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Electricity at the Right Price

Donald Hertzmark

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DONALD HERTZMARK is an international energy and economic consultant, with more than 30 years of experience worldwide in more than 90 countries. He can be reached at <donhertz@verizon.net>.

EXECUTIVE SUMMARY

This paper presents a framework for thinking about electricity pricing in countries with state-owned utility companies.

Main Argument

For many years, electricity utilities around the world used largely similar approaches to both structure and pricing. Utilities were integrated operationally and tariffs were supposed to apply to the company as a whole, not to individual segments such as generation, transmission, and distribution. Unfortunately, many countries allowed electricity prices to drift below the cost of supply, with retail prices often lower than the cost of fuel in generation alone. As demand for electricity grows, fueled in part by these low prices for power, utilities are put in a financially untenable position. They cannot afford to expand to meet new demand and, in some cases, cannot even maintain existing equipment.

Without financial soundness, utilities must rely on external financing, often in the form of supplier credits, export credit financing, or loans from international development banks. If an electricity supply company is relatively large, in terms of its share of a country's overall economic financing, its expansion can eventually impact the financial risk rating of a country. A number of potential solutions exist. They involve bringing in private generation, unbundling of lines of business, restructuring, or even outright privatization. However, if the pricing of electricity is not sound, then none of these potential remedies can work well.

Policy Implications

- The most important business of the electricity tariff is to cover costs of supply, including new generation and network investments. This is the prime directive of electricity pricing. Without cost coverage, there is no amount of clever restructuring, unbundling, or packaged "models" that can work for more than a short time.
- Once cost coverage is achieved, then further complexity can be added to the pricing system, such as where and when to use or supply electricity.
- There is no one correct way to structure the electricity sector; a number of different structures have been able to work as long as the pricing of electricity is reasonably accurate. However, the structure that is adopted must be consistent with the country's commercial and banking capabilities. The ability to regulate the monopolistic aspects of the industry must evolve as well, keeping pace with changes in structure and industry capabilities.

Pricing Electric Power—Why is It so Difficult?

Unlike most "normal" commodities, the pricing of electric power has defied most attempts at a definitive pricing methodology. Some of this difficulty has to do with the history of the industry—growing up as a "natural monopoly"—and much of the rest of the problem is intrinsic to the nature of electricity.

In this section, we discuss the traditional theory of electricity pricing[1] along with the traditional structure of the industry. Problems with pricing electricity—the reasons and the effects of such problems—are presented in the following subsections. A subsequent section presents constructive alternatives and examples of how some countries have approached this most difficult of issues.

The Traditional Theory of Monopoly Pricing of Electricity

Electricity generation and supply has traditionally been thought of as a natural monopoly. To economists, a natural monopoly is an industry where the initial firm in the industry can achieve a significant cost advantage over potential competitors. To allow competition is to exchange higher prices for the technical advantages of monopoly.

For most of the time that there have been organized sales of electric power it has been thought that the industry is a natural monopoly. Why have two or more sets of wires? Multiple generators next to one another, each with a smaller boiler—more surface, less volume in each?[2] And competing distribution companies (again, two or more sets of wires)?

To complement the monopoly structure of the industry, a pricing method was developed, usually called the cost-of-service model, which regulated both prices and returns for entities supplying electricity. From finances to generation technologies to

[1] In a regulated monopoly, the integrated power company is permitted to recover its fixed and variable costs, including new capacity investments with a specified rate of return. This is often referred to as the cost-of-service model of pricing.

[2] The argument that a higher ratio of surface to volume in a smaller electricity plant constituted an argument supporting the natural monopoly concept. In no other manufacturing industry is such an argument advanced.

network layout, the electricity industry developed as an integrated monopoly, its power kept in check by government or regulators.

Financial and cost factors. Based on the idea that competition could only raise costs to consumers, the electricity industry evolved in a vertically integrated structure. The pricing model was for the industry as a whole, not the individual pieces such as generation, transmission, distribution, and system operations.

Technical factors. Because electricity cannot be stored economically for long periods of time, utilities have paid great attention to making power assets perform at the highest capacity. Moreover, since the system needs to be in balance between the generation of electricity and its disposal or use, great attention was paid to efficient operation of the integrated system. A final technical quirk of electricity is that its flow cannot be commanded by the operators of the alternating current (AC) system.[3] In a typical AC power system, power flows obey the laws of physics, not man. Vertical integration and the cost-of-service pricing model were seen as allowing the utility to make the best use of its generation sources and network, moving power and energy from generation to the customer in a largely unidirectional manner. Such an approach minimizes counterflows of power and energy, obviating the need for more elaborate transmission networks.

Vertical integration of electricity systems: generation, transmission, and distribution. Vertical integration in the electric power industry means that key segments of the industry—generation, transmission and distribution, and system operations—are owned and operated by one entity. Until around 1990, this meant state ownership in most of the world aside from the United States and a few others. Even in the United States, the primary model was usually a privately owned, vertically integrated utility regulated at the state level.

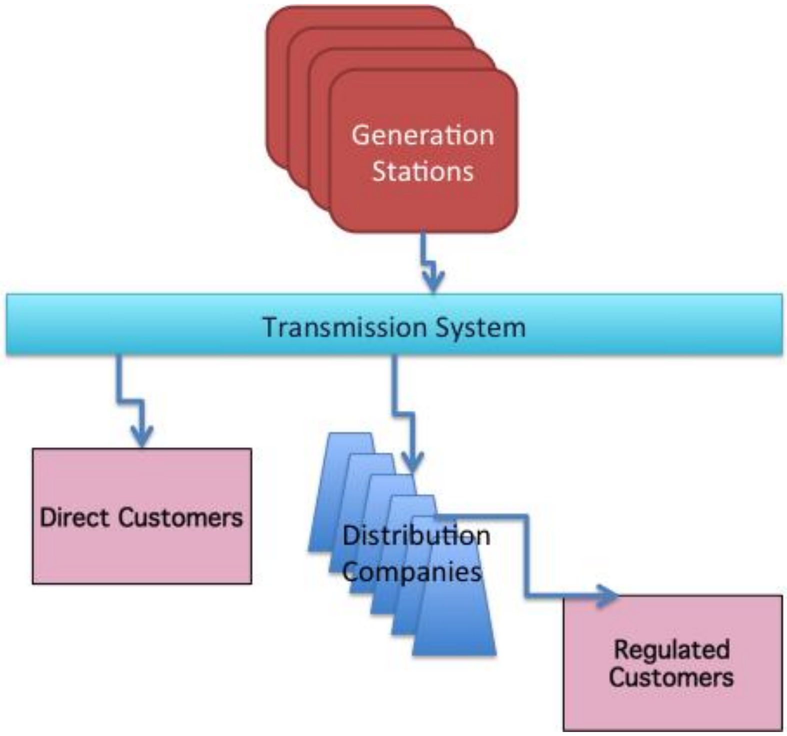
Vertical integration worked in some countries because the system was organized to move power and energy from generators to customers with two big conditions: (1) The monopoly utility has an obligation to serve all customers willing to pay; and (2) a

