang, Honghua, & Sicheng, National Survey Report of PV Power Applications in China, 2013). China will need to develop its domestic PV market in order to reduce the excess inventory.

The Development of Chinese Domestic PV Market

China ranked first amongst all nations in total carbon dioxide emissions in 2013, emitting 29% of the global total. Furthermore, studies suggest China's coal-fired power plants account for 75% of the emissions (Oliver, Janssens-Maenhout, Muntean, & Peters, 2014). The pollutants and soot in China's atmosphere have been linked to 1.2 million deaths a year (Nijhuis, 2014). Serious pollution is a strong reason in support of China's goal to increase PV generation domestically.

Reflecting the growth of recent years, China is now the world's second largest producer of PV power with 18.3GW, a number that reflects less than 1% of China's total electricity demand (Renewable Energy Policy Network for the 21st Century, 2014).

China's 12th 5-year plan, released in 2011, stated goals for installed PV capacity of 21 GW by 2015 and 50 GW by 2020 (Qiang, Honghang, Yanxi, Yurui, & Jun, 2014). To achieve this goal, China must gain the support of private investors to purchase, own and operate grid connected PV power systems. Prior to the most recent 5-year plan, China began incentivizing PV adoption as early as 1999 during the 10th 5-year plan. The Brightness Rural Electrification Program, using PV and wind technology (National Renewable Energy Laboratory, 2004), sought to provide power to nearly 23 million people living in remote areas in Western China. Due to high solar radiation levels and barren desert landscapes, western China is suitable for solar power development, including the development of large scale utility-sized solar farms (Meisen & Hawkins, 2007). The capacity of the farms far surpasses the local need and could export power to the more populous and industrialized Eastern China. However, transmission is difficult in light of the extended distance; transportation and distribution losses would be prohibitively high. Therefore, current government incentive programs, such as the Golden Sun program, lean toward to the projects that are "self-generation, self-consumption" (Climate Connect, 2010). As a result, government incentive programs that support building integrated PV systems and building-attached PV systems, especially roof-top systems, are attracting increasing investment. After China's National Development and Reform Committee commenced the Feed-in-Tariff (FiT) subsidy policy for PV grid-tied applications in 2011, China observed a 400% increase in PV installations (Fang, Honghua, Sicheng, & Dou, National Survey Report of PV Power Applications in China, 2011). China's installed PV capacity nearly doubled in 2012 from 3.5MW (2011) to 6.7MW. In 2013, following an increased subsidy shifting the FiT from .8/kWh to 1.5/kWh, PV installations rose 306% (Fang, Honghua, & Sicheng, 2013).

To test the future success of incentive programs and the PV industry as whole, college students at two of China's prominent universities were surveyed. According to UNESCO, "education will shape the world of tomorrow [and] is the most effective means that society possesses for confronting the challenges of the future" (UNESCO, 2002). With this ideology in mind, college educated students serve as the most likely adopters of PV technology and represent the force attempting to change the current environmental situation in China. Following years of education in science, and likely an education in sustainability, clean energy and renewable energy are not new concepts to most college students. Therefore, students' attitudes towards the PV power industry shed light on the future of China's domestic PV market. Higher education levels indicate higher receptiveness to PV adoption (Schelly, 2010). Although most college students do not possess property or earn high salaries while in school, according to a 2011 poll Chinese college graduates earn a starting salary of 30,000 yuan a year, making it possible for young graduates to invest in a PV system (People's Daily Online, 2011).

Based on the above introduction of photovoltaics, the global PV market, and China's domestic market, we will explore the potential market of Chinese college students. Section 2 will contain a brief literature review. Section 3 discusses the methodology and is followed by a survey data examination in Section 4. Conclusions drawn from observations and suggestions to increase customer adoption of PVS are found in Section 5. We address any limitations and possible future studies in the Section 6.

Literature Review

For an overview of the history, status quo and projection of PV industry in China, readers may want to refer to Zhao et al. (2011), (Zhao, Shi, Chen, Ren, & Finlow, 2011), Fang et al.(2012) (Fang, Honghua, & Sicheng, National Survey Report of PV Power Applications in China, 2013) and Sun et al. (2014) (Sun, Zhi, Yao, & Su, 2014) for detailed information. Historically, academic papers have focused on the public policy instruments used to increase PVS adoption. The incentives fall into two trains of thought: technology-push methods, where the government subsidizes manufacturing, technology creation and innovation; or demand-push policies issued by government to generate a demand within the market (Qiang, Honghang, Yanxi, Yurui, & Jun, 2014). Feed-in-tarriffs (FiTs) are an example of a widely used demand push-instrument which has been implented in several nations, including China. PVS operators are paided a subsidy for surplus electricity generated exceeding their individual consumption, or electricity that is 'fed-in' to the grid.

