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ELECTRIFYING RURAL AREAS: EXTENDING ELECTRICITY INFRASTRUCTURE AND SERVICES IN DEVELOPING COUNTRIES

by

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I. INTRODUCTION

Electricity is an important part of the modern infrastructure of any country. It is taken for granted in developed countries that nearly every household has access to dependable electricity services, yet in many developing countries it is a luxury reserved mainly for wealthier households and businesses in urban areas. There are also problems with uneven coverage, unreliable service, and frequent breakdowns, and in some cases, the public sector ownership and provision of electricity has resulted in a huge budget burden, a failure to invest adequately in the generation, transmission, and distribution infrastructure, and the inability to expand electricity provision to rural areas.

In this paper, I discuss the problems of electricity provision in developing countries, focusing more on the issue of access in rural areas, and the inherent difficulties associated with designing a regulatory regime that promotes an efficient, sustainable, and equitable provision of electricity services. Several recent papers discuss the challenges associated with electricity provision in developing countries: private participation vs. public ownership, capital investment and maintenance of the infrastructure, ways of introducing competition into the generation and transmission sectors of the electricity market, and applying innovative approaches to spurring the spread of electricity to the poor living in remote areas. The focus of this paper will be to examine this literature, and to draw some general insights about the best ways to regulate and structure the electricity market to ensure equitable provision and reach the rural poor.

This paper is organized as follows: in Section 2, I describe the basic economics of centralized electricity provision, including the traditional economies of scale and natural monopoly aspects of this service.[1] I examine the way electricity regulation has developed over time in developed countries, and explore the rationale for some of the recent deregulation and restructuring plans that have been proposed.

In Section 3, I identify the problems inherent in providing electricity to rural customers, and analyze ways in which this problem was addressed historically in several countries, including the United States and China. This section analyzes the evolution of electricity regulation, with a focus on relatively recent pro-market reforms that many countries are considering, or are in the process of adopting. I also briefly discuss a few other developing country case studies of electricity reforms that were promoted in India, Bolivia, and Ghana, and their outcomes.

In Section 4, I present several innovative approaches to solving the rural electrification problem, including a

[1] I recognize that the market is changing, and that distributed generation is becoming more common as countries experiment with deregulation and technology changes. This may have major implications for rural electrification in developing countries, and I will discuss these issues in Section 5.

discussion of new technologies and possible regulatory designs that can address the challenge of making electricity more widely accessible in developing countries. In Section 5, I offer concluding remarks.

2. THE ECONOMICS OF ELECTRICITY

Flip a switch and instantly, the room is full of light. How does this happen? There are essentially three separate parts of the provision of electricity: **generation** of electric power, most often by using turbines powered by natural gas, hydropower, coal, or other fuels; **transmission** of the electric power from the generation station to smaller substations across the grid; and, the **distribution** of the electric currents to individual households and businesses.

Electricity, once generated, cannot be stored (except in limited amounts using batteries), but it can be sent long distances across the grid. A given electricity generation facility has a maximum capacity that cannot be breached, given the risk of dangerous overload that can lead to explosions and electric surges. Demand is uneven, dependent on the weather and time of day.

The infrastructure required for centralized electricity provision includes major capital investment in generation facilities, transmission lines and substations, the grid across which the power is transmitted, and individual distribution lines to link households and businesses to the power network. Given that power can be generated in a location far from the end users, there is less of a need to build dedicated generation facilities in each town, but the transmission and distribution infrastructure must be built to enable each customer to gain access. As more users are attached to the distribution network, the per-customer cost of power provision drops, given that the initial capital investment required to build the transmission and distribution infrastructure is fixed. Thus, there are significant economies of scale associated with attaching more paying customers to the electricity network. This kind of centralized generation and distribution of electricity is currently the most common type used in most countries.[2]

One of the primary ways in which electricity is generated is by spinning giant turbines, powered either by pressurized steam or through harnessing the mechanical energy of hydropower, where the turbines are connected to an electric generator. Various fuels can be used to produce steam (e.g., coal, natural gas, nuclear power, etc.), or the turbines can be spun through the use of water (hydropower), wind, geothermal energy, or solar energy. Once the electricity is generated, it must be transmitted from the power plant at very high voltages over long distances to reach substations where it is "stepped down" and distributed to customers. [3]

[2] Technological change is making micropower possible, meaning that individual firms and villages can supply their own electricity by building and maintaining a local source of power generation. More on this later in the paper.

[3] For an interesting primer on how electricity is generated and distributed, see the following website: http://people.howstuffworks.com/power.htm

In developing countries, especially in rural areas, there is a chicken-and-egg problem inherent in connecting rural customers to the grid. That is, the upfront capital investment costs of building the transmission and distribution network to provide rural access to electricity is extremely high, especially if the customers are diffused through mountainous terrain and/or across long distances. Given the previous lack of electricity, these communities initially have little demand for it, and have not pursued income-generating activities that involve the use of electricity. The trick: how to justify the large upfront capital costs of providing electricity to rural areas by encouraging income generating activities that make use of the electricity once it is provided? In order for such an investment to be profitable over time, rural dwellers will need to learn about electric appliances and machinery that can be used to improve their living conditions, as well as increasing productivity in many activities.[4]

Because demand is unpredictable and the initial capital investment to bring electricity to un-served communities is high, under what circumstances can this service be provided? What kind of regulatory environment must exist to encourage service provision?

