POLICY BRIEF

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Optimal Pricing of Electricity in a World with Affordable Distributed Energy

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Introduction

The electric industry provides indispensable services, consumes vast resources, and is crucial for addressing climate change and several other environmental issues. The industry is in the midst of major changes that present an opening, and a heightened need, to greatly improve electricity pricing policies. Those pricing policies strongly influence the economic efficiency of the electric sector, by affecting consumption, production, technology adoption, and externalities. Improved pricing can better promote prosperity, health, and environmental quality.

This policy brief is intended to be a succinct and relatively accessible description of optimal pricing of electric energy. It will emphasize how policymakers, regulators, and utilities can respond to the twin developments of decreasingly expensive distributed energy technologies (solar panels, energy storage, responsive load, efficiency, and more) and better understood environmental externalities.

Optimizing electricity pricing would affect the pricing of distribution and environmental impacts proportionally more than generation and transmission. As it turns out, improving the incentives for distribution and environmental externalities may be politically far easier to do together than separately, since one would counter-balance the negative effect of the other, from both a customer perspective and the perspective of distribution utilities. Pricing externalities more fully would be likely to raise customer bills, while pricing distribution optimally would be likely to reduce them. Pricing distribution optimally would be likely to leave a utility revenue gap that would need to be filled, while pricing externalities could fill that gap. In addition, addressing each enhances the economic efficiency of addressing the other. The result would be reduced environmental costs and reduced distribution costs.

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Optimality

"Optimal" is used in this policy brief as a synonym for "economically efficient." "Economically efficient" denotes that which maximizes people's welfare. However, we need a measure of that welfare. This policy brief will use the welfare function known as social surplus. It is common in economics because it values a dollar of customer surplus equally with a dollar of environmental benefit, producer profit, and government revenue. Maximizing it maximizes the total benefits as measured in dollars (or any currency). Some of those benefits can be redistributed for the economically needy, for replacing economically inefficient taxes, or for other purposes. This policy brief implicitly makes use of economics' standard assumptions of rationality, such as that market participants will maximize their individual welfare.

This policy brief will principally describe the pricing that is optimal in the absence of constraints such as some prices or rules that cannot presently be changed. Understanding such unconstrainedly optimal pricing is useful even when constraints apply, as they usually do. Developing the optimal pricing in light of those constraints requires a process, and principles, similar to those for developing the pricing that would be optimal without those constraints.

The Basic Prescription for Optimal Electricity Pricing

Optimal pricing, as defined above, involves setting the prices at the levels that will induce the market participants, at each time and place, to produce and consume the quantities that maximize social welfare. Much current electricity pricing practice, and almost all of the literature about how electricity pricing should be changed, reflect a pursuit of objectives different from maximizing social welfare as defined above.

The basic prescription for optimal pricing of electric energy has three parts. The first is that *the price of power, at each location and time, should equal the full short-run marginal cost of satisfying demand at that location at that time*.[1] Full short-run marginal cost includes both direct costs and externalities. The marginal generation for satisfying demand at that location must come from a location or combination of locations from which it can be delivered to that location without violating the limits of any generator, line, or other component in the system. That often affects the optimal prices. Transmission and distribution losses do as well, since they generally require that more or less than one additional kilowatt must be generated in order to deliver one more to a particular location.

The second part of the optimal pricing prescription is that *fixed costs should be recovered in the least distorting way possible*. Following the first part of the prescription is the best way to recover fixed costs. It can recover a substantial portion of fixed costs because prices that equal short-run marginal cost tend to collect considerably more than the direct variable cost of providing the service. This is a result of marginal costs that, in the short run, increase

[1] For an extensive explication of such pricing, see Schweppe, F.C., M.C. Caramanis, R.D. Tabors, and R.E. Bohn, ''Spot Pricing of Electricity,'' Kluwer, Boston, 1988.

with quantity provided and the fact that the potentially large externalities component of such prices cannot and should not be paid as victims' compensation. Unavoidable charges are the next best way to recover fixed costs because, while they do not better align the incentives of market participants with those of society as whole, neither do they worsen the alignment.

The final part of the prescription is that *customer investments that affect future utility fixed costs should, to the extent possible, face fees or rewards equal to their estimated impact on those costs*. Investments, such as adding a new house or a new vehicle charger, are fundamentally different from ephemeral customer choices such as making toast. Investments have long-run impacts, so should face a positive or negative incentive equal to their expected impact, if any, on long-run expected utility costs. Such an impact depends on location and other factors, and can be substantial or negligible. Without applying such incentives, even with otherwise optimal prices, the effects of customer investments on future utility capacity costs can be far from fully reflected in their impact on the customer's expected future electric bills.

