4 CHAPTER – 4

CASE STUDY- DATA AND OFF-GRID VILLAGE DEVELOPMENT

The objective of the case study is to find out if solar PV can provide subsidy-free electricity and meet rural household and community ICET needs. Considering the current strength of local SPV resources and global opportunities of energy efficient ICET infrastructures, I want to see how new SPV energy technologies challenge the rural electric grid in a typical village setting. My study will show that solar technology is least cost, is affordable, and can help villages leapfrog the fossil-grid subsidy age. By getting rid of the rural subsidy obligation for the grid industry, the urban markets can be made economically subsidy free as has been the case worldwide. This is an important contribution to the literature and also has significant practical implication on the delivery of foreign aid, or in the global climate change debate as I will show in Chapter 6. To show that SPVs are competitive, I need to find the capacity and willingness to pay of the villagers. The income and price data from the village will provide the input for demand modeling. Then I compare the demand to costs in Chapter 5.

4.1 Outline of This Chapter

I collected data to understand what type of energy sources to choose and to observe the benefits or problems of the solar electricity. Data on the village's demography, economy, and energy were collected at the beginning of the research in late 2003 to understand the energy consumption, income, household preferences, and whether modern SPVs have any impact on the villagers. The broad outlines of the case study are as follows.

1. Selection of the sample village and data gathering
2. Data analysis at the community, household, individual level
3. Feasibility of SPV electricity for JABA village
4. Implementation of SPV energy based alternate initiatives for meeting the basic ICET electricity needs of villagers:
    - Portable firm and home lighting with the introduction of SPV for lighting
    - Radio, fan, computer, wireless telephone, and internet
5. Study Observations and Analysis

4.2 Village Selection

For the case study, I selected rural areas in the state Orissa in India where I was born and with which I am most familiar. This choice meant I could get resources from my family, relatives, and acquaintances to carry out this project that was expected to continue for at least 5 years. The village Jahangirabad, where I was born, is connected to two more villages, Balabhadrapur and Kalyanpur and all three villages are situated on the bank of a small river (Figure 4-5). I selected the two villages Jahangirabad and Balabhadrapur (here after referred to as one JABA village) both situated on one side of the river. Intensive primary data collection was done in 2003 to understand their energy, income, and quality of life. Although the data is limited to two village hamlets, these are typical villages in Indian eastern plain but are not as poor as the tribal lands in the mountains and forests of Orissa. The results of this study, to my knowledge, can be safely

Figure 4-1 Location of the JABA village in eastern coastal state of Orissa in India

generalized to most plain areas of eastern India with a high concentration of rural population at more than 150 million. The objective was initially to implement small renewable energy projects based on small hydro, SPV, or biogas in order to observe how modern renewable electricity could compete with the existing grid. As these villages were electrified around 1975, I could compare the decades old grid with my private entrepreneurial efforts to provide off-grid SPV lights. If the SPV or other renewables could be commercial and successful in an already electrified village, the SPVs should also be successful in the large markets of India's remaining 20% yet to be electrified villages. As the demography, lifestyle, level of income and fraction of electrification (30-40% of the village households) were very similar to highly populated villages in the eastern coastal plain geographical region of India, I limited my intensive renewable energy project implementation to JABA village. Though only 104 households were selected, they constitute a very wide diversity of income, education, land endowment, social caste grouping, and household sizes. Further this size of the sample household, while being reasonable for statistical inferences, also helped us to limit the financial commitment and the capital investment within my limited annual budget of about $2,000, which later increased to more than $5000 by 2005 and $10,000 in 2008 from voluntary contributions and many fund raising events in India and the USA. The renewable energy implementation in JABA village is very broad (comprising biogas, SPV and some solar heating) and covers numerous end uses of cooking, lighting, running electronics for this thesis. I will focus here on applications of off-grid SPV and the rural grid.

4.3 JABA Village Description

This section contains the data collection and observation in JABA village in Orissa at the community, household, and individual levels. The reason for the selection of SPV is discussed along with the initial mixed result of success and failure of the private supply of SPV lighting. Electricity and kerosene use and income data collected from the door-to-door survey of 98 households in December 2003 will be used in my demand estimates in Chapter 5. The JABA village sample was selected from the geographical region as shown below in the Wikimapia Google Earth pictures (in Figure 4-3 and 4-4) within the polygon.

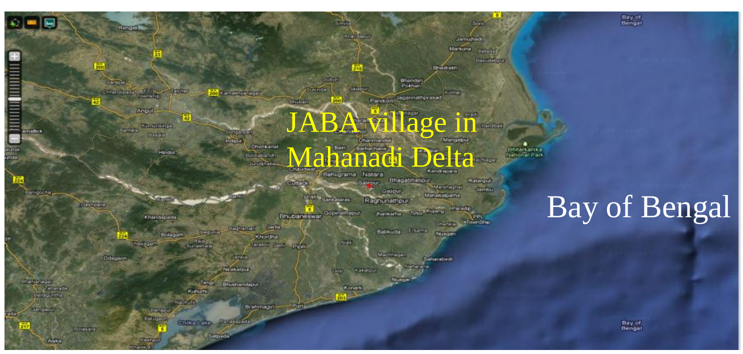

Figure 4-2 JABA village in the Mahanadi river delta of Orissa’s Katak district

Figure 4-3 JABA operation villages are in the middle of plain land of Mahanadi delta

Please note the rows of the green tree lined hamlets in between the network of rivers. This is the famous Mahandi Delta close to the East Coast, Bay of Bengal and one of the most fertile and culturally advanced lands in the state of Orissa. The larger polygon below in Figure 4-4 shows the area where the off-grid renewable projects are implemented and from which the data were collected. The small brown patches in between the green tree-lines in the Google map (Figure 4-5) below are the housing settlements, and the large patches of plain lands are used for agriculture on which the villagers produce mostly rice, pulses, and other grains. Vegetables are produced in small parcels of land surrounding the homes.

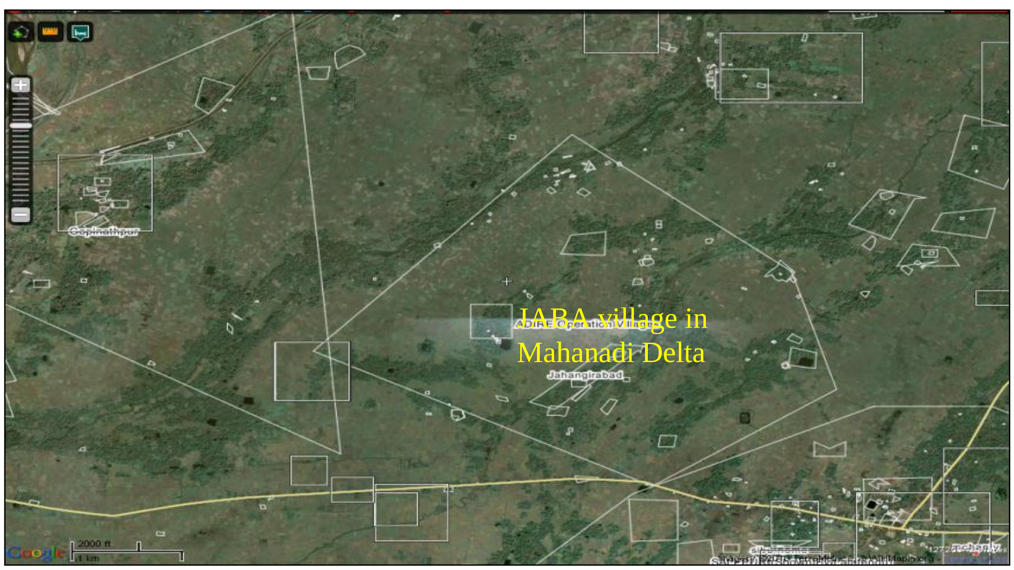

Figure 4-4 Closer view of the area surrounding JABA village

Figure 4-5 JABA village on one side of the small stream Kundi
Source: Wikimapia. 2010. (www.wikimapia.org search words: ADIRE, Katak)

The data collected are from individuals, households, and for the community.

