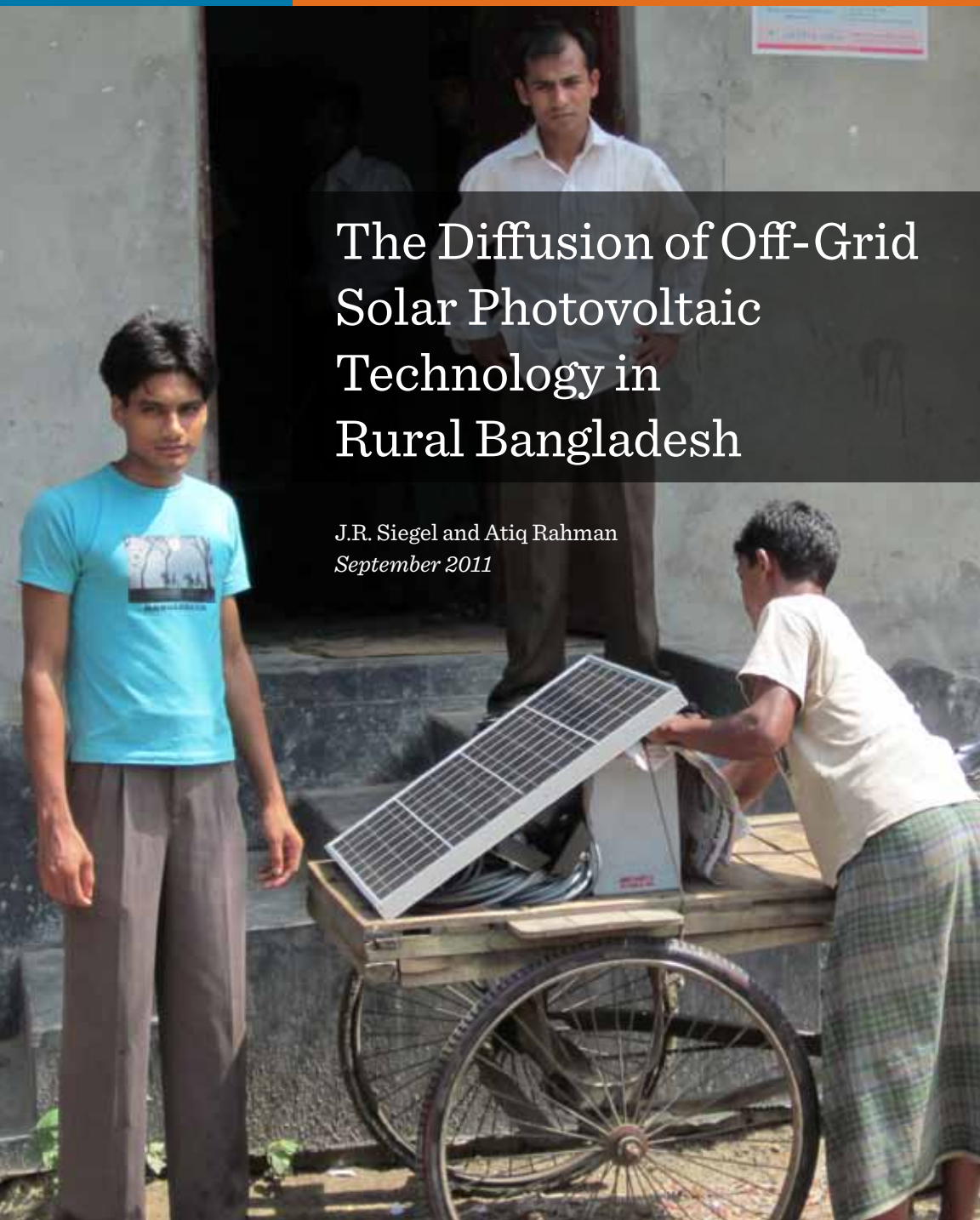


THE CENTER FOR
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THE FLETCHER SCHOOL
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The Diffusion of Off-Grid Solar Photovoltaic Technology in Rural Bangladesh

J.R. Siegel and Atiq Rahman
September 2011



Abstract

This paper analyzes the process through which more than 650,000 off-grid households in rural Bangladesh decided to purchase a solar home system (SHS) from 1996 to 2010. Our hypothesis was that positive word of mouth is the primary driver of these sales. We tested the hypothesized diffusion process through a combination of semi-structured key informant interviews and an examination of 100 households in Panchua Village, including 60 with a SHS and 40 without a system. The data from Panchua Village suggest that the hypothesis was correct, although they do not explain why owner's influenced others to purchase a system. Our analysis of this process adds to the technology diffusion literature by highlighting the role of opinion leaders in SHS diffusion and quantitatively testing the role that word of mouth played in driving SHS sales.

The second contribution of this paper is its analysis of non owner willingness to pay for a SHS. We use the data from Panchua Village to test an alternative hypothesis that the SHS cost reductions provided by the World Bank-financed Rural Electrification and Renewable Energy Development Program were the key driver of sales. Our results build upon the Mondal (2009) and Kamatsu (2010) contention that further subsidies will be needed to encourage the widespread diffusion of SHS by demonstrating that the gap between non owner willingness to pay and overall system costs cannot be bridged by the current level of system subsidies. Limitations of our findings and potential avenues of future research are discussed.

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1. Introduction

1.1 THE ELECTRICITY SECTOR IN BANGLADESH

Despite being one of the poorest and most densely populated countries in the world, Bangladesh is home to a vibrant and rapidly growing off-grid solar energy sector. Located between 20°34'N and 26°38'N latitudes and 88°01'E and 92°41'N longitudes with an area of 143,998 km², the average solar irradiance in Bangladesh varies from 3 to 6.5 kWh/m²/day (Sarkar 2003). In Dhaka, the average yearly solar irradiance available is 1.73MWh/m² (Huq et. al. 2005)—well above the countrywide per capita electricity consumption of 220KWh (Government of Bangladesh 2010). The combination of ample sunshine and high levels of energy poverty make Bangladesh an ideal location for off-grid solar photovoltaic systems (Mondal et. al. 2010).

As of April 2010, only 47 percent of the 160 million Bangladeshis had access to grid-based electricity. Although installed electricity generation capacity is currently 6,033MW, daily production ranges from 3,900 – 4,300MWh. The endemic load shedding is due to the poor maintenance of the power plant fleet (Government of Bangladesh 2010).

Eliminating load shedding and increasing access to energy services are central to Vision 2021, the Government's plan to make Bangladesh a prosperous, middle-income country 50 years after independence (Board of Investment 2011). The June 2010 "Towards Revamping Power and Energy Sector: A Road Map" details how the government will eliminate load shedding and extend electrification to all Bangladeshis by increasing the installed capacity to 20,000 MW by 2021. Achieving 100 percent electrification will be difficult because Bangladesh is a low-lying delta crisscrossed by hundreds of rivers. This topography contributes to the 30,000Tk (\$430)¹ cost of extending an existing grid connection by one kilometer (Barua et. al. 2001). According to Rural Electrification Board (REB) estimates, extending the grid to marginal service areas would "cost approximately US\$400 per connection, not counting the cost of generation investment of US\$500 investment per kW" for a total cost of approximately US\$13 billion (World Bank 2002). Given the high cost of extending the national grid to the entire population by 2021, an analysis of the growth of the off-grid solar electricity can illuminate a less expensive method of extending electricity to marginal off-grid areas in Bangladesh and other developing countries.

Two models have been used to extend off-grid solar to rural Bangladesh: fee-for-service and ownership. The fee-for-service model, which is offered by the Rural Electrification Board (REB), charges households a fixed monthly fee to use the solar home system (SHS) installed on their roofs (World Bank 2009). Off-grid solar is a marginal business for REB, which is tasked with providing "financial support, technical oversight, and long-term direction to the rural electrification program in Bangladesh" (Rural Electrification Board 2010). Since its establishment in 1977, REB has connected over 8 million households to the grid, but its focus on grid-based

¹Throughout this paper, we use a conversion rate of 70Tk to USD 1.

electrification pulled resources away from the fee-for-service SHS project. Indeed, REB was only able to install 12,000 of the targeted 16,000 SHS under World Bank-financed Rural Electrification and Renewable Energy Development (RERED) Program from 2003 – 2009 (World Bank 2009). The same institutional constraints that limited SHS deployment also undermined after sales service, causing many systems to go into disrepair. Conversely, the ownership model, which uses microfinance to sell SHS to rural households, has been highly successful. The RERED Program focused on the ownership model installed 320,000 SHS—far exceeding the target of 50,000 systems (World Bank 2009).

Our analysis of the off-grid sector is focused on the ownership model because of its success and the potential for international replication. The paper begins with a broad history of the genesis and growth of the off-grid SHS sector in Bangladesh from 1996 to 2010. Next, we provide a review of the pertinent scholarly literature on technology diffusion, word of mouth and the renewable energy sector in Bangladesh. Third, it details the SHS diffusion process drawing on the 70 interviews J.R. Siegel conducted in rural Bangladesh. The fourth section tests the hypothesized diffusion process through an examination of 100 households in Panchua Village, including 60 with a SHS and 40 without a system. The data suggest that the hypothesis was correct, although the data do not explain why owner's influenced others to purchase a system. Fifth, the paper tests an alternative hypothesis that the subsidies under the World Bank-financed Rural Electrification and Renewable Energy Development Program were the key driver of sales. Drawing on the same data from Panchua Village, we conclude that the current subsidies to encourage sales do not bridge the gap between non-owner willingness to pay and overall system costs. The paper concludes with suggestions for further research.

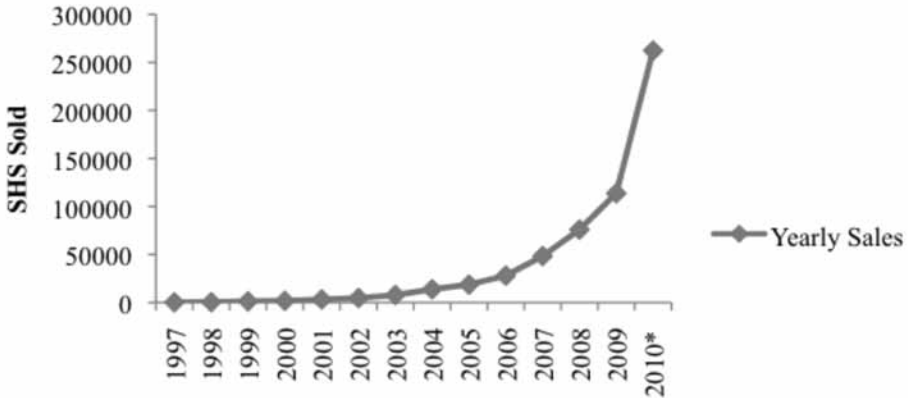
1.2 THE EARLY YEARS: 1996 – 2002

Grameen Shakti (meaning “village energy or power” in Bengali) was established by Grameen Bank executives to “promote affordable, clean, modern and sustainable renewable energy technologies [for] the rural people of Bangladesh” (Barua 2009). When Grameen Shakti began in 1996, approximately 80 percent of rural households lacked access to electricity and therefore relied on kerosene for their lighting needs (BBS 2003), so the potential rural market for off-grid solar was approximately 15 million households² and an untold number of village shops. Grameen Shakti began trying to use microfinance to sell SHS to off-grid households in the Mymensingh and Tangail regions (Barua 2010). Despite the large potential market, Grameen Shakti only sold 500 solar home systems from 1996 until the end of 1998 (Martinot 2000). This was because no one in rural Bangladesh had ever seen a SHS and the cost of a system

²According to the 1991 census, the population of Bangladesh was 106 million; according to the 2001 census, the population was 124 million. Assuming a constant growth rate of 1.6 percent, the population in 1996 would have been 115 million. The rural population without access to electricity was approximately 73.6 million (115million*80% rural population*80% without grid connection) population*80% grid connection) ≈78 million off-grid people/5 people per household ≈15 million households.

was prohibitively high for most households (Barua 2010). In fact, the first systems cost approximately 22,000Tk (US\$ 315) (Barua 2010), or almost four times the average monthly rural income of 6,096Tk in 2005 (BBS 2009).

