5 Key drivers of improved access—service through networks

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Message from the editors

Unless energy can be produced and delivered more cheaply, it will stay beyond the reach of many of the poor. For energy delivered through networks, the costs that matter are not only the unit energy costs, but the costs of extending the network—into an urban slum, for example, or to a rural town. Extending a network can be very expensive—a major barrier to access for poor households and small or isolated communities. A central goal of the reform of electricity and gas networks, now occurring in an increasing number of developed and developing countries, is to provide incentives to reduce the costs of producing energy and getting it to consumers. New technologies in electricity are drastically reducing costs. But transmission costs are still a major hurdle to expanding networks in isolated or lightly populated areas. As a result it is the urban poor who stand the greatest chance of benefiting from network reform. For the rural poor, alternative solutions are required.

Electricity reform is based on the premise that market mechanisms supply electricity much more efficiently than central planning can.[1] But how will the poor, who have the least purchasing power, fare in a competitive electricity market? Will those without access continue to be denied it as electricity supply changes from a public service to a profit-seeking business? And will the poor who have access suddenly find it unaffordable?

One response to these general concerns is that a well-functioning power sector is crucial to macroeconomic stability and growth. It is precisely because poorly run, state-owned electric utilities have been such an impediment to growth that so many countries are trying to reform them. For those who believe that the best way to make the poor richer is to make everybody richer, that is how electricity reform helps the poor.

However, this chapter concentrates on the microeconomic effects: whether reform will make electricity cheaper for the poor who already have access to it, and provide it to those who do not. It analyzes the fundamental costs of generating electricity and distributing it through a grid to rural and poor populations. It describes how electricity reform and technological developments have reduced these costs in recent years and discusses institutional arrangements to ensure that lower costs are passed to customers. It examines whether reform will increase access to electricity for poor households and comments on policies to further the interests of the poor in the context of electricity reform.

Generating and selling electricity: what it costs

The provision of electricity through a grid involves four functions:

- *Generation:* converting primary energy into electricity.
- *Transmission:* the high-voltage, long-distance transport of electricity.
- *Distribution:* the low-voltage transport of electricity from the high-voltage system to the user.
- *Supply:* the selling of electricity to users—metering, billing, and so on.

This chapter's main concern is with reform of the transmission and distribution systems—"the grid"—but it also discusses the innovations in electricity generation that made reform possible.

Box 1 summarizes the cost characteristics of the four functions.

It has been estimated that in England and Wales generation accounts for about 65 percent of the total cost of electricity, transmission 10 percent, distribution 20 percent, and supply 5 percent (Newbery and Green 1996). These proportions vary in different systems. In particular, the start-up

Box 1 **Cost characteristics of electricity provision**

Generation

The costs comprise fixed capital costs and variable operational costs including fuel. Because each type of plant has a different balance between fixed and variable costs, for each type the optimal size—giving the maximum economies of scale—is different.

Transmission

Transmission costs cover building and maintaining the transmission system and operating it (dispatching plant and maintaining voltage and frequency within predetermined limits).

The cost of building and maintaining the system depends on physical factors such as its size and the terrain. The cost of extending it depends on the expected peak demand, but once the grid is built, the cost is sunk and so does not vary with the number of users or the volume of electricity transmitted. The high fixed costs make it unprofitable for more than one transmission system to compete in an area.

Furthermore, the technicalities of minute-to-minute balancing of supply and demand together with the high cost of system failure mean that the natural monopoly extends over the whole integrated system.

Distribution

As for transmission, the high fixed (and low variable) costs depend primarily on the physical coverage of the system (both distance and terrain) and the level of local peak demand.

However, because the operating function is much simpler (it does not involve generator dispatch), the economies of scale are not as great. A country that supports only one transmission system can support a number of (non-overlapping) distribution systems.

Supply

Many supply costs, such as bad debts and the costs of payment collection, vary with the number of customers. These costs are disproportionately high for low-income households, which are more likely to experience payment difficulties and suffer disconnection.