Beyond the discussion relevant to policy, there are several papers analyzing the benefits derived from PV generation, both financial, and environmental, and the influence of those benefits on demand. Pillai et al. (2014) (Pillai, Putrus, Georgitsioti, & Pearsall, 2014) created a metric; prosumer (a producer and consumer of PV power), electricity unit cost (PEUC), to examine near term economic benefits generated from solar PV systems. The study concluded that with FIT and low interest loans, PV owners observed a faster ROI.

Li et al. (2007) provided a good summary for building-integrated solar energy adoption. Social interaction and acceptance has been explicitly mentioned as one of the three factors influencing the solar industry's development along with policy-oriented market and subsidies. Our research focuses on studying this social interaction and acceptance.

Labay and Kinnear (1981) classified adopters and non-adopters of solar energy systems based on demographic and attribute perceptions of the PVS. Kaplan's (1999) technical knowledge, motivation, experiences and familiarity are four critical influences on interest in PV. Under the framework of Diffusion of Innovation, Faiers and Neame (2006) compared a group of 'early adopters' and 'early majority' regarding attitudes towards domestic solar power systems. However, they did not specify the type of solar application.

Schedlly's (2010) paper tests the relationship between residential solar thermal adoption at the county level and three indices by using a logistic regression model. The three indices include a socioeconomic index, an environmental concern index and an environmental index using public data. The paper concluded that counties with higher education levels, less unemployment, and higher levels of disposable or investment income, indicated higher interest in adopting solar thermal technology.

Chen's (2014) study investigated a framework between value, life-style, personality, and environmental behavior intention related to solar power systems. Chen used 203 college students and faculty at a university in Taiwan to test against the structural equation modeling. Chen identified college students as "leading crusaders in the modern environmental movement." Chen and Su (2014) define a strategic consumer as a consumer who waits to purchase an item at a discount, typically following the introduction of a newer replacement product. The impact of their decision on the supply chain performance under a revenue sharing coordination mechanism is explained.

Despite the vast collection of academic papers on PVS, there are few papers that explore the knowledge and views of potential PV customers in China. Therefore, in this pilot study, using a collection of college students as the sample population, we will use the survey data to reflect the current problems of adopting PV so that we can offer suggestions to government, industry and higher education systems.

Methodology and Survey Design

For reasons of accessibility, this survey utilized a convenience sampling method rather than a representative sampling method. Primary data collection was conducted during a 21-day field research trip to Beijing Jiaotong University and Shanghai Normal University in China during the summer of 2014. According to the 2012 China University Rankings (Junmian, 2011), both schools are found on the list of the top 100 universities in China. Beijing and Shanghai are the largest cities in China with slightly over 40 million inhabitants combined (UN New York, 2014). Beijing is the capital of China, and Shanghai serves as an important financial center and business hub. The high civilization status and fast economic development generates a high energy demand, which contributes to a larger potential market for PV residential adoption. Shanghai and Beijing are also on the forefront of higher education in China, with more than 100 public or private universities.

Out of 328 issued to students at the two universities, 275 valid surveys were collected. The survey was carried out during the lecture portion of several classes. All of the surveys were completed in English. As some students lacked fluency in English, only 275 questionnaires were valid. The whole study is based on the 275 questionnaires and to some extent, this survey serves to represent the average college students' knowledge of and common attitude towards PV adoption. Students were asked to complete a 4-page survey designed to evaluate their knowledge of, and potential purchasing behavior for, PV technologies.

A brief introduction of solar PV systems was given in order to clarify the definition and domain of the survey questions. Detailed technology principles, measurements and economic benefits were not discussed in order to avoid potential bias given by the survey administer. The survey consisted of 27 questions on 4 pages, and included a wealth of information. The survey can be divided into five sections: major societal concerns, prior experience with PV systems, attitude towards PV adoption, knowledge of PV systems and demographic questions.