Figure 1: Yearly Sales By Grameen Shakti: 1996 – 2010

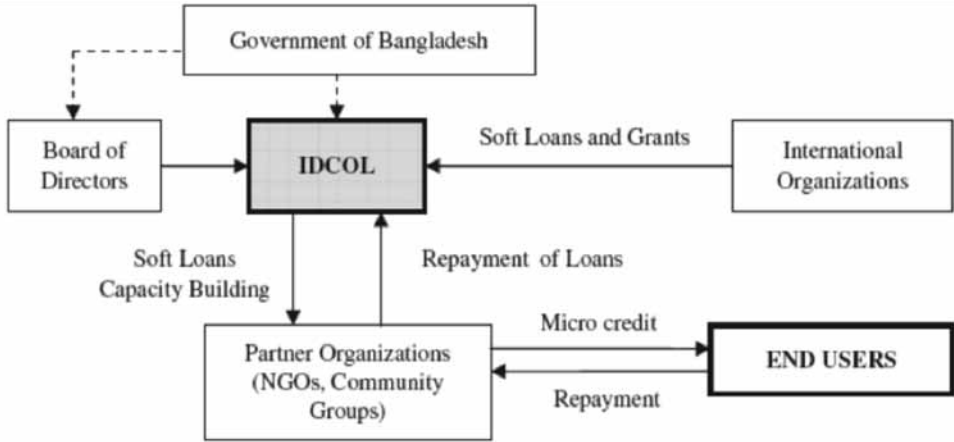


*The total sales number for 2010 were derived by taking the total sales from January to August and assuming that monthly sales were constant throughout the year. (Source: IDCOL, 2010)¹

The sales rate increased once Grameen Shakti extended the repayment period from one to three years after it received an International Finance Corporation/Global Environment Facility Small and Medium Enterprise loan in July 1998 (Martinot 2000). The Government’s decision to lift the import duty and value added tax on solar photovoltaic panels in 1998 also made SHS more affordable (Hossain 2011). These favorable changes allowed Grameen Shakti to sell approximately 1,100 SHS from July 1998 – December 1999 (Martinot, 2000).

In 2002 Grameen Shakti commissioned the Bangladesh Centre for Advanced Studies (BCAS) to undertake a study that measured customer satisfaction with its services. BCAS interviewed 513 Grameen Shakti customers—443 households and 70 commercial shops in the Chittagong, Comilla and Khulna regions—in the Fall of 2002 (BCAS 2003). The study found that 98.6 percent of Grameen Shakti customers were satisfied with their systems; however, 60 percent of consumers believed that the cost of a SHS was “high” and only two customers believed that the technology was “cheap” (BCAS 2003). In fact, the average monthly income of those sampled was 17,637Tk (US\$252)—approximately the 95th percentile for rural household income (BBS 2009). The high cost of a SHS was a key barrier limiting the diffusion of SHS.

1.3 EXPONENTIAL GROWTH: 2003 – 2010

Figure 2: Institutions involved with the sale of SHS

Source: Uddin and Taplin, 2009

The *ad hoc* support of off-grid solar by the Government of Bangladesh and international organizations coalesced into a formalized program following the establishment of the World Bank-financed Rural Electrification and Renewable Energy Development Program (RERED) on December 31, 2002 (World Bank 2002). The project aimed, inter alia, to finance the sale of 50,000 SHS to off-grid customers by extending grants and soft loans to the Infrastructure Development Company Limited (IDCOL), a non-bank financial institution established by the Government in 1997 to finance infrastructure development and renewable energy projects (IDCOL 2008) (see Figure 2). Funding for SHS from other development agencies such as GTZ and KfW were also channeled through IDCOL (IDCOL 2008).

IDCOL passes these savings on to customers by providing Partner Organizations (PO) with buy down grants, institutional development grants and refinancing for every SHS they sell. NGOs and Community Groups that sell SHS are required to go through a rigorous vetting process led by IDCOL before they qualify as POs. Moreover, all POs are required to sell components that are approved by the Technical Standards Committee that includes experts from IDCOL, the Rural Electrification Board, the Local Government Engineering Department and the Bangladesh University of Engineering and Technology (IDCOL 2007). Since 86% of the SHS sold in Bangladesh are done so under the IDCOL financing structure (Chowdhury 2011) this system ensures that all of the SHS sold in Bangladesh are comprised of first-rate components.

The buy down grant reduces the capital cost of each SHS sold by a PO. All customers are required to pay at least ten percent of the remaining cost as a down payment. The outstanding amount is covered by a loan financed jointly by the PO (20 percent) and IDCOL (80 percent). This loan is paid back via a series of monthly installments that

generally continues for 24 or 36 months. IDCOL receives World Bank financing for its portion of the loan and uses this money to extend “soft loans of 10-year maturity with 2-year grace period at 6% per annum interest to its partner organizations” (IDCOL 2007). As predetermined sales thresholds were crossed, the value of each buy down grant was reduced from \$70 to the current level of €20 to facilitate the transition from a sector that relied upon subsidies to one that could stand alone (IDCOL 2010).

RERED reached its target of selling 50,000 SHS in August 2005 and financed a total of 320,000 SHS before the project ended in December 2009 (World Bank 2009). This success was partially attributable to the growth of approved Partner Organizations from five when RERED began to 23 by June 2010 (Husain 2010). The ability of new participants to enter the market after going through a rigorous screening process helped ensure that the market expansion did not result in decreased product and service quality. RERED was so successful that the World Bank renewed it through the end of 2012 and set a new target of 300,000 additional SHS installations (World Bank 2009).

The off-grid SHS sector has created thousands of jobs and unleashed new income-generating possibilities for people in rural Bangladesh. For example, shop owners who install a SHS report increased sales revenue because the improved light from SHS attracts more customers (J.R. Siegel’s personal observation). Myriad households and businesses generate income by charging people a small fee to charge their mobile phone with the electricity generated by their SHS. Grameen Shakti employs more than 7,500 individuals, the vast majority of whom are field assistants that sell, install and provide maintenance services related to SHS (Grameen Shakti 2010). Grameen Shakti also operates 45 Grameen Technology Centers run by women engineers that maintain, repair and assemble the electronic parts of SHS. These centers train and employ underprivileged rural women who generally lack access to other income-generating opportunities. Thus far, these centers have trained more than 3,000 women (Kamal 2010).

1.4 HYPOTHESIS: SALES VIA WORD OF MOUTH

Figure 3: Word of Mouth Hypothesis

Note: A “+” means that the effect is positively related to the cause: as the first variable increases or decreases, the second variable will move in the same direction (i.e. as “Exposure to SHS Benefits” increases, the “Sales Via Positive Word of Mouth” increases). All effects are *ceteris paribus*.

Our hypothesis was that positive word of mouth is the primary driver of SHS sales. We arrived at this hypothesis following a thorough literature review and JRS’ fieldwork. Although the high cost of a system is surely a barrier to SHS diffusion, we believed that the reduction in cost via subsidies from international donors was not as important as word of mouth in stimulating sales. In our view, the diffusion process works as follows: A first adopter is influenced to purchase a SHS by positive word of mouth, marketing, or a targeted installation (see Section 5 for a discussion of these processes). After the installation, the new owner is exposed to the benefits of owning a system such as increased light, decreased indoor air pollution and increased flexibility over kerosene use. Third, the new owner tells other community members about the benefits of owning a SHS and encourages them to consider purchasing one. Some of these people decide to buy a SHS, thereby triggering a new round of exposure, positive word of mouth and sales that continue to drive the explosive growth in sales to this day.

2. Literature Review

Our paper sits at the nexus of the technology diffusion and renewable energy literatures. While there are myriad models of technological change (see Grubler 1998), this paper focuses on the role of word of mouth in catalyzing the diffusion of solar home systems. Social networks and interpersonal communications can catalyze the diffusion process and bring about behavior change (Valente 1995, Valente and Rogers 1995, Rogers 2003). In fact, word of mouth can have a much larger impact on an individual's judgment of a product—and hence his likelihood to purchase the product—than printed information (Herr, Kardes and Kim 1991). The impact of word of mouth is magnified if an opinion leader, influential person or hub transmits it (Valente and Davis 1999, Rogers 2003, Van den Bulte and Joshi 2007, Goldenberg et. al. 2009, van Eck et. al. 2011).

There is tremendous potential for renewable energy technologies to provide energy services in off-grid areas of Bangladesh (Eusuf (ed.) 2005, A.K.M. Islam et. al. 2005, M.R. Islam et. al. 2006, M.A.H. Mondal et. al. 2010). Within this literature there is a consistent focus on the ability of solar photovoltaic technology to electrify rural areas (Eusuf (ed.) 2005, Barua 2001, Sarkar 2003 and Biswas 2003).

The widespread diffusion of SHS has allowed scholars to assess the financial viability of the ownership model. Mondal surveyed 56 households and 10 microenterprises that owned a SHS and carried out a financial analysis of six case studies. His financial analysis calculated the payback period, net present value (NPV) and internal rate of return (IRR) for the SHS investments (Mondal 2010). The four households and businesses that use the SHS for commercial or income-generating purposes all enjoyed payback periods of under three years, a positive NPV and an IRR of over 39 percent, making the SHS a very good investment (Mondal 2010). Conversely, the financial analysis of the two households that only use the SHS for lighting suggests that it is not an economically viable investment unless one considers the social and environmental benefits of the purchase. Mondal concludes that popularizing the SHS will require lowering the cost—ideally to a level similar to what the average household spends on kerosene each month.

