6 Chapter 6

The cost study in Chapter 5 quantitatively showed that off-grid SPV is the cheapest option for the rural poor. In addition, other non-quantified beneficial externalities make SPVs even more favored. So if the SPV is so obviously the electricity option of choice, why is this option not being phased-in in rural India or in other poverty ridden parts of the world? The following implementation issues for SPV electricity learned from the JABA village experiment will shed some light on this issue

6.1 Phase I: Energy-only Solution for Light, Lifestyle Comfort for Rural Poor

In Phase 1 of my case study, which only sought to bring light, I found that the rural poor are not seeking large water pumps or climate controlled homes. What they need are food, water, sanitation, transportation, infrastructure, a comfortable home, and opportunities for community entertainment and production. Many of these needs can be powered by muscles and local renewable energy supplemented by SPV electricity. A solar PV system can be bought from the market and maintained by the villagers. A long lasting 80 W SPV panel can be loaned or leased at a total cost of less than $320 to an average family with monthly income of $100 for powering lights, a fan and a TV. The family can payback the initial capital cost of the panels at less than $5 per month for 6 years at zero discount rate. If a 14% interest rate is assumed the investment can be very easily recovered in a few more years, much before the end of the 25 years of useful life. The household might be asked to buy its own battery system to fill energy needs at night inside homes and portable power supply outside homes. All the village households do not need an 80 W solar panel at the same time. Only 10 W systems are needed for lighting and cell phone charging at the individual family level for the poor with monthly income below $60. They can pay off this cost at less than $2 per month as they pay the cell phone company. Even the very poor with a family income of about $30/month can use a 2 W solar LED light for their bare minimum evening light with much better quality than from a kerosene light and pay for it at less than a dollar a month. A larger solar PV system can be installed in the village community center to meet the needs of a cluster of such poor families. The more advanced 40 W and 80 W SPV panels may be added as villagers learn and improve their skill and production capabilities.

About 10 kWh/month of very efficient SPV electricity can be supplied to each of the un-electrified or poorly electrified 80 million rural households at an upfront cost of $25.6 billion (80W*$4/W*80million) over a period of 5-10 years. This is more than the $13 billion proposed by the RGGVY for the rural grid but involves no recurrent costs for inefficient use of energy, distribution system, related subsidies, losses, and other structural issues of the grid monopoly and elite capture. Recurring O&M, routine metering inspections, and legal actions would not be required. Solar water pumps, bright LEDs and CFLs, and solar powered fans and refrigerators could be procured for greener and more value added services compared to what is possible through kerosene and the electric grid. This would have been economically more efficient and socially more equitable with everyone getting the same amount of government subsidy. Those who want more services could get them from the market place. Rural energy consumption could be disassociated from the cross subsidies of an urban market.

6.1.1 Opportunities to counter the energy divide and elite capture in JABA village

The very distinct, caste based energy allocation of electricity and kerosene along with possible solar electrification in JABA representing a typical village of rural India is shown in Figure 6-1. The area graph shows the darker side of the fossil-grid with the larger dark area representing the electricity deprivation in the village to the lower caste groups. This one graph shows many aspects of an Indian village, such as the energy divide with elite capture (left upper class with more electricity) and the right lower classes that survive on kerosene. Also shown are subsidy lock-in (both electricity and kerosene are subsidized) and the challenges for subsidy free solar electrification in JABA village that could very well be applicable for other rural villages.

The figure also shows the possible opportunities for SPVs. All villagers can be provided some solar electricity based on their paying capabilities. The stacked bars in the figure show this potential level of solar energy penetration in JABA village with 5% of each household's income allocated to the superior SPV lighting or home systems. The larger 40W/80W solar home systems, which can be provided subsidy free for average income homes, are shown in the bottom green bars with white dots. The smaller 10W solar lanterns for less than average income families are shown in the middle diamond patterned bars, and the very cheap rechargeable LED/CFL lanterns for the very poor are shown in the top light green bars. These small systems can be powered by 1-3W SPVs even during cloudy days, through hand cranking, or they can be charged in a village charge shop with daily/monthly rentals. No subsidy, no elite capture, no metering and no inspection are involved in providing such an equitable lighting solution for the village. However, the actual result, I saw in the village is an eye opener that led me to significantly change my perception and understanding of energy intervention for the rural poor in India. The case study for bringing light to poor homes failed because of the many short-term glitches in the SPV products and the social practices of the villagers. Similarly, a competitive market for household lighting also came to a halt as subsidies to fossil fuels and the grid discouraged SPV entrepreneurs from entering the potential rural market without similar subsidies. These short term entry barriers and long term structural operating barriers have led me to look for a better energy solution for the village and assess the lack of demand that makes the grid unviable for long time to come.

