1 CHAPTER -1

INTRODUCTION

Mumbai, India was one of the first cities to adopt the electricity grid and Edison's incandescent light bulb in the year 1882, along with New York and London. However, while the USA, UK, and even China electrified almost all of their households, India still remains the most electricity-deprived country in the world, where more than 400 million people in 78 million homes are without access to electricity with no signs of change (World Bank 2009;2004; UNEP 2008; Cust et al. 2007; MOP 2003; 2005). This is the state of darkness in a country more than 125 years after the first bulb was lit. The fact that more than 50% of rural, poor households in India are still un-electrified despite over a century of the electricity grid exposes deeper problems in grid technology for the rural poor.

1.1 Motivation

The motivation for this research started with my long experience with the repeated electricity market failures in India. The fossil grid problem is not limited to my village, but to all of the rural poor economies of the world. The International Energy Agency (IEA 2002) has reported year after year that 1.6 billion rural poor in the world are cut off from the grid, and the situation has not improved in the last decade. The population growth in rural areas easily offsets any possible growth in electricity connection in most of the un-electrified rural economies of the Indian subcontinent and sub-Saharan Africa. It is time to consider another approach. I will discuss two more motivations why we should explore a subsidy-free rural electrification plan that will remove darkness from rural areas.

Power interruptions in India are an everyday event not only in rural areas separated from the central grid by longer power lines but also in urban areas close to the grid. The reasons for the power interruptions can be attributed to the entire supply chain of the electricity industry: from the lack of the adequate power generation in base-load and peaking plants to the illegal connections and rampant power theft at the consumer end. Clearly, the quality of grid electricity in India is not suitable for modern living commensurate with the digital age that India cherishes. Thus, billions of dollars of investments in power quality improvements through backup generators, storage battery, and inverters are made even in urban India. The rural poor cannot afford that luxury. They have to reconcile with the age-old kerosene lantern. For the rich and educated, the lantern is a symbol of power failure, evening darkness, disease from indoor air, and deprivation of education and productive activities during evening times. Still, the lantern is so popular with rural India's 700 million people that a political party in India uses a hurricane kerosene lantern as an election symbol to entice votes from the illiterate poor. Rural India continues to depend on kerosene, causing economic loss through the negative externalities of local pollution as well as contributing to global climate change (UNEP 2008). However, I will show this lantern can now be powered by solar electricity at a lower cost than kerosene without the externality costs. Solar electricity can power cell phones, TVs, fans, and water pumps that can change rural darkness, disease, drudgery, and deprivation into a healthy, educated, modern, and productive rural lifestyle.

In rural areas, the cost of supplying grid electricity remains high due to the longer length of the distribution line, higher energy losses, poor load growth, and higher operating costs (NRECA 2006; IEA 2002; World Bank, IEG 1995; 2006). On the other hand, income-poor consumers cannot pay for the upfront and recurring costs of grid electricity (Modi 2005; World Bank 2002; Taylor 2000). The average Indian rural household income was about US$96 /month in 2008 (Shukla 2008) and will remain less than $300/month by 2020 even if an optimistic annual rural income growth of 10% is assumed. World Bank (2005) and NREL (1998) and Taylor (2000) assert that nowhere in the world can grid electricity be provided without subsidies to such low-income consumers. The provision of electricity in rural India is driven by government policy with a rural dominant grid monopoly that cannot charge even its short run variable cost (Dubash and Bradley 2005). Indian utilities lose 6-10 billion dollars annually, which is more than 20% of Indian industry revenue. These subsidies equal 1% of Indian GDP (GOI 2009).

Although the electric grid may have been a good solution for urban areas and rich economies, it has little to offer for the rural poor economies any time in the future. I therefore turn to the off-grid, small-scale, SPV-based development plans for electricity-scarce villages to see whether SPVs can address all these issues together. India alone has close to 600,000 villages in 140 million households in this category.