The private market may be responsive if companies can reliably collect payment for services provided (that is, electric meters must be installed and monitored) and if uncertainty is minimized about the rates companies can charge in order to cover not only marginal costs, but also the sunk investment costs of setting up the network, as well as the ongoing costs of maintaining the grid and investing in upgrades to accommodate demand growth. Thus, one key to successful provision is reducing uncertainty about the ability to set rates to cover these costs. The state is in a position to provide a regulatory environment that fosters competition while promoting transparency, consistency between costs and rate-setting, and minimizing the uncertainty firms face about future demand and the ability to recoup capital investment.

A stable regulatory environment can provide the incentive for private firms to pay for the initial investment. Alternatively, the state can finance the capital investment and contract for the electricity services to be provided once the infrastructure is in place. Continued investment and expenditures on upkeep and maintenance of the network must be incurred, and the state must either provide these, or they must be included in the contract provisions with the private firms. As with anything else in economic policy, the incentives must be structured correctly to ensure sustainability.

Since parts of the centralized electricity system retain elements of natural monopoly, given the significant economies of scale associated with transmission and distribution, pricing in this market is frequently regulated to prevent monopoly pricing and to ensure adequate service provision. The

[4] As will be discussed in the case of China, the time lag between making electricity available and adoption is extremely short in many rural communities.

regulation of electricity in developed countries like the US is currently conducted both at the state level, usually through public utility commissions that determine both rate levels and the rate structures utilities can use, and at the federal level, which regulates interstate wholesale pricing of electricity, and maintains the national grids. In the US, this division of regulatory power evolved over time as fragmented community-based regulation became too difficult as the population grew and electricity demand increased.

While it used to be true that electricity was essentially a local, natural monopoly, technological and legal changes have occurred that make it possible to sell electricity across long distances, and this has implications for increasing customer choices of supply from the generators. Thus, the market has the potential to become more competitive and less monopolistic. Economists argue that competitive markets lead to lower prices and more efficient production than do markets dominated by monopolies, and so, they have led the push to deregulate electricity markets to the extent that is feasible.[5]

Many developed countries are pursuing various deregulation programs in order to increase the competitive pressure on electric utility companies to cut costs, lower prices, and improve service provision. In the US, these changes have come about due to technology changes and the passage of the Energy Policy Act of 1992, which "gave the Federal Energy Regulatory Commission (FERC) the right to order utilities to "wheel" power over their transmission lines, making transmission of electricity over long distances possible."[6] In addition, the 2005 Energy Policy Act "offers incentive mechanisms to overcome problems with insufficient investments in transmission to ensure reliability and to minimize congestion costs." [7] Clearly, the restructuring of electricity markets in the US is far from complete, and given the 2000 crisis in CA and the 2003 blackout in the Midwest, politicians' appetites for more reforms have been dulled.

There are wide differences between the social, political, and economic environments in developed and developing countries that have a major influence on the success or failure of electricity reform programs. Unfortunately, much of the policy advice given by many economists and policy makers has been standardized, and the result has been uneven reforms and disappointing results. Several recent

[5] Of course, this is a very much an unsettled issue. There are many voices on the other side of the debate who argue that electricity restructuring should be carefully reconsidered and planned. (For a recent discussions, see Peter Van Doren and Jerry Taylor, "Rethinking Electricity Restructuring," Policy Analysis, 530, November 30, 2004.)

[6] W. Kip Viscusi, et. al., *Economics of Regulation and Antitrust* (Cambridge, MA: The MIT Press, 2001), p. 388.

[7] Performance-based regulation is discussed in an interesting article by Ampiero Nieto, "Performance-Based Regulation of Electricity Transmission in the US: Goals and Necessary Reforms," *Energy Regulation Insights*, NERA, March, 2006. The quote is from page 1 of the article. http://www.nera.com/NewsletterIssue/NL_ERI_EN454_0603_FINAL.pdf

papers document the types of electric power sector reforms undertaken in both OECD and non-OECD countries, and the results of these well-intentioned reforms.[8] I will summarize the basic thrust of these reforms, and discuss the intended and actual impact on the rural poor in a range of developing countries. My ultimate goal is to be able to offer some fundamental lessons we can draw from these reform attempts in order to improve the outcomes in the next round.

3. RURAL ELECTRIFICATION

In this section, I briefly review how large-scale electricity generation was developed and adopted, and how two countries, the US and China, solved the problem of supplying electricity to rural areas. It is my hope that some of the insights drawn from this analysis may inform policy advice for developing countries struggling with rural electrification issues. Rural electrification doesn't necessarily imply the provision of services to the poor, so we have to separately consider the impact of these reforms on the poor.