Individual data: At the individual level, the JABA project team (later christened a non-profit trust named ADIRE) founded by me and led by my 80 year old father, collected the age, sex, education, health condition, needs and expectations of each family member. This allowed us to design our energy system to be of maximum value to the villagers and to prioritize their stated or perceived needs. If electricity is not the essential need at the moment for many individuals, the demand can be quite low. The electric blackouts, low voltage at the distant end of the line, and shorted electrical circuits are so normal that the villagers keep kerosene lamps in standby at all times.

Household level: We collected detailed house types (mud or brick wall; straw, concrete or tin roof), number of rooms, if it contain a bathroom, number of toilets, how much land, how many cows, and other assets that were easily identified from visual observation and face-to-face interview. The number of appliances and electrical devices were also noted during the interviews. The kerosene consumption reported by the villagers is typically their monthly controlled allocation by the government except for a few rich people who report more than their allocation. For grid using households, electricity use was estimated from their monthly bills. In many cases, the bills were not available and I used their recalled average monthly payments, prevailing electricity rates, or the number and wattage of electricity devices to compute the average kWh. However, many electrified villagers also did not know or had never even heard of a kWh. The kerosene and electricity data along with income data were used for the demand estimation.

Community data: Initially the agricultural, forest, grazing land, types, and number of trees, river water flow, and solar radiation data were collected by experienced villagers in very qualitative terms. It was easily noticeable that except for an un-electrified school building of four rooms, there was no other public building for any community gathering. The road was not suitable for motor vehicles and the flooding of river water, when it rained, kept villagers two miles from the local shopping center and paved road. Thus, a normal rain or storm brought the community to a standstill.

4.4 Data Gathering and Analysis

Primary household and community data were gathered with the help of five locally hired staff members in the village based on a detailed questionnaire emailed before the survey was conducted in summer of 2003. The project and data collection was supervised through the internet and ultimately verified in each of our annual field visits from 2003 onwards. This village is partly electrified; had a few rich but otherwise mostly poor households. All poor people are mostly illiterate, but there are a very few highly educated professors and engineers who live outside the village and send money to their parents. Like any caste-based society in Indian villages, I found all four castes in the village with the two upper classes richer and the two lower classes poorer. These classes also follow the same order of their social statuses as presented below with their locally known sub caste in the parenthesis.

Brahmin- teachers and worshippers,

Kshyatriya- administrators, farmers and accountant (sub caste: Chasa)

Vaisyhya- business(sub caste: Behera), and

Harijjana- labor providers (sub castes Bauri, Samal, Sethy) also called *Constitutional Scheduled Caste (SC)* with special legal status designed to bring them out of social and economic backwardness. They benefit from affirmative action programs in higher education and government jobs. All four castes live in perfect amity in this village of 104 households in JABA village. The Bauri and Sethy communities live in the electrified hamlet of the village but the Samal community is about 200 yards away from the nearest electric pole. There has been no demand for the grid supply from the Samal community. In 2009, they were told they would get electricity access through the subsidized program but at the completion of my thesis, nothing has been done.

The economic, skill, and education capabilities of the households in each class are equally diverse across these castes as can be seen from Table 4-1. Many upper class families are also poor because population growth lowered their per capita land holdings and they may have a lower skill level, making them unsuitable for any productive job. They are also hesitant to do pure labor and seek opportunities through government grants.

The closest city Kataka is about 25 miles from this village, but when the project started the village was still isolated from the nearby road from lack of the last mile of connectivity through a bridge.

4.4.1 Preliminary data analysis

The initial primary data illustrates mostly very low income with inequity of income and electrification of this caste-based society. The summary data below in Figure 4-1shows the poor state of the village. Like any other average village in Orissa, land ownership is less than 2 acres per farming households. The lack of sanitation is shown by the fact that only 30% of households have toilets. A clean drinking water supply could only be provided through ten hand pumps at the start of this research project. The new biogas digester, solar lanterns, and LED lights are also recent additions from 2003 of the village experiment arising out of this research.

Table 4-1 The state of JABA village: demography, income and some recent energy transition

Description	**Numbers**	**% of Total**	**Note**
Total Population	417		Total households 104
Farm Earners	87	21%	Total 135 acres
Cash Earners	48	12%	Jobs/Business
Toilets	30	7%	
Water Pump	10	2%	
Households (HH) Income/Energy use	**Number of HHs**	**% of households**	
Poor	100	96%	(Income <$200/m)
Rich	4	4%	(Income > $100/m)
Energy in households			
Wood/Dung	100	96%	Non-commercial 80 Kg/month
Kerosene	100	96%	Subsidized 3 liters/month
Electricity	40	38%	Subsidized from 1970s
LPG	6	6%	Subsidized from 1995
Biogas	10	10%	Unsubsidized from 2003
Solar Lantern	22	5%	5 homes with students subsidized shops Unsubsidized from 2003
LEDs	20	20%	Unsubsidized from 2005

Out of 104 households, only forty families had a grid electricity connection when we started the survey with average connection growth of less than two per year after 25 years of electrification. The village was first electrified in the mid-1970s. The rest of the households could not or were not interested because of unaffordably high costs related to the initial electricity connection, house wiring, and appliances needed to benefit from electricity. Figure 4-6 shows the acres of land in the family and the number of rooms in the house for the different castes. The land endowment and housing size of the upper three classes are much higher than the SC households. The focus of my initial research was on these SC households comprising 40% of the population with no electricity, education, or non-labor income. The SC group has significantly less agricultural land with only labor as a source of income

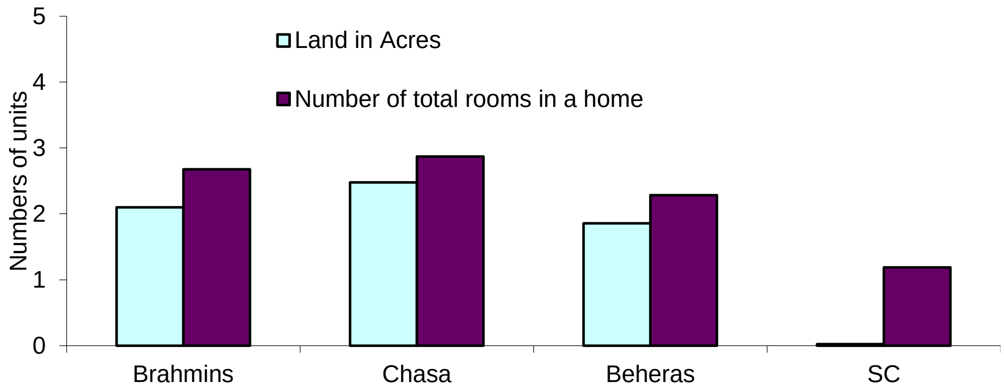

Figure 4-6 The land and resources of the stratified village

From figure 4-7, it is clear that most households have no concrete roofs, which is considered not only a matter of prestige and social status but also a safety issue during the frequent storms that often hit Orissa's coast. Even the upper classes have no toilets in their house, though they have electricity. Most households have one or two rooms, so the amount of electricity to light these homes is small.