[3] Direct current (DC) features directed flows, but is not used at the lower voltage levels of most power systems. Its primary use in recent years has been for extra-high voltage transmission lines.

payment (tariff) system would cover the full costs of supply, with an "adequate" return on investment by the utility.

Figure 1 shows the general configuration of a vertically integrated power system.

Figure 1: A vertically integrated power system[4]



Cover costs for the overall system—the prime directive. In successful vertically integrated utilities, the total costs of service were covered by the tariffs paid by the customers while quality-of-service standards assured adequate investment in both generation and the network. No part of the system was starved of funds. Transfers of funds were generally not from one customer category to another—cross-subsidies—but rather from one segment of the business to another. In that way, shortfalls in funding for transmission could be covered by generation or distribution allowances.

What does not happen in successful vertically integrated systems are two attributes that many state-owned utilities have adopted as an operational approach. These attributes

[4] Figures are provided by the author unless noted otherwise.

have contributed significantly to ongoing operational and financial difficulties in many national power systems. First, many state-owned utilities practice high degrees of price discrimination. Second, the overall revenues of the system are often inadequate to cover the full costs of service with provisions for future investments.

Price discrimination arises when a consumer is charged a different price relative to another consumer of an identical product. In power systems, customers at the same voltage level may be charged different prices—for example, if one is a commercial customer and the other is a residential user. Other than the name of the consumer category, characteristics of the consumption may be nearly the same. In some countries, entire categories of consumers were exempted from tariffs for many years (for example, irrigation customers in India). In other countries, large industries with heavy power demands pay prices that fall well short of the cost of supplying them. In many countries, small residential consumers pay prices that are also far below the cost of service. In many of these cases, average residential tariffs barely cover the cost of fuel for generation, much less the network investments and services and corporate operation of a utility company. If some customers do not pay at all and others do not pay enough, the utility company cannot operate as a normal business entity—it is not creditworthy.

For example, in Indonesia the average revenue per kilowatt-hour (kWh) (~Rp 580–650 per kWh) is roughly the same throughout the country. Nowhere does this average revenue exceed the cost of service, and in most of the country, the cost of fuel alone for gas or diesel generation far exceeds the average price.[5] This means that Perum Listrik Negara (PLN), Indonesia's state-owned electric company, has no internal mechanism to generate funds for expanding or upgrading its generation and network facilities.

India similarly subsidizes small consumers, with the price for these sales at about $0.045 per kWh, less than the cost of imported gas for an efficient new generating station or imported coal for a new generation unit.[6] As is the case for Indonesia, India's power

[5] See U.S. Agency for International Development (USAID), *Indonesia Energy Assessment*, November 22, 2008. At current prices for natural gas in Indonesia, the fuel cost of efficient gas generation is about $0.06 per kWh, more than the average revenue from generation. Where diesel fuel is used the average revenue is less than half the fuel cost of generation.

[6] See Government of India, "Tariff Policy," 2010.

utilities lose money consistently and are dependent on central government subventions for network build-out.

At the same time, without profits to fund future investments, a money-losing utility cannot expand. It must rely on external funds, usually supplied by the government with the assistance of foreign lenders. The utility companies, knowing that their price structure is financially ruinous, may try to offload some of the costs on one or two customer categories, usually commercial businesses and hotels.[7] Hence a price level that does not cover costs begets price discrimination, in an attempt to stem losses, but failing to do so begets further losses and so on.

The conviction that electricity was a natural monopoly led to several key common approaches throughout most of the world:

1. The industry provides a public service and should be controlled by the state. This includes state funding of the industry.
2. Electricity, as a *strategic* industry, must further other national policy goals.
3. Consumption of electricity should be encouraged by building out the system and making the product available at attractive prices.

A key element of natural monopoly theory is that consumption needs to rise, to “deepen,” in order to fully utilize the network. However, as outlined above, low prices encourage consumption, but the more the utility sells, the more it loses—a vicious conundrum.

Where and when—the second directive. Monopoly theory tell us, in some general sense, that electricity use should be encouraged when it is plentiful and discouraged when it is not. Overall, this is not a terribly helpful prescription. To make the best use of the network assets, users of that network need to know when it is most advantageous to use or generate electricity and where. Vertically integrated monopoly systems are not oriented toward providing such information. Even when there is a bias toward private investment in generation, the information provided by the monopoly system is deficient. Consumers

[7] For example, the cost of electricity to commercial users in Mozambique is about two and a half times the price to households or industrial users. There is no cost differential that justifies such price discrimination, and the tariff represents a transfer from businesses and their customers to other users of electricity. India has tried as a matter of policy to keep the prices for those paying the subsidies to just one and a half times the rate paid by the subsidy beneficiaries.

do not know when they should use power, and generators do not know where they should locate—the black box of monopoly remains entrenched.

In the absence of pricing data that informs users and potential generators about where and when to consume or produce, a vertically integrated system can result in investments in fixed assets that are inappropriate to changing patterns of use in the economy as well as generation stations that do not match the locations or duty cycles that the system may need. Such inappropriate investments—"if I had known then what I know now, I would not have done what I did"—are called stranded assets or costs in the power business. In private industry, the charge for such mistakes is accepted by the firm and taken against profits. In a state-owned company, however, the stranded cost is ignored until the utility discovers that it must pay interest charges on assets that produce little revenue.

In relatively small countries with small power systems, good planning can mitigate the risks of accumulating stranded assets. However, as an economy grows, and especially if the country in question has significant regional variation in patterns of economic activity, such centralized direction may not be able to obviate the stranded cost risk that accompanies centralized control. Ultimately, market participants need information and incentives—prices—to know when and where to invest and use electricity.

