Impacts of Electrification with Renewable Energies on Local Economies: The Case of India's Rural Areas

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Working Paper Series Vol. 2013-12
March 2013

The International Centre for the Study of East Asian Development, Kitakyushu

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Abstract

For India it is crucial to promote rural electrification to raise the well-being of the people in its rural areas, which have a larger number of population and households than its urban areas. In rural areas of India, two types of electrification are in progress. One is the electrification through connecting to conventional grid. The other is the electrification with renewable energies such as solar, biomass, hydro and so on. Many studies prove positive socio-economic impacts of the electrification with renewable energies in rural areas of developing countries including India. However, are there any significant characteristics in socio-economic impacts of the electrification with renewable energies? The interest of the study is particularly its impacts on local economies such as the creation of new businesses and jobs, agricultural and other productive activities, and household income. The study investigated quantitatively and qualitatively the impacts of two types of electrification on local economies by conducting the interview survey in two grid connected villages and two solar mini-grid villages in Sundarbans, State of West Bengal, India, and then compared these results in two types of villages to identify significant characteristics in the impacts on local economies in solar mini-grid villages compared with grid connected villages.

First of all, the study found that there are positive impacts of electrification on local economies regardless of the types of electrification. Regarding the significant characteristics in the impacts of solar mini-grid electrification on local economies, the study found that: first the share of the households whose primary occupation is small business is significantly larger in solar mini-grid villages than in grid connected villages; second the electricity is not used for agriculture in solar mini-grid villages because of the small capacity of solar power plants; and third an increase of household income after electrification is significantly larger in solar mini-grid villages than in grid connected villages. The study also found that the shares of households without access to electricity even after their villages were electrified are significantly large and furthermore they are much larger in solar mini-grid villages than in grid connected villages. The coexistence of electrified and unelectrified households in the electrified village must be a problematic issue that should be addressed. Nevertheless, the most important finding in the study is that solar energy is able to provide the required energy for development of local economies in the form of markets, powering the schools, health centers etc.

Keywords: India, local economies, mini-grid, renewable energies, rural electrification
JEL Categories: N75, O13, P25, R11

1. Introduction

In India where the share of rural households with access to electricity through conventional grid is about 65.61% of total rural households whereas the share of urban households with access to electricity through connecting to conventional grid is about 93.83% of total urban households, how to promote electrification in rural areas as well as to meet an

increasing demand for electricity in urban areas is a big issue[1]. To remove the disparity between rural and urban areas in terms of access to electricity, the village-based self-reliance electrification with renewable energies such as solar, biomass, hydro and so on, is evolving across India under collaborative efforts of central and local governments/implementing agencies, businesses, research institutes, local NGOs/NPOs and villages themselves (Chaurey A. et al 2012; Government of India 2011; Palit et al. 2011). For rural villages, particularly in remote, where conventional grid cannot be extended because of economic infeasibility or geographical features of their locations, or where it is not economically feasible to build conventional power plants because of their low population densities, or where power is not available during the evening hours even if they are connected to conventional grid, the village-based self-reliance electrification with renewable energies is a promising alternative. There are many studies that investigated and proved positive socio-economic and environmental impacts of the rural electrification with renewable energies in developing countries including India (for example, ADB 2010; Obrecht 2010). The impacts investigated in these studies cover a wide range of socio-economic and environmental aspects such as education, time availability, safety, communication among villagers, exposure to the outside world, income, employment, new business, agricultural productivity, health and so on. These studies include the case studies on the socio-economic and environmental impacts of decentralized power supply from solar photovoltaic (SPV) system and on the implementation of such a system that were conducted in Sundarban islands of India (Bhattacharjee 2002; Chakrabarti S. et al 2002; Ulsrud et al 2011). However, it is not known from these studies whether the village-based self-reliance electrification with renewable energies has any significant characteristics in its socio-economic impacts compared with the electrification through connecting to conventional grid. This study attempts to fill the gap in the research on the socio-economic impacts of the village-based self-reliance electrification with renewable energies, particularly focusing on its impacts on local economies.

The purpose of the study is to identify any significant characteristics in the impacts of the village-based self-reliance electrification with renewable energies on local economies compared with the electrification through connecting to conventional grid. For this purpose,

[1] "Though most rural villages - about 94% - have electricity access, the electrification rate among actual households is much lower - about 67%" (as per IEA 2012). This is because the prevailing definition of electrification (since 2004) is that "A village will be deemed to be electrified if: basic infrastructure such as distribution transformer and distribution lines is provided in the inhabited locality as well as the hamlet where it exists and the number of households electrified should be at least 10% of the total number of households in the village" (Palit and Chaurey 2011).

the study investigated quantitatively and qualitatively the impacts of these two types of electrification on local economies such as the creation of new businesses and jobs, agricultural and other productive activities, and household income by conducting the interview survey in two grid connected villages and two solar mini-grid villages in Sundarbans, State of West Bengal, India, and then compared the interview survey results in two types of villages to identify any significant characteristics in the impacts on local economies in solar mini-grid villages compared with grid connected villages. In Sundarbans, two different types of electrification are implemented. One type is the grid connected electrification where the villages are electrified through connecting to conventional grid. Another type is the solar mini-grid electrification where the villages are electrified with solar mini-grid systems[2]. In a solar mini-grid village, individual households, shops and restaurants in the village are connected to a solar power plant installed in a village by mini-grid.

Next section (Section 2) discusses the research methodology including the methodological framework and the interview survey conducted in Sundarbans to collect the necessary information and data. Section 3 discusses the interview survey results and the analysis on them. In the end, Section 4 concludes by summarizing the study findings and discussing some issues in the rural electrification with renewable energies.