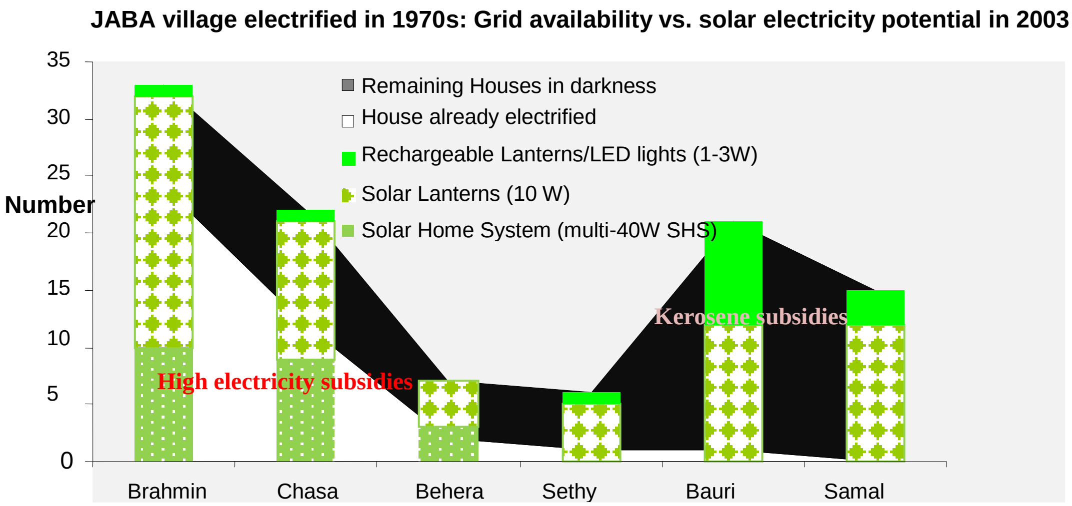

Figure 6-1 Social segregation and energy use: High grid and kerosene subsidies as barriers to entry for off-grid SPVs.

6.1.2 Short term barriers to entry of SPV showed up in Phase I implementation

I started observing many classic socio-economic problems and externalities as possible barriers to entry even during the initial two years of JABA village case study in Phase 1. Most of them might go away with increased learning by doing and using modern energy efficient technologies. These experiences, I believe, could help shape the future strategy in energy delivery to the rural poor. The following lessons learned are also useful for efficient product and process designs for meeting solar electricity markets. They will also have some policy implications on access to solar radiation and social infrastructure for the poor at the least and affordable costs.

1. <u>Externalities:</u> Lack of adequate sunlight due to shadow of nearby trees on many poor households was a handicap that needed close scrutiny of SPV projects. Some households had to return the lanterns, as they did not have enough solar radiation during winter months as their neighbor's trees shaded their property. The expensive solar panels for their lights should not have been offered to these households in the first place. Centrally charged rechargeable lanterns should be adequate for their needs. The fact that partial shade can shut off solar

generation or reduce it to about 10% of full capacity was not understood fully by the users. The possibility of carrying the solar light to the work place and charging it there could not be popularized by the project team because of the unwillingness of volunteers and the lack of any great interest by the beneficiaries to continue the awkward process. These shading issues for the poor are more of a problem for the landless labor class who are crowded in a small area. The more shade insensitive thin film SPVs could solve some of these problems in the future, but for the moment the government would need to step in to solve the solar access issue as in Wisconsin where no household can legally restrict the reasonable solar access of a neighbor. If it is unreasonable to cut a tree that might otherwise provide shade and keep a house cooler, participants may come to a Coasian bargaining solution. The panel may be mounted higher up on a platform at additional costs. Or a party could contract with a neighbor to rent the solar panel and provide a micro-grid power supply for two to four customers in the shaded zone. Another alternative is to have a community charge shop as described by Khandepal and Chouery (2009) where the poor will pay some fee for battery charging for all lighting and ICET devices. Theft, vandalism maintenance, and security/insurance issues will then be moot for the poor households. These are the experiments village users and entrepreneurs can search for, as argued by Easterly (2006). Such searchers may be able to use small modular off-grid systems that planners from national and international development agencies cannot. In that respect the SPV high cost argument often becomes invalid for the technological and market dynamism it provides in rural areas.

2. Free Riders: Another family found that sharing the 1.5-dollar monthly costs amongst families living very closely becomes cumbersome with a free rider problem. The person who contracted with the project team had to pay for the entire cost while others in the vicinity had a free ride on the solar light. If the same customer had purchased kerosene every day, she would have had the leeway not to buy every day and could have forced the others to buy kerosene part of the time. After a solar lantern was provided, the neighbors saved money on kerosene but did not share the cost of the solar lantern. This interesting spillover effect taught us an important lesson. We provided solar street or community lights powerful enough for children to study under in good weather at night and for adults to assemble for evening entertainment and enjoy the modern reliable solar technology at work. For such community use, a subsidy is necessary but the light gives positive externality benefits to all. Some innovative entrepreneurial solution will be required to deal with joint family and communal use. Non-divisibility: Some houses with more than 2 rooms needed more than one solar light

but were not willing to pay double as their kerosene payment was much less than 3 dollar per month. Probably one solar light and one back up kerosene lamp would have been a better solution. But the consumer did not want to experiment as he felt it too risky an investment. During the initial phase, LED light was not very popular due to poor lumen/Watt and frequent battery charging with the lower efficiency of LEDs compared to CFL. Now it is possible to provide two LED lights (one high-powered 3W and another low powered 1W) at the same cost as for one solar powered CFL lantern in 2003-05.

3. <u>Lack of aspiration</u>: The village community has been subject to centuries of isolation and deprivation from material enjoyment. They do not aspire to the comfort and opportunity benefits of modern electrical systems. This lack of aspiration is partly driven by the fact that they lack information, income and opportunity to procure the modern electrical devices. Some households did not see any great value for an electric light, as they did not have anything to do at night. They were uneducated with no children in school. After a day's work, they went for community programs or rested and preferred to spend their money for clothes, food and medicine.