Progress toward Optimal Electricity Pricing

Virtually everywhere, the adoption of the optimal pricing prescription just described is quite incomplete, in terms of both whom it is applied to, and what costs it is applied to. Figure 1 provides a subjective summary of the typical state of affairs in the jurisdictions around the world that have adopted spot pricing of electricity. [2] The darkness of the shading indicates the extent of application optimal pricing to each combination of group and type of cost. The most optimal pricing is the pricing for generation and transmission faced by wholesale generators. It approximates the optimal pricing prescription. Spot pricing is designed to match short-run marginal cost of generation and transmission, and the proceeds from those charges also cover much of the fixed costs of generation and transmission.

In many jurisdictions with spot pricing, some kind of time-varying pricing approximating the spot pricing of generation and transmission applies to large customers as well. In contrast, only a small proportion of the small customers and distributed generators face spot prices. Those spot prices are based only on generation costs and transmission losses and constraints. [3] For almost all generators and customers, pricing of distribution and environment bear little resemblance to optimal pricing. In some jurisdictions, there are cap and trade programs or emission taxes for environmental variable costs, but even in such jurisdictions they tend to cover only one emission type, not be designed to approximate marginal environmental cost, or both. Distribution variable costs are recovered in flat charges rather than charges that reflect

[2] Specifically, nodal or zonal spot pricing based on locational marginal prices. Spot pricing can be adopted in the context of a restructured electricity market or in the context of vertical integration, and has been adopted in both contexts. In jurisdictions that have not adopted spot pricing of electricity, the pricing tends to be even farther from optimal than what is shown in the figure.

[3] Most wholesale generators and many large customers are connected to the transmission system by a dedicated feeder and transformer. In such cases, distribution system pricing is the pricing for the use of that dedicated feeder and transformer. If the generator or customer owns them, then that pricing is an internal matter.

the highly variable nature of distribution variable costs. Distribution fixed costs and some general government expenditures are recovered in part via flat per-kilowatt-hour charges and in part via fixed charges. Those flat charges to recover variable and fixed distribution costs are not an optimal way to do so, but do crudely offset the lack of full pricing of environmental externalities, albeit with much less effectiveness than correct emission pricing because the flat distribution charges do not differentiate between generators that emit much and those that emit little or none. The next several sections will describe how the pricing corresponding to most of these categories of cost can be optimally priced.

FIGURE 1. ECONOMIC EFFICIENCY OF TYPICAL PRICING IN ELECTRICITY MARKETS THAT HAVE ADOPTED SPOT PRICING OF ELECTRICITY

		How close to optimal is the pricing for this group…			
		Wholesale Generators	Large Customers	Small Customers	Distributed Generators
…corresponding to these costs? (darker indicates closer to optimal)	Generation & Transmission Costs				
	Environmental Variable Costs				
	Distribution Variable Costs				
	Distribution Fixed Costs				
	Government Expenditures				

Pricing of Distribution Service: Current versus Optimal

Figure 1 reflects the fact that the last wave of electricity market reform dealt with generation and transmission. Most of the current reform efforts deal with the environment and, in the US, distribution. These are the topics of this section and the next.

The most ambitious distribution-market reform effort is the Reforming the Energy Vision initiative of the State of New York. As part of it, New York is considering the adoption of changes to distribution prices, to make them more economically efficient. This is referred to as LMP+D, where the "+D" reflects the hope of applying locational marginal pricing to distribution. Another part of the current wave of reform efforts in the US is challenges to the policy of allowing net metering without imposing a net metering surcharge. Those challenges are based primarily on the fact that each kilowatt-hour of net metered generation saves or earns the customer the distribution charge in addition to the wholesale generation charge.

Distribution charges are designed to recover the costs of building and operating the distribution system. Current distribution charges do this via a flat charge per kilowatt-hour and a fixed monthly charge. In addition, a large customer typically faces charges per kilowatt for its "peak" electricity use, either at the times of its highest consumption or at the times of the highest system-wide consumption. That is quite different from optimal pricing as defined above and described below.

Optimal distribution prices would be calculated and applied as optimal transmission prices are: they would modify the optimal total price of delivered power in each location on the distribution system, based on the full distribution-level short-run marginal costs of satisfying load at that location. The optimal distribution price at each location would at all times depend on distribution-level marginal losses associated with consumption at that location, which vary over time. At some times, the consumption at a location increases the risk of an outage or of high-load-related damage to some distribution equipment. Occasionally, consumption at a location reduces power quality, posing a risk to the equipment and business processes of other customers. Rarely, consumption at some locations causes a distribution-level constraint to bind. At most times and places, the only one of these situations that has a significant effect on optimal price is losses, because distribution systems tend to be built with a margin of extra capacity. However, the other situations are likely to become more common with greater customer acquisition of electric vehicles and generators. Tighter utility investment budgets, too, could make them more common. All of the other situations contribute to the optimal distribution price when they apply, and at such times they may cause the optimal distribution price per kilowatt-hour to rise well above the level it is typically at today, to deter undue reliability risks and damage.[4]

In short, optimal distribution prices are a tool to increase reliability and reduce costs by reducing load when and where it threatens reliability or damages equipment. They would also, in some locations, help to delay or prevent the need for capacity expansions.[5] These are the supply-side benefits of optimal distribution prices, as defined above.