Komatsu describes the non-monetary benefits of owning a SHS—electric lighting, watching tv, recharging mobiles at home, etc.—and further investigates the impact of the high cost of a SHS on its diffusion (Komatsu et. al. 2010). Komatsu surveyed 308 households that did not own a SHS, including 268 that knew about SHS and 188 who had not purchased a SHS because it was too expensive. According to their survey, SHS owners had an average income that was twice as high as the non owners and there was a statistically significant difference in income between the two groups (Komatsu 2010). Further interviews revealed that a 10 percent price reduction would encourage 61 percent of non owners to consider purchasing a SHS, while a 30 percent price decrease would raise that figure to 68 percent (Komatsu 2010).

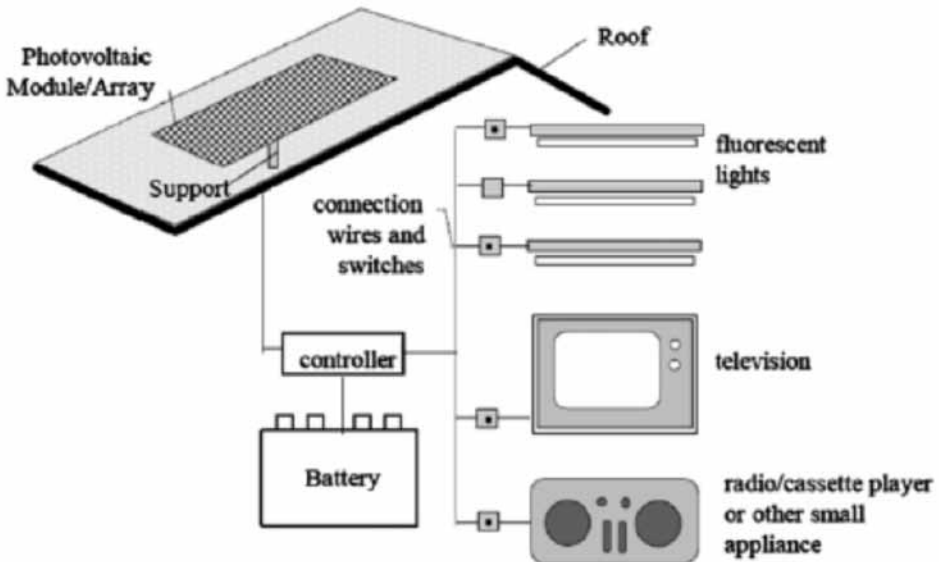
This paper adds to the diffusion literature in two ways: 1) it analyzes the role of opinion leaders in SHS diffusion through key informant interviews; and 2) uses a case study of Panchua Village to quantitatively test the role that word of mouth played in driving SHS sales. These contributions extend the analysis of opinion leaders in technology diffusion to a new technology (SHS) and socioeconomic context (rural Bangladesh).

The second contribution of this paper is its analysis of non owner willingness to pay for a SHS. Unlike Kamatsu (2010), the average income of the owners and non owners sampled in Panchua Village is statistically indistinguishable. Our analysis was therefore able to assess why households that wanted a SHS and belonged to the same socioeconomic strata as owners had not purchased a SHS. Interestingly, our results confirm Kamatsu's finding that the high price of a system was the primary reason why non owners had not purchased a system.

Next, we analyzed non owner willingness to pay for a system. Our results confirm Mondal' (2009) and Kamatsu' (2010) finding that further subsidies will be needed to encourage the widespread diffusion of SHS. Moreover, the data from Panchua Village suggest that the system buy down grants provided by IDCOL are not sufficient to bridge the gap between system cost and non owners willingness to pay. Further research should be undertaken to determine if buy down grants at the present level significantly boosts sales and, if not, whether they should be abolished.

3. Technology

Figure 4: A typical solar home system (Mondal 2010)



Solar home systems are stand alone DC power supply systems that include a solar panel, charge controller, and rechargeable battery that allow the owner to operate appliances such as lights, mobile phone chargers, radios and televisions (See Figure 4) (Meyer 2004). When a photon strikes one of the electronically connected photovoltaic cells that comprise an array, electrons flow from the phosphorous-doped silicon region (N-type) of the cell through the load as direct current before returning to the boron-doped (P-type) silicon region of the cell. (Randolph 2009). The type and number of appliances that can be used simultaneously, and duration of use, is contingent upon the size of the system and the amount of sunlight it receives.

Comparative Analysis

Before analyzing the diffusion of solar home systems in rural Bangladesh, it is instructive to compare SHS to kerosene, the alternative lighting source in off-grid areas. The variance amongst the rates of adoption for technologies is largely explained by five perceived attributes of an innovation—relative advantage, compatibility, complexity, the ability to have a trial and observability (Rogers 2003). Solar home systems enjoy relative advantage over kerosene because they facilitate income generation, provide better light and are more versatile. The average income of households in a village with electricity is 27% higher than villages without electricity (Mohiuddin and Rahim 2005). Moreover, the average income of non-agribased households increases 33% with the introduction of electricity (Mohiuddin and Rahim 2005). Electric lighting also provides approximately 100 times more light than a kerosene lamp without the resulting indoor air pollution, soot and noxious odors (Asaduzzaman et. al, 2009). Solar home systems can also be used to power televisions, radios, mobile phone chargers, small fans and radios. Finally, they are compatible with the values of rural Bangladeshis.

Customer trainings and the high level of interactions between system owners and their neighbors overcome two perceived attributes that could limit the rate of SHS adoption—complexity and the inability to have a trial. The inability of potential customers to understand how a technology works slows down the adoption rate (Rogers 2003). Most of the early adopters interviewed were initially hesitant to purchase a SHS because they could not believe that a panel could convert sunlight into electricity and thought that they were being scammed. Although the process of transforming photons into electricity is complex, customers can be trained on how to use their SHS as it is installed or during a one-hour session in a branch office. The ease with which one can learn how to use a SHS lowers the complexity barrier to diffusion. Although only a select few opinion leaders are given free trials, the vast majority of customers we interviewed saw a SHS working in a neighbor's house before they bought one, which can be thought of as a kind of trial.

There are two additional barriers to diffusion that deserve mention: cost and risk aversion. As was previously mentioned, the average income of the SHS owners sampled in 2003 was in the 95th percentile of the rural population and the price of a 50Wp SHS

(26,800TK, or US\$383) is four times the average rural income. A related barrier is risk aversion. Purchasing an appliance that requires a large monthly installment for three years requires a high level of confidence in the economic future of the family. Moreover, the components of a solar home system can break, and replacing these parts—especially the battery—can be very expensive. The SHS are so valuable that some of the systems were tied on to the roof in an attempt to keep people from stealing them even though all of the solar panels are bolted into the roof to guarantee that they are south facing.

4. Methodology

A combination of qualitative and quantitative methods was used to test the hypothesis. To generate a hypothesis we conducted expert interviews in Dhaka, reviewed the relevant scholarly literature conducted semi-structured interviews in rural Bangladesh during the Summer of 2010. The experts interviewed included senior personnel at: 1) Grameen Shakti; 2) Bright Green Energy Foundation, 3) Infrastructure Development Company Limited (IDCOL); 4) Rural Electrification Board; 5) Bangladesh Rural Advancement Committee (BRAC); and 6) Mr. Dipal Barua, co-founder and Managing Director of Grameen Shakti from 1996-2009 and founder of the Bright Green Energy Foundation.

All of the field interviews were conducted by JRS with the aid of a professional translator. In five days in the Tangail Division, JRS interviewed 25 households and two businesses that owned a SHS. During an additional five days in the Rangpur Division JRS interviewed 18 households and 17 businesses with SHS as well as five individuals without a system. Interviewees were asked when they purchased their SHS, the size of their system, why they decided to purchase a system, if they had any problems with their after sales service and if they influenced anyone else to purchase a system. While in the Tangail and Rangpur regions JRS conducted additional unscripted interviews with dozens of Grameen Shakti employees including field workers; branch, regional and divisional managers; and Grameen Technology Centre managers and technicians. These interviews provided us with an understanding of the diffusion process from the perspective of people working across all levels of the industry. JRS also attended two customer-training sessions in the Kurigram District, Rangpur Division.

The two disadvantages of the interview process (and sources of potential bias) were 1) that interviewees were mostly Grameen Shakti customers; and 2) JRS' presence in rural areas attracted large crowds, which might have influenced interviewees' responses. Due to these potential sources of bias, we formulated surveys for SHS owners and non owners that were carried out by professional researchers from BCAS. The interviews for SHS owners covered 61 questions; interviews for non owners covered 19 questions (see Appendices A and B for a copy of these surveys). We used the data generated from these interviews to test our hypothesis and an alternative hypothesis.

Picture 1: New SHS owners listen to a customer training in northern Bangladesh



5. Innovators and Early Adopters

Rogers (2003) placed innovation adopters into five categories: Innovators (2.5%); Early Adopters (13.5%); Early Majority (34%); Late Majority (34%); and Laggards (16%). In this section we use data from interviews conducted with three innovators/early adopters and several people who began selling SHS before 2000 to outline our hypothesis.

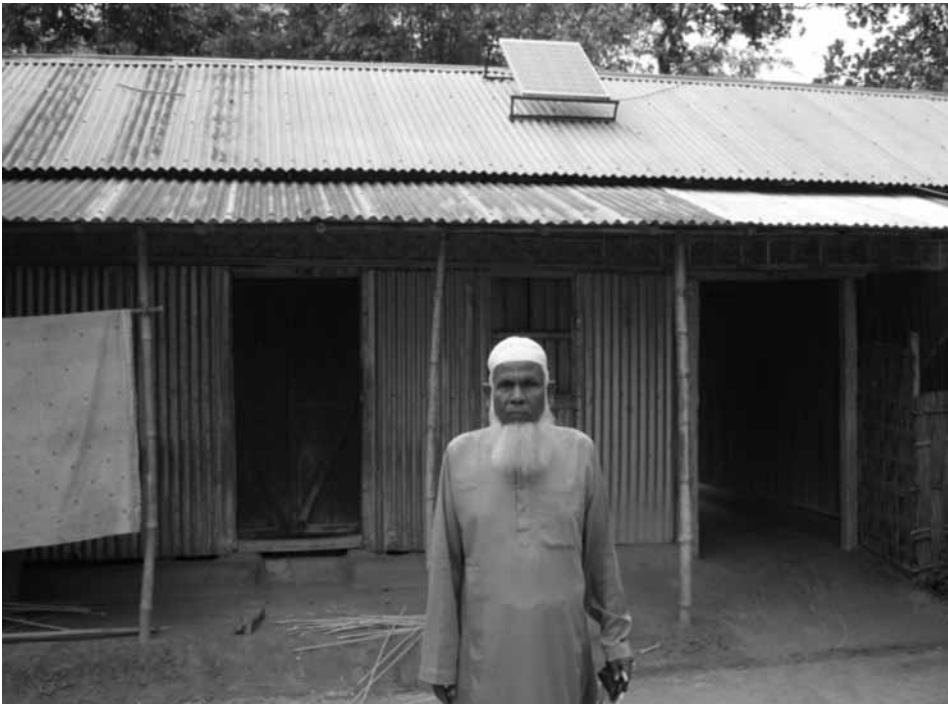
5.1 RAISING AWARENESS

Before selling a SHS consumers must: 1) know that the technology exists; and 2) believe that it is superior to kerosene. To accomplish both of these tasks, Grameen Shakti set up a SHS in village markets week after week to demonstrate that a solar panel could be used to light a light bulb or run a black-and-white television (Barua 2009). In addition to these demonstrations workers went door-to-door distributing leaflets that highlighted how the systems worked and answering any questions potential consumers had about the technology.