But some supply costs are fixed: once supply has been extended to a village, the extra cost of reading another meter in that village is low.

Supply costs vary with the distance of customers from the nearest demand center. The more remote and dispersed the customers, the more expensive it is to administer meter reading and bill collection centrally.

costs of a grid are high and fixed, which means that grids have big economies of scale, in terms of both the number of households connected and the amount of energy transmitted. Thus for grid systems in developing countries, one might expect transmission and distribution costs to be a greater proportion of the total.

There are two key points here. First, physical factors make the fixed costs of transmission and distribution particularly high for grid extensions to remote rural populations. The population density in rural areas is typically low, which means that the fixed costs are shared among relatively few people.

Second, the poor tend to have very low demand for electricity, which means that the average cost per unit consumed will be high because the fixed costs are divided among few units. Furthermore, for the rural poor, this demand tends to be concentrated at peak times (mainly in the evenings as people switch on lights). Since the fixed costs of transmission and distribution depend in part on peak demand, this demand pattern results in still higher costs for poor rural populations.

These points are illustrated in table 1, which gives indicative figures for the relative distribution costs of connecting different numbers of rural households at different distances from the transmission system. The central column shows the unit costs of distribution. The right-hand column shows the unit costs including generation and high-voltage transmission.

As the demand for electricity increases, the fixed costs can be spread. In developing countries, however, it takes time for demand to grow once access is provided: people have to wire their houses and buy electrical appliances before they start to buy electricity. Demand for electricity entails both a switch (not necessarily complete) from other fuels for cooking, heating, and lighting and new demand for electrical appliances such as televisions. Over time, as incomes rise, loads will increase, and load factors will also rise as people buy appliances with constant loads such as

Table 1 **Effects of line length and consumption levels on the relative costs of electrification in Indonesia** (U.S. cents per kilowatt-hour)

Cost component	Unit cost by component	Total unit cost
Generation and transmission	10	
Medium-voltage extension and low-voltage distribution		
3-kilometer spur line, 20 households	45	55
3-kilometer spur line, 50 households	20	30
1-kilometer spur line, 20 households	15	25
1-kilometer spur line, 50 households	7	17

Note: These costs are indicative averages for most developing countries with relatively flat terrain. A few countries are now adopting new, lower-cost network designs.
Source: World Bank 1996, p. 50.

refrigerators. However, this progression is difficult to predict and therefore the returns to investment in extension of electricity grids to rural and poor people are uncertain.

To summarize, providing access to electricity for low-income households—in particular the extension of the grid to rural areas—depends critically on the balance between the fixed and variable costs of transmission and distribution. The fundamental cost characteristics of grid provision do not favor the provision of access to rural and poor populations. Can reform make any difference?

Buying electricity: why it is getting cheaper

The recent wave of electricity reform was facilitated by innovations in technology.

Generation

Until the 1980s the electricity industry was viewed as a unified natural monopoly that produced and delivered electricity. For decades economies of scale had increased in electricity generation, reinforcing the view that it was a natural monopoly.

In the 1980s improvements in turbine technology were imported from the space program and materials science and the price of gas fell (in part because of gas market liberalization in developed economies). This had a radical effect on the economics of generation: the fixed cost of installing a combined-cycle gas turbine (CCGT) plant in the early 1990s in the United Kingdom was around US$600–650 per kilowatt, compared with US$750–800 for oil-fired plant, US$900–1,200 for coal plant, and US$2,250 for nuclear. Falling gas prices reduced the variable costs as well.[2]