The Traditional Theory Doesn't Always Work

The idea of a natural monopoly in electric power was first challenged in the United States in the 1980s. A new law permitted non-utility generators to access the transmission network, selling to utility companies and to direct (bilateral) customers. It turned out that the generation segment, at least, was not a natural monopoly. In fact, electric generation plants are really not that different from any other type of factory: raw materials—fuel, water, enriched uranium—are processed using machinery and produce a manufactured product, electricity.

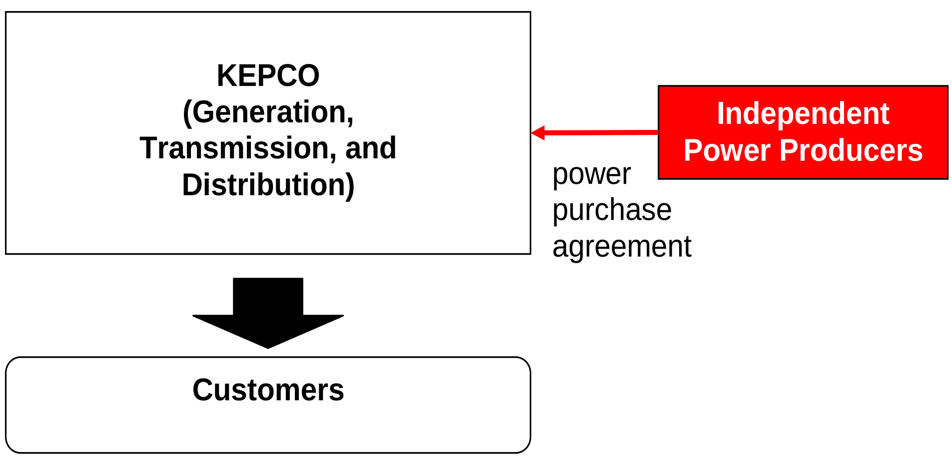
Generation is not a natural monopoly. The owners of the factory need to make sure that the raw materials and equipment are used efficiently, but otherwise there is nothing strikingly different about a factory that makes electricity compared with one that makes steel pipes.

If power generation plants are basically just another industrial operation, then economic theory says that they should compete with each other.

As the 1980s wore on, it became clear that there was indeed quite a bit of competition in the generation segment in the United States and in some other countries. In countries where generators were forced to compete with each other, generation charges came down. For example, retail competition in the United States and the United Kingdom has resulted in reductions in final costs to consumers of $0.01–$0.02 per kWh compared with the prices charged by vertically integrated monopolists.[8]

No longer was it possible to augment the actual costs of generation with other costs of transmission and distribution, especially those stranded costs. Each segment would need to carry its own weight. The era of unbundling had arrived (see **Figure 2** and **Figure 3**).

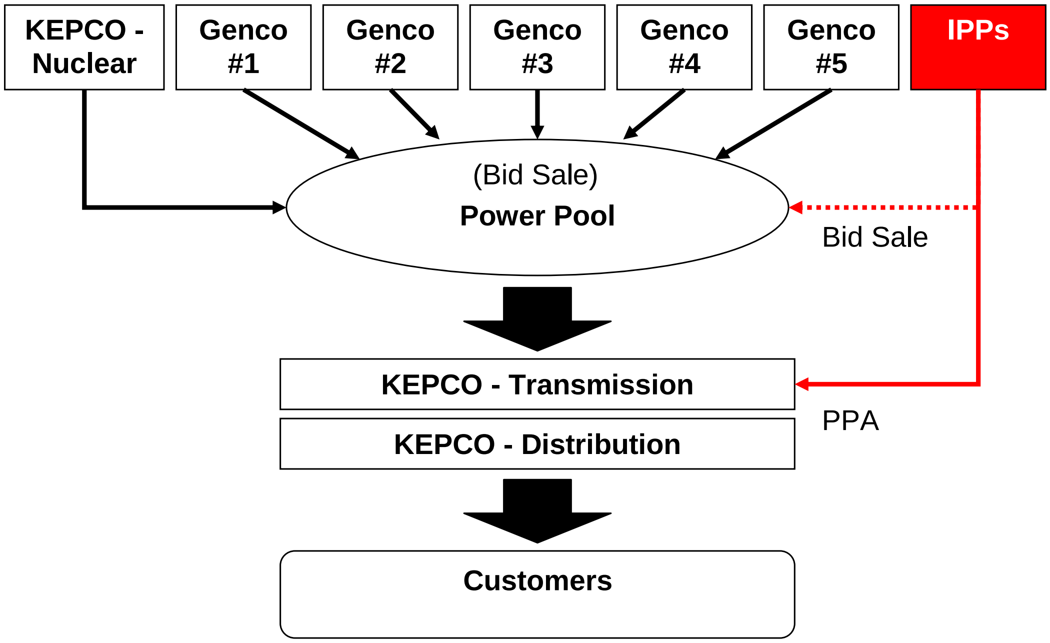
Figure 2: A vertically integrated utility with IPPs (KEPCO circa 1999)



Note: KEPCO is the popular acronym for the Korean Electric Power Company.

[8] The author of this paper is able to verify that he has been able to save $0.01 per kWh in winter and $0.025 per kWh in summer by choosing from among competitive power generators. In Texas, where natural gas is inexpensive, competition has reduced off-peak retail electricity prices to as little as $0.043 per kWh, about what subsidized consumers pay in India, and less than what subsidized consumers pay in Indonesia.

Figure 3: The unbundling of a power system (KEPCO in the mid-2000s)



Transmission and distribution have monopolistic tendencies. While generation increasingly resembles just another competitive industry, the network segments, transmission, and distribution clearly exhibit monopolistic tendencies. In any network, it is generally better to utilize the network as much as reasonably possible.

As competition increasingly dominated the generation segment, the wires/network segments, transmission, and distribution received greater attention and financial support from international financial institutions and national governments. Governments increasingly saw generation as an area where private funds could be mobilized instead of sovereign loans from development banks. As Figure 2 shows, the theory of monopoly remained strong initially and, in most countries, independent power producers (IPPs) were forced to sell into the monopoly network.

