Testimony on
The Effect of Restructuring on Price Elasticities of Demand and Supply

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INTRODUCTION

In its February 15, 1996 Committee Order, the ***ER 96*** Committee asked for information on how restructuring may affect price elasticities of supply and demand (Issue III.A.4). This Staff testimony begins with a definition of the concept of price elasticity. A short discussion of existing estimates of demand elasticities follows. The Staff analysis of demand elasticities concludes with a discussion of how restructuring might generally affect the elasticity of demand. A discussion of supply elasticities is followed by a concluding section.

The Concept of Price Elasticity

Estimates of the price elasticity of electricity demand can provide the answer to the following question: if the price of electricity falls, will consumers purchase a lot more or a little more electricity? The concept of elasticity can also be applied to supply curves, though in this context, the question is whether producers will increase the supply of electricity by a little or a lot in response to a change in price. Obviously, the factors that influence demand response to a change in price will be different than those affecting a supply response.

Quantitatively, an estimated price elasticity measures the percentage change in quantity demanded (or supplied) resulting from a 1 percent change in the price of electricity, other factors constant. Since price elasticity estimates are based on a specific price range along a stable demand or supply curve, changes in price outside that range or shifts in demand or supply can alter the elasticity.

Estimates of the Price Elasticity in the Regulated Electricity Market

Existing estimates of demand and supply elasticities are derived from consumer and producer behavior in a regulated electricity market. The prospect of unbundled electricity services, time of use pricing and choice of suppliers via bilateral contracts suggest presently available estimates will have limited meaning as deregulation is implemented. For the immediate future, residential consumers may continue to purchase bundled electricity from their existing utility or an aggregator and thus existing price elasticity estimates may be temporarily useful for one segment of the restructured market.

Most estimates of demand and supply elasticity are based on statistical estimates of demand and supply functions. Good statistical results are dependent on several conditions with respect to the data and techniques employed. Some examples will suffice to illustrate the point. The model to be estimated should not omit theoretically relevant explanatory variables, for example, a model of demand behavior should (at a minimum) include price of the good, the price of substitutes and complements and real income. Often, demographic variables matter, as does information on existing capital stock (square footage of the home, other appliances). Omitting an important variable can bias the coefficient estimates if the omitted variable is correlated with another explanatory variable. In some cases, a variable is omitted for lack of data. In some markets, simultaneous estimation of demand and supply equations is needed so as to properly identify the influence of demand on consumption, as distinct from the influence of supply conditions. This is particularly relevant where supply conditions are changing over the time of the sample data (or over a cross-sectional data set). Statistical problems, such as sampling error, missing data and small samples (or samples with non-normal probability distributions) can also be troublesome. It should surprise no one that practice is not ideal, suggesting that statistical estimates be interpreted carefully. Neither should statistical results be dismissed lightly as economists take care to avoid or minimize erroneous results.

Bohi (1981) has surveyed several studies of the demand for electricity employing national data.[1] **Table 1** summarizes the estimates of electricity demand elasticities from these studies; since several studies are reviewed, the results are displayed as a range of estimates for the price elasticity of demand. More recent studies, discussed below, support these estimates.

Table 1
Estimates of Electricity Price Elasticities

	Elasticity Estimates	
	Short-run	Long-run
Residential	-0.06 to -0.49	-0.45 to -1.89
Commercial	-0.17 to -0.25	-1.00 to -1.60
Industrial	-0.04 to -0.22	-0.51 to -1.82

Most analysts either disaggregate across customer classes or analyze only one customer class. Residential consumers have different motivation (maximizing satisfaction), different responses to a change in price and (prior to deregulation) face different rate structures than do industrial and commercial users (whose goal is to maximize profits). In addition, common sense and economic theory suggest consumers should be more responsive to a change in price over longer periods of time. Consumers have greater opportunity to adjust their behavior and capital stock - appliances, electric motors, coating processes and so forth - to changes in prices and price structures.

In all three customer classes, the table shows that short run demand is price-inelastic (a 1 percent decline in price will result in a less than 1 percent increase in consumption). More recent studies of short-run residential demand elasticities (Branch, 1993 and Hsing, 1994) estimate elasticities of -0.20 to -0.27, well within the range of the studies summarized in **Table 1**.[2]

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[1] Bohi, Douglas R., *Analyzing Demand Behavior: A Survey of Energy Elasticities*, Johns Hopkins University Press, Baltimore, 1981.