Grameen Shakti focused on areas in which the Grameen Bank had a strong presence. According to interviews with senior officials, this strategy helped Grameen Shakti because the villagers they approached were familiar with the Grameen Bank and microcredit. More importantly, villagers were more likely to believe that SHS were legitimate technologies because they trusted the Grameen Bank. Nonetheless, many of the people who witnessed demonstrations in markets thought that SHS were magical and that Grameen Shakti was trying to trick them into buying an expensive piece of useless hardware since it was impossible to turn sunlight into electricity (Barua 2010). Even those people who believed that the technology worked, were reticent to make such an expensive investment because they were unable to use a SHS on a free trial basis or see one working in a friend's home. These barriers created a situation in which the number of people who were aware of the technology continued to increase, but the number of sales remained close to zero. Thus, the "process of building customer demand and confidence was enormously draining on [Grameen Shakti's] time, resources, and profitability" during its first years in operation (Martinot 2000).

5.2 SALES VIA FREE TRIALS

Picture 2: Mr. Uddin in front of his SHS



The first SHS sold in a village is typically the result of one of three broad processes: 1) sales via free trials; 2) sales via marketing; and 3) sales via word of mouth. Because the barriers to diffusion were so steep, the first system sold in the country—and the first systems sold in many villages throughout the country thereafter—was installed in a local opinion leader’s home on a free trial basis (Barua 2010). Before expanding into a new area, Grameen Shakti asked its colleagues at local Grameen Banks to identify the local opinion leaders (Islam, M.A. 2010). After entering the area, Grameen Shakti field officers went to an opinion leader’s home, explained how SHS work, and offered to install one on a free trial basis. The trial worked as follows: if the opinion leader liked the system, Grameen Shakti requested that he begin paying for it within a month; if he did not like it, Grameen Shakti would take it away free-of-charge. Most of these customers began paying for the system within a week. According to Dipal Barua, “we thought that once people could see the benefits of having a SHS in their home, sales would follow” (Barua 2010).

As of 2006 Grameen Shakti was still installing SHS at opinion leaders’ homes free-of-charge in villages without any SHS. In April 2006, Grameen Shakti sold its first SHS in Kachichar, Kurigram District to Mr. Nasim Uddin, a 70-year old school teacher with seven sons (see Picture 2). Teachers are well-respected professionals in rural Bangladesh, and the flow of remittances from his sons in other parts of Bangladesh made Mr. Uddin a wealthy man by local standards. Although BRAC had sold systems in neighboring areas for years, Mr. Uddin recalled, “I’d never seen a solar home system before salesmen from a variety of NGOs starting appearing at my home and trying to sell me one. I thought that they were running a scam – I couldn’t believe that sunlight could actually produce electricity.” Grameen Shakti offered to install an 85 Wp system at his home on a free trial basis; he gave them his down payment a few days after the system was installed. He estimated that 20-25 households bought their SHS after seeing the technology for the first time at his house and asking him questions about it (Uddin 2010).

5.3 SALES FROM MARKETING

In other areas, the first owner purchased a SHS without the benefit of a free trial. One such community was Shakipur, where Mrs. Suriya Akater purchased the first SHS in 1996. During an interview, her son explained that Mrs. Akater was a Grameen Bank customer who decided to buy a 48 Wp system after seeing a Grameen Shakti demonstration in the village market. Once she bought her SHS, friends and neighbors flocked to her house to see the system, ask her questions about it and inquire as to how they could buy one. Mr. Akater estimated that 150 – 200 current Grameen Shakti customers saw their first SHS at his mother’s house (Akater 2010). Out of this group, Mr. Akater personally referred 20 – 30 would-be customers to the Grameen Shakti Division Manager in Tangail. Mrs. Akater’s decision to purchase a SHS began a process through which positive word of mouth generated hundreds of sales across the Shakipur region.

5.4 SALES FROM WORD OF MOUTH

Picture 3: Mr. Khalek in front of his SHS



Because Grameen Shakti and the other POs slowly expanded across the country, first adopters in many villages saw their first SHS while visiting other regions of the country. Mr. Abdul Khalek, the first adopter in Bagher Bari, a remote village several hours from Tangail, saw his first SHS in Shakipur at a friend's house and was immediately interested in purchasing a system (See Picture 3). Since no field officers had visited his village, however, he did not know how to get one. A few months after he returned from his trip to Shakipur, a field officer from the Grameen Shakti Khalihati Branch visited Bagher Bari. During the visit the field officer gave Mr. Khalek a marketing leaflet; explained how a SHS works; and told him about the cost, financing schemes and warranties associated with purchasing a system. He bought his 50 Wp system shortly thereafter in July 2003.

As a high school teacher with a steady flow of remittances coming from his two sons working construction in the Middle East, Mr. Khalek was a relatively wealthy and well-respected individual. He described himself as someone who was constantly looking for new things that enjoyed being the first person in the village to own a new technology. In fact, our interview took place in a room fitted with a CFL that he bought and installed after he read that it was better than the tube lights that came with his system. After buying his solar home system, he invited his neighbors to come over to his house several times and convinced 12 – 14 of them to buy a solar home system.

5.5 CONCLUSION

Figure 5: Word of Mouth Hypothesis



The first SHS sold in a village is generally the result of a targeted free trial, effective marketing or positive word of mouth. Regardless of how the first SHS is sold, this initial installation triggers a rush in sales; “A rural family benefiting from the technology will tell their neighbors about it and the popularity and demand for SHS soars in that community” (Barua 2008). The word of mouth that Barua singles out is such a powerful marketing tool that Grameen Shakti field officers stop doing demonstrations in school and markets once the number of SHS owners in an area crosses a critical threshold. Although some sales still come from door-to-door marketing, Grameen Shakti officials believe that customer referrals drive sales (Islam 2010). The diffusion curves takes off “once interpersonal networks become activated in spreading individuals’ subjective evaluations of an innovation from peer to peer [i.e. word of mouth] in a system” (Rogers 2003). We decided to test if word of mouth was, indeed, the primary driver of sales through an in-depth analysis of SHS owners and non owners in Panchua Village.

6. Panchua Village

Figure 6: Breakdown of SHS owners by organization and geographical location of Panchua Village

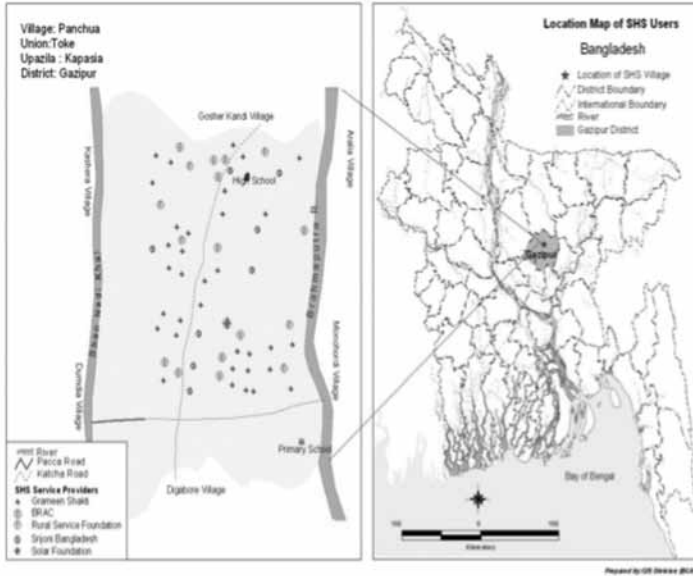
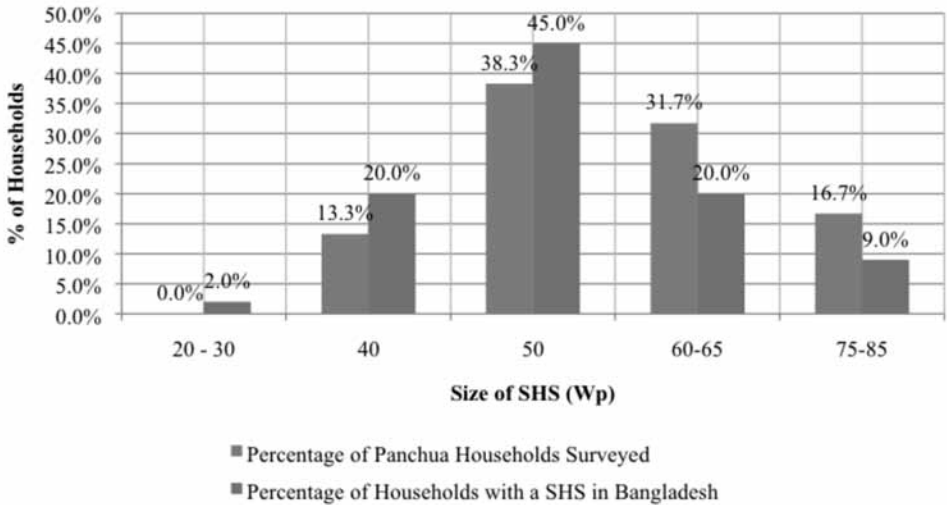


Figure 7: Comparative breakdown of SHS size in Panchua Village and across Bangladesh

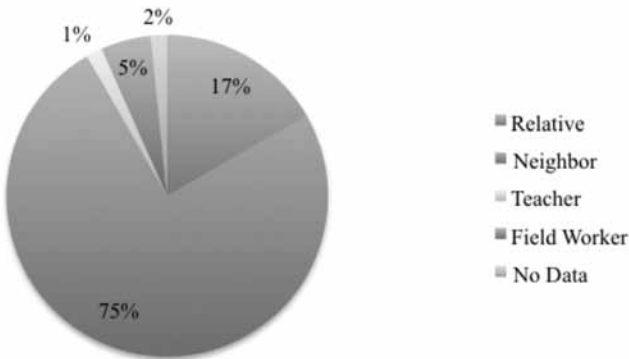


To test our hypothesis that positive word of mouth is the primary driver of off-grid SHS sales, we designed surveys that could generate household-level quantitative data. Professional researchers from BCAS used these surveys to conduct in-depth interviews with 100 randomly selected households in Panchua Village, Kapasia Upazila, Gazipur District (Figure 6).³ Sixty of the households interviewed owned a SHS; the remaining 40 households did not. Panchua Village has a population of 4,959 spread across 1,042 households and 1,267 acres (BBS 2006). The average household size of 4.76 people and literacy rate of 37.24% are slightly lower than the rural national averages of 4.9 and 54%, respectively (BBS 2006). We were unable to find average income data for the village because the government only provides income data aggregated at higher-than-village levels.