As noted earlier, without a clear idea of when and where to generate, invest, and consume, power systems will still misallocate resources. All participants in the electricity network need to know prices for different locations on the network and different supply and demand conditions to allocate resources in an informed manner. It is difficult to know where to build a generation station if there is no information about the relative desirability of various locations for generation stations. In small systems, it is possible to provide such information technically; in large power systems potential investors need market signals—prices—to justify their investments.

Monopolistic power companies have been loath to provide such information, which can be calculated straightforwardly from technical and customer data, for such information would allow the entry of yet another competitive element in the power industry. If power generators can sell to the pool, why can't they sell to customers directly? If competitors know that there is a constraint in the transmissions system that raises the cost of supplying power to some parts of the system, then why not locate nearer the customers and gain the benefit of relieving the constraint? For many vertically integrated utilities, unable to come up with a plausible answer to that question, the result was a functional, as well as financial, unbundling of the power industry (see Figure 3).

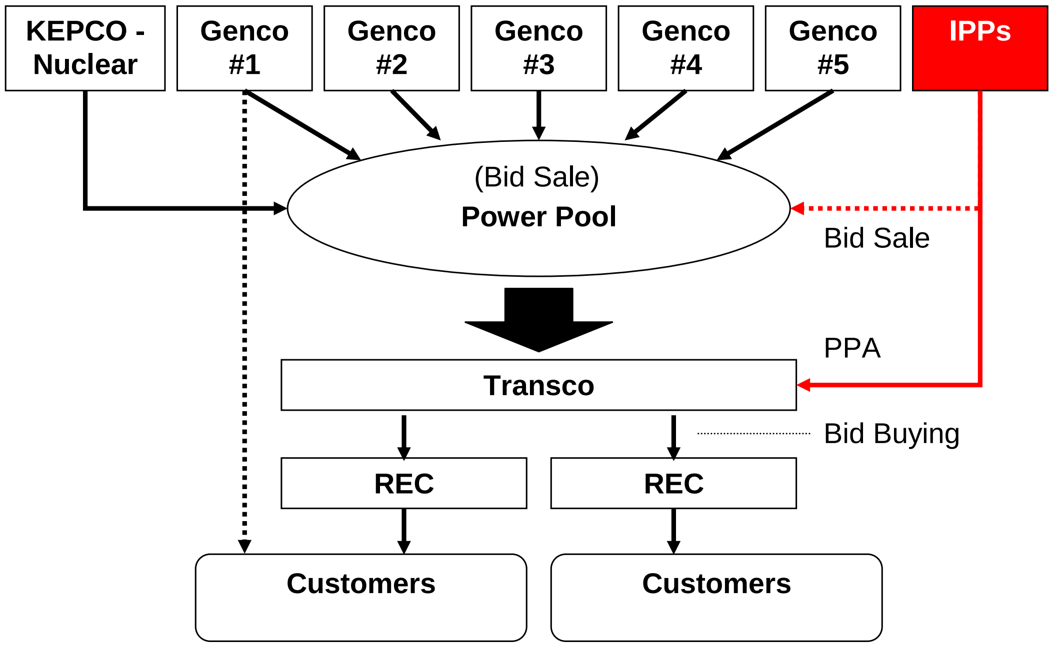
The market structure shown in Figure 3 represents an attempt to provide for some temporary adjustment point for the electricity market before further complexities—multiple sellers and multiple buyers (MSMB)—were added to the electricity market.

The plan for Korea was to break up Korean Electric Power Company (KEPCO) generation into several generating companies (Genco), including the company's nuclear plants. Both the Gencos and IPPs could sell directly to some customers, but most of the transactions would run through a power pool, a mechanism to match supply and demand on the basis of 15–60 minute increments. Regional electricity companies (REC) would then distribute the electricity to consumers. Some larger consumers, those at transmission voltage levels, might be able to contract directly with a Genco, bypassing the transmission company (Transco).

As vertically integrated state-owned power companies have experienced increasing losses in attempts to retain their "natural" monopolies, state owners have been forced, increasingly, to yield to market forces—pool pricing, bilateral contracts, locational pricing—with the hope that some new factor will save them.

It is not clear that the hoped-for rescue is forthcoming. Increasingly, state-owned utilities confront a market with highly variable prices—depending on time of day, location, season—either implicitly, by the refusal of investors to build new plants or explicitly, by locational prices.[9] More prices are needed by generators, consumers, and traders than can be provided by a vertically integrated utility (see **Figure 4**).

Figure 4: A power system with many transactions and prices (KEPCO plans for late 2000s)



As power systems become increasingly sophisticated, the need for a variety of pricing methods expands almost geometrically. Instead of the one price of the vertically integrated system, an MSMB trading system, as in South Korea, the Nordic countries, and elsewhere, requires at least 20 or 30 different generation prices, 15–20 transmission prices, and as many final customer prices as are appropriate—even in geographically compact nations. Every transaction in Figure 4 calls for its own price.

9 Locational prices can be calculated for each node in a power system. Essentially, locational prices represent the relative scarcity of electricity of a specific quality and quantity at a given location and a given time.

Technology has also made natural monopoly theory obsolete. Aside from market forces that have relentlessly pressured vertically integrated utilities, technology has also played a role in making the natural monopoly theory obsolete. The advent of modular combined-cycle power plants, mostly built in factories and assembled on site, has changed the way that plants are built. If a good can be built in a factory and shipped to the customer, then the good in question is not part of a natural monopoly.

Subsidies to Consumers and Across Categories Provide the Wrong Information to Consumers and Investors

As noted earlier, most vertically integrated utilities move money from one segment of their business to others—for example, from generation to transmission or vice versa. As long as the distortions are not too egregious, there is little misallocation of resources.

However, as the system grows and as the magnitude of subsidies grows commensurately, the misallocation of resources can become significant. One of the most important instances of subsidies leading to resource misallocation occurs when one customer category pays a different price than another customer category that has similar consumption characteristics (e.g., voltage level, total use).

Subsidies create a vicious feedback cycle for electricity utilities. The rationale for subsidies is usually either economic—that "we need to support the *xx* industry"—or it is based on ideas of social justice. Both types of cross-subsidies can ultimately result in major losses to the utility and the creation of powerful political forces that militate against cost-recovery pricing even when the national electricity utility faces financial ruination.

When subsidies create a profoundly unsound national electricity monopoly, the results are reflected by increasingly poor service quality. It is a reversal in some ways of the old dictum, "We pretend to pay them (the power company) and they pretend to supply us."