2. Research Methodology

2.1 Methodological Framework

The basic framework in conducting the study is the following. First, to investigate the impacts of two types of rural electrification, namely the rural electrification through connecting to conventional grid and the rural electrification with renewable energies (specifically solar mini-grid system), on local economies, qualitative and quantitative data were collected by conducting the interview survey in grid connected villages and solar mini-grid villages in Sundarbans. Then, to identify any significant characteristics in the impacts of the rural electrification with solar mini-grid systems on local economies, the impacts on local economies in two types of villages were compared and analyzed qualitatively and quantitatively. Since many households in both grid connected villages and solar mini-grid villages have no access to electricity even their villages were electrified, the interview survey

[2] The village-based self-reliance electrification with renewable energies in India can be categorized by energy source (solar, biomass, hydro etc.) and also by system in the case of using solar energy (solar mini-grid system, solar charging station and solar home lighting system).

also included these unelecrified households as well as electrified households to investigate whether there are any impacts of the electrification on unelectrified households[3]. Figure 1 shows the types of villages and households targeted in the study with gray colored boxes.

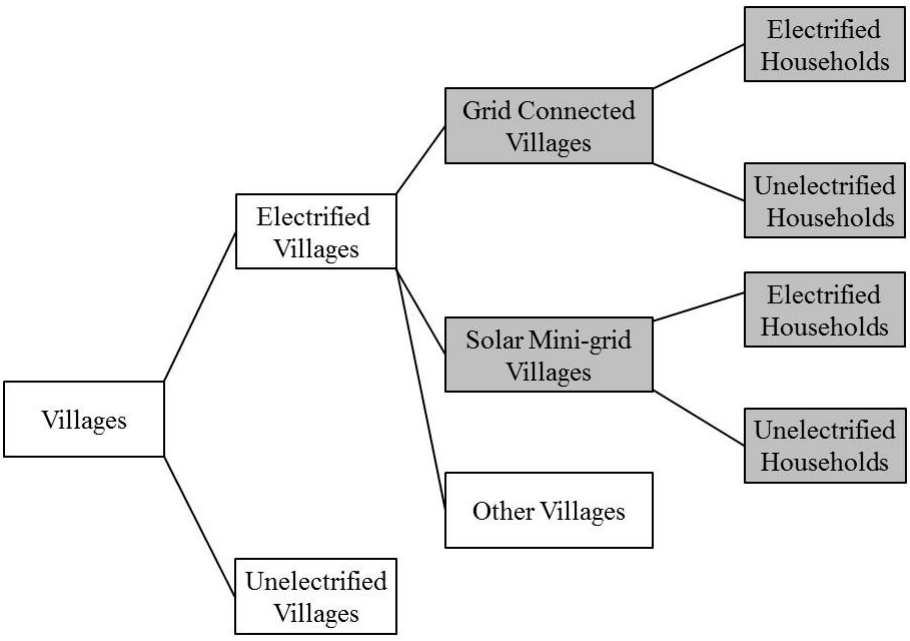


Figure 1. Types of Villages and Households Targeted in the Study

2.2 Interview Survey

The interview survey was conducted in Sundarbans, a delta region in the southeastern part of India's state of West Bengal. Sundarbans was chosen because in the region there are different types of villages in terms of technologies used for electrification, namely, grid connected villages, solar mini-grid villages and so on, and also because many villages there have been successfully electrified with solar-mini grid systems (Chaudhuri 2007) [4]. In addition, the closeness of the locations of grid connected village clusters and solar mini-grid

[3] Many households are not electrified even after their villages were electrified for a variety of reasons: first they are scattered far from distribution lines; second they can not afford the expense of electricity; third the capacity of solar power plants is small; and fourth the power is not often available during the evening hours when households need electricity the most.

[4] Regarding solar power plants in Sundarbans, West Bengal Renewable Energy Development Agency (WBREDA) have installed around 17 solar mini-grids in the region with aggregate capacity of more than 900 kWp. Out of those seventeen, 10 are located in Sagar Island, 2 each in Mousuni, Patharpratima and Sandeshkhali Islands and one in Gosaba Island. Two solar mini-grid villages, Bagdanga and Baliara, where the interview survey was conducted, are in Mousuni Island. The capacity of solar power plants in Bagdang and Baliara is 55kW and 110kW respectively. The mini-grids are funded by the Ministry of New and Renewable Energy (MNRE), Indian Renewable Development Agency, the local government and the World Bank.

village clusters in Sundarbans was expected to cut the cost of conducting the interview survey. The interview survey was conducted by a team of the Energy and Resources Institute (TERI) during December 2012 – January 2013.

To conduct the interview survey in Sundarbans, firstly, two "village clusters" (locally called Gram Panchayat as per decentralized system of governance in India), namely a grid connected village cluster and a solar mini-grid village cluster, were selected. Secondly, two villages from each of these two village clusters were selected taking into account the number of households and the generation capacity of solar power plants so that the selected sample villages are not much different in their size and socio-economic and cultural habits[5]. Figure 2 shows the locations of these four villages (Budhakhali, Bishalakshmipur, Bagdanga, and Baliara). All of these four villages are located in Block of NAMKHANA, District of SOUTH 24 PARGANA, State of WEST BENGAL.