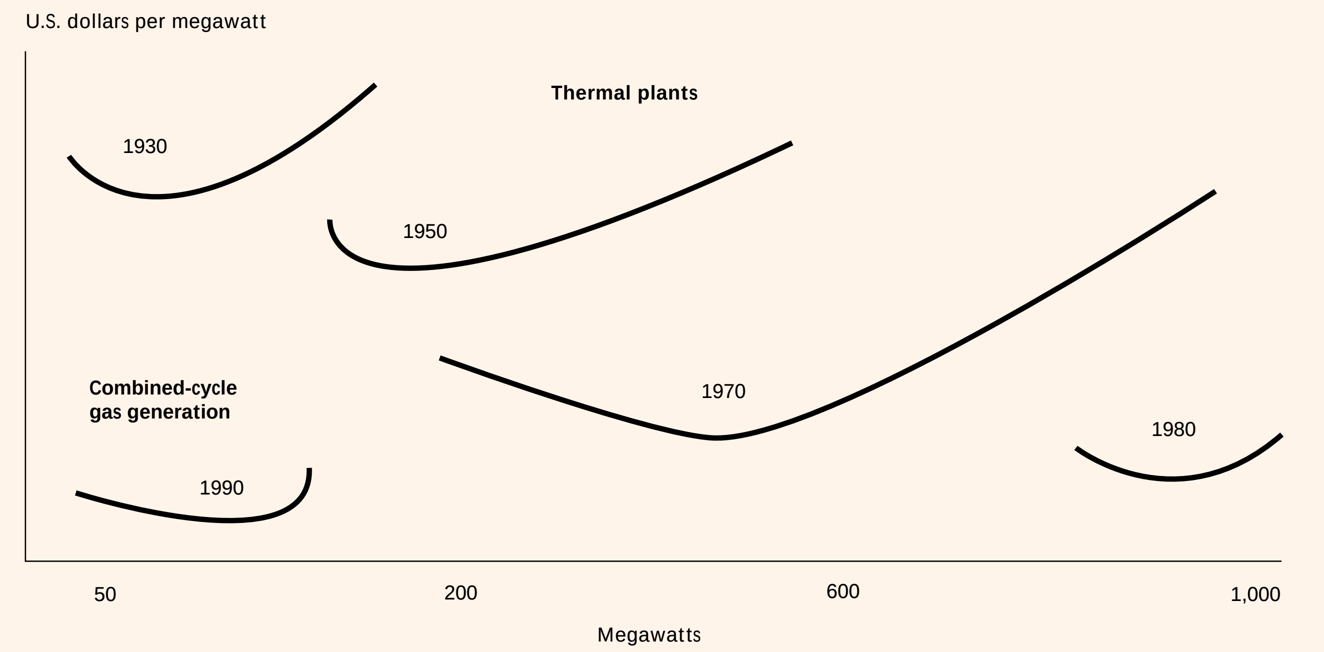
Combined-cycle gas generating units of 50–100 megawatts could by the 1990s be built and run economically—at one-tenth the size of the thermal plants (1,000 megawatts or more) of the 1980s (figure 1). This meant two things. First, generation could be a competitive activity even in relatively small electricity systems. Second, developers other than the state monopoly utility began to want to build power plant—large industrial users as well as independent power producers (IPPs).

Competition and private participation have had further effects on costs. Rather than buying equipment from a favored national supplier, as state-owned monopoly generators had done, new entrants import it if that means lower cost. In turn, this has increased competition between equipment manufacturers, and thermal efficiency has increased, further pushing unit costs down. The thermal efficiency of CCGT stations is now nearly 60 percent (compared with 30 percent or more for other thermal stations), and the cost of installing the latest CCGT technology is now about US$375–450 per kilowatt.[3]

Thus generation market reform should cut costs and reduce prices for customers. Following the introduction of competition in generation and the establishment of a bulk power market in Argentina, bulk electricity prices have fallen fairly consistently (figure 2).