Starving the utility of funds leads to decreased investments as only those projects that are externally funded can be built. With dwindling financial resources, service quality often starts to drop as equipment ages. Poor service quality provides yet another excuse for nonpayment or low prices—why pay Mercedes prices for third-rate service?

Meanwhile, the growth of subsidies attenuates any "message" that the price system is supposed to deliver about electricity use—for instance, where, when, how much, what kinds of plants to build, etc.—the correct prices represent the signal, the subsidies the noise. Until that signal comes through clearly and with funds to back it up, utilities, consumers, and potential investors do not have clear incentives to behave in ways that create a stronger and healthier power system.

What happens when the price signals are wrong? The absence of proper pricing signals fails to inform users about the consequences of when and how they use electricity. Subsidized consumers can, by definition, not contribute to the ability of the power utility to invest in improved network operations and management. Potential investors have no reasonable idea of the potential gains or costs from locating new generation plants at one node or another on the network. This can lead to:

- Too much demand in the wrong places at the wrong time
- Not enough money to build network and generation to meet apparent demand

For too many countries, the results of the absence of proper pricing signals have become far too apparent: insufficient generation investment, unreliable network infrastructure, and the consistent drain of money from countries' treasuries to power monopolies.

Cost Reflective Pricing for Electricity—Is Power Really So Different from Mobile Phones?

Many of the cross-subsidies that aim to reduce the cost of electricity for some classes of consumers are justified on the grounds of social justice and affordability. The results of such policies are entirely predictable and inimical to efficient system operation, much less financial soundness.

When residential users do not pay the full cost of their electricity supply, they will tend to use electricity regardless of when—including peak periods—or other conditions, such as high fuel prices. The costs of losses and congestion as well as fuel consumption are someone else's problem. Even if a consumer does not pay in many countries, the procedures for cutting off service are complicated and time-consuming.

Compare this with mobile phones. There, users know that use requires payment—no pay, no call. And throughout the world, hundreds of millions of impoverished people will make sure that they have enough money to pay for wireless phone service. In fact, in some countries, especially those with spotty electricity service, wireless phone customers will recharge at for-fee service stations, often paying the equivalent of $0.75–$2.00 per kWh, when residential electricity prices are more typically $0.03–$0.10 per kWh.

What to Do?

Although electric power system restructuring has been going on for more than twenty years, there does not seem to be a consensus about which model is the best one, and it is unlikely that there is even a correct answer to that conjecture. However, some restructuring activities have emerged that seem to work in most places where they are tried. In fact, this institutional recipe book provides the basis for the code of conduct for European Union (EU) accession countries.[10] Compliance with this approach by the EU accession countries has generally led to improved service quality and financial stability for the utility companies. The next two subsections discuss the EU approach briefly.

Unbundle the Business Segments

The first step in bringing electric utilities to a state of financial soundness is to assess their current internal operations. How can one determine the assistance that is necessary to bring a utility into operational compliance if the company appears to

[10] Unfortunately, not all EU members were required to take their own medicine. As a result, power utilities in some EU countries, including Greece and Spain, contributed to the financial crisis in which those countries currently find themselves.

outsiders as a large black box? To achieve greater transparency, EU guidelines called for accession country utilities to initiate the following efforts:

1. Separate the financial accounts for each operational segment—generation, transmission, distribution, system operations, and trading, if applicable. This financial separation was to be accomplished even if ownership of the assets remained within a vertically integrated company.
2. Study the assets and performance within each segment against well-understood and published performance indicators (benchmarking). Provide a full and complete picture of the cost of service and operations in each segment.
3. Identify key needs for network and generation upgrades to comply with EU performance standards.
4. Determine a set of initial prices for each segment capable of supporting high-quality operations in that segment.

For Each Segment, Figure Out a Price that Can Cover the Costs of That Segment

By proceeding logically from structure to assets to performance to costs, it was possible for each utility participating in the EU accession scheme to determine the true costs of various segments. For some countries, such as Hungary (see case study in following section), the results of this process permitted them to choose a path of operations and investments that was far more suited to them both operationally and financially than the one they were on. For each business segment, the prime directive of electricity pricing, cover costs, was made explicit. After a short period, usually about three to five years, all cross-subsidies were to be eliminated.

Investments. Following the diagnostic of each segment, it is possible to create an investment plan that relies on the company's and country's priorities and expectations rather than those of equipment suppliers or foreign financial institutions. By placing all of a company's business segments on an equal footing, it becomes possible to use standard financial analysis to compare investments in one segment with those in another.

Incentives. A functioning pricing system provides clear signals to users about the cost of doing, or not taking a decision and action as electricity users or potential suppliers. In a later section, explicit rules about how prices can provide incentives are laid out.

Allow competition where it is appropriate. One of the key flaws of the natural monopoly theory of power systems is its contention that competition in electricity supply is wasteful. As has been amply demonstrated over the past 40 years, the financial destructiveness of financially and operationally unsound electricity monopolies far outweighs the alleged wastefulness of competing factories that make electrons with the aid of capital, labor, and some type of primary energy.

Generation. Most countries have finally understood that the generation segment is just another manufacturing industry when all is said and done. Since the late 1990s, even with the collapse in financing activity after the financial struggles and wars of the early 2000s, more and more countries have implicitly acknowledged that competition in electricity supply is desirable and essential. Most government budgets now simply leave out debt financing of new power generation.

However, like any competitive market, effective competition among prospective generation companies requires that the electricity system provide the right pricing signals. If generators are told to compete for sales in a subsidized market, then prices are likely to contain many other items than just the least-cost generation technology. There is a growing body of evidence from renewable energy markets to support this assertion.

Conservation and efficiency. The other industry segment (or sub-segment) that is most appropriately provided by a competitive market is the one for energy services. Certainly, no one would think that it is the job of the state to fix water heaters or air conditioners.

In a manner similar to the generation segment, the market in conservation, “negawatts,” relies on correct pricing signals such as the final consumer price. If consumers are to make effective and efficient investments in conservation, they can only do so relative to a reasonable accurate price for electricity. Where such a price is absent, government is often obliged to intervene to “correct” the lack of conservation incentives in electricity prices. Where the price signal provides the correct information about the cost of electricity, many government conservation schemes—low-energy light bulbs, water heaters, and the like—are taken up by consumers with little or no government expenditure. Recent work on responsiveness to prices in developing countries indicates that the cumulative impacts of right pricing of electricity can often be greater than those of targeted conservation efforts.[11]

Integrate Competitive and Monopoly Elements Appropriately—How is This Done Using the Pricing System?