[2] Branch, E. Raphael, "Short Run Income Elasticity of Demand for Residential Electricity Using Consumer Expenditure Survey Data," *The Energy Journal*, v. 14, no. 4, p. 111-121, 1993; Hsing, Yu, "Estimation of Residential Demand for Electricity with the Cross-Sectionally Correlated and Time-wise

These estimates support the contention that there is a substantial difference between the short-run price elasticity of demand and the long-run price elasticity of demand, regardless of customer class.[3] Certainly the durability of energy-using capital contributes to this result. In the long run, it appears that consumers are very sensitive to a change in price, and that there may be a substantial lag between a change in electricity prices and consumer response (i.e., consumers respond as their refrigerator, heat pump, electric motor, or coating machine wears out). Note however, that the long run response is quite substantial relative to the short run response. It is also worth noting that estimates of the price elasticity of gasoline demand, an energy commodity for which annual consumer (residential) expenditures are roughly the same as electricity and which are also capital dependent (vehicle specific) are -.3 and -1.0 in the short run and long run respectively (Dahl, 1986; Dahl and Sterner, 1991).[4] The estimates of the price elasticity of demand for electricity are comparable to those for gasoline, though possibly slightly higher in the long run.

Table 1 is less clear as to whether the price elasticity of demand varies across customer classes. Residential consumers are apparently more sensitive to prices in the short run relative to commercial and industrial users. If electricity is a small proportion (say 1 percent or less) of the cost of production for most commercial and industrial users, this result is plausible. However, it appears that commercial users may be most sensitive to price in the long run.

Staff estimated the price elasticity of demand in its energy demand forecasting model by utility service area for ER 94.[5] In general, these estimates are below -.3, and in some cases (depending on year and customer class) are below -.1. These estimates are probably best interpreted as short run price elasticities. In addition, they are consistent with the hypothesis that commercial users are the most sensitive to changes in electricity price of the three customer classes. Additional Staff analysis in progress could shed more light on California-specific estimates of demand price elasticity. Though these estimates are within the range of data in **Table 1**, it is also possible that consumers in California are much less sensitive to changes in electricity prices, compared to the U.S. in general. This conjecture is plausible, given modest space

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Autoregressive Model," *Resource and Energy Economics*, v. 16, p. 255-263, 1994.

3 In economic analysis, the short run and long run are distinguished by different responses. For our purposes here, the short run could be defined as a period of time in which consumer response is limited to more or less use of space conditioning (changing the thermostat setting), or more or less use of lighting, with existing equipment. The long run period is of sufficient time that consumers can consider more efficient space conditioning equipment, variable speed motors and fans, and more efficient coating processes. For the market as a whole, the short run could be a year or less, and the long run up to five or ten years (not everyone will replace capital when price rises).

4 Dahl, Carol,"Gasoline Demand Survey,", *The Energy Journal*, v. 7, no. 1, p. 67-82, 1986; Dahl, Carol and Thomas Sterner,"Analysing Gasoline Demand Elastiticities: A Survey," *Energy Economics*, v. 13, p. 203-210, 1991.

5 California Energy Demand: 1993-2013, Volume III: The PG&E Service Area Forms, p. 6-2; Volume IV: The SMUD Service Area Forms, p. 6-2.

conditioning loads relative to the rest of the U.S. and the implementation of several programs to improve the efficiency of use by all three customer groups in California.

CHANGES IN DEMAND ELASTICITIES DUE TO RESTRUCTURING

As restructuring proceeds, more and more customers will purchase unbundled services. These will include differentiated products such as different levels of service quality and ancillary services such as load following. The combination of direct access, unbundled services, new rate structures, greater availability of time-of-use (TOU) rates and new market participants (e.g., new suppliers, new energy service companies, aggregators and marketers) may possibly have an impact on the price elasticity of demand or supply. Some potential changes to demand and supply elasticities are discussed below. Electricity industry restructuring will affect the price elasticity of demand and supply in other ways that cannot be anticipated with current knowledge.