Most questions were designed with a five-point Likert scale. In the first section of the survey, students ranked major concern among several possible categories: Employment, Energy, Safety, Quality of Life, and Education, and followed by ranking sub-issues within each category. The second portion of the survey was designed to measure prior experience with solar technology with a focus on the PV system. Questions were geared towards usage, observed locations of PV systems, advertisement methods, etc. In the third section of the survey, four questions were posed to gauge the students' technical knowledge of PV panels. Students were asked to rank government incentives and actions, possible and actual, required to increase private PV investment. The fourth section of the survey focused on students' attitude towards PV system adoption, such as the desire to purchase, potential motivations

Table 1.1 College Students Surveyed by Major

Major	Frequency	Percentage of Sample Group (%)
Economics	84	30.55
Engineering	64	23.27
Traffic and Transportatiom	32	11.64
Statistics	18	6.55
Automation	9	3.27
Finance	9	3.27
Science	9	3.27
Computer Science	8	2.91
Communication	7	2.55
Undecided/Did Not Answer	9	3.27
Tax	5	1.82
English	3	1.09
Other*	18	6.55
Total	**275**	**100.00**

*All majors with less than 1% of the sample population including: Clean Energy, Enterprise Management, International Trade, Logistics, Advertisement, Business, Math, MIS, and Wind Power

and barriers that might deter purchase. The last section of the survey identified students' demographic information. Based on the answers to the demographic questions, 55.6% of students surveyed identified female and 43.6% identified male. 69.3% of the students were undergraduate students and 29.6% were in a graduate-level program. Economics, engineering, and traffic and transportation majors were most prominent with 33.6%, 20.4% and 10.8% respectively. For a complete breakdown of students by majors, refer to Table 1.1, 27 different Chinese provinces and Semi-Autonomous Regions were represented in the sample group. 19.6% of the students surveyed originated in Shanghai, followed by Shandong and Anhui with 10.4% and 8.4% respectively. 7.6% of the sample group was from Beijing. Table 1.2 provides a breakdown by Province/S.A.R.

Data Examination

Major Concerns in General

In order to rank social, political and environment concerns, students were asked to select from a 5-point scale, where 5 represented the most pressing issue/concern while 1 represented the least. Students indicated a higher level of concern for issues of public safety than with issues of employment, energy, quality of life or education. Public safety averaged 3.78 out of 5; quality of life was the second highest rank with a score of 3.58; education scored 2.84; energy and employment are the lowest two with 2.48 and 2.47 respectively.

Table 1.2 College Students Surveyed by Province/SAR

Province/SAR	Frequency	Percentage (%)
Anhui	22	8
Beijing	19	7
Fujian	9	3
Gansu	6	2
Guangdong	4	1
Guangxi	4	1
Guizhou	3	1
Hezbei	25	9
Heilonhjiang	3	1
Henan	12	4
Hinjiang	1	0
Hubei	4	1
Hunan	7	3
Inner Mongolia	3	1
Jiang Su	11	4
Jiangxi	4	1
Jilin	5	2
Korea	2	1
Liaoning	9	3
Ningxia	3	1
Shandong	29	11
Shanghai	49	18
Shanxi	11	4
Sichuan	6	2
Tianjin	1	0
Undeclared	9	3
Xinjiang	3	1
Yunnan	2	1
Zhejiang	9	3
Total	**275**	**100**

Energy issues have not been reported as the greatest concern for college students. The lack of concern may be explained by the low cost of utilities in China, and may also predict the potential difficulty of PV adoption among residents. Meanwhile, public safety and quality of life are of the highest concern for students, which indicates a high potential for adoption of PV system because of the ecological benefits a solar PV system generates.

Within the issues of public safety, students indicated the greatest level of concern for food safety with a threat index of 3.72 out of 5, followed by health issues resulting from pollution with a score of 3.31. According to previous data

(Nijhuis, 2014), roughly 1.2 million deaths a year are attributed to pollutants and soot produced by China's coal-fired power plants. The leading issue in the energy sector was pollution from conventional energy sources, with a threat index of 3.06 out of 4. The cost of living and a lack of personal freedoms were the two most pressing issues in quality of life, with average scores of 2.74 and 2.69 out of 4 respectively.

In the education sector, students indicated their greatest concern was the quality of education, scoring 4.08 out of 5.0 on the previously mentioned 5-point-scale. Fear of education lacking innovation also scored high (3.51). Focusing on renewables and sustainable practices, only 14% of the surveyed students had ever been taught sustainability principles. This score is far too low for a country actively seeking to increase the demand for PV technologies and generation.

Prior Experience with Solar Technology

Before examining the use of and purchasing desire for PV, it is important to have context. For a comparison, students were asked similar questions for both solar PV and solar water heating systems. 50% of students surveyed indicated no knowledge of PV technologies, a number ten times greater than the 4.8% of students who were unaware of solar water heating systems. 77.6% of students had used a solar water heater, while 10% had used solar PV. Less than 20% of students (18.4%) indicated a future desire to purchase a solar PV system. 3.2% indicated a prior purchase of solar PV technologies. This wanes in comparison to the same question posed with solar water heaters; 58.4% reported prior purchase and 26.8% indicated a future desire to purchase.