History of the US Experience

Harnessing electric power for consumer and business use was made possible through the research and inventions of many men in the mid-1800s, principally, Thomas Edison, Nikola Tesla, and George Westinghouse. The development and adoption of alternating current technology and the invention of large turbines enabled the large-scale electricity generation and distribution system used in most countries today. When electricity was first made available, it was in the form of direct current (DC) generators sold to individual businesses and customers, a rather expensive proposition. Tesla championed the use of more powerful alternating current (AC) power that could be sent over longer distances and generated in a large, central facility more cheaply, taking advantage of scale economies.[9] Samuel Insull, a former secretary to Thomas Edison, also saw the promise in central generation and distribution of electricity as a profitable business by noting that different customers had different demands over the day, and that he could generate power at a large centralized generation plant more cheaply on a 24-hour/day basis and sell it at different prices based on peak and off-peak demands. Insull was successful in building an electricity empire in Chicago and the Midwest. He also successfully lobbied for the establishment of state utility commissions to set rates based on a fair-rate-of-return pricing, similar to that used in the gas industry, which not only protected his firm from potential competitors, but ensured a profitable return.[10]

[8] J.H. Williams and R. Ghanadan, "Electricity Reforms in Developing and Transition Countries: A Reappraisal," *Energy* 31(6-7), May-June,2006 p. 815-844; Xu Yi-Chong , "The Myth of the Single Solutions: Electricity Reforms and the World Bank," *Energy*, 31(6-7), May-June,2006, p. 802-814.

[9] The battle between Tesla and Edison over the adoption of AC or DC current is legendary. See R. Munson,, *From Edison to Enron* (Westport, CT: Praeger Publishers. 2005) for a full discussiont.

[10] *Ibid*.

Given the economies of scale and the high fixed costs of building the transmission and distribution networks for centralized electricity provision, urban areas initially achieved higher rates of electrification than did rural areas. The U.S. adopted specific programs in order to promote widespread access to electricity in rural communities. The Rural Electrification Administration (REA) was created by the Roosevelt Administration in 1935, with the express goal of enabling farmers to obtain electricity at low cost. Low-cost loans from the REA were made available to non-profit organizations, farm cooperatives, and through state and local governments to finance rural electrification, so that groups of farmers could finance the construction and operation of their own local electricity generation facilities. The program was very successful: by the early 1970s, 98% of American farmers had electricity.[11]

Regulation of the electric utilities largely took the form of state-run public utility commissions (thanks to lobbying by Insull, especially in the Midwest). These boards protected the market from new entrants, and enabled the vertically-integrated monopolies to set rates that covered the full average total cost of provision, including an allowance for future investment. This kind of pricing was known as "rate-of-return pricing," and a variant of it is still in common use by most state regulatory commissions in the United States today.[12]

The Federal government also plays an important role in regulating the electricity industry in the US. Since the 1930s, there have been three major Federal Acts passed that shaped the structure of the industry. They were: 1) The Public Utility Holding Company Act of 1935 [PUHCA], 2) The Public Utility Regulatory Policies Act of 1978 [PURPA], and 3) The Energy Policy Act of 1992. The PUHCA sought to break up the concentration of the industry due to the formation of large trusts as holding companies and the abuses in which they had engaged, including manipulation of subsidies, improper accounting practices, watering-down of their stock values, and capital inflation.[13] Through this Act, the SEC had the power to break up these large holding companies, requiring them to divest their asset holdings until they were of a size "appropriate to operate a single utility in a specific, limited geographic area.[14]

This law essentially prohibited utilities from diversifying into non-utility businesses, and it blocked non-utilities

[11] This historical background on US rural electrification was taken from the website entitled, "The Greatest Engineering Achievements," based on the book, "A Century of Innovations," Chapter 2, "Rural Electrification," published by National Academy of Engineering in 2003. http://www.greatachievements.org/?id=2990

[12] There have been changes in how prices are set that employ more incentive-based methods to encourage firms to lower costs, improve quality, and innovate. See W.Kip Viscusi, et al., *Economics of Regulation and Antitrust*, 4th Edition, Cambridge, MA: MIT Press, 2005, p. 436-442.

[13] Chapter 4, "The Federal Statutory Background of the Electric Power Industry," in *The Changing Structure of the Electric Power Industry 2000: An Update*, p. 1. http://www.eia.doe.gov/cneaf/electricity/chg_stru_update/update2000.html

[14] *Ibid*., p. 1.

from participating in the wholesale market for electricity. These provisions were later modified in the Energy Act of 1992 "to permit both utilities and non-utilities to build, own, and operate power plants wholesaling electricity in more than one geographic area."[15]

The National Energy Act, of which PURPA is a part, was passed in the wake of rising oil prices due to the OPEC oil embargo in the mid-1970s, and it was designed to encourage conservation and improved efficiency in the operation of US energy markets. PURPA specifically **required** electric utilities to buy whatever amount of capacity and energy were offered wholesale by "qualified facilities,"[16] and that the price for this power be set at the in-house cost to the utility had it generated that power itself. This was known as the "avoided cost" of production.