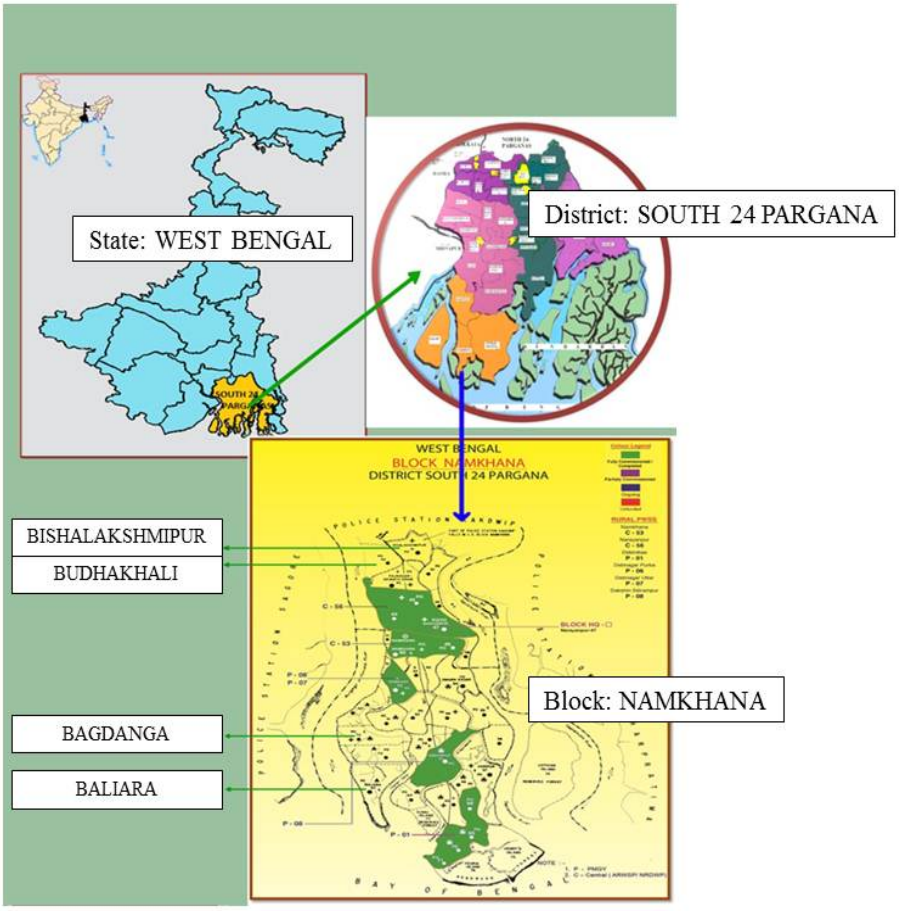


Figure 2. Locations of Selected Four Villages for Interview Survey

[5] If the number of households or socio-economic and cultural habits in those selected villages is very different, the impacts of electrification on local economies become biased.

In the end, 50 households (40 electrified and 10 unelectrified) were randomly selected from the two grid connected villages (Budhakhali and Bishalakshmipur) and two solar mini-grid villages (Bagdanga and Baliara) respectively. However, to investigate the impacts of electrification on the village markets in detail, the sample size of electrified households in the solar mini-grid villages was kept almost equal for small-business households and farming/salaried workers/other households since the solar mini-grid has been predominantly providing electricity to the market area as well as to individual households (but not for agriculture). The solar mini-grid was designed and built in such a way that it can cover the market as well as domestic houses. Since the demand from market was high and the mini-grid was also built near to the market area, everybody in the market availed electricity connections. However, for the large village with the limited capacity of solar power plant the distribution line was not possible to be taken to every corner of the village (otherwise technical loss will be more and quality of electricity will be poor) and as a result all households could not be connected. In total, 100 households (80 electrified and 20 unelectrified) were randomly selected for the interview survey. Table 1 shows the numbers of households in four villages selected for the interview survey and also the numbers of households randomly selected in these four villages for the interview survey.

Table 1. Number of Households in Villages and for Interview Survey

Village	Technology used for electrification (Time of being electrified)	Number of households in village			Number of households for interview survey		
		Electrified households	Unelectrified households	Total	Electrified households	Unelectrified households	Total
Budhakhali	Grid connected village (2000 June)	1,293 (80.4%)	316 (19.6%)	1,609 (100.0%)	35	6	41
Bishalaksh-mipur	Grid connected village (1997 April)	1,162 (59.0%)	807 (41.0%)	1,969 (100.0%)	5	4	9
Subtotal		2,455 (68.6%)	1,123 (31.4%)	3,578 (100.0 %)	40	10	50
Bagdanga,	Solar mini-grid village (2001 March)	160 (21.0%)	602 (79.0%)	762 (100.0%)	20	5	25
Baliara	Solar mini-grid village (2003 April)	300 (18.5%)	1,323 (81.5%)	1,623 (100.0%)	20	5	25
Subtotal		460 (19.3%)	1,925 (80.7%)	2,385 (100.0 %)	40	10	50
Total		2,915 (48.9%)	3,048 (51.1%)	5,963 (100.0 %)	80	20	100

In conducting the interview survey in selected four villages, first, village level data such as the total number of households, the numbers of households by primary occupation etc. were collected from the Gram Panchayat office as well as local Revenue department office, and then households level data such as their primary occupations and monthly income etc. were collected from the heads of the households or any senior members of the households. The interview survey included the households running small business such as shops, restaurants, and repairing mobiles etc. in local markets (the owners of these small businesses are from the same locality), the households of salaried workers and of labor workers as well as the households of farming.

3. Interview Survey Results and Analysis

This section compares the impacts of electrification on local economies, specifically on the creation of small businesses and jobs, agricultural and other productive activities, and household income, in grid connected villages and solar mini-grid villages based on the interview survey results. It also discusses significant characteristics in the impacts on local economies in solar mini-grid villages compared with those in grid connected villages.

3.1 Impacts on the Creation of Small Businesses and Jobs

To investigate the impacts of electrification on the creation of small businesses and jobs, it is useful to look at how the occupations of the households in the village changed after the village was electrified. The results of the interview survey at household level show that many households started new small business after the village was electrified. Eleven out of 40 electrified households in grid connected villages answered that after the village electrification they started new businesses or jobs for additional income, for example, a new job as an electrician, betel leaf producing, husking business, groceries business, mobile shop etc. whereas 9 out of 40 electrified households in solar mini-grid villages answered that after the village electrification they started small groceries shop, photo studio and printing shop, carpentry shop etc. Even unelectrified households benefit from the village electrification. In grid connected villages, 1 out of 10 unelectrified households answered that after the village electrification it started new small business and 3 answered that they would start new businesses or jobs if they can have access to electricity. In solar mini-grid villages, 1 out of 10 unelectrified households answered that after the village electrification it started new small business in the market and 1 answered that it would start readymade garment making. These

interview survey results are understandable since having access to electricity makes it possible to start small shops, restaurants or small businesses in the village market.