The size of the SHS owned by households interviewed in Panchua Village is similar to the breakdown of the 320,000 SHS sold under the Rural Electrification and Renewable Energy Development Program from 2003 – 2008 (Figure 7). Although we do not seek to extend the analysis to the whole of Bangladesh, the similarities between the households surveyed in Panchua Village and national averages makes the analysis a good starting point from which to study the SHS sector in Bangladesh.

6.1 LEARNING, PURCHASING AND INFLUENCING

Figure 8: How SHS Owners Learned About the Technology



The first step towards purchasing a SHS is acquiring knowledge about the technology. In Panchua Village, 93 percent (56 of 60) of SHS owners surveyed listed a neighbor, relative, or teacher first when asked how they learned about SHS (Figure 8). In contrast, only 3 households first heard about SHS from direct contact with a field worker from

³All of the primary data gathered in Panchua Village was done through in-depth question and answer sessions. The data collected was not cross-referenced with any other sources. While we are aware that individuals may not have provided completely accurate data—especially regarding sensitive topics such as their monthly income—we trust the reader to determine how, when and where to attach caveats to the following analysis.

a PO. The first household to purchase a SHS in the sample did so in 2004—eight years after Grameen Shakti began selling SHS and a year after the introduction of RERED. By 2004, POs had penetrated many regions of Bangladesh and were expanding rapidly. It is therefore likely that some of the owners interviewed had seen a SHS in another part of the country before the first field officer arrived in Panchua. Nonetheless, the role of word of mouth in transmitting knowledge of SHS underscores its importance in the diffusion process.

The second step in the process is buying a SHS. We asked owners to list up to three reasons exemplifying why they made the purchase (Figure 9). The top two responses, improved quality of light and an increased ease of studying, are both related to the one hundred-fold increase in light from a kerosene lamp to a SHS. The third most common response was mobile phone charging for personal use or income generation.⁴

During almost every interview conducted with a senior official at a PO, he would take out a calculator and explain how it would be cheaper for a household to use a solar home system for light than kerosene lamps when considering the entire 20-year lifetime of the SHS. While this statement is true, it suffers from two flaws: 1) most SHS are paid back within three years, so the discounted net present value of the cost of the system is potentially higher than the net present value of the monthly payments for kerosene; and 2) only one of the households surveyed in Panchua Village listed saving money on kerosene as a reason for purchasing a SHS. None of the customers we interviewed mentioned the cost of kerosene unless they were asked them how much money they spent on kerosene each month before buying a SHS. While the first issue is of interest from an academic perspective, the fact that the overwhelming majority of owners interviewed did not consider the long term costs—be they discounted to find a net present value or not—means that this line of inquiry is largely irrelevant from a practical standpoint. Although looking at long-term savings might resonate in economic models, it does not seem to influence the decisions taken by people on the ground that these models are meant to explain. Our data suggest that short-term costs and benefits overwhelm potential long-term savings when households are deciding whether or not to purchase a SHS.

The final step in the diffusion process occurs when a system owner influences another household to purchase a SHS. Seventy-eight percent of the owners surveyed (47 of 60) stated that they influenced others to buy a system (Figure 11). There was not a discernable relationship between how an owner learned about SHS and how many additional households he or she influenced to buy a system. Taken together, these findings support the hypothesis that word of mouth is driving the diffusion of solar home systems in Panchua Village.

⁴In many regions of Bangladesh, households with a SHS charge neighbors' a 5 – 10Tk fee to change their mobile phones.

Figure 9: Depiction of why owners decided to purchase a SHS

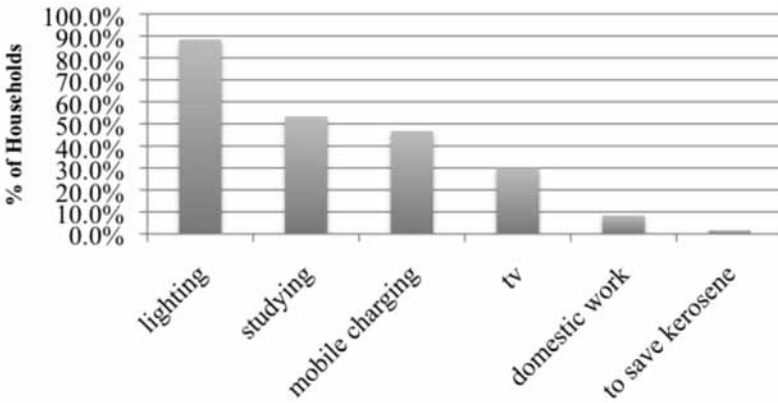
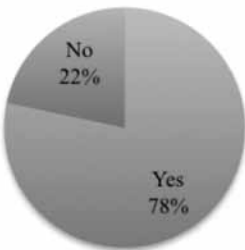
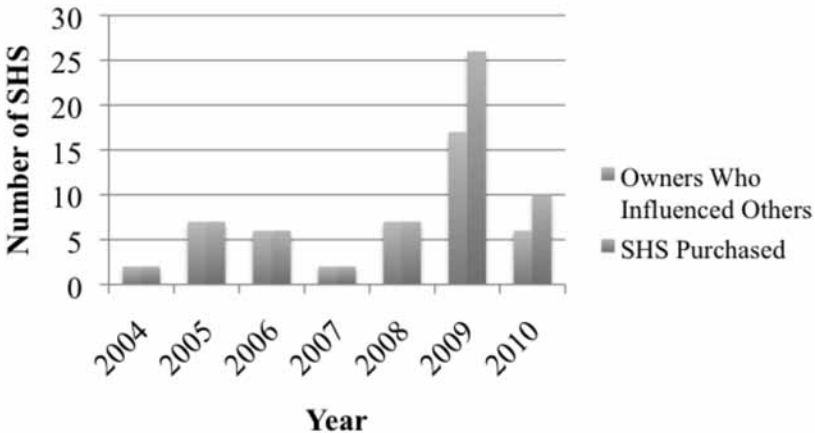


Figure 10: Graph displaying whether or not owners influence others to buy a SHS



6.2 WHAT CAUSES PEOPLE TO INFLUENCE OTHERS?

Figure 11: The Role of Time with SHS in Influencing Others to Purchase a System



This section investigates why some owners actively influence other people to adopt a technology that is new and significantly more expensive than kerosene in the short-run. It analyzed which (if any) characteristics of an owner are correlated with 1) the decision to influence other household(s) to buy a SHS; and 2) if so, how many houses. The first factor we considered was the amount of time a household has owned a SHS. As Figure 11 shows, every customer that bought a system from 2004-2008 influenced at least one additional household to purchase a SHS—and every owner that had not influenced another bought his system during the 18 months before the survey was conducted. The ability of anyone to see a solar panel on one’s roof suggests that, over time, an interested neighbor will eventually ask an owner questions about his system and proceed to purchase one. The relative bunching or clustering of customers from each PO (Figure 6) demonstrates how owners tend to influence neighbors to purchase a SHS from their service provider. Since field officers visit each customer to collect the payments every month, any tip that a neighbor is interested in purchasing a system could send the field officer to a new customer’s house. In fact, the survey respondents claimed to have influenced a total of 201 households to purchase a system (Table 1). Although some SHS owners in the village were not sampled, it is very likely that several survey respondents had the same household in mind when they asserted that they had influenced others to purchase a system.

Having determined that the length of system ownership correlates positively with having influenced over others to buy a SHS, the next question is whether a relationship exists between the purchase year and the number of households influenced. The results of this analysis are depicted in Table 2 and show that there is not a relationship between the number of years a household owned a system and the number of people its members influenced. Although this finding is surprising, it might be attributable to a triggering effect. For example, an owner who purchased his system in 2004 might have influenced three people who, in turn, influence an additional 22 people for a total of 25 households. The original owner created a cascading ripple of sales throughout the village and beyond, but is only directly responsible for three additional sales. As the early adopter interviews discussed above demonstrate, influencing one opinion leader to adopt the technology can do more to aid the diffusion process than convincing several people who are not enthusiastic champions of the SHS to buy.

Table 1: Comparing purchase date with the number of households influenced

| | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 |
|----------------------------------|------|------|------|------|------|------|------|
| Influenced No One | 0 | 0 | 0 | 0 | 0 | 9 | 4 |
| Influenced 1 - 2 People | 0 | 2 | 4 | 1 | 0 | 11 | 3 |
| Influenced 3 - 6 People | 2 | 5 | 2 | 0 | 4 | 6 | 2 |
| Influenced 10 - 20 People | 0 | 0 | 0 | 1 | 3 | 0 | 1 |

Table 2: Breakdown of how many people each owner influenced

| Number of People Influenced | Number of Adopters | Percentage of Owners |
|-----------------------------|--------------------|----------------------|
| 0 | 13 | 21.7% |
| 1 | 5 | 8.3% |
| 2 | 16 | 26.7% |
| 3 | 7 | 11.7% |
| 4 | 3 | 5.0% |
| 5 | 8 | 13.3% |
| 6 | 3 | 5.0% |
| 10 | 1 | 1.7% |
| 11 | 1 | 1.7% |
| 15 | 1 | 1.7% |
| 17 | 1 | 1.7% |
| 20 | 1 | 1.7% |

6.3 THE ROLE OF AFTER SALES SERVICE

This section analyzes the role that after sales service plays in determining if a system owner will influence others to purchase a SHS. According to Dipal Barua, the three keys to success in the SHS market are, in descending order: 1) after sales service; 2) bill collection efficiency; and 3) new installations (Barua 2010). The importance of good after sales service was confirmed anecdotally during interviews with customers and officials. For example, a customer near Kurigram became so disillusioned with the slow and unreliable after sales service of his PO that he convinced his brother and several friends to purchase their SHS from a different company. The positive word of mouth that stimulates sales can quickly transform into a cycle of negative word of mouth that can decimate future sales. Indeed, negative information has a more profound impact on potential consumers than positive information because it helps them differentiate high- from low-quality products (Herr et. al. 1991).

After a household purchases a SHS, it is guaranteed free after sales service throughout the duration of the payback period. Because the field officers that sell, install and fix minor problems are also the bill collectors, customers can receive basic maintenance services when they pay their monthly installments. Once a household finishes paying off its system and becomes its outright owner, however, the free maintenance services end. Most of these owners have the option of enrolling in an annual fee-for-service maintenance agreement with their PO, but very few decide to do so. As of June 2010, only 17,404 of the 93,002 (19%) Grameen Shakti customers that owned their systems outright elected to sign a maintenance agreement (Grameen Shakti 2010). Grameen Shakti charges 300Tk (US\$4.30) per annum for such an agreement even though the cost of sending technicians to service these systems outstrips this yearly maintenance fee (Rabbi 2010).

The low level of owner participation in the Grameen Shakti maintenance program despite its unsustainably low price calls into question the importance of after sales service in the diffusion process. Without access to long-term maintenance agreements, the chances of system breakdown, and thus negative word of mouth, should increase. As expected, the time it takes field officers to fix a problem is significantly longer for households that have paid off their system than those that are still paying monthly installments (Figure 12).