4. <u>Lack of incomes</u>: Most of my customers were paying by exchanging labor and were satisfied with the product. By allowing poor households to work for their payments, I was able to provide them with light even with their low incomes and the lack of a capital market in the village. The collection of cash dues from the poor with their many competing mandatory health and social expenses remained a great challenge. Though no one has sold a solar lantern borrowed from us, it came to our notice that many have sold their cows, land, and rice stocks to pay for a son's medical costs, a daughter's marriage or for other social obligations. Social security and critical medical care programs from the government as in developed nations could solve some of these issues. The variable monthly income stream of the poor affects their ability to pay and any persistent pressure often led to the return of the lanterns. So far as we could allow them to pay with labor, payment was not a problem. Although there has not been a single buyer who was willing to pay for the lantern up-front, there has been no default in payment by shop owners.

5. <u>Skill and complementary factor shortages:</u> The solar charging of radios, fans, computers and mobile phones was theoretically possible, but there was not enough local capacity to provide training, minor operating and design adjustments in the pins, switches, outlets and connectors, and maintenance services. In a holistic approach, we need capacity building of

local entrepreneurs as well as the complementary skill based technical training for applying renewable energy to rural applications.

6. Non-competitive device suppliers: The existing suppliers were all located in the state capital catering to the government programs and had no incentives to be customer friendly. Even the most reputable manufacturer took a long time to rectify a common switching problem of lanterns that we faced frequently. Quality problems of solar systems in the local rural market made them less lucrative than in the hot markets in developed nations led by Germany and the USA. The demand driven price increase and the silicon shortage in 2005-07 brought solar investment to standstill, and we had to wait until 2008 for the next round of price decreases. To gain reputation and consumer confidence, local manufacturing, modern customer management systems, and more training centers will be required to change the perception of solar devices as unserviceable.

Phase I of the case study research was to bring light to promote future sustainable development. Such a rudimentary Alternative Development Initiative with Renewable energy and Energy efficiency (ADI-RE) that I introduced for household lighting, however, failed to be self-sustainable as the small savings from solar light could easily be wiped out by health costs or other social obligations There were also many other initial problems of new technology dissemination that perhaps could have been solved with enough effort. But the big government subsidy to fossil-grid competitors could not be addressed by the project team. I address this long-term structural barrier that will discourage market for off-grid SPVs in the next section.

6.1.3 Long-term structural challenges observed in Phase I energy-only initiative:

As described above, introduction of off-grid SPVs in rural India require some promotional efforts to transfer skill as well as micro financing to let the rural poor learn by doing. But there are certain structural issues that need government attention. Theoretically, demand and supply for SPVs match and will continue to do so in the future. However, that is not enough for the SPVs to make a dent in rural India without addressing the core issue of anti-competitive subsidies to kerosene and the grid. On the contrary, the government continues to subsidize the inefficient grid and kerosene, while these same ration shops with additional private market entrepreneurs could instead create more supply channels to sell SPVs and efficient electric devices. Not only energy subsidies, but also food, fertilizer, agricultural loans and housing all are provided at subsidized rates to villagers without expectations of returns to the costs. The total subsidy value constitutes a significant part of the villagers' incomes that are not transacted at market rates. Thus, the lack of a market and proper price signals are perennial problems in the rural economy. Thus, selling SPVs in rural homes at their true cost is infeasible.

A grant of one solar light to each un-electrified rural household through the kerosene distribution channel of government controlled ration shops would have diverted kerosene subsidies to the solar devices, nullified the anti-competitive nature of the kerosene subsidies, and the transaction costs of small payments. But our small project team has no resources to change a mammoth government bureaucracy. Many government announcements to reduce the kerosene subsidies and provide funds for solar lanterns during this ADI-RE project implementation (2004-2009) in JABA (including the very top, competition-friendly, current prime minister) were made, but no action has been taken.

Rural households are different and their needs varied widely based on their income, family size, occupation, skill, lifestyle and other preferences. Not all of them are searching for easy subsidies and many try to experiment with new technologies and to develop skills so that they can be financially independent. Despite the subsidy barrier, the story of Babaji Bhoi, a labor turned semi-skilled mason will be useful here. His example will also show subsidies can not only reduce the demand for clean and competitive solar systems but also lower the demand for the poor quality of grid to the extent of making it completely uneconomical.

Babaji rented a solar lantern 5 years ago from the project and was the first beneficiary to have paid off all his dues, even after electrifying his home with subsidized grid electricity three years back. He values his little solar system that could power a light, radio, and cell phone. His school-going children experimented with LEDs and an SPV panel while saving energy from the grid. His electricity bill averages 9-12 kWh/month and he pays just about a dollar to the grid company for this electricity. He does not pay anything for the lantern as it is free for him now after paying one and half dollars each month for 5 years. He gets reliable solar electricity for his masonry work, his children's education and ICET needs, and his wife's work in the cow shed and kitchen garden at night. The subsidized grid could not solve many essential rural activities for which Babaji has come to depend on SPVs. Thus, solar electricity is a credible grid substitutes if a competitive market place emerges on its own. If the government realizes the cost of grid subsidies and removes them, that day could come much sooner.