Tariff differentiation represents an important element of tariff design and structuring. In principle, pricing may generally be differentiated on the basis of a number of cost drivers. For electricity pricing, the most important of these are geographic location, voltage level, and time-of-use. These are briefly discussed individually below.

Advantages and disadvantages of locational tariffs. Geographically differentiated tariffs are typically considered where there are market conditions that lead to differential costs imposed by particular customer groupings due to geographic location. There are various advantages and disadvantages associated with geographically differentiated pricing.

One advantage is improved cost-reflectivity. While it may be argued that any departure from spot nodal pricing of electricity leads to loss of economic efficiency, some measure of geographic variation in network usage charging would clearly provide a greater measure of economic efficiency than none. Another advantage is less cross-subsidization. Geographic differentiated charges will result in more cost-reflective charges, thus reducing the level of cross-subsidization between different users of the system.

Disadvantages include few beneficiaries. If the geographic location-based price signal to the various transmission zones is not passed on to end consumers, then there is little chance that these price signals will improve investment efficiency. There is greater

[11] A recent integrated resource plan sponsored by the Millennium Challenge Corporation indicated that the cumulative impacts of pricing reform on demand were noticeably larger than the effects of specified conservation and efficiency programs by almost a factor of two. See ICF International and CORE International, "Malawi Power System Project Studies—Phase II Integrated Resource Plan (IRP) for Malawi," August 2011. The elasticities used in the IRP model were derived from World Bank, "Subsidies in the Energy Sector: An Overview," July 2010.

complexity in network charge design and information requirements than for one postage stamp (geographically uniform) tariff.[12]

Voltage level. Electricity supply tariffs are often differentiated by voltage level as different customer off-take voltages generally entail different infrastructure and different associated costs. These aspects relate particularly to network infrastructure, where lower voltage levels generally imply more extensive use of network infrastructure (e.g., transformers and transmission/distribution lines). In other words, lower-voltage customers effectively make use of more infrastructure than higher-voltage customers. Consumer electricity charges should be differentiated on the basis of voltage levels.

Time-differentiated tariffs. Time differentiation of tariffs is based on the recognition that costs vary by time. This is particularly relevant for generation costs that increase and decrease depending on the demand for electricity and the power plants and fuels used to meet demand. Recognizing this, time differentiation may cover seasonal, peak, intermediate, off-peak, or even hourly-differentiated rates.

Time-of-use differentiation is considered to be a powerful tool for not only ensuring cost-reflectivity of generation charges but also for promoting energy efficiency.

If generation charges are eventually to be differentiated based on time-of-use principles, then it is logical that the charges to transmission customers for network losses should also be differentiated on the same basis. On the other hand, fixed transmission costs don't vary over time, and hence it is recommended not to introduce time-differentiated use-of-system (UOS) capacity charges.

The relationship between revenue requirement, costs, and charges. In seeking to achieve cost-reflectivity in charges levied, a number of different network charge components may be applied. Generation is, and must be, whatever it is. For the network costs, each charge component is designed to recover specific network costs in the most economically efficient way. In summary these components are:

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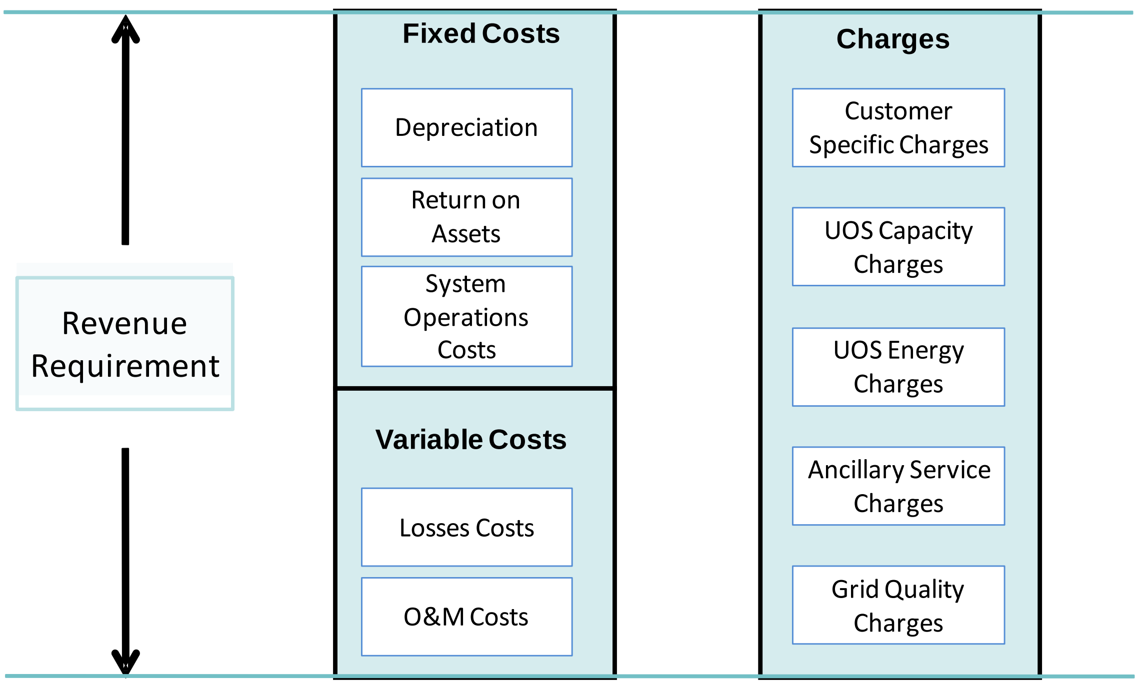
[12] A postage stamp tariff will generally consist of generation charges, charges by time period, average transmission costs, and the costs of the system services—voltage support, regulation, reserves, reactive power, etc.—needed to ensure reliability and quality of supply. A geographically differentiated tariff will assign costs to the transmission zone in which the costs are incurred. The number of prices will then be expanded as the number of zones increases. Further, the tariffs will need to make explicit as many of the system services charges as is feasible. This generally means separate charges for reserves and reactive power and a general services charge for the other ancillary services.