This discrepancy does not seem to impact customer satisfaction with after sales service—the results for the 33% of users who paid off their systems were almost identical to that of households that still paid monthly installments! (Figure 13) This finding could be due to the lower expectations regarding after sales service amongst households that have paid off their systems. Furthermore, customer satisfaction with after sales service does not appear to be highly correlated with the number of additional users an owner influences (Figure 14). This result might be explained by the potential time lag between influencing others to buy a system and having to wait longer for service as a result of paying off the system. These findings call into question the importance of after sales service as a driver of customer satisfaction. Further research is needed to determine if these findings were aberrant or indicative of a larger phenomenon.

Figure 12: Comparing Maintenance Response Times

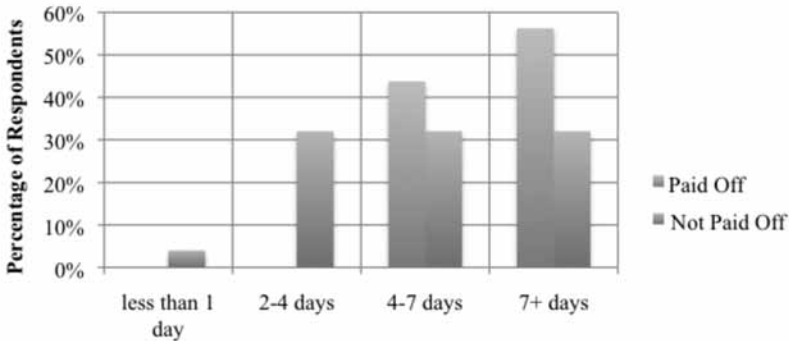


Figure 13: Level of satisfaction with After sales Service

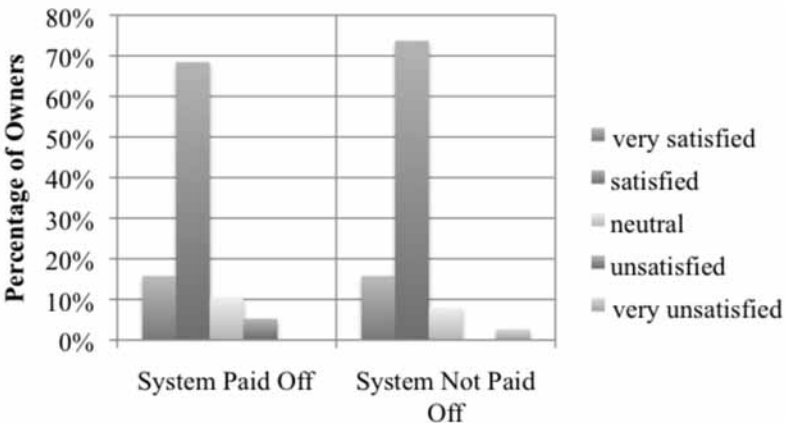
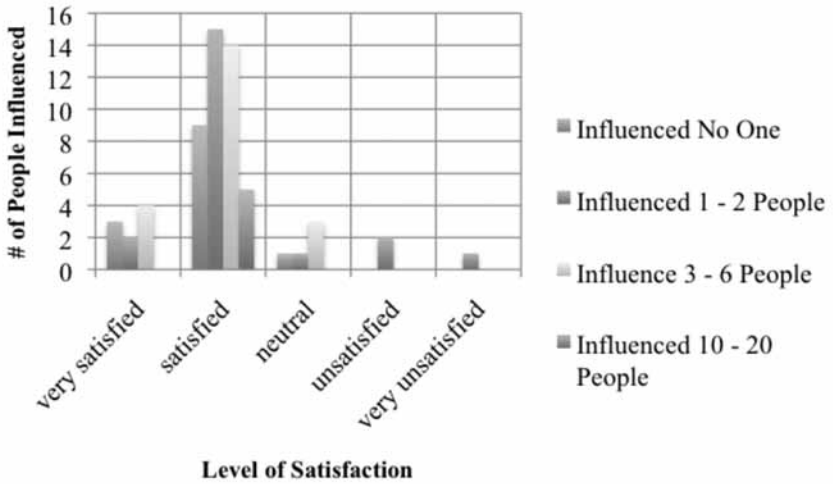


Figure 14: The Relationship between after sales Service and Influencing Others



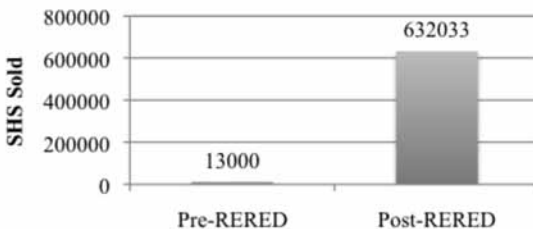
6.4 ALTERNATIVE HYPOTHESIS: SALES VIA PRICE REDUCTIONS

Figure 15: Role of Price Alternative Hypothesis



Note: A “-” means that the effect is negatively related to the cause (i.e. as the “price” decreases, the “potential market” increases. All effects are ceteris paribus.

Figure 16: Comparison of SHS sales from 1996 – 2002 to those from the introduction of RERED on December 31, 2002 – June 2010



The introduction of RERED on December 31, 2002 was followed by an exponential increase in the number of SHS sold (Figure 16). As section 1.3 detailed, RERED lowered the price of SHS by offering subsidies to POs for every system they sold. The majority of industry experts interviewed believed that the subsidies lowered the price a SHS, thereby increasing the potential market size, boosting sales and causing explosive sectoral growth (Figure 15). Because of the prevalence of this view, we tested this alternative hypothesis using interview data from Panchua Village in the following section.

6.5 COMPARING OWNERS AND NON OWNERS

6.5.1 LEVEL OF INCOME

We began testing this hypothesis by comparing the average monthly income of system owners to non owners in Panchua Village. Because of the high cost of a SHS, we expected the owners to have significantly higher incomes than the non owners (Table 3). The average self-reported monthly income of the 60 owners interviewed was 18,716Tk (US\$267), well within the top 5% of all rural incomes (BBS 2009). The average self-reported income of the 40 non owners was not far behind at 15,550Tk (US\$ 222), also within the top 6% of rural incomes (BBS 2009). Due to the small sample size, I performed an “Independent Samples Test” to test the null hypothesis that there was no difference between the mean incomes of the owners and non owners. As the chart below demonstrates, I was unable to refute this null hypothesis (Table 4). Despite the 3,000Tk (US\$43) difference in mean incomes between the two groups, the two averages are statistically indistinguishable.

Since cement and brick are more expensive than traditional building alternatives, a large discrepancy in the material used in owner and non-owner homes could indicate that the survey data on income was unreliable. However, the construction materials used by the two groups were nearly identical (Figure 17). This finding increases our confidence that the monthly data collected was accurate. Because the average income of the two groups is not statistically distinguishable, the following analysis examines why non owners with the same average ability to pay as the owners have not purchased a system.

Table 3: Average monthly income of owners and non owners

| | N | Mean | Std. Deviation | Std. Error Mean |
|----------------------------------|----------|-------------|-----------------------|------------------------|
| Monthly Income Owners | 60 | 18716.67 | 14156.321 | 1827.573 |
| Monthly Income Non owners | 40 | 15550.00 | 11566.862 | 1828.882 |

Table 4: Results of the “Independent Samples Test”: Comparing Average Monthly Incomes

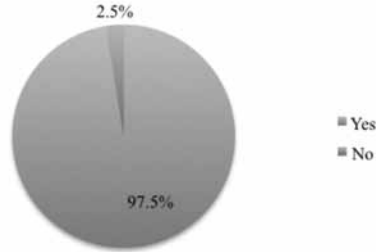
| | Levene's Test for Equality of Variances | | t-test for Equality of Means | | | | | | |
|------------------------------------|---|------|------------------------------|--------|-----------------|-----------------|-----------------------|---|----------|
| | F | Sig. | t | df | Sig. (2-tailed) | Mean Difference | Std. Error Difference | 95% Confidence Interval of the Difference | |
| | | | | | | | | Lower | Upper |
| Equal variances assumed | 3.301 | .072 | 1.176 | 98 | .242 | 3166.667 | 2691.760 | -2175.043 | 8508.377 |
| Equal variances not assumed | | | 1.225 | 93.891 | .224 | 3166.667 | 2585.504 | -1966.990 | 8300.323 |

Figure 17: Depiction of the type of household each interviewee lived in



6.5.2 WILLINGNESS TO PAY AND SYSTEM COST

Figure 18: This figure demonstrates that almost all of the non owners interviewed wanted a SHS



Every non owner surveyed used kerosene for lighting and was familiar with SHS. With the exception of one household, every interviewee wanted a solar home system (Figure 17). Moreover, a representative from a PO tried to sell or advertise a SHS to 21 of the 40 households interviewed. Despite the high level of interest in the technology, levels of income similar to those of the owners and a marketing campaign, these households had not elected to purchase a SHS. This sections seeks to determine why this was so.

We begin our analysis of by deriving an average price range for a SHS. Since 85% of the SHS sold under RERED ranged from 40Wp – 65Wp, we used the Grameen Shakti prices for those sizes to create an average price range of 21,400 – 32,800Tk (US\$306 – 469) (Table 5). This range is well above the average monthly household income of 6,096Tk (US\$87) in rural areas (BBS 2009). The cost of a SHS is, however, spread out over several years through the use of microfinance. The majority of POs offer repayment plans similar to the three pioneered by Grameen Shakti: 1) a 15% down payment with an annual service charge of 6% paid on the remaining 85% over 36 monthly installments; 2) a 25% down payment with an annual service charge of 4% on the remaining 75% of the price over 24 monthly installments; and 3) a 100% down payment with a 4% cash discount. Using these options, the typical consumer purchasing a 40Wp – 65Wp SHS pays a 3,210 – 4,920Tk (US\$46 – 70) down payment.

Table 5: The cost of SHS sold by Grameen Shakti as of July 2010

| System Size | System Price (taka) |
|-------------|---------------------|
| 20 Wp | 11,700 |
| 40 Wp | 21,400 |
| 50 Wp | 26,800 |
| 60 Wp | 31,300 |
| 65 Wp | 32,800 |
| 75 Wp | 36,900 |
| 80 Wp | 38,400 |
| 85 Wp | 40,800 |

(Grameen Shakti 2009)

Non owners are willing to pay significantly less than the bottom of this range as down payment. As Figures 19 and 20 show, only 2.5% of non owners are willing to pay a down payment of more than 2,500Tk (US\$36), yet 93% of owners paid more than 4,000Tk (US\$57). The gap between non-owner willingness to pay and the amount paid by owners is roughly 3,000Tk. This large chasm between the two groups indicates that the high upfront cost associated with purchasing a SHS is a major barrier limiting future sales.