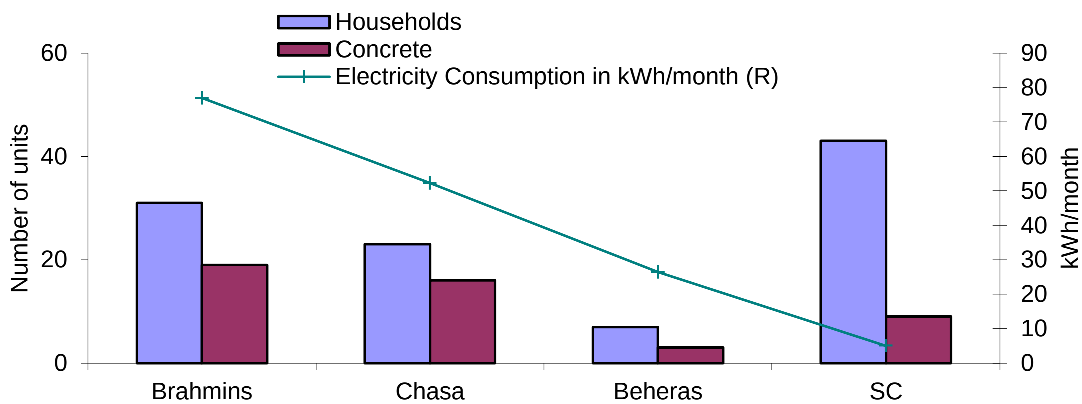

Figure 4-7 Housing and electricity consumption of the stratified JABA village

This encouraged us to try solar lantern and LED based solutions as well as to set up community facilities where a cluster of houses could try the solar-powered lights, TVs, and fans. These services could be supplied to households with a monthly fee to make the electricity service subsidy-free.

4.4.2 Income, expenditure budgets and spending profile

Table 4-1 shows the correlation between the high penetration of electricity and the economic and educational achievement across these castes: the higher classes are on the left and the lowest backward group with little education is on the right in Table 4-2.

Table 4-2 Household data (monthly average) 1 $ = 43.5 Rs. (Indian Rs)

	Social Groups	**Brahmin**	**Chasa**	**Behera**	**Harijan(SC)**
A	**Occupation & Education**				
1	Major Occupation	Service, Farming, Worship, landlord	Service, Farming, Petty contract / politics	Cow herds, farming	Washing, lease farming, land less labor
2	Highest Education	PhD/ Graduate	College	High School	High School
3	Majority Adult Level Education	High School	High School	Elementary	Elementary
B	**Demography**				
1	Number of Households	33	22	7	42
2	Total Members	152	90	37	138
C	**Sources of Income**				
1	Cash Income from **(Rs./month)**	3826	3695	3629	1450
2	Crop Income from Farm **(Rs./month)**	1591	995	1157	0
D	**Mandatory Expense**				
1	Food Exp. @ 10 Rs./day/head	1636	1227	1586	1000
2	Disposable Income after Food per month	3780	3464	3200	450
3	% Household with less food than minimum	0%	0%	0%	7%
E	**Energy Use**				
1	House % electrified	76%	55%	29%	5%
2	Number of rooms in a house	4	3	2	1
3	Electricity kWh/month	99	100	93	60
4	Electric heater Y/N	9%	0%	0%	0%
5	LPG access (Numbers)	5	1	0	0
6	Kerosene in liters	4	2	2	3
7	Fuel wood in Kgs	97	87	87	80
8	Fuel Expense Rs.	175	118	111	113
9	Electricity Expenses per electrified household Rs.	128.4	122.8	112.5	75
10	Electricity +Fuel Expenses Rs.	269	185	144	113
11	As % of Disposable Income	7%	5%	5%	23%

Source: JABA Case Study, 2009 Data collected in 2003

From the village survey, I estimated that a daily food expense of about Rs.10 per capita is required for minimum nutrition. With this level of food expense, I found about three SC families that did not have enough food to eat. The majority of the SC families and even many upper class families are undernourished due to malnutrition, unhygienic cooking practices, or eating stale food. The lack of proper storage facilities for the cooked food and the poor quality of the houses also adds to food contamination. The households also suffer from many water borne diseases, which are curable at a low cost through proper sanitation and clean drinking water. Neither a poorly funded government nor the villagers themselves (with their low education and cultural practices) have implemented these low cost efforts. The cost of numerous festivals, rituals, and family rites are considered indispensable compared to discretionary health and education spending. Regarding health related spending, our data showed that around 80% of the villagers had never been to a hospital nor had they consulted a doctor for years.

The relevance of such economic conditions is that villagers have many unmet needs and are badly in need of developmental aid besides just clean energy and electricity. Thus extending the grid, as has been the case for years, will not lead to the automatic increase in subsidy free demand for electricity. The energy expenses for lighting, electricity, and cooking have to be balanced with expenses for other daily necessities including food, drinking water, health, and education many of which have non-electric inputs. The doctors, medicines, teachers, electrical devices, and comfortable houses are all required to attract and retain these skilled people. Thus, social and economic development is also essential for SPVs or the grid electricity to be used productively and to be paid for. Electricity demand for such impoverished villages can be very small to begin with and can be easily supplied effectively through SPVs.

An electricity grid, which is important for large scale production, delivery and electrification of a rich home, has no use in such poor homes and communities with few appliances and cannot be paid for and will remain unviable. But SPV electricity on a small-scale could be viable because the monthly payment will be low. Light and small ICET devices such as a small TV and a cell phone can be easily and affordably powered from the sun and stored in rechargeable batteries to be used just when and in the quantity required. SPV supply, being modular, can suit the electricity budget of the poor, which is no more than $2-5 per month. The SPV delivers value to the community when complementary inputs such as a health center and schools exist that have appliances, lighting fixtures, or even computers to be used by skilled people. If health centers and schools need electricity, they can buy SPV electricity or rent it as and when they need it. Extending an electric grid at a huge cost, as in the RGGVY plan, to a school boundary without a budget for a school building, wiring, electrical devices and teachers and teaching aids will not be subsidy free and is economically wasteful.

Sources of Income: The data in Table 4-3 to 4-5 explain the basic economic activities and the factor incomes in JABA village. As the skill is only based on manual and primitive labor, the income for most villagers is at the subsistence level. These levels of skill, income, and socio-economic development do not show that village electrification has played any significant impact on modernizing or improving the productive potential of the villagers. Some income comes from government jobs or contracts, but most villagers are still farmers, farm laborers, or religious workers with minimal subsistence income.