Qualifying facilities wishing to enter the wholesale market were exempted from rate and accounting regulation by the Federal Energy Regulatory Commission (FERC), SEC regulation under PUHCA, and from state regulations on rates, finances, and the way in which they were organized. In essence, this Act opened the electricity market to entry from smaller generators who faced fewer restrictions and regulations, and since this "avoided cost" price wasn't linked at all to the actual cost of production, it saddled electric utilities with long-term power contracts, requiring them to buy more expensive electric power even if they had an adequate supply to meet demand at the time.

Important changes in the competitive landscape of the US electricity market really began in the early 1992 with the passage of The Energy Policy Act. Major modifications in PUHCA were made which enabled the entry of non-utility generators to sell into the wholesale market. These new exempt wholesale generators (EWG) were not subject to PURPA's restrictions, and utilities weren't required to purchase from EWGs. There were also transmission provisions that enabled FERC to require utilities to "wheel" or transmit power across their lines.

Independent system operators (ISOs) and regional system operators (RSOs) were created to monitor and facilitate open, nondiscriminatory access of the grid to all power producers, so that electricity could be traded across the country. This meant that the wholesale electricity market was opened substantially to competition in the generation sector, and it pushed producers to cut costs and increase efficiency.

Given the interstate nature of the market, the federal government was in charge of regulating access to the grids and to ensure the rates charged were "appropriate to permit the utility to recover all legitimate, verifiable economic costs incurred with transmission services."[17] At that time,

[15] *Op. cit..,* p. 3.

[16] Qualified facilities had to either be cogeneration plants (those producing electricity and another form of energy (heat or steam usually) from a single source of power) or renewable energy producers (using biomass, solar, wind, waste, geothermal, or hydroelectric power to product electricity.)

[17] *Op. cit.,* p. 6.

the political winds were blowing in the direction of a market-based, competitive system, yet, because state regulators still monitored and set retail distribution rates for in-state utilities, the regulatory system remained fragmented.

Within the US, the movement towards a more competitive electricity market has been far from smooth. We have witnessed the failure of Enron---the largest bankruptcy in US history; the California electricity crisis in 2000; and an enormous regional (Mid-Atlantic) blackout in 2003 due to cascading failures in an antiquated transmission structure that continues to face problems with overloading and the use of old mechanical switching technologies.[18]

Several states have continued to experiment with various electricity market reforms, and many have been successful in that prices have fallen and efficiency has increased. Others have seen few or no gains from painful restructuring, and are moving back towards the old regulation models. According to Munson, some of the lessons learned from these restructuring efforts include the following:

1) Utility sales of power plants have shown that nuclear plants are worth far less than their book values, but conventional natural gas- and coal-fired plants sell for more than their book values, indicating that past investments by utilities were certainly not evaluated correctly when they were made;
2) Much of the new construction of power generation plants is focused on smaller capacity plants, indicating a shift away from centralized power generation and distribution, and towards "distributed generation;" and,
3) The deals that monopoly utilities made to have their "stranded costs" covered allowed them to shirk responsibility for bad investment decisions, leaving consumers holding the bag.[19]

These findings clearly indicate that the US electricity market is still a long way from being competitive, and that the monopoly utilities still have tremendous influence on the process and outcomes. In addition, the promises of lower prices and costs and increased efficiency through deregulation may not be as dramatic as initially believed. Trading in the deregulated markets is vulnerable to manipulation and distortion, resulting in even worse outcomes for consumers compared to a more concentrated vertical monopoly structure.[20]

Rural Electrification in China

The Chinese government has been particularly successful in recently achieving nearly universal access to electricity (98% according to the IEA

[18] "America's Electricity Crisis: Bring Me Your Powerless Masses," *The Economist*, 21 August 2003.

[19] Munson, *op. cit*. page 131.

[20] H. Trebing and S. Voll, "Infrastructure Deregulation and Privatization in Industrialized and Emerging Economies," *Journal of Economic Issues*, 60 (2), June, 2006.

report on energy and poverty.[21] This achievement is mostly due to the huge commitment by the central government to mobilize financial contributions and commitments at the local level. The central government directly financed infrastructure investment, with local governments implementing the plans, including several huge dam projects (e.g., Three Gorges Dam). In some rural communities, the government introduced mini-hydropower plants that utilize the annual run-off of local rivers for hydropower generation. In order to ensure year-round reliability, these communities still need to be connected to the grid, but this innovation enables the production of cheaper hydropower especially during certain seasons. Government subsidies paid for half of the total investment in each plant, and the local governments contributed the remaining share.[22]

The central government maintains central control over pricing, but this has evolved to a more market-based system through corporatization of the state-owned enterprises in which the SOEs are responsible for managing their costs and output decisions, while also being allowed to retain part of their profits.[23]

China has struggled with capacity expansions as demand has grown, alternating between supply gluts and shortages. There are also problems with corruption and political control, as well as many layers of management. There is a huge bureaucracy associated with electricity provision and pricing: power is sold from the provincial level to the county; then to the township level, and from there, to the village level; and finally, directly to households. This layered structure increases management costs and drives prices up. While some changes have been made, the cost of electricity in China is still higher per kilowatt hour (kwh) than in many developed countries.[24] The government increased electricity prices this summer to reflect rising costs of coal.

