CHAPTER-7

CONCLUSIONS AND SUGGESTIONS FOR FURTHER WORK

Almost half of India's 80 million rural households lack electricity even after 125 years of electrification. Even urban customers use battery backup systems because of the unreliable grid electricity. The longer and more frequent power interruptions in the villages lead to the use of ancient energy forms in rural areas. Poor or rich, electrified or not, many still use kerosene lanterns. This motivated me to study why all the rural poor economies in the world have not solved these problems when off-grid SPV technology is emerging as an important source of small scale electricity. SPVs can power most of the modern electrical devices and gadgets, which are getting more efficient day by day. I show that such modern gadgets can be used by poor homes in developing countries to leapfrog to the new century of modern renewable energy and energy efficiency.

My literature review identified three drivers of poor rural grid conditions: rurality, poverty, and power market inefficiency that lead to the perpetual subsidies and a vicious cycle of underinvestment and high costs.

Rurality drives the high peak demand for electricity. Availability of biomass encourages heating energy bypass. Poverty is widespread. With average rural household income of about $100/month, many families use low or no grid electricity. This poverty also leads to the lack of demand for refrigeration, low community and street lighting loads, and low rural business and industry loads, which also contribute to low utilization. Thus, the electricity market fails for several reasons. Very low demand and high average costs of a natural monopolistic grid fail to provide enough revenues. Political support and subsidies attract politically savvy bureaucrats or entrepreneurs that depend on the subsidies and government contracts to perpetuate the monopoly. Electricity market inefficiency results from the regulated monopoly dependent on subsidies and plagued by lack of choice, moral hazard, adverse selection, and elite capture. Political entrepreneurs try maximizing profit from government subsidies, innovative accounting practices, spending resources on government patronage, or the political process of regulation rather than focusing on innovation, value creation, and cost reduction. The “market entrepreneurs” who seek profit by creating customer value and reducing supply costs cannot enter in this environment even if the market is no longer a natural monopolistic with emerging SPVs.

I showed that the existing non-transparencies and anti-competitive nature of the current rural grid when jointly managed with the urban grid has led to the investment, operating, and usage inefficiencies in the long rural grid supply chain. The rural grid franchise monopolies are considered unavoidable now or in the future with the hope that funding can be supplied through cross subsidies from the profitable urban and industrial consumers. However, the data and evidence in the Indian power sector from the last two decades do not support the sustainability of cross subsidies, nor do they imply that grid supply to the remaining 80 million off-grid homes will lead to higher revenue and better quality of power. On the contrary, they show ballooning losses and administrative mispricing of electricity leading to the choking off of funds to the otherwise profitable urban power sectors. They further suggest that government investments in an outdated rural subsidized grid are inhibiting emerging competitive and innovative off-grid SPV technologies.

This study is timely, appropriate, and provides counter intuitive results about the rural fossil-grid framework, as the developmental economist and central planners might argue in favor of continued fossil-grid subsidies. It is often argued that subsidies are, in any case, not large, in absolute dollar terms, because the needs of the poor are small, and perhaps international donors would not mind providing these subsidies. Both these arguments were found unconvincing and counterproductive based on this research. The supposedly small subsidies have created larger problems of fossil-grid inefficiencies in the entire supply chain from production and operation to the end use devices. International aid has never been adequate or poor-friendly. Government subsidies of the fossil-grid system not only perpetuate inefficiencies, but they compound the problem of lock-in and retard a transition to clean development. It is perhaps better to make the system clean, competitive, climate friendly and compatible with rural culture so that subsidies will not be required.

In spite of the many market failures of the fossil-grid paradigm, the literature shows that the electric grid networks function relatively well for urban and rural areas of developed high-income countries. With the grid having no substitute in the advanced countries, the literature also shows that developed countries like the USA can probably replace fossil fuels with renewable energy systems to be delivered through the same grid, though at a somewhat higher cost, but these costs are affordable due to their high incomes. In the last century, when the off grid-technologies such as SPVs were not mature enough as a credible substitute, the rural grid was the only option left, and USA style rural electrification was ported to mid-income and rural poor economies of the world.