Customers would receive these supply-side benefits because utilities would pass most or all of the savings on to the customers. In addition, at the many places and times when the

[4] Optimal distribution prices per kilowatt-hour would have a higher average for some customers than for others, based on location and on temporal pattern of electricity demand. Electric rates already differ geographically. However, policymakers could, if they wished, compensate for this new geographic rate difference by establishing lower monthly fixed charges for established customers in locations with newly increased average per-kilowatt-hour electric distribution prices.

[5] This would happen as a result of optimal distribution pricing based on short-run considerations. In addition, it is possible that in places where slowing the growth of peak load can delay or prevent the need for expensive new capacity investments, it is optimal to raise on-peak distribution prices more than is justified by short-run considerations alone, to encourage customer adoption of peak-shaving and peak-shifting technologies and practices such as more efficient air conditioning and delayed charging of electric vehicles.

optimal distribution price would be lower than the current prices, a switch to optimal prices would mean savings for those customers.

There are two problems with those savings. The first is that a switch to optimal distribution pricing would be likely to significantly reduce the revenues utilities receive for distribution, which would need to be made up some other way. The second is that the lower average distribution price would induce customers to use more power, which would increase the negative environmental externalities of power generation. Fortunately, optimal pricing of environmental damages can solve both of those problems. It is the topic of the next section.

Pricing of Environmental Damage: Optimal versus Current

Calculating the socially optimal price for allowing an environmentally damaging activity involves estimating the marginal cost to society of the activity (e.g. the social cost per ton of CO2 emitted) and charging the resulting price to those who are responsible for the activity. Current environmental charges can be described as incomplete. Virtually everywhere, they are absent or are a product of an emission cap rather than approximating the estimated marginal social cost of the damaging activity. A few jurisdictions, such as British Columbia, do have emission charges designed to approximate the estimated damage, but typically only for carbon dioxide.

Distribution and Environmental Pricing Reform: Better, and More Viable, Together

What this policy brief defines as “optimal” distribution pricing is only optimal if the prices for environmental damage (and generation and transmission) are also optimal. Environmental damage prices below their optimal values reduce the benefit of “optimal” distribution pricing because reducing the flat distribution charge would increase environmental damage. That effect which would likely be economically inefficient in the presence of such sub-optimal environmental damage prices. In addition, optimal distribution pricing may not be politically viable if the resulting reduction in per-kilowatt-hour distribution rates has to be made up by increasing the monthly fixed portion of customers’ electric bills. That disproportionately hurts two customer groups who are favored for understandable reasons: low-income customers and energy-efficient customers.

“Optimal” environmental pricing, as described above, would likely still be beneficial without a change to distribution charges, but it would be more beneficial if accompanied by optimal distribution rates. More fundamentally, the fact that optimal environmental pricing would raise rates seems to be a major impediment to its political viability.

In short, optimal distribution pricing may not be politically viable on its own because it would reduce customer payments without a good way to make up the difference to utilities, while environmental pricing may not be politically viable on its own because it would increase customer payments without a good way to make up the difference to customers. However, if both optimal pricing policies were adopted, the increased environmental damage charges could fill the revenue gap left by the optimal distribution pricing, with less increase of customer bills than would result from the environmental pricing change alone. From a societal perspective, this combination would reduce both environmental damage and the cost of the distribution system. By luck or as a result of suboptimally charging for environmental damage only enough to fill the distribution revenue gap, the combination could also have approximately zero effect on the average customer's bill.

Pricing for the Use of the Distribution and Transmission Systems When Not Congested

Fixed costs are those that, in the short run, do not change with the quantity of electricity consumed. The cost of having built a distribution or transmission line is an example. Most fixed costs in the electric industry are associated with infrastructure and services that are also mostly "non-rival." Non-rival means that an additional user does not interfere with other users' use. For example, when a distribution or transmission line has spare capacity, as most do most of the time, it is mostly non-rival, meaning that one additional kilowatt has no impact on the use of the line for delivering other kilowatts (except a small impact on the portion of each kilowatt lost as heat, and that is correctly dealt with by marginal loss charges). Because using the line usually does not increase any costs other than losses, optimal pricing of electricity includes no charge for the use of lines when they are uncongested, other than a charge per kilowatt based on the marginal loss rate.