Pro-Market Reforms in Other Countries

In many other developed countries, similar pro-market electricity reforms began in the late 1980s, when economists and policy makers became convinced that deregulation would lead to lower prices for consumers, faster innovation, more efficient and better service provision, and less pressure on government budgets. Changes in technology made it possible to un-bundle electricity generation from transmission and distribution, and the belief in the efficiency of competitive markets led policy makers to advocate reforms that would deregulate the market. Of course, deregulation meant moving away from monopoly and toward competitive markets, but not the end of regulation. For the market to work well, it still had to be subject to regulatory oversight to prevent abuses, along with the rule of law, the ability to enforce contracts, monitor usage, and to be able to collect payment for usage.

[21] The report can be accessed at http://www.iea.org/textbase/nppdf/free/2002/energy_poverty.pdf

[22] Ling Chao, "Electricity Scheme Lights Up the Lives of Rural Residents," *China Daily*, May 12, 2004.

[23] Xu (2006), p. 6

[24] "Power Politics," *The Economist*, 6 June 2002.

It is hard to believe that any economists saw the electricity market as having the potential to be perfectly competitive, with numerous small producers all selling at marginal cost, earning zero economic profits, behaving atomistically, and with free entry and exit. The current centralized supply reality of electricity provision, as discussed in the previous chapter, flies in the face of such a naïve belief. Even if power generation can become a more competitive market, the power still has to flow over the grid, and the grid has many characteristics of a public good.

The transmission and distribution infrastructure must be maintained and expanded as demand rises, yet no firm has the wherewithal or the incentive to make these investments if power can be wheeled over the grid without sharing these costs. Since electricity, once produced, cannot be stored, this also implies that this market would remain imperfectly competitive, even if deregulated. Thus, the importance of maintaining a strong role for the government in regulating and monitoring this market remains. This does not suggest that there is no room for introducing more competition into this market, but that the utopia of perfect competition does not exist here.

The driving forces behind electricity reforms were numerous, depending on the country in question. For OECD countries, the main reason for reform was improvement in the functioning of the market through more competition, and the hoped-for efficiency gains, cost savings, and lower prices that such reforms were expected to bring. By introducing competition, policy makers believed that prices would fall to long-run marginal cost, and that the market would reward the more efficient and innovative producers with higher profits. The government would act more as a "referee" in ensuring that the market functioned smoothly, but it would get out of the business of setting rates and deciding where and how to invest in capital projects.

Since the technology of electricity provision was available to all countries, the belief in the gains from increased competition led to the push for the same kinds of policy reforms in developing countries, too. The World Bank, in 1992, changed its lending focus for electricity sectors in developing countries, away from specific project lending, and toward policy lending. According to Wu, "any country borrowing from the Bank on power projects would have to agree to move away from a 'single national electricity utility as a public monopoly' and adopt ownership, structural, and regulatory reforms."[25] In many cases (e.g., China, India), increasing demand for electricity and the poor performance of state-owned firms created pressure for reforms, while in other countries (e.g., Thailand, Bolivia, etc.), budget pressures and macroeconomic crises precipitated the push for reforms.

The "standard prescription" for electricity reforms in non-OECD countries included the following:[26]

[25] Wu, *op. cit.* p. 2.

[26] This list and the term "standard prescription" are taken directly from Williams and Ghanadan

- Corporatization (separate the utility from the government ministry, install private managers, and adopt a clear accounting system);
- Commercialization (use of cost recovery in setting rates, reduce or eliminate subsidies, enforce collection);
- Legal framework (adopt energy laws to mandate restructuring, permit private ownership, including foreign participation);
- Regulatory framework (remove regulatory function from the ministry, create an independent regulator, and legally define the scope, methods, and authority of the new regulator);
- Independent power producers (create by privatizing state utility generation, Greenfield development, power purchase agreements);
- Restructuring (vertical and horizontal unbundling, create independent transmission company, separate profitable services for sale to private buyers);
- Privatization (outright sale of state-owned firms, stock sale, joint ventures); and,
- Competitive markets (single buyers, bilateral forward contracts, cost-based pool, bid-based pool).

The World Bank promoted a set of key reform steps that focused on the financial aspects of power reform, neglecting issues of access, equity, and environmental issues in the initial design of the reforms. While it is true that many of these issues should have been addressed at the state and local levels, it soon became clear that they were neglected, and this contributed to the uneven results and, in some cases, the failure of the reforms to achieve their expected goals. In addition, the Asian Financial Crisis in 1997-1998 and the California electricity crisis in 2001 also had a major negative impact on the willingness and the ability to implement the reforms as planned.