The impacts of electrification on the creation of small businesses and jobs are also reflected in the distribution of households by primary occupation. Households in the village can be categorized into six groups according to their primary occupations: farming, small business, salaried (government), salaried (private), agricultural workers and landless. Farming households have their own land for farming. Their livelihood depends on growing crops (paddy, vegetables etc.) and selling them in the market. Small business households run small business such as garment shops, restaurants, mobile repairing etc. Salaried households have family members who work for the government or private companies. Agricultural workers work as laborers in other farmers' land in lieu of a daily wage or share in the cropping (called share-cropper). They don't own the farming land themselves, but may have some land only for residing/house. Landless do not own any land (farming or residing/house) and earn their livelihood by working as laborers in agricultural field or fishing for daily wage. They live on rent in someone's house or in small houses built on government land. Primary occupation is a main source of income for the household. Figure 3 shows the distribution of the households by primary occupation in four sample villages based on the interview survey at village level (refer to Table 1 for total numbers of the households in four sample villages). Not surprisingly, the share of farming households is the largest in all of four sample villages. Its share is 70.2% in Budhakhali, 70.4% in Bishalakshmipur, 68.8% in Bagdanga, and 74.6% in Baliara. Though there is not any significant difference in the share of farming households between grid connected villages (Budhakhali and Bishalakshmipur) and solar mini-grid villages (Bagdanga and Baliara), there is a significant difference in the shares of small business households and landless households between them. The interview survey results show that the share of small business households in solar mini-grid villages is much larger than the one in grid connected villages. It is 17.1% in Bagdanga (130 out of 762 households) and 9.9% in Baliara (160 out of 1,623 households) whereas 4.4% in Budhakhali (70 out of 1,609 households) and also in Bishalakshmipur (87 out of 1,969 households). Regarding the share of landless households, it is much smaller in solar mini-grid villages than in grid connected villages. It is 3.0% in Bagdanga (23 out of 762 households) and 3.9% in Baliara (64 out of 1,623 households) whereas 9.3% in Budhakhali (150 out of 1,609 households) and also 9.3% in Bishalakshmipur (183 out of 1,969 households).

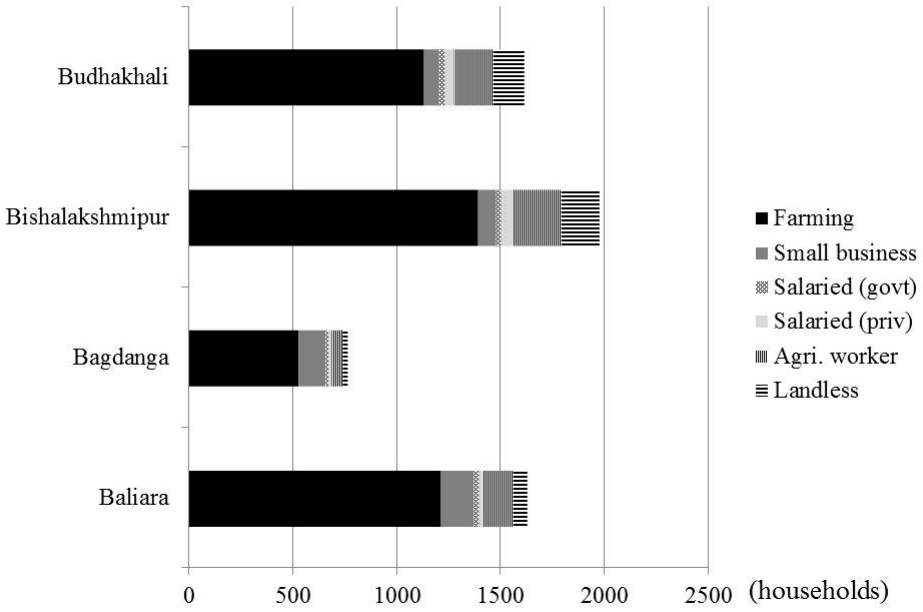


Figure 3. Distribution of Households by Primary Occupation in Four Sample Villages

To analyze the cause behind the larger share of small business households in solar mini-grid villages compared with that in grid connected villages, the numbers of small businesses and shops in the markets of two types of villages were investigated. Table 2 shows the types and numbers of permanent small businesses and shops in four sample village markets before and after electrification[6]. Before Bagdanga and Baliara were electrified in 2001 and 2003 respectively, the numbers of permanent small businesses and shops were approximately 80-82 in Bagdanga market and 30-32 in Baliara market. However, as of the interview survey, there are approximately 120 in Bagdanga market and 160 in Baliara market. These numbers of permanent small businesses and shops in two markets of solar mini-grid villages are almost the same as the numbers of small business households in Bagdanga and Baliara as of the interview survey (130 and 160 respectively). Therefore, it is likely that in two solar mini-grid villages the electrification gave the incentives to start the new businesses in the market to their households. Since the solar mini-grid was designed and built in such a way that it can cover the market as well as domestic houses, the households in the solar mini-grid villages must have high incentives to start new business in the markets either as a primary income source or as a secondary income source. Budhakhali and Bishalakshmipur have their common market named Ukilerhat Babosaye Kalyan Samity. Before Budhakhali and Bishalakshmipur were electrified in 2000 and 1997 respectively, the number of permanent small businesses and

[6] New types of business such as battery charging units, photo copier, photo studio, pharmacy etc., for which the people had to go to a main town in Namkhana by crossing the river, were also started.

shops in the market was only 150. However, as of the interview survey, there are approximately 750 permanent small businesses and shops in Ukilerhat Babosaye Kalyan Samity, which is much larger than the total number of small business households in Budhakhali and Bishalakshmipur (157). It suggests that quite a few households outside Budhakhali and Bishalakshmipur run small businesses in Ukilerhat Babosaye Kalyan Samity. However, it is not clear from the interview survey results why in two grid connected villages the electrification did not give the incentives to start the new businesses in the market to their households.