Students were asked to note which solar PV installations they have observed. 61.2% observed residential applications of PV technologies, 30% observed PV technologies in a solar farm application, 43.3% reported seeing solar PV technologies on commercial buildings and 47.6% noted application of PV technologies on government buildings. Investment in solar water heaters is and will be far more prevalent than PV technology, yet an increase in government participation with PV will increase awareness amongst potential customers, and may possibly increase participation rates.

Students were asked questions to test receptiveness to and awareness of PV technology marketing. Television advertisements for PV panels were most commonly observed, with 78% of students indicating they have observed PV systems advertised in television ads. Other common advertisement medians included the internet and Weibo (a popular social media site), with observation rates of PV advertisement of 69.6% and 38.4% respectively. 67.6% of students surveyed selected television as a reliable source of data, Internet was selected by 42% and recommendations from friends, family, and peers was selected by 38% of students as a reliable source.

Knowledge of PV systems

Narrowing the focus on PV knowledge, students were asked 4 questions on the specifics of PV technologies. Students were asked to choose a realistic time period to recoup investment cost (typical ROI), select an efficiency range for PV panels, and answer two basic dichotomous questions. Answers were either marked reasonable or unreasonable. 19% of students were unaware that solar power is a renewable energy source. Roughly half (56%) gave reasonable answers for average panel efficiency answering either 0-25% efficiency or 26-50% efficiency. 77% of the students gave reasonable answers for average ROI with 43.6% choosing 2-6 years and 34.8% selecting 7-12 years. 80% of students were aware of government-funded financial incentives to purchase PV technologies, which indicates that an increase in education for sustainable practices and green technology would create a more interested and educated target market.

Attitude towards PV System Adoption

A high initial investment cost for PV systems was most frequently selected as a barrier preventing adoption, endorsed by a 64% sample set. Peoples' attitude and lack of concern for the environment, followed by inadequate technology, ranked second and third as barriers preventing growth, with 43.6% and 42.8% of the sample population endorsing the reasons.

Students were asked to rank several strategies to increase customer participation with solar PV, on a scale of 1-5 with 1 being the least effective and 5 being the most effective. Possible answers included: cash discount on the PV system price, a discounted electricity rate for PV producers connected to the grid, low interest loans to assist with project cost, or a restriction on conventional energy sources. A sanctioned restriction of fossil fuel imposed on utility companies was the highest ranked with a 2.71. Low interest loans to help negate the high initial investment cost ranked closely behind with a score of 2.55. Thirty-eight perecent (38%) of students strongly agreed, and 20% agreed, that investing in solar PV technology will have an effect on improving the environmental situation.; and, 69.6% of students were optimistic about the growth of the PV industry and the growth of the adaptation of PVS for residential installations in China.

Conclusions

This study offers the first look at the knowledge of students and their attitude towards PV adoption on the roof top. China's college students serve as a potential market for solar

PV systems in the next five years. The study results indicate that college students currently do not prioritize energy as an issue directly related to safety and quality of life. However, the results also clearly demonstrate that the emphasis on pollution issues will lead this generation to consider renewable and clean energy as an alternatives to conventional energy.

On one hand, the results show that there is a limited percentage of college students who are aware of PV adoption, especially when compared with awareness of other solar energy applications, such as solar water heater. On the other hand, given the evidence presented from these results, students do not possess sufficient knowledge of solar PV technology. The inclusion of topics of sustainability in the public and collegiate education agenda is one possible solution to this shortcoming.

Based on the discussion above, the results suggest the importance of advertisements and effective communication among government, the PV industry and potential customers. Traditional methods of promoting PV systems, such as television, are dominant. However, there are other media avenues more accessible and interactive to the young generation (college students), and exploration and utilization of alternative channels is crucial. Although the government provides support to the industry and the customer, additional demonstration projects could be established to increase visibility.

Overall, the majority of students believed, despite their sensitivity to the initial investment of the products, that the future PV market is promising. With significant advancement of technology and continuous cost reduction, PV rooftop systems will be popular among young families in China in the next few years.

However, limited by the accessibility of the data, this research included some bias. The sampling method implemented was a convenience sampling taken from only two schools. Additional research based on a larger population, using well-designed sampling methodology, could better identify social acceptance among young, future customers. However, this pilot study can provide direction in order to gauge and analyze the attitude

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