To what extent were these reforms implemented, and how were the rural poor largely affected? To answer these questions, I will now turn to some specific developing country case studies, done by Xu, and Williams and Ghanadan, as noted:[27]

1. Bolivia: In Bolivia, one company (ENDE) controlled 80% of the total power generation and it operated the grid. While ENDE could self-finance its day-to-day operations, it relied on public debt to finance capital investment projects. Generation and distribution were already partly unbundled when reforms began in the early 1990s, and Bolivia privatized its energy assets through capitalization, which consisted of selling 50% of its state-owned electricity shares through competitive bidding to international investors. The new owner retained these proceeds in order to finance future capital investment. The remaining shares were invested in an old age

op cit., pages 5-6. I have paraphrased their terms and discussion.

[27] In this section, I am summarizing the findings of these authors, but not offering any of my own analysis.

pension fund in order to finance employee retirements. This enabled the reformers to convince the labor unions, industry, and citizen groups, who were opposed to the sale of Bolivian assets to foreign investors, to support the privatization reforms.

Poor households in Bolivia had been receiving subsidized rates on electricity prior to the reforms, and a gradual phase-out of these subsidies was part of the reform package. Rural access to electricity remains limited, although it rose from 16% to 25% of the rural population between 1992 and 2001.[28] On the positive side, the reform program resulted in complete privatization of the electric power sector, significant investment increases in distribution, transmission, and generation, and an improvement in the Bolivian government finances.

However, access for the rural poor has remained relatively sparse. Since it was never an explicit goal of the reforms, then the reforms cannot be blamed for the lack of progress in this area. The political winds have recently shifted in Bolivia, and the current government looks less kindly on foreign investment and control of Bolivia's infrastructure (witness the recent decision to re-nationalize the natural gas fields in Bolivia and to renegotiate all of the natural gas supply contracts with foreign investors), so it is unclear what will happen next in the electricity sector.

[28] Williams and Ghanadan, *op. cit*. page 10. The authors note that rural access rose from 16-25% between 1992-2001, but that these gains were due to infill of the existing grid near urban areas rather than rural area grid extensions.

2. Ghana: Prior to the reforms undertaken in 1993, Ghana's generation and transmission of electricity was handled by the Volta River Authority (VRA), a monopoly that sold power in Ghana to the Electricity Corporation of Ghana (ECG) for distribution, and also directly to large industrial customers and those in nearby countries who paid in hard currency. While the VRA was profitable, the ECG lost money (both were state-owned), and did not offer reliable service. The reforms aimed to diversify the source of Ghana's electricity generation, away from hydropower and towards thermal generation, with the help of a World Bank loan. Competition in generation was also supposed to have been introduced, with the proposed unbundling of the VRA and a reorganization of the transmission and distribution networks into segments by geographic location.

Unfortunately, the reform plan was never implemented, and Ghana continues to suffer from supply shocks due to drought, the loss of its biggest customer (Kaiser Aluminum), and excess capacity made worse by the expensive commitment to purchase thermal power generated by natural gas. More recently, Ghana has improved its energy outlook by diversifying its energy sources (including access to the West African Gas Pipeline and participation in the West African Power Pool), implementing changes in its pricing structure, retiring debt, and undertaking several restructuring reforms. Ghana currently has a relatively high rural access rate

(averaging 50% or more) compared to its other African neighbors.[29]

3. India: India's electricity sector was formerly state-owned, with the ownership divided between the central government and the states. While about 30% of electricity generation is seen as a well-run and profitable part of the business (run by the National Thermal Power and National Hydropower Companies), the State Electricity Boards (SEBs) are in poor financial straits given their poor management and failure to meter and charge many of their customers. These are vertically integrated state-run entities that generate about 60% of India's electricity, and also handle distribution. Poor service and the use of cross-subsidies to the poor give large industrial customers the incentive to generate their own electricity, and this worsens the finances of the SEBs. Rural access is very limited, with only 46% of the population connected to the grid in India, including only 33% of rural residents (compared to 82% of urban residents.)[30]

India's initial reforms addressed capacity expansion, through the encouragement of IPPs (independent power producers). The government received proposals for 190 projects which would have increased electricity availability by 75GW and cost more than $100 billion, but only 15 of these proposals made it through the final approval process. Of those that were ultimately built, several were mired in controversy. Enron built a 26GWgas-powered plant in Dabhol, but the state did not honor the financially-unsustainable take-or-pay contract, and the plant sat idle.[31]

Not all of the reforms were national; states began to initiate their own reforms to address the supply shortage. Orissa was the first state to unbundle and privatize services provided by the SEB, including generation and distribution. Transmission was still in state hands, and tariffs were raised, subsidies were cut, and assets were sold. Unfortunately, not many private investors were interested, and some who did invest eventually pulled out, complaining of government interference. Tariffs were increased even though service quality remained low, and little new investment in distribution was made, so access was not improved. An independent electricity regulator was created, and this concept was copied by other states, with some success.