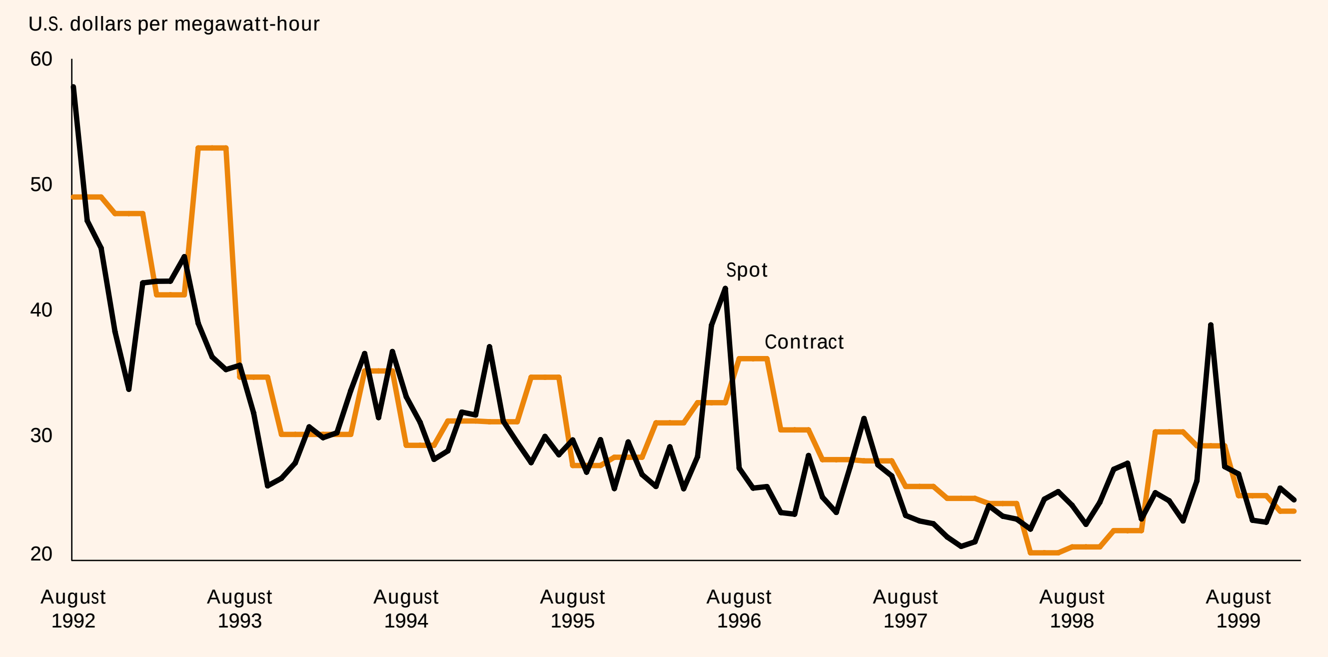
In other cases there have been difficulties, however. In England and Wales, for example, anticipated reductions in bulk electricity prices failed to materialize after competition was introduced and the bulk power market established, even though primary fuel prices were falling (figure 3). This has been blamed on the manipulation of bulk power prices by the larger generators. In other words, competition was not fully functioning. Trading arrangements intended to eliminate such behavior are planned.