- energy charges
- individual customer charges (or connection charges)
- charges for use of system capacity
- use-of-system energy charges
- ancillary service charges
- grid-quality charges

In a well-designed pricing system, the various charges will add up to the utility's total revenue requirement. This approach is depicted in Figure 5.

Figure 5: The relationship between revenue requirement, costs, and charges



It is noted that the adoption and application of a particular pricing methodology for a specific category of charge is not mutually exclusive. Proposed approaches may apply a combination of principles as the different methodologies focus on various aspects of network costing and pricing. The various options need to be assessed in terms of how well they satisfy and balance the different pricing principles, objectives, and strategies, including:

- simplicity
- stability (also over the longer term)
- fairness—does the tariff treat users with similar consumption patterns and profiles the same? Are there "undue" transfers from one consuming group to another?
- reflection on usage
- promotion of long-term efficiency, but minimized distortion to usage for short-term efficiency
- regional competitiveness

In other words, once the objective of cost coverage has been decided, there can be multiple pathways to that objective.

Implementation

Once a government is committed to a financially sound electricity sector, it faces the daunting issue of the transition. How can consumers be moved from low prices and low quality to higher prices and improving quality of service? As with the actual methodologies for calculating charges for various service components, there is no one right way to do this.

What has worked in many countries is the implementation of cost coverage first and thereafter pursuing the elaborations such as time of use, location, and ancillary services. (See the last section of this paper for examples). In other words, countries should devise a pricing system that covers costs—first historic costs, then all costs going forward. Once costs are covered, then countries should encourage efficient use of the network by devising charges that will encourage efficient use and providing resources for upgrades and expansion.

What Have Others Done to Address These Issues?

Examples from Three Systems

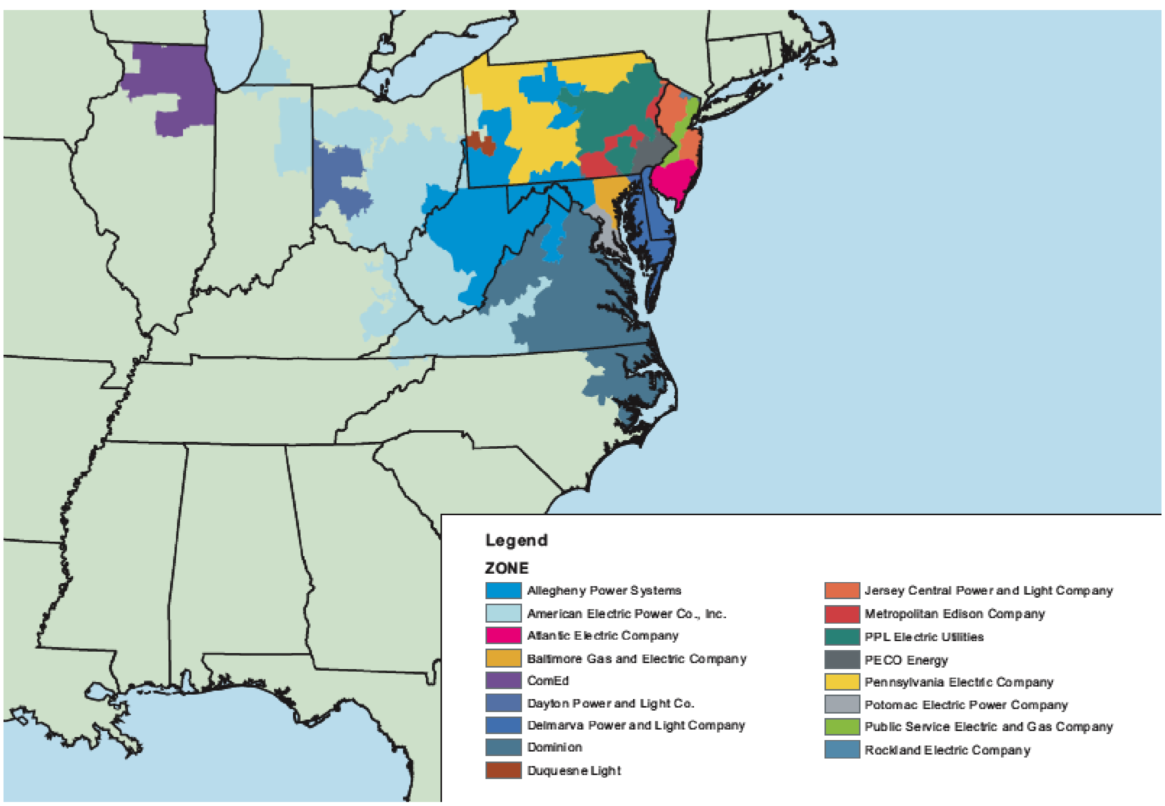
In this section, we look at three widely different systems, those of the Pennsylvania, New Jersey, and Maryland regional transmission operator (PJM RTO); NordPool Spot;

and Hungary, to try to distill lessons about power system pricing that are relevant for Asian nations.

PJM—a large and sophisticated system (the NASCAR racer). The first example, perhaps a long-term goal but not a short-term desiderata, is the very efficient and sophisticated PJM system in the United States. PJM is a regional transmission organization covering all or parts of fifteen U.S. states. The pool of the original states—Pennsylvania, New Jersey, and Maryland—was organized originally in 1966 following a severe grid collapse in the eastern United States. Expanded now to cover about 17% of U.S. electricity supply, PJM permits its members to purchase power and energy at more than 2,500 locations with various transmission and use-of-system charges.

Members of PJM have a total generating capacity (as of 2010) of 166 gigawatt (GW), with 145 GW peak demand. The network is immense, with more than 100,000 kilometers (km) of transmission and more than 2,500 injection/withdrawal nodes. Each node has its own locational marginal price (LMP).

Figure 6: PJM System, 2010



Source: PJM website, http://pjm.com/about-pjm/how-we-operate/territory-served.aspx.

The terms for PJM membership are severe. Each member must supply or purchase key system goods and services that ensure efficient and effective operation of the overall system. Products that are priced for PJM members include the following:

- scheduling, control, and dispatch
- capacity reliability services
- reactive supply and voltage control from generation sources service
- regulation and frequency response service
- energy imbalance service
- operating reserve—spinning reserve service, operating reserve—supplemental reserve service
- real-time, cost-based energy market
- daily capacity markets
- monthly and multi-monthly capacity markets
- real-time competitive energy market
- transmission rights auction
- day-ahead market for energy
- regulation market
- spinning reserve market

The PJM contract is demanding. Members must provide their own reserves and other system services, have a plan to purchase them on the market, or buy them from PJM itself.