With adequate perseverance and time to challenge these government subsidies, it could be possible to prove the practical success of the off-grid SPV model. This example explains how the alternative modern SPV systems are not only essential but they also reduce the market size of the grid so it no longer makes any commercial sense. But the government subsidies to the grid still continue as the largest structural barrier to entry of off-grid renewables and energy efficiency.

6.2 Phase II: Developing Sustainable Villages by Phasing in Off-grid SPVs for Meeting Modern Inputs and Outputs:

Bringing electricity to the village either through the grid or by SPV has not shown any significant income impact for JABA households, though it has provided higher amenities and a better quality of life. However, lifestyle alone cannot pay for the costs. SPVs are affordable only if the income impact of these solar devices or some other driver is strong enough.

6.2.1 Observation of an integrated development

When the rural poor, mostly illiterate, have so many competing essential needs such as bringing food to their families, meeting numerous social obligation, surviving from disease, and dealing with catastrophic disasters, it is naive to believe the prediction of a subsidy-free solar solution based on the partial equilibrium demand study presented in chapter 5. This is a great lesson I learned from the case study in the first 2-3 years. It convinced me that a lower cost SPV energy-only solution to rural development is not guaranteed and might very well fail as it has failed for the grid-only solution for the past four decades.

However, I became curious to know how much electricity would be required for developing a new resource efficient sustainable village from the ground up. This led me to extend the research for few more years. For the remainder of the chapter, I will present my observation of the integrated but phased implementation of some of the renewable energy and energy efficiency projects in the village community and production programs.

Despite the commercial failures, Phase I showed the commercial success of portable solar lanterns to provide night light for various purposes including home study, a health camp, shops, and community events. 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. 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. In Phase II of my village level experiment I osught to provide the four socially relevant outputs that require electricity: health, education, lifestyle, and comfort through energy and various other products and services.

6.2.2 Phase II Principles: Energy for producing more balanced outputs

The perceived primary needs of the villagers were not energy services as such, as they do not have the devices and facilities to use modern ICET. In order to create a positive spillover effect of modern energy, it is necessary for rural communities to get all the HELP services together, as shown in Figure 6-2, as no one of these is sufficient alone. An entire portfolio of health, education, quality of life,/livelihood and production (HELP) services must be provided to develop villages and make them habitable for modern living. All of these can be provided in a phased manner based on the specific needs and abilities of each household and community without requiring huge resources at one time.

The ultimate objective of society is not to provide a few light bulbs to the villagers but to provide them the essential energy services for achieving healthy, comfortable, educated, and productive livelihoods. I will pool together all products and services that provide income under the output called production. Production is necessary for the rural poor to acquire and maintain a good standard of health, education, and lifestyle. Also, a basic purpose in life is to be engaged in productive employment and to be useful to society in some way by producing goods and services.

The costs of conventional health care, education, and large scale production are very high and these services are extremely capital, skill and energy intensive. They can be provided at lower costs in urban areas with high scale economies harnessed by the presence of a large number of high income customers exactly as we saw in the electric grid analysis before. The adoption of these services in rural India with completely different natural endowments of land, labor and resources requires a complete redesign. In the rural production system, the entire output delivery has to be integrated as efficiently as possible.

RE based HELP Activity Summary, Phase II (June 2005 - July 2008)

With an additional $30,000 study investment in the last 5 years, I have not seen the demand for electricity in the village to be higher than what can be obtained from the SPVs for running a middle class Indian home. The community houses, schools, and shops in the village are also no bigger than 2-4 rooms, are less than 1000 square foot, and do not use air conditioning or refrigerators. The only devices they need immediately are light bulbs, fans, TVs and may be a computer and some LED displays which can all be solar powered.

Lesson from the first phase of the case study indicated serious underdevelopment and a need to provide the village with basic social services and infrastructure for modern living. I tried to introduce all these four services together in Phase II, as the ADI-RE-HELP initiative.

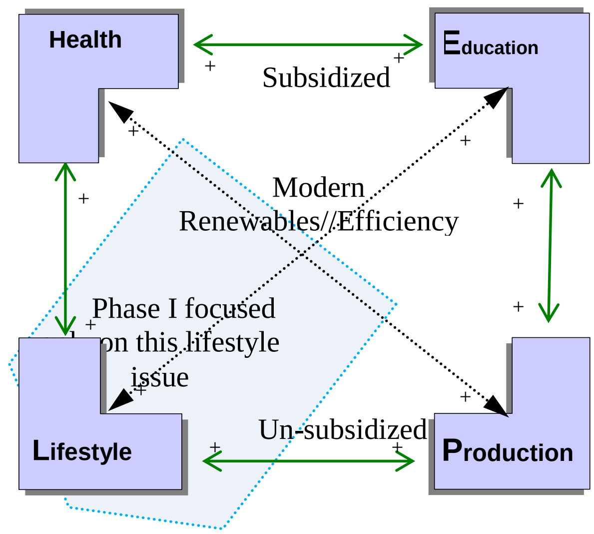

Figure 6-2 Phase II: ADI-RE-HELP expanded from the restricted Phase I using local clean and renewable energy for sustainable community development (most HELP services will use remote electronic services to reduce the transportation costs)

This second phase, introduced in late 2005, took a more holistic approach. I researched energy technologies and their linkages to village production. I considered community energy demand for shared facilities, such as a health center, in overall but phased village development within our limited budget. (For more details of Phase II see Kar and Dahl (2005; 2010)) I also expected quantitative data on productive and community demand for the village. To my surprise, I found that the productive and community demand is not more than household demand. Many of the same solar devices used for average homes are adequate for community, social and productive events in the village.