Table 4-3 Income sources and activities in JABA village in 2003

Factors	Households own	Available units	Average Factors/HH	Income per month	Total village income per month	Household Income per per month
Skill	20	30 people	1.50	$ 100.00	$ 3,000	150.00
Labor	95	200 people	2.11	$ 25.00	$ 5,000	52.63
Farm Land	58	136 acres	2.34	$ 40.00	$ 5,440	93.79
Housing Land	104	50 acres	0.48	$ 10.00	$ 500	4.81
Waste Land	Com-munity	25 acres	0.24	NA	NA	NA

Table 4-4 Occupation in JABA village in 2003

Breakdown of the village activities	Population	Fraction %
1. Daily chores household	94	23%
2. Farm earners cultivation seasonal job	87	21%
3. Cash earners productive year round in government supported work	48	12%
4. Children unproductive	75	18%
5. Men idle unproductive	96	23%
6. Sick	15	4%
Total	415	100%
Breakdown of the 12% or 48 year round productive workers as (3) above		
Small Business	13	3.2%
Service in government jobs/funded projects	9	2.2%
Driving	6	1.5%
Mechanic	5	1.2%
Religious workers	5	1.2%
Medicine store	3	0.7%
Carpenter	2	0.5%
Computer (live outside the village)	2	0.5%
Mason	2	0.5%
Contractor	1	0.2%
Total	48	12.0%

Table 4-5 JABA village household electricity use and incomes

Group Name	Primary Income Sources	Fuel Sources	Number of household s	Consumption kWh/month (Q)	Price c/kWh (P)	Income /month (Y)
Electrified Poor	Labor	Electricity	32	70	3	55
Non-electrified Poor	Labor	Kerosene	58	1	90	53
Electrified not so Poor	Skill, Capital, Land	Electricity	8	200	3	240

Source: JABA case study, 2009

4.5 JABA Village Energy Data Analysis

Table 4-6 shows the energy consumption in JABA village compared to all of India, Eastern India, and Orissa. There is less firewood use in the village. The average electricity use is relatively high, possibly because the village has been electrified for a much longer period than the average households/villages in the comparison.

Household energy spending and willingness to pay:

Residential energy spending is dependent on the household size, type of house, residents' activities, weather conditions, culture, income, price of energy, and the actual availability of the energy resources. Only four households have adequate income to regularly consume their 2 liter monthly quota of heavily subsidized kerosene available at $0.50 or 30% of the market price. It is a valuable fuel for lighting and cooking as a cheaper and much more predictable alternative to grid electricity. Only two families had installed cow dung based biogas plants costing about $60 under a matching government subsidy program. Many others still use cow dung as cooking fuel with all its negative effects on the health of women and children. Only two houses of the lowest socio economically deprived 42 SC households have electricity for lighting. All others do not have the land to keep cows or grow biomass for cooking fuel. They spend a considerable amount of time daily gathering biomass and often consuming unhealthy food in the absence of adequate fuel. The next forty relatively well-off households that have electricity, struggle to regularly pay their roughly two-dollar monthly electricity bill, which is heavily subsidized from the local utility. Sixty households still do not have electricity after decades of electrification and 3 years after the launch of the high profile RGGVY program in the country.

Table 4-6 Comparisons of JABA village energy consumption with that in India, Eastern India and Orissa

Sl No	Item		JABA	Orissa	East Coast Plain	India
1	Firewood	Kg/capita/day	0.69	2.10	1.19	1.22
2	Cow dung	Kg/capita/day	0.29	0.43	0.52	0.4
3	Agricultural residue	Kg/capita/day	0.65	0.65	0.73	0.47
4	Kerosene	liters/household/day	0.09		0.12	0.13
5	Electricity	kWh/all household/day	1.50		0.43	0.54

Source: Estimated from Dutta et al. 1997; Pohekar et al. 2005; MNRE 2009; and JABA case study

The electricity deprivation of the SC communities is shown in Figure 4-8. The two SC communities belong to economically and socially weaker sections of the society and have no electricity connection as shown in the right categories. Of about 100 resident families (4 families are non-residents) needing electricity service, 60 very poor families with incomes less than $50/month, still did not have the subsidized electricity by 2008. These families use inefficient kerosene lamps due to very low subsidized kerosene costs, which are not available to SPV devices. The rate of growth of the grid electrification of the village was less than 2% per year considering only about 30 households connected in 2003 and only about 40 households connected in 2008.This slow connection rate is despite the promises of the RGGVY in 2005 to connect all these poor houses to the grid. A recent survey showed that many poor homes in the un-electrified SC cluster have been provided electric wiring for about a year now, with a grid line yet to come near their homes.

The upper class families with a greater desire for reading and writing aspire to get an electricity connection. The villagers do not use many expensive electrical appliances as could be seen from Table 4-7. Only one house uses room heating and a washing machine, two houses have water heaters; four houses have refrigerators and eight households use water pumping in the absence of any piped water supply. After damage to the color TV from extreme voltage variations, one family spent around $100 for a stabilizer but could not afford to repair the TV. Therefore, it is clear to me that there is hardly any consumer paying capacity or willingness to pay for the government grid electricity that is being planned for these communities.

Only an affordable and reliable source of energy will be sustainable. Even a small quantity is acceptable, if they can pay only a little now and consume more as their income grows and the technology proves reliable and becomes acceptable.

Most of the villagers were living in mud and thatched houses with very little cash expense to maintain until the 2000 super cyclone damaged their houses. After the cyclone in 2000, the government gave grants for building one roomed houses, but still only 30% of the houses have a concrete roof.[1]

This research, therefore, tried to assess how small the demand is for electricity, and why many families do not even care to acquire electricity services. An initial observation in the village showed very low demand for energy and electric lighting in most of the homes. This result matches with the recently released study in villages in Utter Pradesh (MNRE, 2009).

Even in electrified homes, the types of appliances used were not very efficient when we started the survey. Fluorescent tube lights were used by only 35% of electrified homes. However, in a later survey, we found that many electrified homes switched to fluorescent lamps with the efficiency awareness spread through this project, reduced costs of lamps, and the one-year warranty provided by the suppliers.

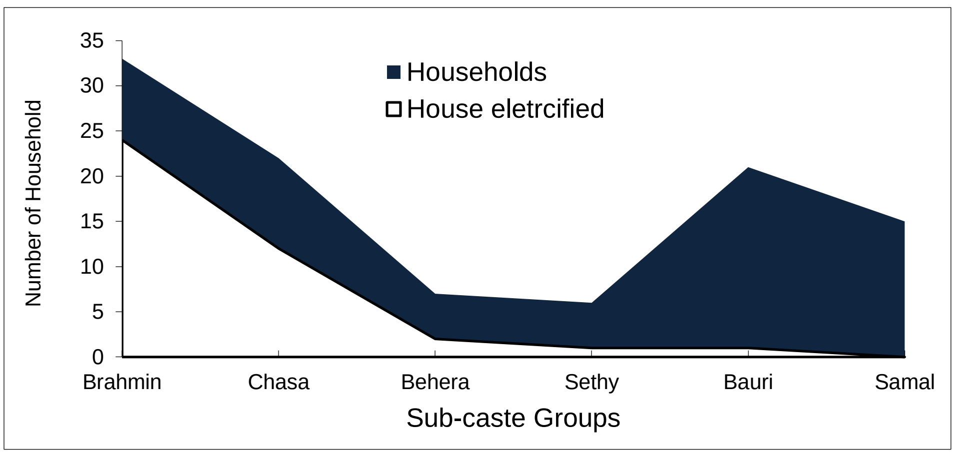

Figure 4-8 Electrification in JABA village by numbers in each caste group (2003)