1.2 Contribution to Literature

The existing literature has largely ignored the true economic costs and overestimated the value of a small quantity of grid electricity of dubious quality to poor homes in rural India or any developing country. Rural grid electrification programs, from the New Deal of the 1930s in high-income USA to the most publicized, successful electrification programs in mid-income Chile, Peru, South Africa, Tunisia, China, and Thailand today, have all been subsidized. These subsidies are needed to compensate for higher upfront and operating costs in the face of lower revenue per mile in contrast to urban systems (Steven et al. 2009; World Bank 2000 - 2009). It is no wonder a high subsidy is part of the grid system everywhere in the low-income world. The grid expansion in India that started with a new Government scheme called Rajiv Gandhi Gram Vidyutikaran Yojana (RGGVY), a Village Electrification Plan to electrify all villages and 23.4 million poor homes, has been criticized by Bhattacharyya (2008; 2007; 2006), Singh (2007), Dubash and Bradley (2005), and Srivastava (2007) amongst others as likely to meet the target of rural wires but without electricity flowing through them. This plan is similar in objective to that of South Africa during the past decade that assumed that consumers prefer unlimited power 24/7 with no consideration towards their willingness and capacity to pay the cost of such high quality power. The high fixed costs of grid electricity in rural areas are known. Despite such high costs, the grid supply is not adequate, reliable, or safe in most developing countries (MAIT 2008; ISA-NMCC 2008; Wartsila 2009).[1] In India, the chronic shortages of peak capacity, 5-20%, and energy shortages up to 10%, have been reported by the CEA (2009) year after year for decades.

A few recent policy research paper including World Bank ((Khandker et al.2009) have argued that the benefits of rural electrification in Bangladesh and Vietnam surpass the marginal costs. However, my review of these study indicates that the grid electrification cover more affluent rural consumers only if the revenue per kilometer is more than $600 per month as in Bangladesh implying the cherry picking of already developed and rich customers for grid electrification. More than 70% of the rural households who are poor cannot pay the access and concurrent charges. All these projects are justified on socio-economic considerations with 100% capital subsidies and some operating cost subsidies still required even for the apparently richer customers. Such electricity projects could be argued to have positive spillover effects on the poor by way of more jobs in the rich households with electricity and ambient lights in the evening. But can these or even higher spillover benefits not be obtained from off-grid solar photovoltaic (SPV) and other modern renewable energy technologies while providing electricity to all without subsidies?

In the twenty-first century, modern technology has brought significant improvements in energy efficiencies, and renewable energy development has reached some technical maturity, especially the decentralized SPVS that I will show is the most appropriate for rural electrification of the rural poor. The cost reduction of SPVs over the last decade has been exceptional, with an average reduction in the price of 20% for each doubling of production (Prometheus 2009; IEA 2008; Schott Solar 2008; NREL 2002). The SPVs are now ready to compete with the grid in remote rural areas as indicated by much recent literature (Winrock 1998; Taylor 2000; IEA 2002; MOP 2005; Greenpeace 2008; Nouni 2008).

None of the past literature by the UN/World Bank, academics, or policy research and governmental organizations has clearly established or unambiguously accepted the possibility that currently available off-grid SPVs are sufficient to electrify and modernize villages. Bradley (1998), Taylor (2002), and Guru

[1] Often power failure is a common problem of all rural areas in the world though of differing severity. In the most modern grid of the world, I have heard of power failures in rural areas of upper Wisconsin and Michigan, USA lasting a few hours but they are almost unheard of in urban areas in normal situations. Our field experiences in the villages of Orissa, India show the down times due to thunderstorms, stolen conductors, and burnt transformers kept the electrified village in the dark for 10 days at a time in July 2009 (JABA Case study, 2009). World Bank (2001) reported the loss of load probability in the state of Bihar in 2000 on the order of 40%. In the context of India, recent reports by the NMCC (2006), MAIT (2008), and Wartsila (2009) bring out the costs of power failure in the range of between annual $10 billion for manufacturing down time alone to $60 billion for the entire country including the backup power supply costs. These power disruption costs range from 1% to 6 % of the GDP.