General principles can provide qualitative guidance as to whether consumers and producers will be more sensitive to a change in price after restructuring occurs. With respect to demand, consumers will be more sensitive to price

- the greater the number of substitutes
- the greater the proportion of the consumer's budget
- the greater the amount of time consumers have to adjust to a change in price.

In the short run, restructuring may not have much effect on consumer behavior, both because consumers have limited short run options for responding to changes in price and also because the market will take some time to implement. If the long run result of restructuring is a competitive market, it is not unreasonable to believe consumers will be well-informed about their consumption choices, most customers will buy electricity and (possibly ancillaries) metered via time of use pricing, energy services companies will provide a full array of conservation options, transmission access will be readily available and transmission constraints will be minimal, and there will be enough suppliers (of energy and energy conservation) that market power will be largely absent.

The regulated market includes some elements of this ideal competitive market. For example, industrial customers whose demand exceeds 500 kW are already on time-of-use metering and some have bargained directly with the utilities for rates more closely aligned with marginal costs of serving them. There already exists a market for surplus power from the Southwest and Pacific Northwest. There is a small and limited market for energy conservation, though it is growing. In part, this means that more widespread implementation of, for example, time-of-use pricing, will have a smaller impact on the price elasticity of demand for electricity than would otherwise be true.

Competing Suppliers

The act of establishing competing suppliers (more substitutes) will increase the price elasticity of demand faced by individual generation companies (so long as transmission is inexpensive and open access prevails), though its effect on the price elasticity for the entire market demand for electricity is unclear. In the long-run, the stimulus of market forces may result in additional substitutes; self-generation is already one option for large industrial customers and distributed generation (if economic) could allow that option for other end-users.

Bilateral Contracting

The behavior of buyers relying on bilateral contracts is likely to differ from consumers purchasing power from Western Power Exchange (WEPEX). Intuition suggests that buyers in bilateral contracts are probably more sensitive to price, otherwise, bilateral contract buyers would not be willing to incur the cost of negotiating (and enforcing) a contract. There are other potential motivations for a bilateral contract. For example, some buyers may be attracted to bilateral contracts if contracting reduces price risk (or reduces exposure to price volatility). Contracting may also be attractive to buyers who demand a certain level of power quality (higher or lower than that delivered from the Independent System Operator), or other attributes of electricity consumption, that can be more easily contracted for outside purchases from the ISO. These other factors aside, increased bilateral contracting will increase the price elasticity of demand. It is not clear how much electricity will be sold via contracts and whether that share of the market will grow over time.

Unbundling of Electricity

Unbundling electricity into distinct commodities such as energy, reliability or spinning reserve, quality, such as voltage control delivery to customers, could have some interesting effects with respect to the price elasticity of demand. Consider first the market for reliability and quality. It is likely that fees for these services will be smaller than charges for electricity consumption, and thus a much smaller proportion of consumer expenditures than total electricity is now. [6] Other factors equal, this would suggest relatively price inelastic demand for many ancillary services. In addition, it would not be surprising that there are fewer suppliers of reliability and quality than of electrons or that this segment might be served largely via contracts.

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6 Though ancillary fees may be small for most customers, this will not be true of all customers. For example, some industrial and commercial users may have total costs for some services other than electricity equal to (or even higher) than their electricity costs. Such customers are unlikely to be large purchasers of these goods relative to the market as a whole.

At the same time, unbundling of the "single package" service will increase price elasticity because it will increase the number of substitute goods available to consumers. Unbundling will provide consumers with numerous options regarding, for example, voltage control, reliability, energy efficiency services, power management, and billing and metering options. As the number of products customers can choose and as the number of substitutes for those products increase, consumers will be more sensitive to price. However, they will also be purchasing goods not currently available. Thus, unbundling may have conflicting effects on the price elasticity of demand for electricity.

Time of Use Rates

Time-of-use (TOU) rates, where the kilowatt hour charge depends on whether the customer's load is at 3 am or 3 pm, permit prices to be aligned more closely with the marginal cost of supplying electricity. Increased use of TOU rates will allow customers to more closely match the benefits they receive from their service with the cost of that service. This increased use will also increase the efficiency of the generation system. Unlike other capacity constrained industries, such as airlines and phone companies, electricity prices usually do not vary by the time of day for other than large customers. After deregulation of the airline, trucking and railroad industries, all three have been able to improve operating efficiency. This improved use of scarce capital reduced costs and prices to customers. It is impossible to guess how much of an improvement in efficiency in generation and distribution will occur as a result of increased use of TOU rates (nor will all of the efficiency accrue to in-state generators).