Table 4-7 Number and types of appliances in 2003 used by the electrified households

	Bulbs	Fan	TV	Tube-light	Water Pump	Refrigerator	Water heater	Washer/ Drier
Total numbers	184	78	32	17	8	4	2	1
HHs have	40	32	32	14	8	4	2	1
HHs do not have	64	72	72	90	96	100	102	103
% HH don't have	62%	69%	69%	87%	92%	96%	98%	99%

[1] Inadequate household income evidently works against any credit offer for housing from the commercial banks that led to the government decision to provide grant. The same credit issue also explains why there is no market for consumer finance in rural areas from the electricity appliances to the grid connection costs or modern SPV devices. As a government grant is limited in a developing country with low tax base, it is essential to target such grant and subsidies wisely to reduce the future costs and increase revenue. I thought that SPV devices could meet this objective very well. A one-time investment in solar light will reduce the cost of the electricity connection and perpetual subsidies for the electricity or kerosene costs. It might also increase the education and income of the villagers if they use the brighter, pollution-free, safe light during evening times instead of kerosene. Instead of a grant to households, it is felt that the SPV lights can be paid for by the households on a daily/weekly/monthly basis as is done for the kerosene.

The picture below shows the energy using assets of one middle class home with an income above $200/month. They are still using the primitive wick lamps shown in between two kerosene hurricane lanterns. Also shown are a kerosene container bottle with a blue funnel on the top and a camphor-fuming device (extreme right behind the wood pole and on the right of a big rice storage silo) for repelling mosquitoes in an electrified home.

Figure 4-9 Kerosene lanterns in a grid electrified home

The data that we collected also showed us various important unmet needs of the villagers. Water, toilets, roads, and a hospital were most needed by the villagers as inferred from the survey results shown in Table 4-8 below. When we estimated the budget to meet these very basic needs, the energy budget was only about 10% of the total.

Table 4-8 What the villagers need the most-Not Energy ($1= Approx. 45 Rs).

Important Basic Needs	**Number of people wanted**	**Quantity Planned**	**Budget in Rs.**
Toilet	210	42	50,000
Road	186	2 Km	50,000
Bridge	101	200 meters	200,000
Hospital	66	2 beds	50,000
Water Pump	53	5 KW	50,000
Water	47	10 Hand pumps	50,000
Energy	12	20 solar lights	70,000 (11%)
Park/Library	1	1 building	10,000
Temple	15		100,000
Total Initial Investment Plan in 2003			630,000

Only 12 people showed an interest in some form of energy for light or cooking fuel. Even after villagers were told about the solar lights and shown the solar lantern in action in the village-park, during road construction, and for farm production activities, the interest of the poor remained lukewarm as the cost was perceived to be high, and to make this affordable a small micro loan would be necessary. Unless the very poor are provided modern education, health, services and production tools, they do not see the need for electricity and are not willing to pay for it. When they are not willing to pay for the low cost SPV, it is hard to imagine how they will pay for the higher cost grid power. This might explain the very low growth of the grid connection, less than 2% per year, and the continuing need for high subsidies for the uneconomic rural grid. This low growth is a commercial problem for the grid business as grid supply and investment cannot be controlled in small lots to meet the current needs of the rural poor. However, the SPV based lighting, ICET, can be exactly matched with the poor's demand level, and the capacity factor of such devices would be higher than that of the grid. The government provision of solar lights to 100% of the electrified villagers in the state of Haryana for study also shows the poor value of the grid for education. This could be equally applicable to this Orissa village. I inferred from this case study that starting with small portable SPV based lighting, phone, and TV and then graduating to higher electricity loads for pumps, fans, and transportation will avoid such redundant investments in both the grid and the SPV in Indian villages. This will drive economical and ecologically sustainable development without the worry of global warming and local pollution. Such a phased implementation will be subsidy free and encourage efficiency that has not been possible in the rural grid business.

Electricity, the most expensive subsidized fuel in rural India, is mostly used by the rich villagers, while kerosene is used by the poor. (See Table 4-9 for energy subsidies in JABA village.) The rich households get about $12/month of grid electricity subsidies at 90% of the cost as can be observed from Table 4-9. This important information can indicate the barriers that government subsidies can create to adopt new technologies. While looking for a comparison of the true average costs of the grid with the SPV systems, I could not get any publicly available data from the Indian utilities but could roughly impute the grid costs based on the literature (Owen, 2004; Miller, 2003) of at least 30 cents/kWh This led me to consider introducing the SPV to compete with grid as an individual entrepreneur. All poor and rich villagers including my family members are not convinced that I can make the argument that SPV is cheaper than grid when the SPV upfront cost is so high and grid upfront cost is negligible and the monthly costs villagers pay are about $2 as shown in the table. It is also difficult to convince villagers to pay the true costs of SPV as they do not appreciate that they get about 90% subsidies in the grid supply because it is not mentioned anywhere in the bill or newspaper. However, they still complain that grid power is unaffordable compared to their income. To spend 2-4% of income only on electricity when the food and milk share is 90% of the remaining costs is not a small matter for them (Bose and Shukla, 2001). This is an initial problem of any commercial venture around an SPV system in Indian villages. The more the grid is subsidized, the more will be the need to subsidize SPVs to enter the rural market.

Table 4-9 What is subsidized the most? Grid electricity!

Source	Quantity / month	units	Market Price $/unit	Market Cost $/month	Subsidized Price $/unit	Subsidized Cost $/month	% Income spent	% subsidies
Electricity	70	kWh	0.30	14	0.03	2.10	2-4%	90%
Biomass	80	Kg	0.30	24	0.30	2.40	2%	0%
Cow Manure	50	Kg	0.00	5	0.00	0.00	0%	0%
Kerosene	3	Liters	0.80	2	0.25	0.66	1%	70%

4.6 JABA Village Renewable Energy Feasibility

Various renewable energy resources such as biomass, hydro, wind, biogas, and solar in the village can be considered. I will show that SPV even at its current high price could be the best option with the lower village consumption and skill levels in the face of adequate solar resource endowment in the village. I will also show that though they cannot be developed immediately due to lack of skill and awareness, the other available renewable technologies can be usefully applied in the village and will be cheaper than the grid. I have deferred the implementation of these projects in the village but will take them up later if the SPV prices do not fall significantly in the next 5-10 years, and/or if the village demand for electricity increases to a high level where SPV cannot meet those needs. After 7 years of observation, I see that neither the villager’s skill nor demand have increased significantly enough to explore the mini-grid solutions. Before I discuss the opportunities and issues of the solar project in this case study, I briefly review the village energy resources that prompted us to select SPV.

4.6.1 Energy endowment and technology selection (state Orissa and JABA village)

Biomass: The state of Orissa is full of agricultural and forest lands; agriculture taking up a very high percentage of the geographical area in all the districts. Rice is a big part of the cultivated crops. Rice husks are normally used as cattle feed, and rice straw bales are often used as thatch for poor houses. After a year of use as shelter, they are further used as organic decomposition in an open pit. Both rice husks and straw are very useful for biomass energy applications. In addition, there are special kinds of wood, which can be transformed into biomass power that are available in the forests of Orissa, but not close to JABA village. Due to current alternative uses of the existing biomass resources, the cost of transportation for distant wood, and the complexity involved in setting up a biomass power plant and getting the skills to run them, we did not consider biomass an option for the village.