Table 2. Numbers of Small Business and Shops before and after Electrification

Village	Market	Types and numbers of permanent small business and shops	
		Before village electrification	After village electrification
Budhakhali (Grid connected)	Ukilerhat Babosaye Kalyan Samity	Types of permanent small business and shops are not available (Approx. 150).	Hotel, medicine shop, stationery, groceries, hardware, electrical instrument, oil mill, rice/flakes husking, milk shop, wine shop, restaurant, green vegetables, fruit, jewelry, fish vendor, book stall, ration shop, garment shop, confectionery, cycle repairing, saloon, mobile selling and repairing shop, tea stall, meat shop, iron grill and window making, carpentry etc. (Approx. 750).
Bishalakshmipur (Grid connected)			
Bagdanga (Solar mini-grid)	Bagdanga Market	Mainly groceries, readymade garments, tea stall, stationery and etc. (Approx. 80-82).	Groceries, tea stall, stationery shop, electrical instruments, fish vendor, photo copier and photo studio, green vegetables, restaurant, confectionery shop, jewelry, cycle repairing, carpentry/furniture making, cloth stores, medicine, hardware, tailoring shop. (Approx. 120)
Baliara (Solar mini-grid)	Baliara Market	Mainly groceries, garments, tea stall, stationery and etc. (Approx. 30-32).	Groceries, tea stall, stationery, electrical instrument, photo copier and photo studio, mobile recharge and repairing shop, medicine shop, tea stall, tailoring shop, carpentry/furniture shop, confectionery, jewelry, cycle repairing, watch repairing. (Approx. 160)

3.2 Impacts on Agricultural and Other Productive Activities

The results of the interview survey at village level show that two grid connected villages use electricity for lighting/fan/TV at households, small business and shops, school/health centers, and street lights, and also for irrigation water pumps and other agricultural equipments such as paddy thrasher, whereas two solar mini-grid villages use electricity only for lighting/fan/TV at households, small business and shops, school/health centers, and street

lights, but not for agricultural activities. The solar power plants were installed under the government program for providing only basic electricity services to remote areas and so agricultural load was not considered while implementing the plants as this would have needed a much higher capacity plant thereby increasing their capital cost. Furthermore, in grid connected villages electricity is available 20-22 hours a day whereas in solar mini-grid villages electricity is available only five hours in the evening. The limited power supply in solar mini-grid villages is understandable because the capacity of solar power plants is only 55 kW in Bagdanga and 110 kW in Baliara[7]. In the grid connected villages, after the electrification, many farmers started (1) double cropping and multi cropping owing to electricity for irrigation water pumps though previously a very little number of farmers did so and (2) producing betel leaf in the villages since females can work on cutting betel leaf inside their houses owing to lighting by electricity. The households in grid connected villages also produce readymade garment and do muri (puffed rice) making and zori (embroidery) work in addition to agricultural products such as rice, betel, chili, green vegetables and pulses. However, the households in solar mini-grid villages do not produce any other products besides agricultural products such as rice, green vegetables and betel.

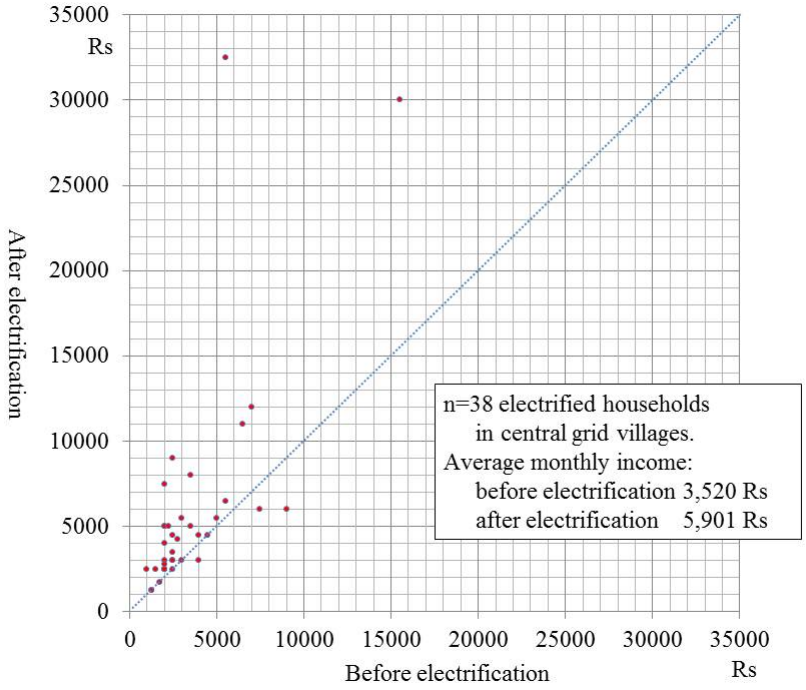
In addition, according to the results of the interview survey at household level, 11 out of 24 farming households in grid connected villages answered that using electricity increased agricultural productivity and that in the future new cold storage can be available for preservation of agricultural products (and fish).

3.3 Impacts on Household Income

Figure 4 and Figure 5 show the monthly income before and after electrification for electrified households in grid connected villages and solar mini-grid villages respectively. Though the number of interviewed electrified households in grid connected villages is 40, 2 electrified households were removed from the analysis because of unavailability of the data on their monthly income. Therefore, the number of sample electrified households in grid connected villages is 38. Similarly, though the number of interviewed electrified households

[7] Because of the small capacity of solar power plants, 79.0% of the households in Bagdanga and 81.5% of the households in Baliara do not have access to electricity whereas in grid connected villages, only 19.6% of the households in Budhakhali and 41.0% of the households in Bishalakshmipur do not (refer to Table 1). Regarding the fee to have access to electricity, the households in the solar mini-grid villages paid 500 rupees when they took connection in early 2000. The monthly fee based on flat rate is 75-135 rupees which is about 1.0-1.8% of the average monthly income of sample electrified households in solar mini-grid villages after electrification (7,595 rupees). One rupee is equivalent to 1.77 Japanese yen as of March 13, 2013.