The rewards for submitting to this RTO discipline are commensurate. Generally, PJM members can maintain lower reserve requirements relative to capacity than would be the case outside PJM. In addition, members have many options for delivery of capacity and energy. The high degree of connectedness provides members with increased "immunity" from price spikes or outages elsewhere in the system or from the failure of a few generators.

Data needs for operating the RTO are extremely high and PJM must maintain real-time monitoring and market-activity surveillance to prevent market manipulation. The real-time data system also permits the operator an opportunity to take action in response to LMP price movements.

NordPool—an unusual mix of state and private investment. NordPool (see **Figure 7**) consists of Norway, Sweden, Finland, and Denmark. The pool operates under national law and EU regulations with both physical and financial markets. The vast majority of NordPool activities are financial, not physical.

Figure 7: NordPool System, 2010

Source: NordPool website, http://www.statnett.no/en/The-power-system/Production-and-consumption/State-of-the-Nordic-Power-System-Map/

NordPool member utilities have peak generating capacity of 95 GW, with 150 terawatt-hours per year (TWh/y) in sales. The maximum transfer rate among the members is relatively small, at roughly 20 TWh/y. The core generation, accounting for 90% of the system, is based on Norwegian hydroelectric plants and Swedish nuclear plants. Denmark's electric power system combines coal and wind primarily.

Transfer capacity is limited, as noted in the small proportion of transfers to total sales. The connections among the members range from 1.8 GW–2.4 GW from one country to another.

NordPool's pricing approach is a combination of full market operation for generation and regulated network pricing for transmission and distribution. Their approach is designed to work in a mature system, but some attributes are likely transferable to other systems. These attributes include charging customers according to voltage level. Performance standards are determined by benchmarking, and once set, are used to established pricing allowances and penalties for grid-induced loss of load.

Standing behind NordPool is the well-developed financial system of the Nordic countries. Perhaps the most important key to understanding NordPool's success comes from Lt. Harry S. Callahan: "Understand your limitations."

Hungary—a "good enough" approach that works well. Hungary, now a member of the EU, began the 1990s as a former Warsaw Pact member, its economy and energy systems geared toward heavy industry and physical allocation rather than pricing system allocation. The country's problems in the power sector were many and wide-ranging.

The end of central planning left Hungary with excess generation capacity based mostly on coal, and the generation stations were inefficient and dirty. Not only were these plants uncompetitive once generators had to pay market prices for fuel, but membership in the EU forced Hungary to join its single energy market with a fleet of uncompetitive power stations.

With its high-cost legacy generation, the country had few natural advantages as a generator, but was burdened with 8.6 GW of generation capacity. Compensating for its unfortunate generation situation was a prime location for electricity trade—a central location relative to major generation stations in Germany, Austria, and then Yugoslavia.

The solution seized upon by the country was to become a trading hub for electricity. Hungary accomplished this by adopting a pricing model that is the very essence of simplicity and elegance.

Cover Costs (Prime Directive)

For more than a decade, the pricing system for electricity was based on a simple model. It included a charge for purchased or generated energy and power. Electricity charges were based on a cost of service plus rate of return model.

- Energy charges were invoiced on an actual-cost basis. This meant that imported energy was priced at its actual cost and not subsidized by either the transmission or distribution segments or by other customer categories.
- Fixed costs include depreciation and return on capital employed (net asset value), as approved by the country's regulator.
- All other cost categories were covered by the network invoice. These costs categories include the following:
    - operational costs and losses
    - system control and operation
    - system services, including reserves, congestion, and reactive power (from generation)
- Congestion and reactive power charges act as proxies for time and locational distinctions

The positive results for the country were significant and are difficult to argue with. More than 2 GW of old coal-fired generation has been retired, replaced by 1.4 GW of modern gas-fired power plants. While international trading has increased, net imports have fallen because the country now has a better match between the location and types of generation needed and the locations and types of power plants on the ground.

Hungary's "good enough" approach to tariffs allowed the country to transition to a power generating system that reflects energy policy priorities for the country, such as cogeneration, heat, and power. At the same time, the utilities are financially stronger inasmuch as the tariffs cover all costs of supply including new capacity. The pricing system also provides reasonable signals regarding congestion and location of new generation. The electric power system is now strong enough financially to implement a more sophisticated tariff when appropriate.

Lessons from Other Power Systems

The prime directive of electric power pricing is to cover costs. Without cost recovery—and this includes own generation, purchased power, network investments, operations, losses, and trading—the electricity supply company cannot be creditworthy. Inevitably, its physical assets will suffer and the company can become a financial liability to the country and a drag on its economic growth .

Electricity tariffs need to signal to both consumers and current or prospective suppliers both when to use or supply electricity and why one location or another is better suited for a new generation plant or steel furnace. At the same time, these tariffs need to reflect the country's energy policy priorities—cogeneration, regional development, and prime-mover types, among others.

Many countries have started to restructure their electric power systems. Generally, the direction is in favor of greater trade within a country and with its neighbors, as appropriate. Trading, when it is motivated by willing buyers and willing sellers, is generally beneficial. At the same time, it is easy to adopt solutions from other countries wholesale, regardless of whether the packaged solution is a good fit for the country.

Restructured systems with electricity trading require a lot of data. It is important to ensure that the system's methodology and structure are not too sophisticated for the available information and the ability to apply those data. The types of trades cannot go beyond what the local trading entities (counterparties) can support financially or what the country's banking system can accommodate.

As the system is unbundled and trading increases, countries need to implement standard protections against anti-competitive behavior. This means increased attention to market monitoring and fraud prevention.

Improving the quality of service is fundamental to more efficient and effective applications of electricity to the country's economy and society. Most countries with successful power supply systems use some form of performance benchmarking to devise key performance indicators (KPI) for service quality. While this is strongly advised, it is also important to make sure that the KPIs reflect what can be accomplished in each power supply system both technically and cost-effectively.

Increased financial strength of electricity supply companies is a key outcome of improved price-setting. As a general rule, other investors are willing to build generation plants where prices are rational. Consequently, this can free funds to build as large a network as possible. Like all good things, there can never be too much network.