Micro Hydro: In JABA village, there is a small water stream called Kundi River. It has water only during the monsoon and is almost dry during all other seasons. The river is extremely dependent on rain and canal water and, located in a plain area, may require a large reservoir in this populous terrain. It would be very expensive to have a minimum water head for a conventional micro hydro plant. The river water, during the rainy season, as a dam or a dyke will not create any usable water head due to the excessive flooding. Thus, a micro hydro project was immediately abandoned. But a waste area of about 25 acres in the river bank on one side of JABA provides good opportunities to harness solar and biomass energy for export to nearby villages or future local consumption.

Small Wind: The availability of another important energy resource, *wind,* is low in JABA village. Wind maps of India indicate no good wind potential in this location. The capital and skill required to set up, operate, and maintain a wind plant is also difficult to find here.

Thus, with no cheap land, capital, skill, and water resources available for biomass, small hydro and wind power projects, they were dropped. So now, we are left with two more viable rural energy resources. The first is cow manure for the production of biogas (a gaseous mixture of methane and CO using the anaerobic digesting process) popularized by the Indian government for heating and cooking applications; this is practical in almost 40% of Indian rural households with 3-4 cows. The second is modern solar electricity using SPV technology that was yet to be popular in rural or urban applications, when we started this project.

Biogas: The biogas energy sources in JABA are about 167-200 cattle with an average of two cattle per household. Cattle dung is widely used as a dried fuel cake for cooking. Women, besides their other daily chores, normally prepare this cheap but dirty fuel when they have no other productive jobs. The biogas program to convert this useful organic matter to both energy and fertilizers is very large in India. JABA got this technology only in the last 5 years with our effort. It is possible to convert biogas to electricity through cheap gasoline generators to back up SPV electricity, but we do not find that necessary at the current level of village demand. This is a valuable energy source for electrical energy at a price lower than SPV for village production centers. However, it lacks the portability, modularity, safety, and low operating and maintenance benefits of the SPV, which is more useful to power small electrical and ICET devices of the poor households in the village. In order to provide a large amount of clean heating energy and reduce the need for household solar electricity, biogas projects were implemented in JABA. This, however, helped only the relatively richer households with enough cows, land and access to water and cheap unused labor. Most of these households also have access to the highly subsidized grid electricity. Further, the use of biogas for cooking by the richer households can hinder the economies of scale electricity grid. Thus having chosen SPV, I will turn to SPV resource endowments in the village.

SPV electricity: SPV was selected for domestic lighting due to year-round availability of solar energy in JABA village, and the access to enough land area to generate solar electricity from private rooftops and backyards without requiring land acquisition or the complex organization to manage a hydro or biogas project. I will describe the more recent solar endowment data now available for Orissa from a study by Diederichs (2009) as the local information was not available at the start of the project. We depended on a NASA study, which is not very different from the data we have now. The following data will show the minimum and maximum solar endowments that can be used as the range of solar insolation available in the village.

Solar Resources of Orissa: In the entire state of Orissa, the air temperature varies through the year from 17 °C to 32 °C and the ground temperature varies from 18 °C to 36 °C. The annual mean temperature is amongst the highest on earth, with an annual average of about 28 °C. The most important factor is the "Insolation incident on a horizontal surface". Its annual average values are between 4.68 kilowatt hours per square meter per day (kWh/m2/day) and 5.00 kWh/m2/day. The daylight hours do not vary very much throughout Orissa, with a maximum in June/July and clear skies most of the time except the rainy season. The clear sky days vary from an annual average of six to nine days with the clearest sky during the month of December. Another important factor is the insolation clearness index **K**. This factor is calculated by the insolation on a horizontal surface over the insolation on top of the atmosphere. In all of Orissa the annual average values vary from 0.50 to 0.54 and the monthly average values from 0.31 to 0.64. This variation is also due to the changing of seasons. The high amount of clouds during the rainy season prevents the sunrays from reaching the ground. The daytime cloud amount all over Orissa follows a graph formed as a bell with a minimum in the month of December (between 18 % - 30 % of clouds) and a maximum during the wet season in the month of August (80 % - 90 %).

Image 1: Graph with highest and lowest districts values for monthly average insolation incident. [kWh/m2/day]

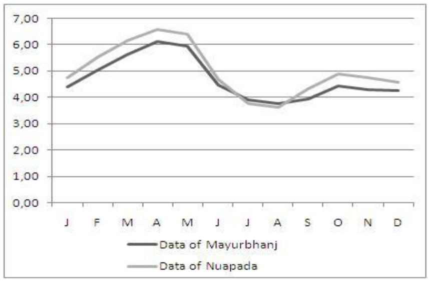

Image 2: Graph with highest and lowest districts values for monthly average insolation clearness index K.

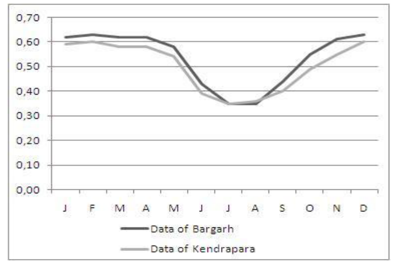

Image 3: Graph with highest and lowest districts values for monthly average clear sky days. [days]

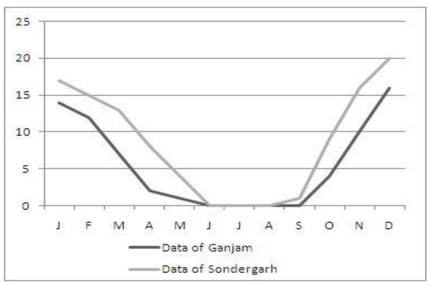

Image 4: Graph with highest and lowest districts values for monthly average daylight hours. [h]

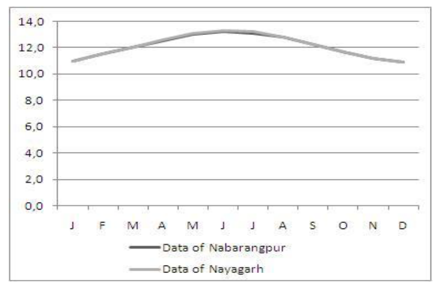

Figure 4-10 Endowment of Solar energy in Orissa
Source: Report of Opportunity - August, 2009 Nicolas Martin Diederichs

In the JABA village, one of the primary local energy resources is solar energy, which is available throughout the year except during 2-3 monsoon months on the Indian east coast. These rainy days are not too bad for solar systems unless the clouds cover the sky continuously for 3-4 days. Mostly the continuous cloudy days are limited to only a few days of the week in August-September. The river, “Kundi” on one side of the JABA village has good potential through the in-stream hydrokinetic machines, which are being developed to produce electricity without requiring a dam. This will help in the rainy season when the river stream has plenty of high speed, high volume water flowing to complement the lower solar supply. The possibilities of running low head turbines with a pumped storage facility with water stored through solar pumping during the daytime may be feasible in the future to avoid evening battery storage for other productive uses during the intermittencies caused by cloudy days. In the future, biogas and biomass can also supplement SPV electricity if the price of SPV does not fall rapidly. I believe that by the time the village skill and demand is sufficiently high in the next 5-10 years, the SPV price would have fallen by half. In that period, if electricity use is significantly higher than it is today, the SPV would require supplements during cloudy and night hours of operation from any of the other renewable resources discussed above. The micro-grid or hybrid power generation in the community could help meet the need for light in community streets, buildings, and production centers. It is also possible that instead of the lead acid batteries that are being used now, more powerful but clean and safe lithium phosphate batteries will be available to store solar energy for portable applications including for electric vehicles and bikes.