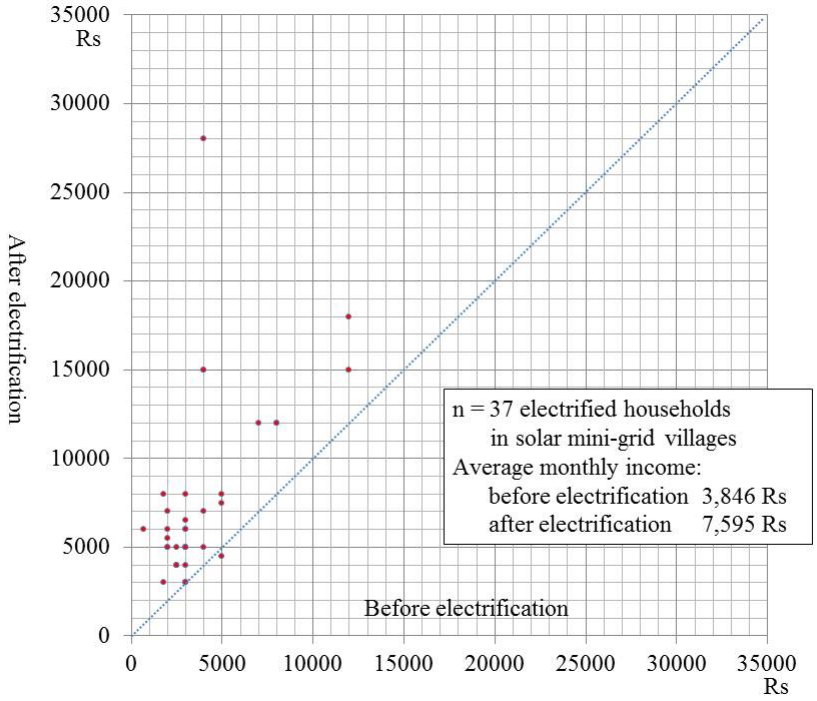
in solar mini-grid villages is 40, 2 electrified households were removed from the analysis because of unavailability of the data on their monthly income and in addition 1 electrified household (a salaried worker for government) was removed as an outlier since its monthly income is too large (70,000 rupees) compared with other households. Therefore, the number of sample electrified households in solar mini-grid villages is 37. Both figures indicate that there is an increase in monthly income after the electrification for a majority of the households in two types of villages. More accurately, for 29 out of 38 sample electrified households in grid connected villages their monthly income increased after the electrification whereas for 33 out of 37 sample electrified households in solar mini-grid villages their monthly income increased after the electrification. The average monthly income of 38 sample electrified households in grid connected villages increased by 67.64% (from 3,520 rupees to 5,901 rupees) in nominal terms whereas the one of 37 sample electrified households in solar mini-grid villages increased by 97.48% (from 3,846 rupees to 7,595 rupees) in nominal terms [8]. To test whether an increase in monthly income after electrification is statistically significant, one-tailed t-test was conducted. Its results show that an increase is statistically significant at significance level of 0.01 (Table 3).



Note: Since there are households whose incomes before as well as after electrification are the same, the number of dots in the figure (32 dots) is inconsistent with the number of sample households (38).

Figure 4. Monthly Income before and after Electrification: Electrified Households in Central Grid Villages

[8] The Planning Commission, Government of India, set the poverty line at 965 rupees per capita per month in urban areas and 781 rupees per capita per month in rural area.



Note: Since there are households whose incomes before as well as after electrification are the same, the number of dots in the figure (26 dots) is inconsistent with the number of sample households (37).

Figure 5. Monthly Income before and after Electrification: Electrified Households in Solar Mini-Grid Villages

Table 3. Descriptive Statistics on Monthly Income and Significance Test Results on Monthly Income Change (Electrified Households)

	Electrified households in grid connected villages		Electrified households in solar mini-grid villages	
	Monthly income before electrification	Monthly income after electrification	Monthly income before electrification	Monthly income after electrification
Sample size (n)	38		37	
Mean	3,519.7 Rs	5,902.3 Rs	3,845.9 Rs	7,594.6 Rs
Standard deviation.	2,740.1 Rs	6,541.8 Rs	2,542.4 Rs	5,174.5 Rs
Maximum value	15,500.0 Rs	32,500.0 Rs	12,000.0 Rs	28,000.0 Rs
Minimum value	1,000.0 Rs	1,250.0 Rs	700.0 Rs	3,000.0 Rs
P- value (One-Tailed t-Test)	0.002867**		0.00000244**	

**: Statistically significant at $\alpha = 0.01$

To analyze the cause behind the larger increase of average monthly income in solar mini-grid villages than in grid connected villages (an increase of 97.48% against an increase of 67.64%), the impact of electrification on average monthly income by primary occupation was investigated. Since the size of land holdings affects the income from farming, farming households were divided into two groups by the size of their land holdings measured in unit of 'Bigha' (1 hectare = 7.5 Bigha): farming households with 0.5-2.5 Bigha land and farming

households with 3-7 Bigha land. Salaried (public and private) households were removed from the analysis because they are not found in sample households in solar mini-grid villages and also because monthly income of such occupation is not affected by electrification. Furthermore, the households whose primary occupation is agricultural workers were also removed from the analysis because those households were not found in sample households. Figure 6 and Figure 7 show the average monthly income in four different primary occupations, namely farming with 0.5-2.5 Bigha land, farming with 3-7 Bigha land, small business and labor work (landless), before and after electrification. They show that for all of four different primary occupations an increase of average monthly income is significantly larger in solar mini-grid villages than in grid connected villages. This is likely to be attributed to the higher average monthly incomes in farming (3-7 Bigha land), small business and labor work in solar mini-grid villages compared with those in grid connected villages. Table 4 shows the average monthly income by income source based on the data of sample households. It indicates that the average monthly incomes of farming, small business, and labor work are larger in solar mini-grid villages than in grid connected villages. Since many households have double income sources of farming and small business after the village electrification, such a double income is very likely to increase the average monthly income of the households whose primary occupations are either farming (3-7 Bigha land) or small business in solar mini-grid villages more than in grid connected villages.