(2003) have outrightly rejected renewable subsidies while the World Bank and the Government of India (GOI) favor subsidizing both the grid and renewables as if they are complementary technologies in the rural areas of poor countries. All studies more or less accept the inevitability of the electric grid for development even though the grid monopoly is unfair and inefficient, with negative environmental externalities. Cato studies by Taylor (2002) and Bradley (1997) went a step further and even ridiculed renewable energy as neither clean nor green. One of their arguments that renewables are not cheap is valid in the context of the USA and developed countries that have enjoyed a reliable and safe electric grid for almost a century now and are still locked-in to a vast amount of fossil energy. However, a majority of Americans lived in urban areas and could provide subsidies for rural electrification during the U.S. take off stage in the 1930-1950s. Even the World Bank's economist (Saghir 2008) argued that the grid is so heavily subsidized in developing countries that the competitive off–grid suppliers do not have any chance of matching resources. A recent World Bank (2009) report, however, states that the subsidies made available to off-grid renewable projects are much less, 20-30% of the upfront costs, than for the grid. Even the Indian Ministry of New and Renewable Energy, which is supposed to promote clean and renewable energy has remained biased against the poor and rural areas (Miller 2009). Their top-down programs support large systems and big businesses to develop a market that is pro-rich and grid based and often anti-competitive (MNRE 2009; World Bank 2008; Redulovic 2006). The votary of competition and private capitalism, the Cato Institute (Taylor 2002; Bradley 1997) and the American Enterprise Institute (Joskow 2008; 2006; Green 2006; 2009) also support electric grid regulation and fossil fuel as inevitable.

None of these studies or any studies from MNRE and the UN system have analyzed the roles of off-grid SPVs for creating a low cost, competitive market in a conservation rural culture with a sunny climate where the necessities are mundane (food, drinking water, roads, and rain/storm proof shelter) that do not depend on huge amounts of grid electricity. Even where a huge amount of grid electricity has been supplied at subsidized rates, inefficiency and low productivity have plagued the grid and the end-use farm and household consumption. This opportunity of using SPVs was never available to developed nations during their rural electrification phase in alleviating the market failures of a monopoly fossil grid that, I will argue, have created some of the acute problems in the Indian electricity grid systems. These problems are high transmission and distribution losses up to 60%, high commercial losses of monopoly distribution utilities up to 30%, loss of national income up to 6% from inadequate and poor quality of power in urban areas (Wartsila 2009; MAIT 2009), and excessive ground water use (Dubash 2008), loss of soil fertility, and pollution (USAID 2009).

The same characteristics of rurality, poverty, and inefficient grid electricity supply that have moved rural India backwards can now be an ideal combination of opportunities for the application of modern renewable solar and biomass combined with the efficiencies of usage technologies to create a virtuous cycle for the transition to sustainable rural prosperity. Heavily populated Indian villages are the prime candidates for using modern technologies to leapfrog from extreme rural backwardness, because the expensive lock-in to inefficient fossil-grid technologies has not yet occurred. No country in the world has such a large un-electrified population in rural areas where the renewable energy resources of solar and bio energy are abundant.[2] Rural India might be saved from a futile and outdated development path because modern SPVs can achieve better lifestyle improvements at a lower cost now and at even lower costs in the future. However, not much research has taken place on SPVs potential. Whereas the renewable literature is saturated with cost benefit studies based on production costs none have looked at the demand side of the equation.

The World Bank rural electrification evaluation study (2009), based on historic data and willingness to pay, does not consider the true opportunity costs of energy and capacity of the rural distribution system. They also did not consider the future demand and supply curves of the grid verses SPVs, and if the same or better benefit cost ratio can be obtained from cleaner off-grid SPV energy systems.

I will show that modern SPV technology is cheaper than grid only electricity and requires no subsidies. Thus, it can be argued that if the grid subsidies cannot be removed, the SPVs deserve a fair regime where they get at least similar subsidies and market support as the rural grid in terms of per unit efficient energy use. SPV electricity can harness modern developments in energy generation and efficient use (examples: Compact Florescent Light (CFL)//Light Emitting Diodes (LED)//small Liquid Crystal Display (LCD) TV, irrigation and drinking water pumps at a household and farm level of consumption.

In a dynamic dominant firm model framework, I will consider the increasing demand of rural households possible through income effects and the decreasing costs of off-grid SPVs through learning curve effects using data from secondary sources. I will show that SPVs are not only competitive for the very poor now, they show increasing promise in the years to come. Thus, this thesis will be a valuable practical contribution to the theory of the dominant firm. It is the beginning of literature on the development of sustainable, subsidy-free competitive energy markets in rural areas that will promote similar studies and calm debates on global warming and the grid verses SPV costs in other developing countries. The study, by establishing the cost and demand superiority of the SPVS for rural modernization, will encourage international debate to focus on SPV based development to stop migration, dependence on fossil fuels, and decrease carbon and pollution emission.

The recent Indian government announcement of a solar mission for 20% of electricity to use massive untapped solar potential and skilled human resources by 2022 is also pointed in this direction.