The release of this research study is especially timely due to two recent but important missions of the Indian government that were unknown to me when I first started this research. First is the Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY), a rural grid expansion mission that started in 2005 to provide rural grid electricity to the remaining 80 million un-electrified homes. Second is the Jawaharlal Nehru National Solar Mission (JNNMS), an SPV expansion mission, proposed very recently in 2010, within the grid framework to remove fossil externalities costs from the grid. My study finds both of these solutions inferior to the off-grid SPV as reviewed below.

Solar electricity triggered my attention during my early engineering education, but at that time the technology was in its initial state, though it's potential to remove hunger from the world through water pumping was being discussed 25 years back. Within solar electricity, I explored two options, the SPV-off-grid and SPV-grid options with results as noted below

Four research questions were formulated to see if the highly subsidized RGGVY option is the best electrification option for the rural poor as opposed to off-grid SPVs. Although such SPVs are one of the costliest renewable energy technologies, they are highly valuable due to their portability, modular properties, and complementary to the platter of cheap rural biomass and biogas technologies that can provide heat.

A village case study was designed around the author's native JABA village to experiment with off-grid solar electrification and gather data on technological feasibility, cost, demand, and other implementation issues. This study provided the primary survey data for the cost and demand analysis and showed the opportunities and the barriers to entry of modern technologies that need more policy action. The grid cost data were collected from the Indian government's recent national rural electrification program and solar cost data was taken from the local market in Orissa. My village-level case study provided the income, energy expenditures, and demographic data from 98 households for a unique semi log demand curve for lighting that included both kerosene and electricity costs.

The integrated demand and supply analysis of the grid and SPVs showed that grid is cheaper only if the rural grid can be supplied at ½ kW peak load and inefficient appliances are used by the poor villagers for consumption of 30kWh/month of electricity as dictated by the Indian government. I found off-grid SPV electricity is cheaper than grid electricity for the rural poor in India when they use efficient appliances and devices. Under the more efficient use of 10 kWh/month, the advanced CFL/LED devices can be used for the same or better quality of service. The grid average cost then becomes higher than solar electricity by a factor of two due to efficiency. I found the grid average cost is so high because of the higher peak time use with high variable costs, high fixed costs of longer distribution lines, larger distribution losses, and higher operation and maintenance costs in rural areas that cannot be distributed to the non-existent rich customers or industries in rural areas. This expensive marginal energy costs more than 12c/kWh in the wholesale market with additional costs of the losses of 35% and more when transported through long transmission and distribution lines. Additional distribution investment is conservatively estimated at $460/kW. High operation and maintenance costs add another 5-7% depending on the terrain and remoteness of the villages. The average cost for a 30 kWh per month of electricity supply could be in the range of 31-45 c/kWh while the revenue earned is only 3-4 c/kWh. The off-grid

SPV costs are about 38 c/kWh. The grid is cheaper for the very poor only if consumption is higher than 20kWh/month with maximum capacity demand lower than ½ kW. Such a low capacity is unlikely and also difficult to enforce in a grid environment with metering and technology limitations. SPVs are cheaper when consumption is lower than 20 kWh per month and there is no problem of enforcement and metering as they are off-grid devices and use efficient appliances by design.

On the demand side, I observed that rural demand is very low because of low incomes, off-grid subsidies for kerosene and diesel, and the availability of primitive biomass for cooking and heating. My demand estimates suggest that under no circumstances can the rural grid supply be subsidy-free with the low current villagers' average income below $100/month. The off-grid SPV can be subsidy free for the rural poor in India. Although low economies of scale operate against the grid there are no such diseconomies of scale for modular off-grid SPV systems. Rather, conservation and efficiency are helpful when designing more efficient SPV systems. The rural information, communication, and energy needed to run radios, TVs, cell phones, CFL/LED lamps, and other appliances can all be supplied at the same or lower average cost of around 38c/kWh using SPV based systems instead of grid electricity within the government mandated 30 kWh/month/household.