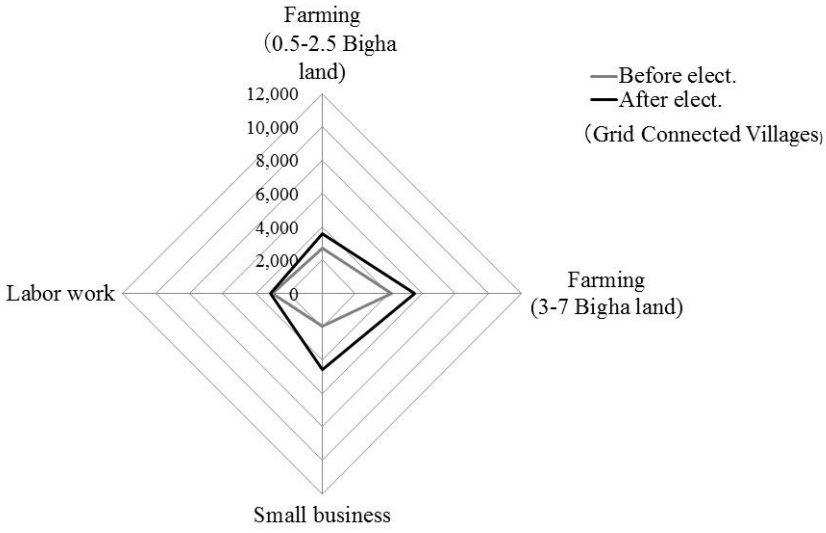


Figure 6. Average Monthly Income in Four Primary Occupations in Grid Connected Villages

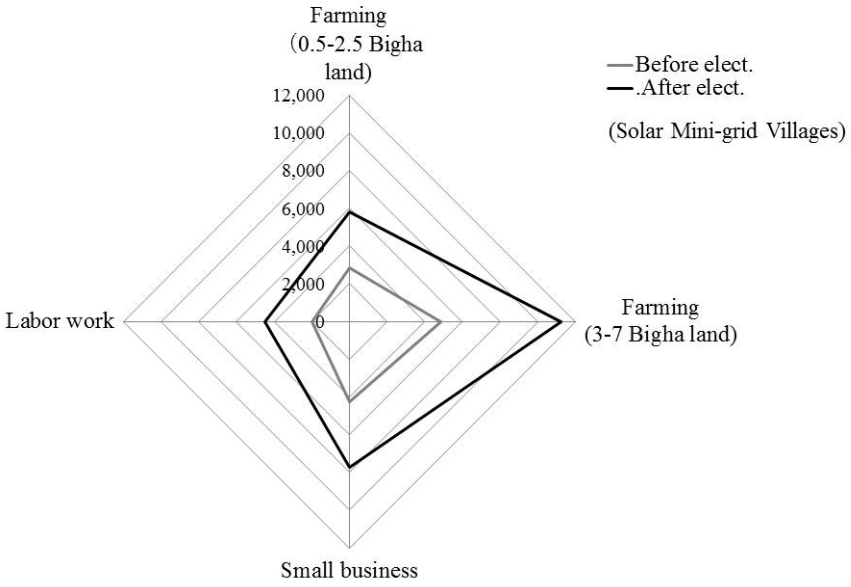


Figure 7. Average Monthly Income in Four Primary Occupations in Solar Mini-grid Villages

Table 4. Average Monthly Income by Income Source

(Rupees)

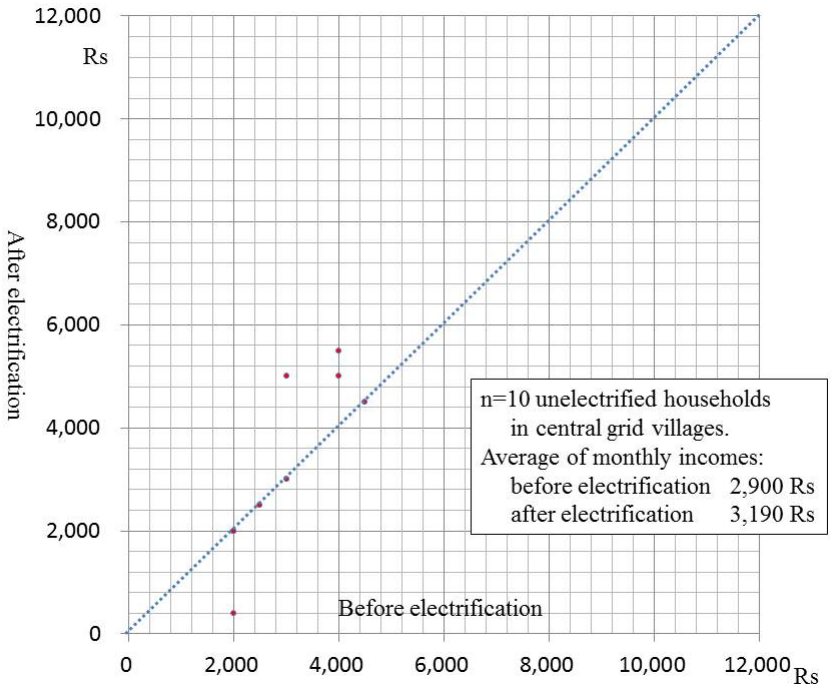
	Farming (0.5-2.5 Bigha land)	Farming (3-7 Bigha land)	Small business	Labor work
Budhakhali & Bishalakshimipur (Grid connected villages)				
Electrified households	2,656	3,136	3,596	3,123
Unelectrified households	N/A	3,000	2,600	3,500
Bagdanga & Baliara (Solar mini-grid villages)				
Electrified households	1,962	4,550	4,891	4,028
Uneletrified households	1,000*		5,000	4,889

*Land size is not available.

Furthermore, even unelectrified households benefit from the village electrification in terms of income. Figure 8 and Figure 9 show the monthly income of sample unelectrified households before and after electrification in grid connected villages and solar mini-grid villages respectively. They indicate that there is a significant increase of monthly income after electrification in solar mini-grid villages (more exactly, 9 out of 10 uelectrified households) whereas there is not in grid connected village (only 3 out of 10 unelectrified households). The results of one-tailed t-test conducted to test whether an increase in monthly income after electrification is statistically significant show that an increase in solar mini-grid villages is