Figure 1 **Cost curves showing optimal plant size, 1930–90**



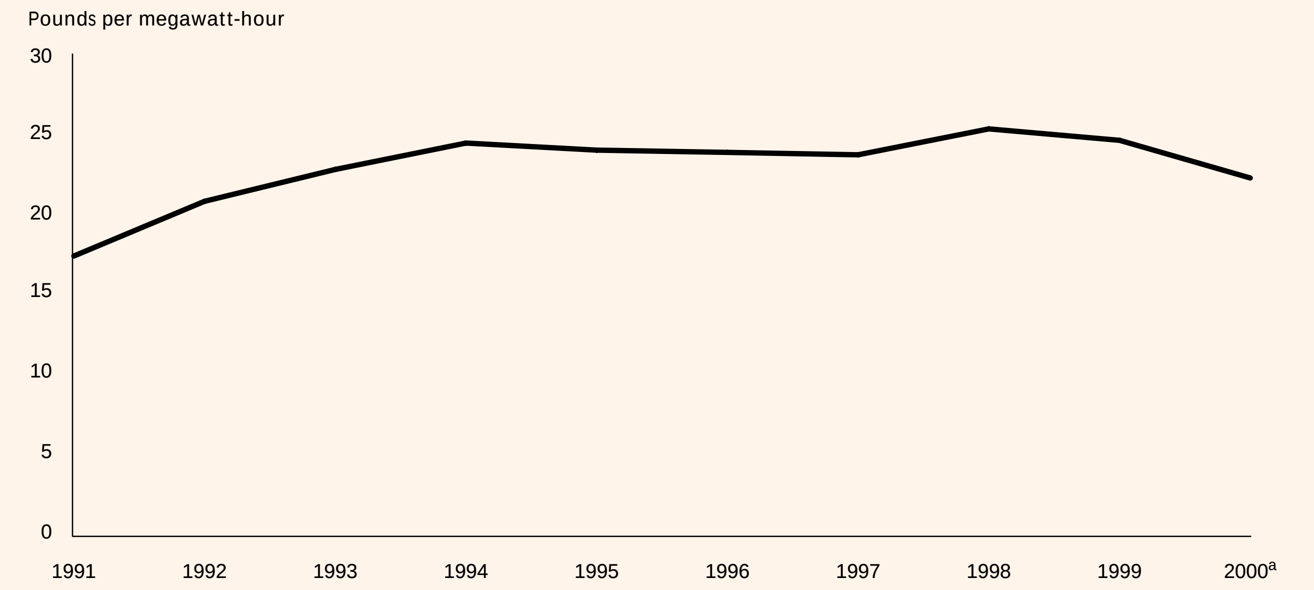
Source: Hunt and Shuttleworth 1996.

Figure 2 **Bulk electricity prices in Argentina, 1992–99**



Source: CAMMESA 2000.

Figure 3 **Average annual demand-weighted Electricity Pool of England and Wales purchase price, 1991–2000**



Note: The years refer to fiscal years, ending in March.
a. Average for April to October 1999.
Source: Electricity Pool of England and Wales 2000.

Some developing countries have also had difficulties in harnessing the full benefits of IPPs. A key question in generation reform is how to set up a bulk power market that delivers the benefits of reduced costs while still attracting private investors. Offering long-term power purchase agreements to IPPs attracts investors, but the greater the security (in terms of guaranteed purchase volumes and prices) offered by the contract, the less sharp the incentive for cost reduction and the less scope for the power purchasing agency to adjust its purchasing to achieve least-cost dispatch.[4]

To ensure that the full benefits of competitive generation reach customers, it is necessary to introduce competition in supply. If supply is provided through the local monopoly distribution company, customers cannot shop around for cheaper electricity. The monopoly distribution company can shop around, but has no incentive to do so as it can pass on generation costs to its captive customers. However, competitive suppliers will need to purchase power as cheaply as possible, thus ensuring that lower generation costs are passed to retail customers.

Transmission and distribution

Having recognized that the electricity industry comprises a number of distinct functions, governments have begun to separate transmission, distribution, and supply.

While transmission and distribution have in many cases been separated, and distribution split among a number of companies, both functions retain their natural monopoly characteristics in any one area because of their high fixed costs. However, the introduction of private participation through competitive tendering for concessions (to identify the least-cost provider) has captured many benefits in terms of lower costs.

Increased competition in the equipment markets has reduced the price of many of the fixed cost components. Installation has also proved cheaper when done by private contractors rather than utility employees.[5]

More generally, the private sector is simply more efficient as a consequence of its profit seeking. For example, when private distribution began in Buenos Aires there was a dramatic reduction in theft. Since theft was particularly prevalent in slum areas, this reduction in theft cut the difference between the cost of supplying these areas and the electricity tariff and enabled the distributor to supply slum areas with reduced subsidies (Albouy and Nadifi 1999).

Equipment costs can also be reduced by relaxing equipment specifications and adopting international standards. In the United Kingdom, for example, over the past five years the cost of electric plant in real terms has fallen by 10–15 percent (Fairbairn 2000).