The break-even household income for the grid to be subsidy free was found to be $200/month for the unrealistically low ½ kW capacity, while the average village household income is less than $100/month. I found that the break-even consumption for a subsidy free grid is 40 kWh for a more realistic connected load of one kW. The threshold household income for this consumption amount is about $400/month. Even with the optimistic assumption of 10% annual income growth, the current rural Indian household income of $100 per month can only increase to $300/month, much less than the threshold income found above. As income grows one could expect that the grid will be cheaper than off-grid SPV. However the learning curve effect makes the off-grid SPV even more attractive. Thus, a subsidy free grid supply cannot be achieved in rural India by 2020 and possibly beyond as the SPV prices are coming down but grid prices are not. The dominant grid firm in the face of open access with no regulatory or market barriers and no preferential taxes and subsidies will eventually lose its dominance and have to compete.

A "dominant firm" model was used to assess the economic feasibility of the grid in rural areas by 2020. The demand model showed that rural demand for grid electricity is very low and the grid average cost is very high. Thus, an unstable monopoly is surviving with unsustainable subsidies. Such low demand in rural areas might be the result of the large use of free and cheaper biomass, biogas, and solar thermal energy relatively easily accessed by low-income rural consumers and will continue in future. In a dynamic framework using learning curves, I showed that even costly renewables like SPV electricity can compete with the rural grid, economically meet the rural demand, reduce the needs for rural energy subsidies, and enable private or community organizations to deliver energy services in competitive markets. The theoretical foundation of the dominant grid firm was used to show that subsidies are not required for SPVs now or in future, while the energy and development experts agree that the rural grid will continue requiring subsidies for a long time to come.

Under JNNMS, the SPV-grid along with other renewable grid options are being suggested for India as a panacea for climate change, recent high increases in grid prices, fossil fuel scarcity, and pollution control. Its target is to expand to 20,000 MW SPV and large solar thermal power generation by 2022. Though JNNMS has an off-grid SPV component, it is small at less than 200 MW by 2013 and only 2000 MW by 2022. These grid connected SPVs do not solve the large investment costs and high losses of the Indian distribution system, which can be avoided if off-grid SPVs are deployed. This study found that pursuing a highly subsidized SPV-grid neglecting the opportunities of subsidy-free off-grid SPV will compound the problems of subsidies and anticompetitive outcomes. The SPV-grid has the potential to be the next economic disaster after the recent power sector privatization debacle of the last decade. Grid connected large scale SPV systems are considerably more expensive than the fossil grid and would carry with them the current inefficiencies, moral hazards and adverse selection, which have already mired the Indian grid with revenue and investment deficiencies. It would not remove the essential rural problems of low access and high costs but would rather delay investment in a sustainable future and likely require continued fossil fuel use through off-grid kerosene lanterns, diesel pumps and gasoline generators negating whatever environmental benefits SPV would have created in the grid. Further, the entire 20,000 MW future solar mission is hinged on the funding available from the UNFCC, which is doubtful after the failure of Copenhagen talks. I found that the grid based “solar mission” is the most expensive option and would do even more to crowd out a far better solution of off-grid SPV based sustainable rural development.

My biggest surprise from the above work is that the SPV can be subsidy-free for the rural poor in India. My second surprise is that electricity demand is very low and a small amount of reliable quality electricity can meet the needs of rural home and community to make them modern and productive. With such low demand, the grid will never be subsidy-free. SPV delivered through the grid will be much more expensive than the fossil-grid, and the urban sector will be required to cross-subsidize most of these high costs. The supposed clean nature of an SPV-grid will also be lost due to the unreliable nature of the Indian grid needing more fossil-fuel powered decentralized small generators or kerosene.