After little effective reform occurred at the state level, the central government passed the Electricity Act of 2003, in which a uniform national framework

[29] See the report available at http://siteresources.worldbank.org/PROJECTS/537857-1134770349044/20760161/EDAP-PID-Nov-11-2005.pdf. According to this project update from the World Bank, rural access has increased considerably, thanks to a community-focused project called Self-Help Electricity Program (SHEP) started in 2005.

[30] Williams and Ghanadan, *op. cit.*, p. 11. It is important to note that rural electrification and access to electricity for the poor are not necessarily synonymous. Not all who live in rural areas are poor, nor do the poor only live in rural areas. In a World Bank working paper by Foster and Caridad Arujo, "Does Infrastructure Reform Work for the Poor? A Case Study of Guatemala," Washington, DC: World Bank, 2001, the authors specifically analyze coverage, availability, and take-up rates. They find that the coverage and take-up rates can differ widely.

[31] Williams and Ghanadan, *op cit.* , p. 11.

was constructed, requiring metering, the payment of subsidies from state budgets, and punishments for electricity theft. The bill also included consumer protections and mandated rural electrification, but without funding for these mandates, little has happened. In fact, farmers were offered free electricity after the election in 2004, another setback to promoting financial sustainability in the electricity sector.

These case examples demonstrate several different attempts to change the nature of the electricity market in both developed and a sample of developing countries. Clearly, no country has found an easy way to do this, and all have experienced setbacks and crises. In the next section, I pull together what the deregulation experiments have taught us, with a specific focus on the access of electricity to the rural poor.

4. INNOVATIONS AND REGULATORY DESIGNS

There is a difference between the question of how to best achieve rural electrification in developing countries, and how to best ensure that the poor have access to electricity services. The two concepts have become synonymous in many discussions, but they do not necessarily mean the same thing. Rural electrification in some countries has meant electricity access for the wealthiest rural residents, while the poor remain marginalized. The focus of this section is on assessing some of the shortcomings in the regulatory structure that need to be addressed in order to achieve sustainable rural electrification that specifically focuses on access for the poor.

The economics of electricity have been changing as technology changes, and as governments respond by deregulating markets. Unfortunately, some of these experiments in deregulation have been disastrous in developed countries, so the path forward to advising developing countries on how to promote electrification, and how to regulate it, is mixed. There are some basic principles that must be borne in mind when designing an electricity reform program. Here are some of the problems that arise from well-intentioned aid and expenditures on electricity infrastructure, taken from a recent GNESD (Global Network on Energy for Sustainable Development) study on renewable energy technologies and the poor: [32]

- Equipment failures due to inappropriate technology, install-ed without training or support to ensure sustainability;
- Too high cost of initial investments in renewable energy technologies (RETs) for the poor individuals and communities to afford ;
- Mismatch between the energy provided and what is needed (e.g., type and, affordability) due to a lack of understanding about community needs;
- Focus on providing big, centralized grid-based electricity systems, which may make sense

[32] GNESD, "Poverty Reduction: Can Renewable Energy Make a Real Contribution?" May 2006. http://www.gnesd.org/Downloadables/PovertyReductionSPM.pdf

for large urban communities, but are too expensive and difficult to install for dispersed rural communities, especially those that are poor;

- Financing for and a lack of ongoing R&D that focuses on the environment and resources in poor communities for RETs has been spotty and sparse;
- Inadequate development of income-generating uses of RETs by poor households has limited the RET sellers' ability to obtain financing, given high risk and low profitability perceptions; and,
- Case studies show that the real barriers to adoption of RETs in developing countries are not technological, but they are attributable to the absence of an enabling environment that allows the customers to communicate what they really need with those who can provide it (holistic link between donors, RET providers, and local users), along with the training and education necessary to operate the RETs and to maintain them.

From this list, it is clear that providing electricity access for the rural poor in developing countries is much more a problem of information and creating an enabling environment, rather than just attracting donor funds to build centralized generation and distribution facilities and networks. Certainly, it is useless to build an expensive network if individuals lack the ability to make use of it, or cannot afford the services provided, or lack the ability to maintain it once donor support is withdrawn.

5. CONCLUSION -- LESSONS LEARNED

It is clear that centralized electricity production, transmission, and distribution cannot be treated as a truly competitive market, given the capital-intensive nature of production, the huge sunk costs, and ongoing investment requirements involved. Thus, while technology enables generators to wheel power across long distances, the transmission and distribution segments are networks that have high fixed costs, implying that the market will still be dominated by relatively few, large firms.

It is also true that there is a public goods nature to electricity provision, in the sense that maintaining the grid cannot be profitable for one firm given that all firms use it, and that regulation of pricing, upkeep and maintenance of the grids, and oversight of the system must stay in some kind of central authority's hands. Of course, it is preferable that this oversight authority be independent from the central energy authority in the government to avoid politicization of the decision-making.