However, transmission and distribution remain local or national monopolies. This means, first, that incentives to reduce costs are not as sharp as they would be under competition (although the profit motive supplies some incentive), and second, that savings that are made will not be freely passed to consumers. Therefore, where these monopolies are privately owned, regulation is necessary.

Incentive-based regulation, such as the CPI–X price cap methodology, involves a balance between giving utilities the incentive to reduce costs and ensuring that cost reductions are passed to the consumer. The utility keeps some of the savings, but must pass the rest to the consumer.[6] In the United Kingdom incentive-based regulation has been broadly successful in reducing prices to domestic consumers, even though bulk prices have not fallen (figure 4).

Supply

The potential for competition in supply, which, with relatively low fixed costs, is not a natural monopoly, has been recognized and is being acted on in many countries (partial opening of the market to supply competition is a requirement of the European Union directive on the single market for electricity, for example). As a result of competition, in the United Kingdom the cost of meters has fallen by 39 percent over the past five years.

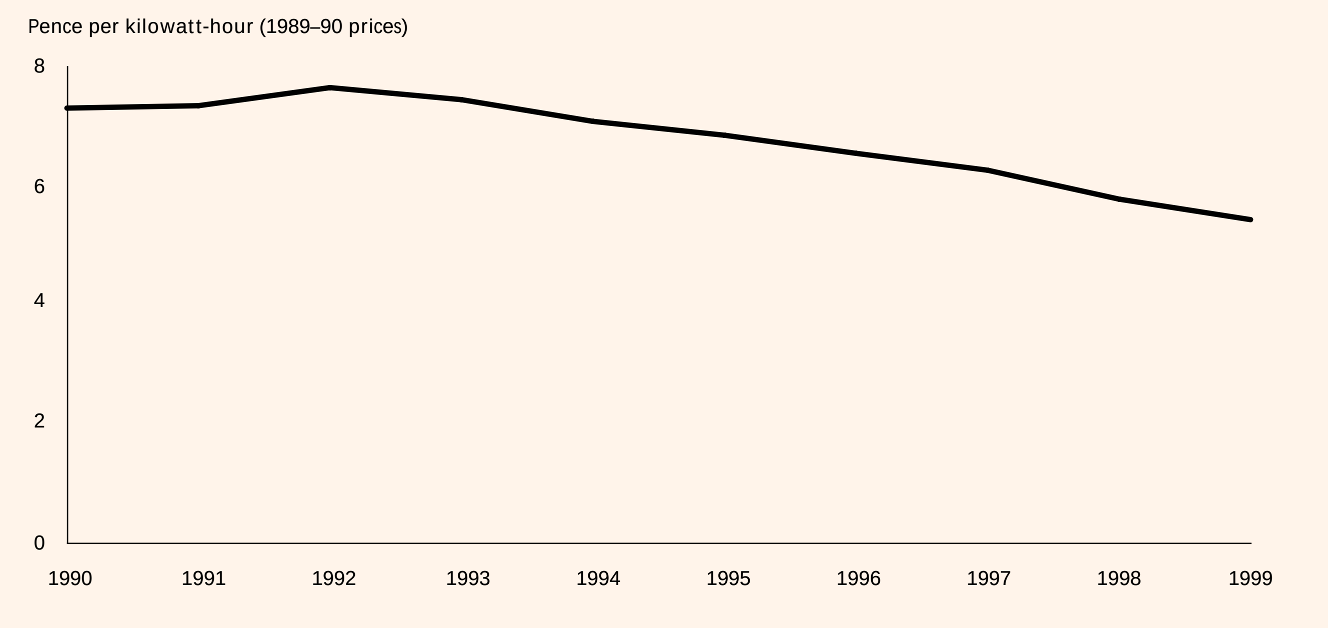
However, competition in supply is so far confined largely to more developed markets, where companies can offer a number of supply services (such as electricity and gas) together and can differentiate themselves by service quality and brand. In developing countries the costs of supply can be reduced in other ways, notably through increased local involvement. Employing someone to read meters in a village is cheaper if that person does not have to travel a long distance from the nearest town. Local participation in bill collection and maintenance can also be effective. For example, in Bangladesh locally managed cooperatives buy power from the grid and distribute it locally. They have a better record on billing, maintenance, and reducing losses than that of the main power utility in charge of urban distribution (World Bank 1996).