4.6.2 Solar lanterns introduced at individual family level

Though both lighting through SPV and cooking through biogas were implemented, the focus here is on SPV. Even in the grid electrified homes, the hidden costs of the grid electricity are high due to the need for a backup battery and kerosene lanterns. The rural lifestyle and production activities require portable lighting and ICET devices. These additional considerations plus the appearance of compact fluorescent emergency lanterns in the local market by the turn of this century persuaded me that SPV would be more useful for numerous portable applications. A solar lantern which is a sturdy rechargeable lantern powered by the SPV panel of 7-10 Watt was first introduced in 2004 and subsequently expanded in 2005. All products and services were procured from the open market without any subsidies and often paying the value added taxes.

With the objective of providing basic energy needs of the rural people through renewables in a cost effective and environmentally friendly manner, I started by addressing the basic lighting needs in 2004 through various financial mechanisms, including my own investment, and donations from friends and relatives. I donated one solar lantern to the village temple, another to a family with school going children and installed one solar system in my home in the village, which also worked as the project control room for the initial 3 years. My larger home system runs computers, fans and a battery charger for other hand tools and gadgets. It also served demonstration purposes. Twenty more solar lanterns were given to poor families with school going female children in 2005.

In order to lessen the burden of household work, such as collecting and cleaning kerosene lamps, and encouraging girls to go to school, priority was given to those families with school going girls. Solar lanterns were introduced at around Rs.3500 ($80) per lantern and were given to people through a micro financing credit loan. One solar lantern, on a normal sunny day, provides light for 4-5 hours when charged fully during the day. People had the flexibility to pay back in monthly installments of $1.5 for five years, either in cash or through labor that might be required by the research project for any village developmental work. The monthly installment was calculated based on the existing average monthly spending per household for subsidized kerosene lamps. It also recovers my initial investment reducing the subsidies burden.

Figure 4-11 Demonstrating solar and LED lanterns

These portable solar lanterns provide night light for various purposes including home study, a health camp shops, community events, etc. as can be seen from the pictures below on the left. Besides being portable, solar lanterns increase productivity because they provide reliable power anytime anywhere in contrast to the Indian Government's welfare program for the poor providing one incandescent lamp to each family in the village (shown below at the right side). The same amount of light can be delivered through a much safer and more productive LED/CFL lamp powered from battery SPV systems without subsidies for value-added activities requiring portability, reliability, and flexibility for multiple uses.

SPV systems given to individuals and shops were monitored regularly. Two local electricians were trained in solar electricity systems and a micro finance team was entrusted to organize the rental business, train users to maintain a good credit rating, and make productive use of the lanterns so that we recover the full cost of the solar lanterns. The plan was to use the collected money for the monthly salary of the solar electrician and for purchasing more solar lanterns. Initially we planned to rigorously enforce collection and payment discipline. However, the transaction costs to collect less than one dollar a month became so high that we thought of waiving the initial costs of small systems for the first time. Later, however, we redeployed the high cost solar lanterns by renting to shop owners who saw more value in reliable light and adopted smaller LED lamps at less than $40 for poor homes. We could waive the upfront costs of

LED lamps and distributed a few of these lights without solar panels free. Many high school children got excited to build their own LED lamps with support of the solar technicians and the battery recharging stations we had built. This will make anyone wonder how the electric grid company with its government bureaucratic structure can do a successful business in rural India where they collect only $1-5/month of total revenue per household that is not more than $200 /month even if all 100 households are grid electrified. This in all likelihood will not recover the costs of the billing, collection, and customer management costs leaving aside the expensive on-peak electricity costs and the huge sunk capacity costs of the distribution assets. The centrally planned and government owned/regulated grid operators have no capacity, ability, and knowledge or motivation to take up these small scale but valuable projects.

Figure 4-12 Contrasting multi-purpose SPV portable light with the rigidly fixed grid electricity light in rural application for poor

Source: JABA CASE STUDY, left panel and RGGVY, MOP website photo on the right: the grid connection cost is about $500 plus a current economic costs of 18 cents/kWh*100*6 /1000 kWh/day = 10 cents/day against the portable solar lantern cost of $80 and no recurring costs.

Solar lighting system introduced at community level: Besides the solar lanterns, with an outside donation, one solar lighting system supporting two lights and one fan was installed in the local primary school, which had been running without electricity. Solar home lighting systems

(SHS) are larger capacity solar systems of 40W with a 40AH (Ampere hour) battery tailored for a small household to provide 3-4 hours of light for two 13W CFLs with the possibility of using a 12V DC fan or a low watt TV. It can also be used as emergency backup power for the rural grid. Using these solar lights, evening reinforcement classes were conducted for free for the village children who needed after school advice or tutoring. This solar system is not as portable for day-to-day outdoor use as a solar lantern and costs about $300, which is clearly unaffordable for most families in the village. This home lighting system is, however, found to be very convenient as backup grid support as an uninterrupted power supply (UPS) for running fans, computers and some domestic appliances that do not require a lot of energy. The project work in the village used this system for reliable solar power for community gatherings, health camps, and water pumping as the grid supplies blackout for hours and days at times without any notice. The performance of the solar systems was closely monitored and two local youth were trained in solar light maintenance.

Figure 4-13 Roadwork at nights using solar lantern to avoid the scorching heat in summer
Source: JABA case study, Orissa being close to the tropics, summer nights are not as short as northern latitude countries. Therefore, farm and street lights are required for longer hours and will have more value.

Solar Photovoltaic and LED based programs: SPV based lighting and entertainment created additional labor time at night and encouraged human resource development through learning and better health. Harsh Indian summers are known to affect labor productivity. In the summer, solar energy is plentiful and is being captured through SPV panels in solar portable lanterns and radio for use at night. The workers relax during the summer heat in their home with solar operated fans and work on the farm during the cooler night. The lights are also used for outdoor work, sewing, weaving and other income related endeavors. Solar powered lights and LED lights have also given lots of income generating opportunities by renting them out during public festivals, weddings and other private ceremonies in nearby villages.

Collections of service fees for solar lanterns were regular when the local electricity was disconnecting a large number of customers for nonpayment of electricity dues. As soon as the subsidized grid supplies were restored with lax enforcement by a government managed grid operator, collection of dues for solar lights were drastically reduced.

4.6.3 **Observation of a phased development plan**

It would have been easy to provide SPV electricity to all 60 un-electrified households at less than $10,000 but the lack of road, bridge, school, transport vehicle and health facilities would not have helped villagers even with electricity. Further, it would have been much cheaper to use the supply of heavily subsidized grid electricity than the off-grid SPV that I introduced (Grid subsidies are over 90% though later I prove the grid is more expensive than SPV) but no transformation in rural, health, education, lifestyle, and production would have been seen without reliable electricity and a supporting infrastructure. Therefore proposed began to phase in electricity in addition to other supporting services. I introduced small solar lightning ICET systems to build local skill and infrastructure from the large unused cheap labor force of the village. This possibility of doing things in phases and the impossibility of doing everything in the village with the help of villagers also helped me wait for the SPV price to come down through international efforts in research and development. In spite of my best effort, the skill set of the villagers has not come to a level where they can use a large amount of electricity such as for running an electric car or refrigeration plant. Thus, the demand for electricity still remains low to power a few lights and small water pumps. Only recently we have a plan to produce organic food by irrigating a few acres of land during the dry season and are planning to buy a 1kW solar water pump at a cost which is 50% below the cost five years ago.