The crux of the rural electrification problem in developing countries is linked to the ability of the rural poor to pay for electricity and the sunk cost of extending the grid, and the relative lack of demand for electricity initially. If we consider electricity a fundamental need in a developed society, then the investment must be undertaken. Paying for it, especially in a poor country whose

budgets are already under strain, is only part of the problem. Ensuring adequate ongoing investment in the grid, building excess capacity as the population and demand grows, and determination of local needs and growth projections are all critical issues to address.

Some basic lessons:

- ***Metering and payment***: Establishing a link between usage and payment is essential. If customers do not pay for the electricity they use, then the power must be shut off. Prevention of electricity theft is important for establishing a profit motive for provision and continued investment.

- ***Understand the crux of the failure to connect to the grid:*** Is it a supply-side problem (lack of local infrastructure that makes connection possible?), or is it a demand side problem (infrastructure is adequate, but some households choose not to connect?). These problems have very different solutions, so it is important to know why rural electrification is less than complete.[33]

- ***Local buy-in and training:*** plans that involve local citizens in delivering and maintaining local electricity provision can help to promote protection of the system, increase the likelihood of payment, and enable the villagers to increase their skills and competency in maintaining electricity services. An innovative project in the Lao PDR features a hire-purchase mechanism for small villages, choices of supply technology, and the training of a village electricity manager to provide sales and maintenance of local equipment.[34]

- ***Flexible arrangements:*** Permitting a wide variety of private, commercial, joint ventures, and public-private partnerships in the generation, distribution, and transmission segments of electricity markets is key to ensuring adequate capital investment and reliable supply. There is no "perfect" competitive structure that fits every country. The structure of ownership and the degree of competition to introduce depends on the level of development, the quality of the central and local institutions, and the ability to enforce contracts, collect tariffs, punish electricity theft, and to repatriate profits.

- ***Regulation:*** An independent power authority should be created, with the power to ensure that open access to the grid is maintained; that power providers do not charge monopoly prices; that competition is introduced,

[33] This interesting issue is discussed in the context of Guatemalan infrastructure reforms in the late 1990s. See V. Foster and C. Araujo, *op. cit.*

[34] Adam Harvey, "Village Electricity in Lao PDR," *Renewable Energy for Development,* 17(2), May 2004..

where possible; and, that adequate tariffs are collected to ensure new capital investment to accommodate demand growth and maintenance of the infrastructure is ensured.

- ***Make the reforms specifically "pro-poor."*** One suggestion is to introduce a "social tariff," or a much lower electricity rate for households using a small amount of electricity (e.g., monthly use of 100 kilowatts per hour or less), as well as for the government to pay for the initial connection of these households to the grid. Poor households tend to use much less electricity compared to wealthier households, so targeting the social tariff to those households using an amount at or below a relatively low threshold specifically targets the poor.[35] This would encourage poor households to connect to the grid, and it would improve the efficiency of power provision. Typical sources of heat, light, and cooking fuel for the poor include candles, burning wood or other biomass, and kerosene lamps, which yield much less illumination and heat, and create more indoor air pollution than electricity. Given their low relative efficiency, the implicit cost of power provision is substantially more expensive per kilowatt hour than electricity. Thus, by encouraging the poor to switch to electrification, several other problems can also be addressed: improved health (less indoor air pollution), time savings (less need to collect firewood or other biomass), and cleaner, more efficient power for multiple uses, including more productive micro-enterprises.[36]

It is interesting to note that as pressure on the grid increases in developed countries and fuel costs rise, resulting in rising costs of electricity, there are incentives to investigate on-site electricity production alternatives for large consumers of electricity. These alternatives include cogeneration plants and the use of small gas-fired generators. For example, Dow Chemical Company in the US uses its own cogeneration plants to source 95% of its power, saving the company $40 million annually.[37] On the supply side, a new service market is developing which involves energy service companies (ESCOs) installing and maintaining energy-efficient systems in buildings and facilities, shopping for the best energy deals, and saving their customers money on their energy bills while creating a profit for the ESCOs. Technological changes may make the notion of a centralized transmission and distribution system obsolete in the future.

[35] The idea for this social tariff came from Foster and Araujo, *op. cit.*, p. 31, as it was used in Guatemala.

[36] It is clear that changing energy sources will require new investment in appliances that utilize electricity. This may open up vistas for small business opportunities (i.e., individual or group investments in washing machines, dryer, televisions, etc. that may be made available to multiple families on a user fee basis, etc.)

[37] Munson, *op. cit.*, p. 147.

This has major implications for developing countries and especially rural electrification. It is not a foregone conclusion that electricity provision to remote locations involves connection to a central grid. On-site, stand-alone generation facilities located in rural areas may be able to provide electricity more cheaply and more efficiently than connection to a centralized system. In some climates, solar and wind-powered generators may be feasible and cost-effective.

Given the technological advances in electricity generation, there may be many lower-cost options for supplying power to customers that doesn't involve an enormous capital investment in a comprehensive transmission and distribution infrastructure. Let the innovative entrepreneurs gain access to these markets, and by ensuring that the rule of law is applied, contracts are enforceable, and a transparent and fair regulatory structure is in place, maybe the lights will come on in the rural areas.