Electricity for the poor: does cheaper mean better?

Cheaper generation has reduced the total cost of providing electricity. That should mean lower prices for the poor who are already served by a grid. Reductions in the fixed costs of transmission and distribution equipment, and innovations to reduce the costs of supplying remote areas, improve the prospects that grids will be extended to rural areas.

However, there are two important caveats. First, for the poor to benefit, lower production costs must be passed on as

Figure 4 **Electricity price for standard domestic tariff customers in the United Kingdom, 1990–99**



Note: The years refer to fiscal years, ending in March.
Source: U.K. Department of Trade, Statistical Office 1999.

lower prices. In many developing countries tariffs have risen following reform as subsidies have been withdrawn (despite cost reductions). In many respects this benefits the poor,[7] but it does make access to electricity less affordable. One solution is to direct electricity subsidies much more precisely to the poor, for example, through the introduction of lifeline tariffs.[8] More generally, the design of the tariff system is crucial in determining how the benefits of electricity reform (in terms of lower costs) are distributed among different customer classes. If electricity reform is to benefit the poor, tariff policy must be designed with their needs in mind.

Second, the fixed costs of transmission and distribution equipment have not fallen enough to make it profitable to extend the grid to all areas. Given the huge difference between cost of supply and (socially or politically) acceptable tariffs for some rural populations, extensions of the grid to these people must be subsidized if they are to happen at all. There are two ways in which this can happen: within the utility by cross-subsidy from profitable customers (under an obligation to extend service) or with subsidies from outside the utility, for example, from a rural electrification fund.

Conclusion

Reform of grid-based electricity provision will not revolutionize access by the poor. The cost structure of grid provision, so unfavorable to extending access to rural populations, is not fundamentally altered by electricity reform. However, reform unambiguously moves the overall level of costs in the right direction. At the margin, cost reductions imply both increased affordability of grid services and increased viability of grid extensions. As long as the introduction of competition and profit-seeking private participation is combined with regulation and tariff design that is sensitive to the needs of the poor, electricity reform is a positive step.

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Notes

1. Reform of grid-based energy services has concentrated on the generation and distribution of electricity. Electricity networks are far more extensive than gas networks in most parts of the developing world and reform of gas networks has been less widespread. This chapter therefore discusses electricity reform, although many of the important points apply to both industries, given the parallels in terms of network economics.

2. Although the widespread adoption of CCGT as the new technology of choice was linked to the fall in the price of gas, the technology can run on diesel. This discussion therefore also applies to countries with no access to gas.

3. The cost estimates are from Richard Fairbairn of PB Power Ltd.

4. For a more detailed discussion of this issue see Bacon 1995.

5. This is one reason why employment in the electricity industry has fallen dramatically following reform. This is a controversial social effect of reform and one that has direct implications for the poor. However, the subject is beyond the scope of this chapter.

6. CPI–X achieves this by fixing allowed prices for a given period, during which the utility can retain the profits arising from any cost reduction. At the end of this period the price cap is reviewed to ensure that over the long term the benefits are passed to consumers.

7. Since energy subsidies are a larger proportion of GDP in many developing countries and benefit the well-off more than the poor (because the well-off use more energy, particularly electricity), reductions in subsidies will tend to benefit the poor in fiscal terms, particularly if the funds are redirected toward social policies. For further discussion of energy subsidies see World Bank 1996 and International Energy Agency 1999.

8. Lifeline tariffs essentially involve subsidizing electricity only at the very low levels of consumption typical of poor households. The subsidies apply to very small amounts of electricity and do not cost too much. This policy has been successful in Thailand; see Tuntivate and Barnes 1997.

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