Local suppliers for computers, laptops, projector, cameras, and printers being technology intensive have very poor service support in the village. The internet is the only source for online help from our camp office in the U.S.A. We provide maintenance for these technologically advanced products and for solar panels for health equipment like nebulizers and oxygen masks. Broadband internet would have helped us deliver these services more efficiently, but is still not available in this village. The existing dial-up internet connection is too congested to transmit educational photos and videos from Google, Wikipedia, PBS kids.org, and others. While we felt the lack of this infrastructure is a handicap for village development, a similar handicap was not felt for lack of or insufficiency of grid electricity as the SPV electricity was adequate for the current needs

Figure 4-14 Solar power removes rural darkness and drudgery

Source: JABA Case study: Picture starting in upper left and going clock wise are:1. A traditional kerosene lantern converted to an LED lantern by our village technician at the cost of $10, 2. Solar powered fan, light, TV, water pump available in local market. 3. Solar LED lights being used during festival, 4.Safe 12V DC solar CFL lamp closer to the idol being worshipped 5. Small $5 LED based lighting more safe, weatherproof, and portable for rural mobility 6. Comparison of the small LED light indicated in 5 with a wick lamp.

Figure 4-15 Solar water pumping during building construction which require either manual or very low 40-100W efficient DC pump

Source: JABA case study (2005-2009)

Solar powered street lights expanded for community safety and productivity: Four solar powered street lights were installed by local solar technician in JABA village streets. The light posts were built by local resources with locally produced compressed earth blocks. A solar powered community center meets Health, Education, Lifestyle support and Production (HELP) needs.

Figure 4-16 Solar lights installed by a local technician on village streets, solar street light near the BioCafe in a formerly pitch dark unsafe street corner

Adividya Mandir, a new school in JABA to provide modern education to the socially deprived, is now fully powered by SPV for lighting, fan, laptop charging, projector, water pumping, and regular health camps. High powered LEDs have been used in the health center building and village café. The solar energy center equipped with LED and battery-charging devices regularly provides battery charging and maintenance services to the villagers and streetlights, school students, and amenities of the Adividya School and ADIRE staff. The off-grid solar powered health center and school is shown in Figure 4-17.

Figure 4-17 SPVs to power an energy efficient off-grid building with classrooms equipped with laptops, lights, fans, projectors, and LEDs for day and night activities, which also works as the health, adult learning and entertainment center

Now we have enough background information and data from this typical Indian village to calculate the costs of SPV and the grid as well as demand functions for villagers of various income groups and finally to calculate if SPV and electricity subsidies are, in fact, required. We will also use these derived functions to analyze if a subsidy free rural grid supply is possible by 2020. Table 4-8 summarizes the energy use and income data of the JABA village from which 98 usable data points out of 104 total households were collected and processed for cost, price, and demand analysis. Some of the relevant grid and kerosene energy and income data will be further analyzed in chapter 5 with more implications of the study to follow in Chapter 6.

4.7 Summary of the Case Study

The electrified JABA village in Orissa, selected for this data and field experience, enlightens us about the cultural, economic and financial issues involved in supplying grid and modern SPV electricity to rural households in India. The incomes of the villager households were found to be below $100/month. The electricity consumption was limited to 60% of households with consumption mostly limited to lighting fans and TV. The large amount of biomass and cow manure used for cooking reduces the need for electricity. The electricity needs were not found significant enough to justify the electricity grid. A few 40 W solar home light systems that can power a middle class village home is adequate to meet the basic health, education, and production needs in community building and shops. The unreliable grid alone could not have met these needs without SPV support.

Though the deployment of SPV for domestic and community application was technically successful, there remain significant information barriers as to the true cost and demand, anti-competitive grid pricing, and lack of a skill-base to create a big demand for any form of electricity unless highly subsidized. In the next chapter, I will provide the economic theory for the cost comparisons, demand and supply curve estimation, and their dynamic interactions with the support from the literature. The consumption data of kerosene, grid, the cost and demand for electricity for the basic needs of the villagers as collected in this case study will be used to complete the empirical analysis for answering whether off-grid SPV is cheaper and subsidy free now and in the next 10 years compared to the grid. I will show methods to fund the off-grid SPV programs in Chapter 6 by removing the existing grid inefficiencies as discussed in the literature review.

Table 4-10 Basic statistical summary of JABA village demography, energy and incomes

	Population	***Age***	***Land***	***Rooms***	***Kerosene***	***Fuel-wood***	***Cattle***	***Milking Cow***	***Cow dung***	***Monthly Cash Income***	***Farm income***	***Food***	***After-Food Net Income***	***Electricity spending***	***Fuel Expense***	***Elec+Fuel***
	Nos.	**Years**	***Acres***	***Nos.***	***Liters***	***Kg***	**Nos.**		***Kg***	***Indian Rs/Month***						
Household Count	104	104	102	103	97	99	99	99	73	101	104	104	104	99	99	104
Sum	417	3622	135	215	283	8165	167	45	2505	285050	74100	125100	234050	4720	12520	17240
Mean	4.01	34.83	1.32	2.09	2.92	82.47	1.69	0.45	34.32	2822	712.50	1202.88	2250	47.68	126.46	165.77
Standard Error	0.23	0.87	0.15	0.15	0.12	3.65	0.15	0.07	2.26	264	88.70	67.54	275	6.42	5.70	10.32
Median	4	34	1	2	3	80	2	0	30	2000	300	1200	1300	0	110	135
Mode	3	34	0	1	3	80	0	0	30	2000	0	900	2000	0	110	110
Standard Deviation	2.30	8.87	1.50	1.57	1.20	36.35	1.50	0.66	19.28	2651	904.54	688.81	2800	63.86	56.68	105.26
Sample Variance	5.27	78.76	2.26	2.47	1	1322	2	0	372	7028424	818192	474458	7839878	4078	3213	11081
Kurtosis	9.67	0.00	1.58	6.93	11.99	2.70	2.05	1.60	4.48	7.95	4.35	9.67	6.84	4.56	3.96	4.73
Skewness	2.33	0.25	1.19	2.04	2.57	0.53	1.00	1.37	1.46	2.39	1.64	2.33	2.16	1.71	1.97	1.60
Range	16	44	7	10	9	200	8	3	120	16700	5100	4800	18200	350	280	670
Minimum	1	17.5	0	0	1	0	0	0	0	300	0	300	-1200	0	40	0
Maximum	17	61.5	7	10	10	200	8	3	120	17000	5100	5100	17000	350	320	670
Largest(3)	10	52	5	6	6	200	5	2	75	10000	2700	3000	8000	220	310	416
Smallest(2)	1	18	0	0	1	0	0	0	0	300	0	300	-1100	0	50	0
Confidence Level95%	0.45	1.73	0.30	0.31	0.24	7.25	0.30	0.13	4.50	523.36	175.91	133.96	544.53	12.74	11.31	20.47