The stated objective of the solar mission is to drive down the SPV price to make it competitive with the retail price of electricity by 2020 and with coal plants by 2030 (MNRE 2010). Thus, this proposal is not only timely, but it will provide the theoretical and empirical support for the cost reduction of SPVs as well as to show the result of increasing subsidies for the grid if off-grid solar is not promoted to challenge the dysfunctional rural grid dominance. This will also bring about competition faster. By effectively separating rural areas from the urban electricity supply from two different sources, similar to what has been proposed by Reddy (1998), my research will show that the fossil-grid inefficiencies are not needed, but off-grid SPVs are necessary and sufficient for a clean, efficient and unsubsidized Indian village economy of the new century.

Much of the input data on energy consumption, income, and other human needs for a rural poor economy come from the development literature and my primary village development experiment. Similarly, the outputs of the study also inform the development literature about the costs, benefits, and potential role of competitive SPV markets. My research also has global implications for low cost clean development using renewable energy, energy efficiency, related skill and infrastructure in a competitive market environment.

1.3 Research Objectives

I have four research questions in this thesis. The first question of my research is to find out if the electric grid and solar PV can provide cheaper electricity to meet rural household and community demands with special emphasis on modern information, communication, energy, entertainment, educational, and electronic lighting (CFL/White LED) technologies, together designated as ICET. This question will be answered by comparing SPV average cost with the rural grid cost for the average monthly consumption of 30 kWh that the government has set up as the lifeline rate in rural India.

The second question of the research will be to determine whether fossil-grid and SPV electricity can be delivered in a competitive market without subsidies. I will evaluate the demand curves from the village in Orissa, and use the demand curves along with the long run cost curves developed in the first question to show that subsidies are essential for the grid but not for SPVs.

The third question is to determine how much income is required to provide subsidy free grid electricity to poor villages in India in a static framework. The rural electric grid has less opportunity to achieve the scale economies, considering the off-grid subsidies for kerosene and diesel and non-subsidized primitive biofuel the villagers use when their current average income is only $100/month.

The fourth and last question is the application of a dominant firm model. For this question, I take a dynamic look at the future when income, price, and technology will all have advanced. I ask whether subsidy-free electricity service can be achieved within the next 10 years when household income is still expected to be less than $300/month. A case study in the poor state of Orissa will provide model inputs and will illuminate the appropriateness and implementation issues of the cost effective and energy efficient SPV technologies.

The four questions are summed up below.

Q1. Is off-grid SPV electricity cheaper than grid electricity for the rural poor in India?

Q2. Can off-grid SPV electricity or grid electricity be subsidy free for the rural poor in India?

Q3. What are the break-even incomes for the grid to be cheaper than off-grid SPVS?

Q4. Can this break-even income and consumption be reached for the electricity grid to be competitive and subsidy free by 2020?

1.4 Outline of the Research

With this introduction to the grid verses off-grid debate, the detailed literature review for this proposal will be presented in Chapter 2. I will first describe how the fossil-grid paradigm, which has worked well in the developed world even in rural areas, has failed for rural India. I will show that rurality, which increases costs, coupled with widespread poverty, which reduces demand, makes the rural grid infeasible. Then I will show even if the technical grid supply and demand could be achieved with higher income or urban-rural joint management, the Indian fossil-grid system will continue the current high inefficiencies, poor quality and unreliable electricity. The many hidden externality costs will compound these problems. Then I will discuss the literature of emerging SPV energy technology and its potential for India in a grid and off-grid framework. The theory and research methodology of the off-grid SPVs will be described in Chapter 3.

A case study of a typical Indian poor village provides many of the experiment, inputs and insights for my study. I describe its energy endowments, the technological feasibility of off-grid SPVs for rural uses, and the methods of data collection from the village with a qualitative demand analysis for the households and community in Chapter 4. The modeling and analysis of demand and supply of grid and SPV electricity to answer questions 1-4 will be in Chapter 5. The results suggest that the removal of grid and kerosene subsidies can lead to a subsidy free unbundled electricity market in urban and rural India.

Chapter 6 will contain the practical observations of more recent case study research. They indicate the possibility of using SPVs, other local renewable energy, and energy efficiency to develop self-sufficient villages with the related skill, micro finance, and modern internet infrastructure for remote deliver of the necessary social and production services at lower costs than by conventional methods. In return the villages will provide to urban and developed countries emission offsets at lower costs than developing a renewable grid for urban areas. Chapter 7 will contain the conclusions of my research and suggestions for future work.