Figure 19: Survey results of how much non owners are willing to pay as a SHS down payment

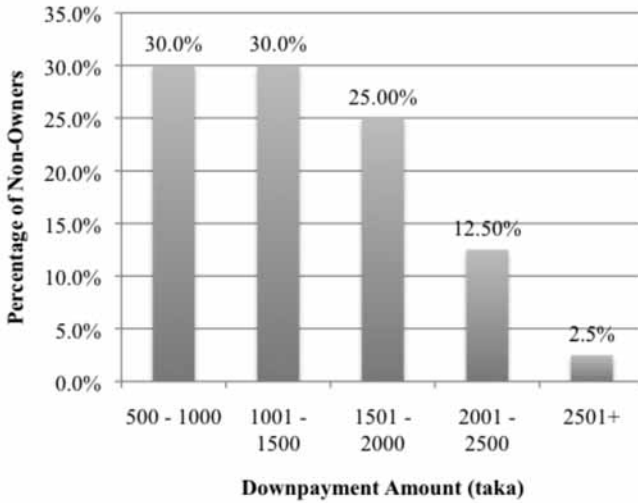
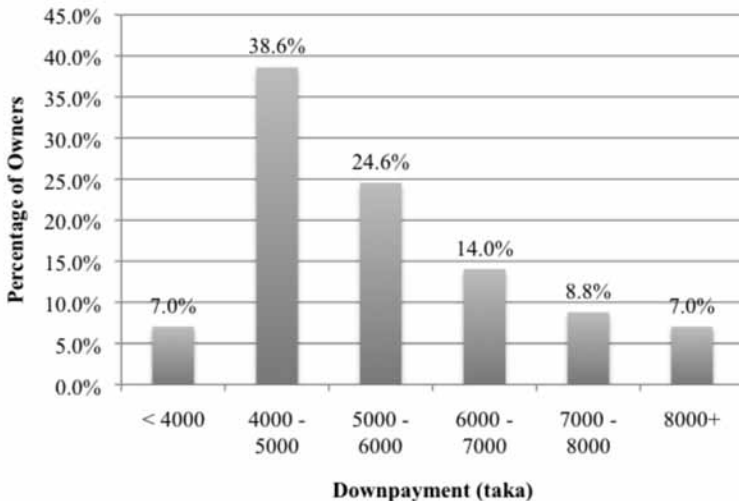


Figure 20: Survey results depicting the amount of money owners put down when they purchased a SHS



The second component of SHS price concerns the monthly installments. The vast majority of non owners are not willing to pay a premium for a SHS despite their interest in substituting a system for kerosene. Eighty-seven percent of non owners are only willing to spend 200Tk (the lowest option provided) or as much as they currently spend on kerosene per monthly SHS installment (Figure 21). The fact that 82% of households spend 200Tk or less per month on kerosene creates a virtual price ceiling of 200Tk per month for most households (Figure 22).

This price ceiling is well below the monthly installments paid by most owners (Figure 23). In fact, less than two percent of owners pay less than 500Tk per month—or two and a half times the willingness to pay of most non owners. Seventy-five percent of owners pay at least 700Tk per month. The 500Tk gap between non-owner willingness to pay for each installment and the amount paid by owners is a second barrier to future sales.

Figure 21: Survey results depicting how much non owners are willing to spend on SHS installments

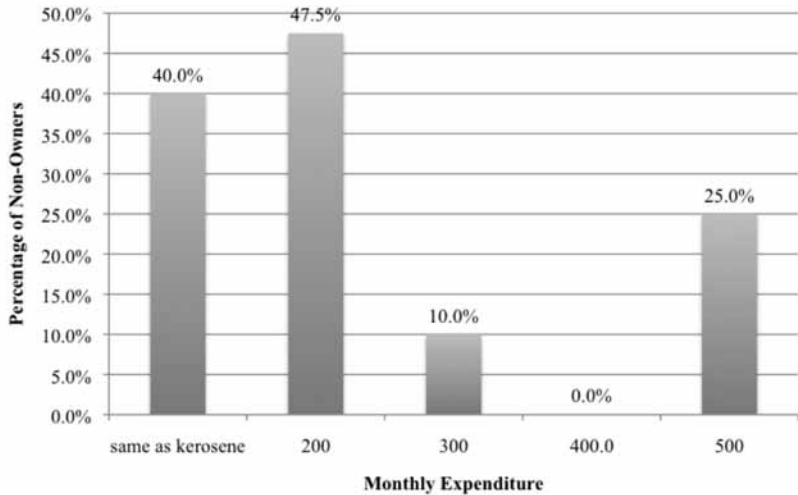


Figure 22: Survey results depicting how much non owners spend on kerosene per month

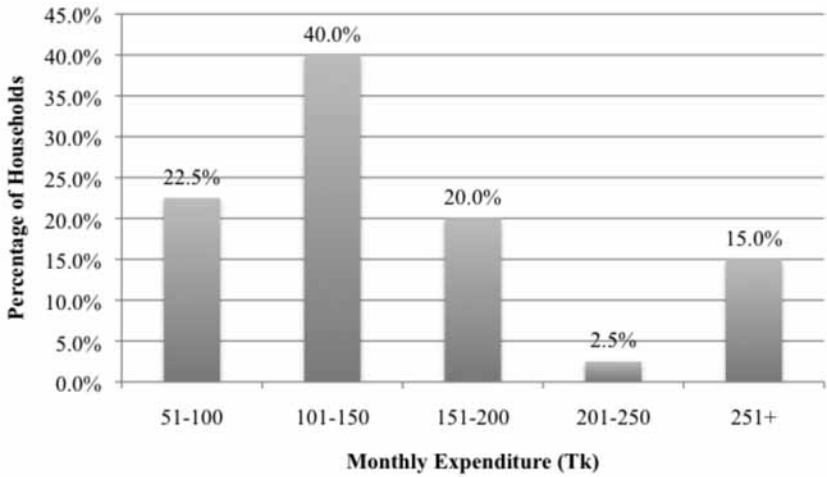
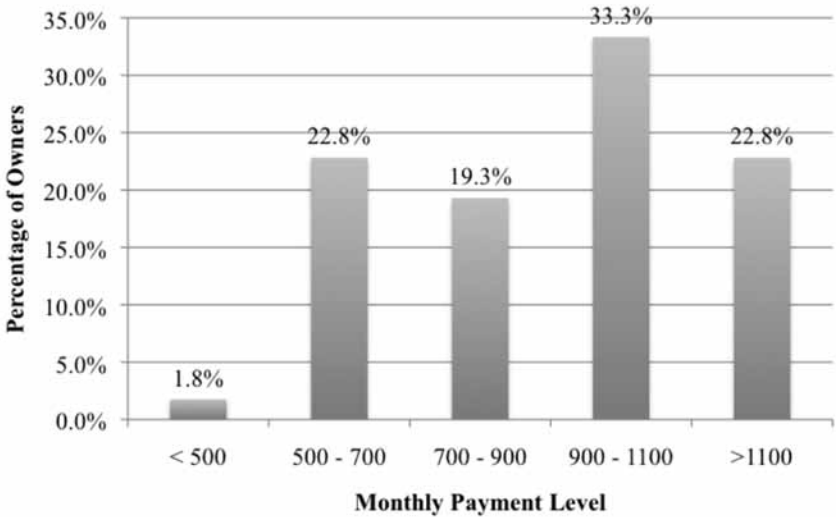


Figure 23: Survey results of how much owners spend on their monthly SHS installments



6.5.3 COMPARING RERED AND WILLINGNESS TO PAY

The final step in analyzing the alternative hypothesis is comparing the gap between system costs and non-owner willingness to pay to the subsidies provided by RERED. When RERED began, POs received a \$90 grant from IDCOL for each SHS it sold. A US\$70 buy down grant reduced the price paid by end-users, while the remaining \$20 was allocated for institutional development (IDCOL 2010). As was noted above, the grant payments have been systematically reduced over time with the eventual goal of making the industry self-supporting (Sadeque 2010). As of March 2010, the overall grant level was €22, of which €20 was a buy down grant and the remaining €2 were for institutional development (IDCOL 2010).

The analysis of Panchua Village suggests that the current level of subsidies being offered through RERED via IDCOL will not significantly increase the market for SHS due to the gap between system cost and non-owner willingness to pay. To illustrate this contention, let us assume that the Grameen Shakti price of 21,400Tk (US\$306) for a 40Wp system is pre-buy down grant. At the current exchange rate of €1 to 96Tk, the €20 buy down grant is equal to 1,920Tk. Subtracting the grant from the system price, we find that the price will be reduced to 19,480Tk (US\$278). Assuming the consumer opts for the 15% down payment and 36 monthly installment financing option, the buy down grant will reduce the down payment by approximately 288Tk and the monthly installments by 54Tk.⁵ Although these calculations are relatively crude, they demonstrate that the current price reductions provided under RERED bridge neither the 3,000Tk+ down payment gap nor the 500Tk+ monthly installment gap between the willingness of non owners in Panchua Village to pay and the cost of a system. The exponential growth in SHS sales across the country and the goal of making the industry self-sufficient make it unlikely that the subsidies will increase at all, especially to the level needed to induce these households to purchase a system. It therefore follows that eliminating the subsidy will barely reduce the demand for system in Panchua Village. More research is needed to determine if eliminating the buy down grants would negatively impact SHS sales in other regions of the country.⁶

6.5.4 BARRIERS TO DIFFUSION

Every interviewee was asked their opinion of the three largest barriers limiting the diffusion of SHS (Figure 24). According to owners, the primary barriers to diffusion are all related to cost—many respondents listed three areas of cost (overall cost, down

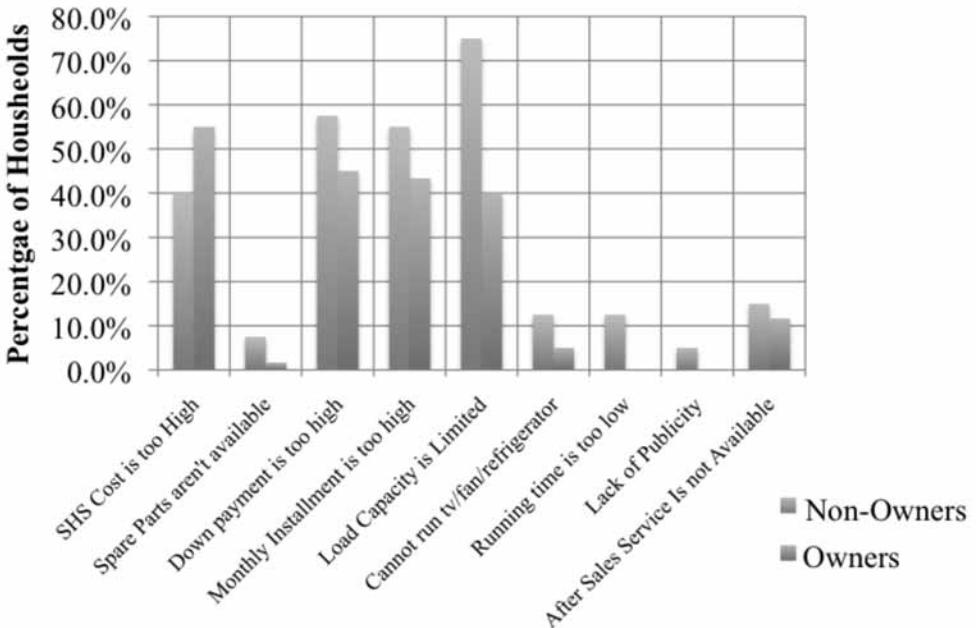
⁵To approximate the difference in down payments, we solved for the difference between 15% of the full cost of 21,400Tk and the post buy down grant cost of 19,480Tk. For the monthly installments, we took the amount of principal remaining after the down payment and multiplied it by the 6% interest rate over three years (e.g. $(21,400 * .85) * (1.06^3)$). We then divided this number by 36 and subtracted the difference to find a difference in monthly installments of 54Tk.