6.2.3 Barriers to high electricity demand in Phase II implementation: Skill and infrastructure shortages

ADIRE Trust in JABA, an off-shoot of my project to implement the ADI-RE- HELP initiative, is promoting a clean sustainable village cluster around JABA village. But this effort is not without challenges as described below in each of the output sectors.

Social and non-productive sector (health, education, and quality of life) issues: The first lesson learnt by our ADIRE study team in the village from the health initiative is that we need donations and charity to get these services to the poor first before insisting that they use solar lights. When the citizens are so poor that they cannot buy nor can the government provide bed-nets and clean water to prevent malaria, diarrhea, and communicable diseases, how effective is a subsidized rural grid to provide rural health services? Rather, I found that the demand for electricity to provide such basic services as lights, fans, pumps, and ICET for school use can not only be supplied easily with SPV, but they can also be shared with health center projects and be loaned for production or village festivals. This way we can minimize the costs of a separate health center. The portability property of the SPVs is valuable here and increases the capacity utilization factor that the fossil-grid cannot achieve.

Without skilled teachers, teaching gadgets and the skill to operate those gadgets, no grid electricity or solar electricity will change the education services in rural and poor economies. These as yet unavailable complementary skill sets, modern infrastructure such as good roads and broadband internet, and computer maintenance services are essential for attracting education professionals from the urban areas. Where a small road could be completed by our team, broadband services can only be provided by large corporations or the government and it is not expected that this will be available soon. We found poor internet connectivity a critical bottleneck to bringing outside skill and educational material to the village. Computer repair services are also expensive and support services for these high technology devices need to be improved

Lifestyle improvement is required to attract and retain skilled people for further improving the school, health and production services in rural areas. Most of these lifestyle enhancing energy services do not need subsidies, and the poor are willing to pay the services if they see the tangible benefits and have a smooth income without natural or health related calamities. The subsidies are also not required for the community use of off-grid SPVs; they can be a part of the bundled cost of providing community services. Where the community services are provided by the local government, community life could be more comfortable with off-grid SPV as the unreliable grid is not able to provide the same comfort. This knowledge that SPVs can be so useful for community applications, it appears, is not yet widespread and may not exist in the Indian development policy arena.

This implies that if the government, instead of subsidizing the grid and kerosene provides these subsidies to improve the health and education of rural poor communities, the un-electrified communities can pay for part of the costs of the basic electricity services out of their health and education budget. They can also minimize their electricity expenses by taking the minimum required quantity from the market or social entrepreneurs selling SPV products. Individuals, when assured of social security to survive diseases or emergencies and when able to provide much needed education for their children, can also pay for the household energy services. A solar light instead of a kerosene lamp, a smokeless kitchen instead of a biomass or cow dung cake stove can promote a much healthier and safer rural life. Unfortunately the government unintentionally promotes rural disease, darkness, and deprivations simultaneously through kerosene subsidies even to 100% electrified villages to offsetgrid unreliability and non-affordability.

Production bottlenecks: Despite the availability of funding for an electric vehicle for the village productivity growth, we have not been able to develop the confidence and skill within the village community to maintain and operate the vehicle. Although we can provide the SPV electricity, we are still awaiting the availability of a good electric transport vehicle model and after-sales support. It is envisaged that the battery van that we will procure will be charged from the same solar panel that will be used to pump water for agriculture. We were planning to buy two Soleckshaws (solar battery operated rickshaws) which will be used for school children as well as transporting produce from the village to the city market. These much publicized Soleckshaws were supposed to be implemented in Delhi for the Commonwealth Games but were recently abandoned because of poor design, marketing and customer education.

Temporary failures of our community biogas digester used to run the village-café resulted from a shortage of manure and management skill to collect, process, and manage plant operation. Many other production projects such as the brick making plant also initially failed for a lack of skill and management expertise in the early stage. The low level of trust amongst the staff and villagers, early in the project, was tackled by team building projects. Nevertheless, I expect that significant investment will still be required to develop the necessary skills. All these skill building and management activities are not cost free and all villages in India are not endowed with suitable connections to charitable organizations to freely provide these services. Thus, it is essential to develop good rural management practice skills. A solar technician, a plumber, a mason, and three teachers have been exposed to modern manufacturing centers in Auroville, Tamil Nadu and Pondicherry for promoting renewable energy and sustainable building practices in the village since 2005.

6.3 Transition to Phase III in Search of Renewables Based Skill, Capital and Infrastructure

Most of the HELP outputs in the conventional development paradigm are based on dominant fossil-grid technologies. However, Phase II showed us their incompatibility or higher costs for JABA village application. This incompatibility is no different than the case of electricity delivery through the rural grid. A moment of reflection will show that the handicaps of rurality, poverty, and large scale inefficiency that jeopardized the market equilibrium for rural electricity are also responsible for lack of market equilibrium in most of the other output categories. Large scale health services, education, and production activities are difficult to develop in villages and accessing them from cities involves long transportation costs and wasted labor time that the rural poor can hardly afford. All these outputs are subsidized by the government but with no good results as we saw in one example of our core discussion of electricity in the rural grid industry.[1] Such poor implementation in the Indian welfare system is wasteful and not worthy of replication.