If the grid is economically inferior up to 2020 and the alternative can be provided subsidy-free even today, it does not make any economic sense to subsidize the grid in the name of the poor and perpetuate a non-working government subsidized grid-monopoly in rural India. An often ignored important economic benefit of off-grid systems in rural India is the creation of a competitive clean energy market. This market could possibly end the electricity monopoly and energy deprivation in the same way that modern cell phone technology erased the telecom monopoly and communication deprivation in rural India. Recently, cell phone industries, through competition and wireless infrastructure, have provided low-cost communication service at $2/month. This has led to heavy customer sign ups to build the volume necessary for a scale economy that the wired telephone business could not provide earlier. Thus, while the wired telecom business is subsidized in rural areas of India, the cellular business is unsubsidized and multiple market players have entered with huge investment funds. Similar options are available for multiple competitive players to supply rural energy services for $2 per month solar lanterns to $10/month ICET services. But this cannot easily be done in the monopolistic grid framework.

I also explored development issues in my three phased development initiatives at JABA village. They showed that the porting of the inefficient fossil-grid has not worked and porting the renewable grid technologies to rural poor economies may also be a disaster for rural poor economies. On the contrary, the case study experiences and the cost and demand analyses suggested a completely separate off-grid market for the rural poor. In this market, demand clears for SPV electricity with no burdens of subsidies, externality costs, and elite capture. The barriers to entry identified in Phase I need government action to remove subsidies and promote off –grid SPVs in rural India immediately. Phase II showed the need to focus on resource mobilization for the unmet social issues of land reform, health, social security, insurance, internet broadband, and physical infrastructure that are often impossible to implement in the private sector. The control of energy services in rural areas can be left to the millions of market entrepreneurs to innovate and search for reliable, affordable, and safe local renewable energy, and not to seek subsidies as in the present fossil-grid regime. The third phase of the case study recommends economic development efforts that can foster local renewable energy generation, equipment manufacturing, energy services, and diversified production capacity in rural areas itself leading to the final ADI-RE-SKILL-HELP phase of development. In this alternative development initiative (ADI), the village produces the final outputs of health, education, lifestyle, and other products/services (HELP) in a phased manner starting from a very small scale with minimal subsidies and using renewable energy and resource efficient technologies (RE) not possible in a large scale fossil-grid system. This step will require a happy combination of rapidly growing modern urban skill and capital in RE sectors to be used to modernize villages with their vast endowment of unemployed land and labor. These four factor resources can be combined together only when the physical infrastructure such as roads and broadband services (referred to here as SK-I-LL) are made available for remote operation of ADI-RE–HELP projects. This will increase the availability of skilled labor, credit, social security, and insurances in the village through partnerships with the local technical and skill training institutions, micro finance organizations, infrastructure providers, and many philanthropic individuals or small organizations. Government and large funding institutions can help accelerate this process but are not essential for this model to work. The donors and investors can directly watch online as their investments remove poverty and hardship through the internet and ICET.

On the developmental aspects of the off-grid SPV, my biggest surprise came from the case study experience as the solar lights could not on their own bring any appreciable development other than the lifestyle improvement and villagers showed very little willingness to pay the fees. But when the complementary input factors were provided, the productive capacity of the villagers and social outputs such as health and education could be improved. These positive externalities require larger investments in the non-energy sectors and the lumpy grid investment at huge costs cannot achieve these multiple investment needs. The off-grid SPVs, however, could meet the phased development plan much easier at lower costs without any stranded capacity due to their modularity. My last surprise was how the off-grid SPVs funded through a reasonable emission tax will be less expensive for India than the costs of the current fossil-grid system. While the more developed world's urban utilities still struggle to incorporate renewable energy and energy efficiency in their business model, India's poor can build these resources from the ground up.