Charges that do not match marginal avoidable costs are "distorting," meaning they give customers or suppliers an incentive to do something other than what is best for society as a whole (them plus everyone else). Such distorting charges cause customers to consume power that brings them less benefit than the cost to society of producing it, or to forego consumption of power that brings them more benefit than the cost to society of producing it.

Charging for the use of non-rival goods is distorting, so it is optimal to not charge for their use, and to instead cover the costs of providing them via charges that reduce costs by being set equal to short-run marginal direct costs and short-run marginal external costs. The optimal recovery of the fixed costs of non-rival goods is partly decoupled from the use of those goods. The next section discusses it.

Recovery of the Fixed Costs of the Distribution and Transmission Systems

The key principle for optimal recovery of the fixed costs of electric infrastructure and other largely non-rival utility services is to collect them in the ways that create the least distortion, as that term is defined above. A few principles of how to do that are worth highlighting.

First, the best way to recover fixed costs is through prices that match the marginal effect of the priced activity on costs. Such pricing causes customers to take actions that reduce costs. The optimal way to recover the fixed costs involves establishing such pricing, where practicable, on all activities that cause costs to increase costs for people other than the person doing the activity. Charging for the actual avoidable marginal costs of using the transmission and distribution system is a crucial part of optimal pricing, and is discussed in other sections of this policy brief. Charging the sources of pollution and other negative externalities for the estimated costs they impose on society would reduce the large distortion that results from leaving those externalities largely unpriced, as they are now. It would also produce a large amount of revenue that would allow for reducing the distorting charges currently used to recover fixed costs.

Second, unavoidable charges are the next best way to recover non-rival costs because they do not change incentives. Monthly fixed charges come close, especially if they are understood as such by customers and if they do not cause customers to move or to disconnect from the grid.

Third, to the extent that the above two methods are insufficient and non-rival costs must be covered in part via distorting charges per unit sold, their recovery should generally be spread widely. It is generally better that the charges to recover the costs of non-rival goods be a small portion of the cost of many goods, rather than a large portion of a few and none of the rest. The reason for this is that the welfare loss from a charge on a good increases exponentially, rather than proportionally, as the cost of the good or service moves farther above its marginal cost.

Fourth, the optimal charges to recover the costs of non-rival goods should be lower where the quantity purchased is more sensitive to price. This implies that a rate plan that applies to customers with more elastic demand should have a smaller per kilowatt-hour component for the recovery of fixed costs than should a rate plan that applies to customers with less elastic demand. Ramsey pricing is the term for pricing based on this principle.

Optimal Taxes

The principles just described, for the recovery of the costs of non-rival goods such as distribution lines with spare capacity, apply to the recovery of the costs of government via taxes. If electricity were optimally priced, reflecting all costs including negative externalities, it might or might not still be socially optimal for electricity bills to include a positive tax to cover a portion of general government expenditures.

Optimal Pricing of Customer Investments that Affect Future Utility Fixed Costs

A customer making an investment (e.g. adding a new house, photovoltaic array, or energy storage system, or replacing an inefficient air conditioner), might affect the expected size and cost of the distribution line (or some other infrastructure) serving the neighborhood, the next time it is replaced. Under optimal rates, that might raise or lower the expected rates in the neighborhood until the line is replaced, providing part of the optimal incentive for the customer to make a an investment decision that would be socially optimal in the sense of optimally helping to reducing the needed size and cost of the new line. However, once installed, the new line will probably have spare capacity, for reasons of reliability, so it will probably be non-rival most or all of the time, meaning that rates will contribute little to the recovery of the fixed cost of the line. In such situations, when an identifiable customer action materially affects future utility costs in a way that the customer does not already face through rates, it is appropriate to impose an additional charge for the difference.

Optimal Pricing Adjustments Resulting from General Equilibrium Considerations

The above discussion of optimal pricing does not take into account the interactions of prices with distortions in the economy, such as distorting taxes. Such distortions change what the optimal prices should be. Calculating the adjustments that should be made in light of such distortions is the province of general equilibrium modeling in economics.

Implications for Net Metering and Distributed Generation

Net metering exists to approximately compensate for the lack of correct pricing of externalities. Correctly pricing those externalities would remove the reason for net metering's existence. In addition, optimal pricing would provide correct incentives for adoption, design, and operation of distributed generators.

Conclusion

There is much room for making electricity prices closer to optimal, as defined above. This policy brief has described optimal pricing of electric energy, providing a three-part prescription that includes aligning prices with marginal avoidable costs and recovering other costs in the least distortionary ways possible.

The gulf between current practice and optimal pricing is particularly large for pricing of distribution service and environmental impacts. New technologies make such pricing changes easier to implement and more important to consider. Current efforts at electricity policy and regulatory reform are motivated largely by these considerations. Optimal distribution and environmental prices considerably enhance each other's benefits. In addition, the opposite impacts of each on the variable charges make it likely that each of the two is more politically viable if both are adopted together.