I have also been worried about whether the resource transfer from urban donors will continue long enough for our village experimental to be successful. This led me to start Phase III in 2008. My goal has been to quickly develop an unsubsidized model village with a diversified production base for replication elsewhere in India and other rural poor economies.

This alternative rural production model needs to use rurality, poverty, and the efficiency of small scale processes as enablers not handicaps. SPVs can provide the needed electricity for household, community and production without subsidies. Similarly, from my experience of the fund raising activities for the village, I could see the willing support of friends and a growing number of green minded individuals for some amount of capital and skill transfer to direct beneficiaries in the village. Modern internet and Skype/Yahoo services make it possible for individual donors and investors to observe the use of their money. Therefore some initial amount of capital to start a project is not difficult to get. Even doctors and teachers are willing to do remote consulting. Thus some amount of urban skill can also be delivered through the internet as tele-services, where broadband connectivity is available. The subsidy-free delivery of other inputs requires villagers' to not only acquire production skills but also the ability to trade their product and bargain for a reasonable price. One product perhaps the villagers can sell in the future international emission market is their ability to use off-grid renewables and save carbon and pollution and trade them as emission offsets. That is a long term goal of this phase and requires bargaining skills that I myself do not have. But most of the villagers lack even the basic skills of building trust, managing small shops, organizing small companies, or even non-profits to keep proper accounting and to deal with the city based government auditors

Table 6-1 indicates how the much needed but higher skill and energy intensive electric transportation, solar water pumping, and electric power based production activities originally planned for Phase II could not be taken up and had to be deferred to Phase III for lack of appropriate skill and village resistance to new ideas. But from 2008, we have been trying to bring appropriate technical and managerial skills that will be compatible with renewable energy and energy efficiency (RE) to optimize the use of village land, labor, and conservation habits. I will

[1] Easterly (2006;2008) and Sen (2005) have brought out interesting insights to the failure of rural educational and health services in a top-down framework. Lal (2006) has shown the failures in the case of farm production and wastage in irrigation water and electricity supply. Jha and Ramaswamy (2010) have recently shown that the food produced in a few states in India and distributed by the federal and state governments to rural poor involves a huge 71% waste in public funding. Poor targeting, elite capture, pilferage and high distribution costs all are well known in any top down model in the Indian welfare system.

indicate here the technological opportunities to reduce costs and increase efficiencies of such a sustainable village development phase. I will also indicate how critical is the need of RE based skill and small scale capital, which in turn will require a new set of physical infrastructure such as a local road transport network and high quality global broadband internet. The electric grid, which was earlier thought of as an essential rural infrastructure is off this list, as my JABA experiment has shown me that SPVs can totally replace the rural grid as cell phones have completely replaced rural wired phones in rural India. I have not found much academic literature relating to villages leapfrogging the conventional development paradigm with modern ICET and off-grid renewable energy. In order to trigger a much wider interdisciplinary research in the main line micro economics and sustainable development literature, I will only introduce here the broad concepts that I learned from my case study.

Table 6-1 Renewable energy for lighting, information, cooking, weatherization, transportation to RE-HELP in a phased manner

Renewable Energy for Lighting, Information, Cooking, Weatherization, Transportation				
Phases→	**Phase II**		**Phase III**	
RE →	**Solar PV**	**Biomass - Solar Thermal - Biogas**	**biomass//solar thermal SPV Power**	
Technology→	**Home Lighting//Efficient Electronics (ICET)**	**Clean Heating/Cooking**	**Electric Motors for Pumping/Grinding/ Climate Control**	**Electric Transportation**
Healthy/safe life	LED/CFL below 20W weatherproof evening lights for homes /street	Clean, smokeless stove for food	Clean water, cooling fans, hot water, food storage	Availability of doctors and health workers
Education and lighting	Laptop/TV/LED Projectors/DVD/home lights More time for learning less superstitions and l less closed mindedness		Better health, more time and timely information are enablers for learning	More time for learning, more access to schools, skills, and library
Energy and comfortable lifestyle	Solar lantern/radio /TV/computer based information in homes/community hall for villagers to enjoy.	Solar/biogas save time and create choice for girls /women to enjoy leisure or work	Efficient appliances: fans, pumps, grinders, food processors, broadband internet for entertainment video	Less foot travel but more healthy, nightly, summer work in local farms/shops
Production, well-being	Production ideas given, Access to market, and flow of information improved	More time for production with lighting and micro irrigation supply	Tube-wells//pumps bricks, hand pumps, organic farming	Access to inputs, markets, finance, skills, and entertainers

6.3.1 Technological opportunities of sustainable rural development

Phase III of the village development postulated that the urban factors such as modern renewable energy and efficiency (RE) based skill (S) and micro finance to buy RE devices and efficient capital goods (K) along with the modern rural infrastructure (I) of roads and broadband internet are essential to make the land (L_1) and labor (L_2) of rural areas more productive and a source of income. Taken together these five inputs are denoted here as SKILL. This select set of

RE based urban skill and capital with the rural factors land and labor can form a compatible set of factor inputs RE-SKILL for subsidy-free renewable energy based development. This is an improvement over the previous Phase II (ADI-RE-HELP) initiative. In the earlier initiative, all the outputs including high paying skill and capital were sourced from urban areas, where they are currently available with no focus on their possible development in rural areas.