⁶According to officials at several POs the subsidies and financing offered by IDCOL are necessary for their organization to remain solvent. The role of these soft loans is beyond the scope of this paper, and it is important to note that we have disaggregated IDCOL's issuance of subsidies for selling SHS from its extension of credit.

payment amount and monthly installments). Although non owners viewed these cost-related factors as critical, their primary concern was the limited load capacity of the SHS. A possible explanation for this difference is that owners become content with the advantages a SHS provides over kerosene after they purchase a system, while non owners are unwilling to purchase a system until it is able to provide additional services such as running a fan and television. It is interesting to note that neither group listed poor after sales services as one of the most important barriers.

The non owners’ focus on load capacity and cost as barriers to diffusion bode poorly for future SHS sales growth in Panchua Village. Although photovoltaic cell efficiencies are improving every year, it is unlikely that these improvements will increase the capacity of an off-grid SHS to supply the grid-based services without significantly increasing the price. Moreover, the price of a SHS is expected to increase in the short run as increasing sales rates continue to drive down the subsidies offered to POs. In the long run, however, the cost of a SHS should decrease once all components of the SHS are manufactured domestically. With the exception of tube lights and solar panels, all of the component parts of SHS are currently manufactured in Bangladesh. However, Rahimafrooz Renewable Energy plans to set up the first solar panel assembly plant in Bangladesh to take advantage of the growth in off-grid SHS sales (Parvez 2009). It is unclear whether price reductions resulting from these changes will be enough to bridge the gap between non-owner willingness to pay and system costs in Panchua Village.

Figure 24: Graphical depiction of the top three reasons barriers to SHS diffusion according to owners and non owners



7. Conclusion

The off-grid solar home system sector has grown exponentially since the first systems were sold in 1996. This growth was driven by (i) ample sunshine; (ii) a pre-existing infrastructure of microfinance institutions; (iii) superior energy services provided by solar pv over kerosene; (iv) the support of domestic and international institutions; and (v) word of mouth. This paper argues that while first four factors were necessary, the process has been driven by word of mouth starting with first adopters like Mr. Khalek and slowly trickling down through society as a whole.

To test this hypothesis a random sample of SHS owners and non owners in Panchua Village were asked the series of questions provided in Appendices A and B. The data demonstrate that word of mouth was the key driver in knowledge dissemination and sales growth. Ninety-three percent (56 of 60) of SHS owners surveyed first learned about SHS from neighbor, relative, or teacher and 78 percent of owners asserted that they had influenced others to purchase a SHS. The data was not, however, robust enough to determine which characteristics of an owner are correlated with influencing others to purchase a system, and more research is needed to address this question.

The next section of the paper analyzed the alternative hypothesis that price reductions are the key driver of off-grid SHS sales by comparing owners and non owners in Panchua Village. Interestingly, there was not a statistically significant difference between the average income of the owners and non owners. This finding allowed for an in-depth look at why some households elect not to purchase a SHS despite having the same ability to pay as the owners.

The comparative analysis indicates that the gap between the amount a SHS costs and the willingness of the non owners to pay was much larger than the subsidies currently being offered. This finding does not suggest that the higher level of subsidies in the past did not stimulate sales that then triggered word of mouth. However, due to the increasing SHS sales rate across the country and desire of donors to make the industry self-sufficient, it is unlikely that subsidies will return to a level that would drive new sales in Panchua Village. Given the limited geographical scope of this analysis, it is imperative that more geographically diverse studies that draw upon the preliminary conclusions put forth in this paper be undertaken.

The off-grid solar sector in Bangladesh has brought a superior form of lighting to millions of rural Bangladeshis, created thousands of jobs and provided rural Bangladeshis' with new opportunities for income generation. This case study provides many useful insights for policy makers interested in extending energy services to the more than 1.5 billion people who still live off the grid around the globe. Bangladesh did not create a new technology to build this industry; rather, it has succeeded because it was the first place to find a mechanism (microfinance) for putting the technology (solar PV) into the hands of the rural poor. Although this combination might seem obvious in retrospect, the pairing did not yield significant results immediately. In

fact, sales did not grow significantly until the sector integrated the specialties of non-profits (consumer knowledge and entrepreneurial experimentation), international organizations (mobilization of capital and institutional capacity), the government (institutional capacity and market formation) and academics (technical standards and market formation) in 2003. As other countries look to extend energy services to rural areas, they should look to the Bangladesh model as one that succeeded through its leveraging of local advantages, clear policies and patience.

Picture 4: Pronoy and JR outside a Grameen Shakti branch office



Appendix A

QUESTIONNAIRE FOR HOUSEHOLDS WITH SHS

Basic Questions

1. Last Name of SHS owner
2. Location (Village, Union, Uz., District)
3. SHS Owner? (Yes, No)
----- If "no," go to the other Questionnaire -----
4. Type of User: (Commercial, Household)
5. Household Size
6. Number of workers
7. Income Source(s) (Agriculture, Business/Trade, Service, Wage Labor, Remittance (In country), Remittance (Overseas), Livestock/Fish Culture/Poultry, Shrimp, Other)
8. Monthly Expenditures
9. Total Monthly Income
10. Type of House (Cement, Tin, Brick, Mud/Traditional, Other)
11. Organization you bought SHS from? (GS, BRAC, OTHER)
12. System Size & Load Description (lights, mobile charger, tv, plugs, etc.)
13. Date of Installation
14. Payment Type (Cash, Credit)
15. Down Payment _____
16. Number of Total Installments _____
17. Payment per Monthly Installment _____
18. Have you ever failed to make any monthly payments? (Yes, No)
19. If yes, why?
20. What happened?
21. How did you learn about SHS?
22. Why did you decide to buy a SHS?
23. Did you influence anyone else to buy a SHS? How many people?
24. Have you completed all payments for your system? (If yes, ask questions 26– 33)
25. Have you received any services since you finished paying off your system? (Yes, No)
26. Does your organization offer any maintenance options once you own your SHS?
(Yes, No)
27. If yes, do you have a maintenance agreement with your service provider?
28. Why or why not? What is the cost? _____ Tk
29. If not, how do you get maintenance services?
30. Do you need to pay for these services? (Yes, No)
31. Would you be interested in signing a maintenance agreement with the organization that sold you your SHS if it was available? (Yes, No)
32. Would you go to a local technician for long term service if he or she was well-trained? (Yes, No)

Household Characteristics: System Uses

33. System Uses: (Students Studying, Income Generation, Lighting, TV, Mobile Charging, Radio, Domestic Work, Other)
34. Which items have you had to replace?
35. Where did you get the replacement parts?
36. How long did it take to get the replacement parts?
(≤1 day, 1 – 2 Days, 2- 4 Days, 4- 7 Days, 7+ Days)
37. Have you gotten your battery recharged? How much did it cost?
38. If you replaced your battery, how much did the new one cost?
39. Did you get any money for your old one? (Yes, No)
40. If yes, How Much Money? _____ Tk
41. What is your level of satisfaction with your system? (Very Satisfied, Satisfied, Neutral, Unsatisfied, Very Unsatisfied)

Household Characteristics: Training

42. Did you receive an informal training regarding how to use your system when the system was installed? (Yes, No)
43. Did you receive a formal training? (Yes, No)
44. If yes, did you have to pay for it? (Yes, No)
45. What is your level of satisfaction with your training?
(Very Satisfied, Satisfied, Neutral, Unsatisfied, Very Unsatisfied)
46. Would another training session be beneficial? (Yes, No)

Household Characteristics: After Sales Service

47. During the installation period (before the system is paid off) did you need to pay a technician to come to your house/shop to fix problems? (Yes, No)
48. If Yes, how much? _____ Tk
49. If you have a problem with your system, how long does it take for someone to come and fix it? (≤1 day, 1 – 2 Days, 2- 4 Days, 4- 7 Days, 7+ Days)
50. Are you satisfied with your level of after sales service? (Very Satisfied, Satisfied, Neutral, Unsatisfied, Very Unsatisfied)

Household Characteristics: Long Term Issues

51. What are the key barriers limiting the diffusion of SHS?
52. How will you get long term service for your SHS (i.e. after it's paid off)?
53. How much are you willing to pay for long term service per year?
(300 Tk ≤, 300 - 500 Tk, 500 – 700Tk, 700 – 900Tk, Other)
54. Would you be interested in signing a long term maintenance agreement with the organization that sold you your SHS if it was available? (Yes, No)
55. Would you go to a local technician for long term service if he or she was well-trained? (Yes, No)
56. What is the best way to provide long term after sales service?
57. When do you think the national grid will connect your village?
58. What will you do with your SHS when this happens?
59. What are biggest problems and issues you're facing as a SHS owner?
60. How could these issues best be resolved?

Appendix B

QUESTIONNAIRE FOR HOUSEHOLDS WITHOUT SHS

Basic Questions

1. Last Name of SHS Owner
2. Location (Village, Union, Uz., District)
3. Type of User: (Commercial, Household)
4. Household Size
5. Number of workers
6. Income Source(s) (Agriculture, Business/Trade, Service, Wage Labor, Remittance (In country), Remittance (Overseas), Livestock/Fish Culture/Poultry, Shrimp, Other)
7. Monthly Expenditures
8. Monthly Income
9. Type of House (Cement, Tin, Brick, Mud/Traditional, Other)
10. Do you know about SHS? (Yes, No)
11. Do you want a SHS? (Yes, No)
12. What do you use for lighting?
13. How many liters of kerosene do you use per month for lighting?
14. How much money do you spend on lighting each month?
(0 – 50Tk, 50 – 100Tk, 100-150Tk, 150-200Tk, 200-250Tk, 250Tk+)
15. How much per month would you be willing to pay for light from a SHS per month?
(Same as kerosene, 200Tk, 300Tk, 400Tk, 500Tk)
16. What is the highest down payment you are willing to pay for a SHS?
(500Tk, 750Tk, 1,000Tk, 1250Tk, 1500Tk, 1750Tk)
17. Household Characteristics

Household Characteristics: Marketing

17. Have anyone come to your house to advertise a SHS? (Yes, No)
18. Did they try to sell you a system? (Yes, No)
19. In your opinion, what are the key barriers limiting the diffusion of SHS?

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