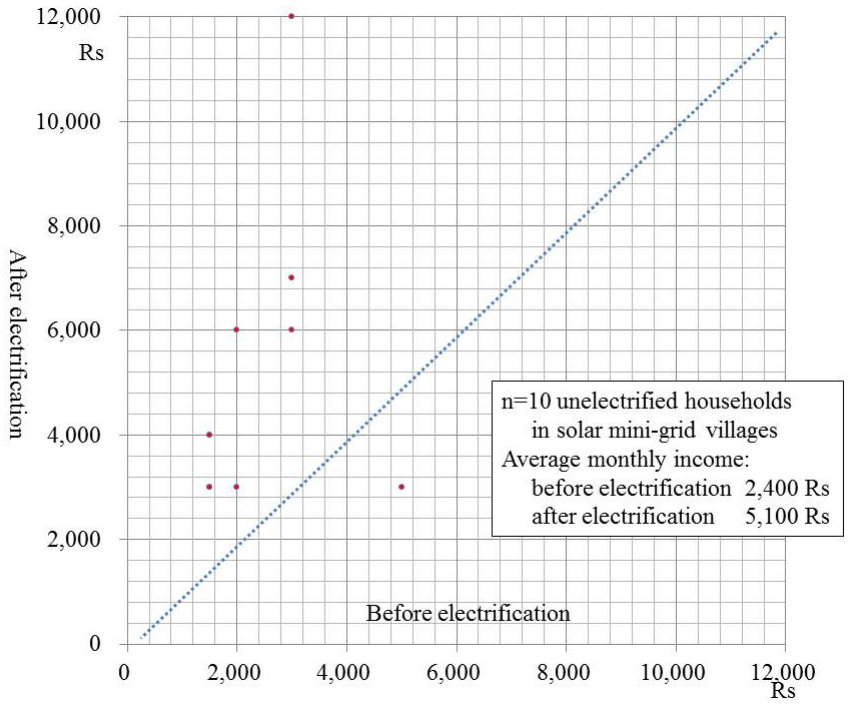
statistically significant at significance level of 0.01 whereas an increase in grid connected villages is not statistically significant (Table 5). According to the results of the interview survey at household level in solar mini-grid villages, as the causes behind an increase in monthly income, 5 households said “an increase in daily labor fee” (since they work as laborer in addition to farming), 3 households “family members migrated to work,” and 1 household “starting new business.”

The electrified households are better-off by electrification compared with unelectrified households. The average monthly income of sample electrified households after electrification is 5,901 rupees in grid connected villages and 7,595 rupees in solar mini-grid villages (refer to Figure 4 and Figure 5) whereas that of sample unelectrified households after electrification is 3,190 rupees in grid connected villages and 5,100 rupees in solar mini-grid villages (refer to Figure 8 and Figure 9).



Note: Since there are households whose incomes before as well as after electrification are the same, the number of dots in the figure (8 dots) is inconsistent with the number of sample households (10).

Figure 8. Monthly Income before and after Electrification: Unelectrified Households in Central Grid Villages



Note: Since there are households whose incomes before as well as after electrification are the same, the number of dots in the figure (8 dots) is inconsistent with the number of sample households (10).

Figure 9. Monthly Income before and after Electrification: Unelectrified Households in Solar Mini-grid Villages

Table 5. Descriptive Statistics on Monthly Income and Significance Test Results on Monthly Income Change (Unelectrified Households)

	Unnelectrified households in grid connected villages		Unelectrified households in solar mini-grid villages	
	Monthly income before electrification	Monthly income after electrification	Monthly income before electrification	Monthly income after electrification
Sample size (n)	10		10	
Mean	2,900.0 Rs	3,190.0 Rs	2,400.0	5,100.0
Standard deviation.	966.1 Rs	1,704.5 Rs	1,125.5	2,846.1
Maximum value	4,500.0 Rs	5,500.0 Rs	5,000.0	12,000.0
Minimum value	2,000.0 Rs	400.0 Rs	1,500.0	3,000.0
P- value (One-Tailed t-Test)	0.1911		0.00703**	

**: Statistically significant at $\alpha = 0.01$

4. Conclusion

The study found that there are positive impacts of electrification on local economies, namely the creation of new small businesses and jobs, agricultural and other productive activities, and household income, regardless of the types of electrification. Regarding

significant characteristics in the impacts of the electrification with solar mini-grid systems on local economies, the study found that: first, the share of the households whose primary occupation is small business is significantly larger in solar mini-grid villages than in grid connected villages; second, the use of electricity is not allowed for agriculture in solar mini-grid villages because of the small capacity of solar power plants; and third, an increase of household income after electrification is significantly larger in solar mini-grid villages than in grid connected villages. However, the further study is necessary to ascertain whether these characteristics in the impacts on local economies found in sample solar mini-grid villages can be generally found in the rural electrification with renewable energies. The study also found that there are electrified and unelectrified households in the same village. Particularly, the share of unelectrified households is much larger in solar mini-grid villages than in grid connected villages though many of the unelectrified households in solar mini-grid have solar home system in their houses, procured either through bank financing or subsidy under the Ministry of New and Renewable Energy (MNRE) program. Furthermore, though unelectrified households also benefit from village electrification, the coexistence of electrified and unelectrified households in the same village is problematic for both grid connected and renewable based electrification villages as some households do not take connection due to higher cost of connection or inability to pay the monthly tariff. Nevertheless, the most important finding in the study is that solar energy is also able to provide the required energy for development of local economy in the form of markets, powering the schools, health centers etc.

The choice between the electrification through connecting to grid and the electrification with renewable energies depends not only on their benefits such as positive socio-economic and environmental impacts but also on their costs such as the costs of power generation and distribution and of relevant maintenance, which are reflected in electricity price. Furthermore, the interview survey found that while the solar mini-grid electrified households said that the quality of electricity was good and there was no voltage drop at the end of the distribution line, those who had grid electricity complained about the quality of electricity and said that there was always drop in voltage making it problematic to run appliances such as refrigerators, fan etc. With decreasing capital costs of SPV and other renewables and almost similar benefits and impacts on local economy, as this study points out, renewables should also be considered as a means of electrification for providing basic electricity services in all rural areas (and not just areas where grid electrification is not feasible) in addition to conventional grid extension. This will not only assist in faster pace of electrification as lead time for decentralized

technologies are lower, but at the same time will also address the impacts of climate change. However, these may require more comprehensive study on costs with advancement of technology as well as intended use for electrification (e.g. basic electricity services, small businesses and or agricultural connections etc.) to determine which type of rural electrification is appropriate for a specific area.

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