Phase III of this case study is also designated as a highly integrated alternative development initiative to show the linkages of all essential inputs with outputs and their positive spillovers. I will show in future that the input set (RE-SKILL) and output set (HELP) in the alternative development framework can be inexpensively procured, produced, and localized in rural areas like JABA. The development from primitive production to modern production systems can be facilitated by off-grid renewables in short but quick steps. This initiative probably will provide opportunities for more positive feedback between and within each inputs and outputs as shown in Figure 6-3. The virtuous positive feedback loops as shown in Figure 6-3 solves many of the intertwined rural problems. This figure also explains the need for a simultaneous integration of the four outputs, HELP, and also the factor inputs, RE-SKILL, for rural production optimization. This co-optimized process is the integration of modern skill and capital goods, which are the outcomes of urban innovations and underemployed land and labor available as rural endowments. The infrastructure necessary for the complete sustainable development will be roads, electric transport, and broadband network. I expect this integrated ADI-RE-HELP-SKILL process to deliver the essential human needs at lesser private and social costs than the conventional dominant fossil-grid compatible process.

This new phase is expected to remotely deliver health, education, and production skills through broadband network inexpensively, often involving volunteers from across the world (as in Wikipedia) for the necessary skill development in the rural area itself. This will make rural production independent of the long-term urban subsidies. In this way rural development can be made competitive, pro-poor and sustainable without participating in the present urban crises of pollution, migration, and climate change. This might also minimize the role of government or large development agencies, as individuals and small organization can participate in the development process in JABA.

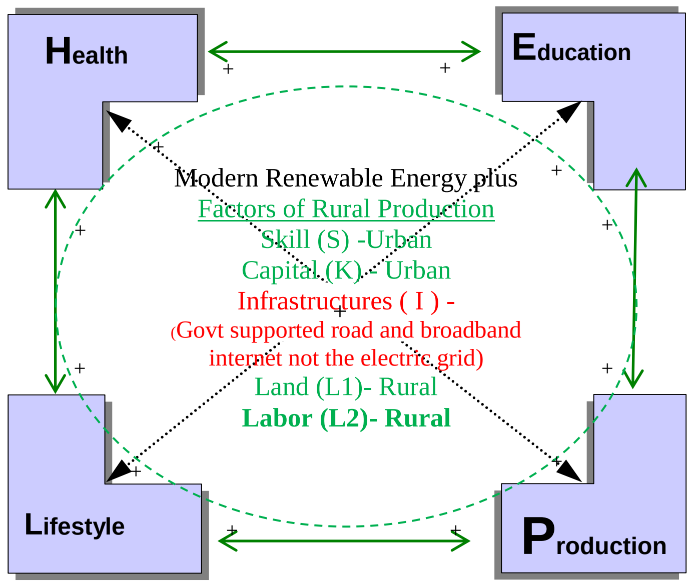

Figure 6-3 Phase III: ADI-RE-SKILL-HELP phase optimized for clean, sustainable rural development (most external factor and output services will use distance based tele-services)

As discussed before, electricity is a derived demand from HELP services, which together drive demand for other input factors, such as more skill, capital, land, and labor. Increased factor incomes will in turn create demand for HELP services in developing rural areas. The important difference between the RE-SKILL and the conventional development process is that the former retains the current traditional societies in their own habitats. It brings in essential skill, capital, and infrastructure using modern wireless ICET and energy efficient transportation network such as off-grid solar energy, cellular phone, internet, tele-services and electric vehicles. The model, however, retains the current healthy lifestyle of using bicycles, walking short distances, and using muscle power for productive activities.

The conventional development paradigm is very intrusive and expensive. It involves large scale physical movement of labor to cities, it breaks down families, it requires the acquisition of land and resources for urbanization, and it needs an expensive transport network. In the conventional development paradigm, as in the cities, the labor force and resources migrate to where only fossil energy, not renewable energy can be extracted or used optimally. Urban skill and capital take decades to accumulate, and they are not able to flow to rural areas as engineers, doctors, architects, and capitalists prefer to live in cities. RE-SKILL turns this paradigm upside down with surprisingly interesting results. There is small scale efficient optimization instead of large scale economies of the dominant fossil-grid systems. However, urban areas will eventually also need to unlearn the skills needed for the fossil grid systems (which I call DE-SKILL) and

RE-SKILL to the new paradigm. My earlier recommendation of removing fossil fuel subsidies and taxing fossil fuels enough to reflect their true costs is appropriate in the urban setting as well. Correct pricing should hasten the day when renewable energy resources are used more in both rural and an urban setting.

I will now show how the development literature should be informed by my experiences of this paradigm shift with the positive spillover effects of small scale environmentally sound systems empower the rural poor, women, and socially backward rural communities.