Each of the three case study pahses showed that development does not involve a large amount of energy but requires reliable, portable, and affordable local renewable resources backed by modern efficient devices. Many social and under development problems, no doubt, stand as barriers to entry. But these problems can be addressed through learning by doing, providing accurate price signals, better education on the costs and benefits of the SPV technologies, and the removal of other market failures.

In essence, I suggested a more optimized rural economic development model that can be taken up by numerous searchers in tiny steps but that will be a giant step by the larger society for a sustainable world. The core infrastructure to achieve these will be the efficient rural roads and broadband internet connectivity to create a bidirectional flow of resources between rural and urban areas. The core financing mechanism can be the savings from the existing inefficiencies of the fossil-grid, future savings from the off-grid SPV, and the transfer of emission credits and emission taxes.

The rural electrification study through off-grid systems has not been getting enough attention in the academic literature for lack of funding. The costs and benefits of other renewables in various rural settings must be examined in more detail and should cover larger areas than the one village done in this study. From the time of the data collection and analysis, many new conservation and efficiency measures have been introduced in modern appliances, and the rural grid loads have declined further, which our demand analysis has not captured. It might be useful to observe the new demand curves of the villages, which we postulate will be much lower than what the 2003 data indicates.

It is possible for the academic, large donors and multilateral development agencies to take up more such interdisciplinary studies that might change their current focus on the grid based solutions. More research can be done on funding for clean development and income transfer to the rural poor. Along these lines, I plan to do further empirical research to learn more about the consumption behaviors of poor households and especially women to any payments for emission credits if introduced later. Transfers of emission credits to households or to the bank account of the homemaker women may be a good mechanism as demonstrated by Md Yunus of Garmin Bank, through his novel micro finance, and Bunker Roy, through his Barefoot college training to women in solar technologies. Studying the choices and allocations of households and women for HELP services will determine if paternalistic government targeting of a specific sector provides more social welfare than a more liberal direct cash payment.

The partial equilibrium cost and demand theory presented in this thesis for an ideal subsidy-free rural electricity market may not work in practice due to large scale underdevelopment and missing complementary inputs and outputs. A new case study of a co-optimized rural production in a general equilibrium framework may be taken up for further study if not yet done by interested development economists and policy planners. The optimization of inputs and outputs in this initiative does not require sophisticated linear programming, but rather techno economic study of the cost and demand of the small scale health, education, and production projects of the villagers. As the villagers see and use the new technologies finding them affordable and operable in their own home and communities, off-grid renewable systems will not only improve their quality of life but will also develop a thriving, market-based optimization of input and outputs. Thus, future study should focus on how to bring such modern technologies and a competitive market to the rural world, where the inherent sustainability and prosperity do not require fossil fuel or a migration to cities run by fossil fuel. This proposal, I believe, will reduce the growth and level of current global warming faster than the present regime of unending negotiations on who should start cutting greenhouse gases first. The climate change debate should include and monetize the huge potential of the rural world as a source of sustainability. More work should be done to investigate how the fossil fuel emission charges can be passed on to the rural poor as social security or for market penetration of clean energy in an off-grid framework for poor economies to thrive and sustain both their conservation culture and the planet.

This research, though long, complicated, and continuing gives me satisfaction because of its potential and timely implications for the world's rural poor world. That a subsidy free electricity service is possible in rural India and has great implications not only for the rural poor in India but for the entire population of other countries that are rural, poor, and have electricity market inefficiencies. It not only indicates the efficient technological solutions for the core poverty and rural deprivation issues that have bothered me for over a decade, but it also suggests future solutions to global warming and sustainability issues that were not in my original research agenda. It is up to humanity to take the next steps to end the global warming debate by solving rural problems that will not only reduce rural poverty and pollution through modern health, education, lifestyle, and productive services but also regulate the fossil fuel based urban development and pollution and reduce or reversed migration to urban areas.