6.3.2 Small scale economic optimization in Phase III

The rural transformation and skill building from primitive renewable energy to modern renewable energy requires more thorough research and development with deployment of these small scale production systems in one village at a time. Many of the renewable based capital and skills are emerging rapidly and are even gradually being adopted by industrial nations to satisfy their increasing distaste for fossil-grid energy. The rural interest of sustainable development can also be well integrated with such emerging urban RE technologies such LED lighting and display, SPVs, smart phones, e-readers, rechargeable batteries, electric vehicles, and green manufacturing. Although I cannot go into a quantitative general equilibrium development analysis, which I leave for a future study by interested researchers, I will conclude this chapter with how this phase is being implemented in the JABA village and with some of the positive results.

This phase helped us to use rural labor and land more productively. More than twenty jobs have been created, reverse migration has been apparent with about five semi-skilled workers returning to the village, land prices have increased with the school and other civic facilities installed in the village. Instead of massive labor following the fossil-grid urban production system, the smaller RE-SKILL production system has followed the energy resources, labor, land and consumers, all available in the villages. The higher factor incomes will eventually lead to rural empowerment, gradually increasing the bargaining strength of the rural poor and empowering them with access to better services. The inefficient transportation of energy, resources, labor, and final products has been minimized. The productive use of off-grid renewables will now support a transition from primitive skill to a modern RE-SKILL without destroying the core village social fabric of living for food, festivals, friends, and freedom.

Some villagers have developed a “can-do” attitude by experimenting with smaller but modern devices and modular production systems instead of depending on donors for all these services as subsidies that reduce the incentive to work and develop skills. Fortunately, modern technologies to achieve all the multiple but complementary inputs and outputs are available in small, modular, and flexible form with some help from modern technology suppliers or social entrepreneurs. They can experiment on their own and learn to optimize their welfare at much lower costs than is possible in the fossil-grid development system. This case study experience brings an interesting insight to the unintended consequences of the foreign aid that often goes to subsidize urban infrastructure, civic supply and slum rehabilitation as a magnate of more in-migration and more fossil fuel consumption with attendant externality costs. These involve very expensive transitions: fossil-grid powered homes, business plants and transport infrastructure will need renewal to make them suitable for the new renewable energy paradigm; capital and skill already deployed in the fossil-grid may get stranded; and customer education to make behavioral changes is also costly. International development agencies still subsidize the urban development projects which do not need any subsidies. They, however, do not provide adequate services to rural areas which can achieve clean development with a fraction of the urban subsidies diverted as investments for social and physical infrastructure for rural development. The long and oblique path to fossil infrastructure development and back to renewables can be avoided through the ADI-RE-SKILL-HELP model and should be further studied. A pleasant surprise of this new model is that while achieving small scale village level development, it can also gradually be extended to other villages. This will ultimately lead to large scale manufacturing and distribution economies for renewables and efficiency across all the nations of the world, poor or rich.

6.3.3 Summary and potential funding: Emission /carbon offset trading

The main implication of my study is that fossil-grid systems, with their high distribution costs, poor reliability, and market inefficiency play no role for sustainable development of poor rural economies. I have argued that once households, communities, and the rural economies are self-sufficient in rural energy along with the missing factor inputs (skill, capital, infrastructure) to meet their HELP needs, the demand for cross-subsidies from the urban rich will be moot. I also showed that the villagers might not migrate to cities if they can adopt off grid SPV and other renewables and receive urban like amenities in rural areas. The "rurban" villages will undergo such a transition to prosperity without losing sustainability using modern technologies. These modern villages also harness the benefits of globalization of health, education, entertainment and other lifestyle support services through wide spread ICET use without losing control over local production. This is in sharp contrast to the top-down input-output production models used by the central planners with disastrous results in the fossil-grid system.

International support and obligation for climate support might grow as unbundled rural and urban energy markets are made clean and efficient. The climate change debate must focus on how much money can be saved in no regrets-rural solar electrification and on how much global warming gas can be reduced through reduced migration to cities.

The village economy can greatly benefit from the expansion of renewable energy industries. This would be true both for harnessing renewable resources at the local level and for creating a renewable energy industrial base that would serve local markets. This self-sustaining model, which is expected to be subsidy-free, will be run by market entrepreneurs who can borrow investment funds from international and national funds created from the emission taxes or from trading emission credits. In this process, we could see that the sustainable development model meets the perfectly competitive market in rural poor economies of the world. The remaining barriers to the market, such as the lack of roads, health, education, and internet connectivity, can be initially supplied by the government and development agencies. Soon, after a threshold level is reached, the skilled workers and entrepreneurs will emerge in the rural areas to take care of the market enabling infrastructure.

The rural poor who do not emit and may never emit pollution by using off-grid renewables can be paid the 3-10 MT CO_2 offset that they would have emitted in urban areas in India or the USA. This will provide significant income growth at the minimum CO_2 price of $30/MT projected in the USA (Nordhaus 2007; British Colombia carbon tax: http://www.carbontax.org). The feasibility of directly providing cash grant to villagers in lieu of migration and emissions to allow them to develop productive skills and invest in renewable energy technology and efficiency will be an interesting study of great global importance. This possibility should be further researched and widely disseminated amongst the donors, investors, and development agencies to bring sustainable development to rural poor economies of the world at the least cost. Such a policy will, simultaneously, bring many positive benefits including more competitive markets, clean energy, and rural development.