Though several utilities have conducted experiments with TOU rates, they have not been implemented on a widespread basis. For example, approximately 3.7 percent of PG&E's residential customers are billed via TOU rates. There have been both technological and economic barriers to widespread TOU rates for residential customers. For the three investor-owned utilities, there are approximately 8.3 million residential customers statewide and residences account for roughly one third of electricity demand. Time of use pricing requires metering capable of recording consumption at peak and off-peak times. Transaction costs for new metering capability are high due to device costs, maintenance costs and meter reading costs. For widespread residential use of TOU pricing to occur, new technologies in the telecommunication and computer industries may need to reduce the transaction cost of this type of pricing.

In California, TOU rates are required for all large electricity customers, specifically, those customers with demand over 500 kilowatts. For example, data from PG&E's 1995 FERC Form No. 1 shows there were, on average during the year, 1,066 customers purchasing power from rate schedule E-20 (service above 999 kW). The Energy Commission database on the 300 largest electricity customers indicates these customers consumed 21,310 GWh in 1992 (slightly more than 13 percent of all electricity sold). Thus, it is reasonable to conclude that a considerable portion of the electricity sold to large customers in California is already priced via TOU rates.

Increased use of TOU rates could increase the overall demand elasticity. TOU rates increase the number of substitutes and options available to consumers. Consumers will face higher peak rates (summer afternoons), relative to current rates, and lower off-peak rates (winter mornings). Consumers will be more sensitive to peak period prices than they are to current rates (i.e., one could think of peak demand as being for a different good), though this is exactly when preferences for electricity use are highest. Consumers may be able to substitute air conditioning during high cost periods vs. low cost periods. There may be some prospects for additional technological developments similar to variable speed motors and fans in HVAC applications. Programmable microchips are inexpensive and it would not be surprising, for example, to see appliance manufacturers produce heating and cooling equipment or refrigerators or electric water heaters that can be cycled at certain times of the day, or possibly integrated house management systems (currently available but not in widespread use). Similar technology could be applied in commercial use and manufacturing, though such applications may be limited.

Satisfaction Works and Bright Line Energy Survey Analysis

A 1996 survey by Satisfaction Works and Bright Line Energy (SW-BLE), "The Market for Electric Energy in California," provides additional information on customer characteristics. The survey results, which covered 1,300 large California customers, are summarized below. As with any survey, the results should be interpreted with care; the more precise and well-defined the questions are, the more likely the answers are to be a reflection of customers' actual behavior.

This survey shows that 50 percent of the commercial and 56 percent of the industrial customers surveyed are likely to look for new suppliers when direct access is available. However, of the 24 criteria used to evaluate the performance of their electricity supplier, competitive price was ranked 18th by commercial customers and 21st by industrial customers. Customers ranked reliability and customer service related criteria among the top three.

Though electricity price appears to be ranked low, the largest differences between customers' expectations and their perceptions of utility performance are in the areas of price and supplier responsiveness to reducing the customer's energy costs. Forty-five percent of industrial and 49 percent of commercial customers would choose another supplier for a price reduction of 10 percent or less. However, when customers most likely to choose another supplier were offered lower prices or enhanced service, such as guaranteed long term availability of power, backup power capabilities, stable prices, better power quality or custom energy management services to reduce costs, over half preferred enhanced services.

Two plausible interpretations of these results in the context of the price elasticity of demand are sensible. First, it seems clear that commercial and industrial consumers will be highly sensitive to changes in price among competing suppliers. As the earlier discussion pointed out, implications for the demand faced by competing suppliers has little, if any, implications for the price elasticity of market demand, as opposed to the demand curve faced by individual suppliers. Second, customers care, in some cases a great deal, about attributes of electricity consumption other than price.

Restructuring Experience in Other Countries

Studies of other countries that have deregulated electricity provide information on demand elasticity after restructuring.

In Wolfram's (1995) study of market power in the British electricity spot market, she concludes British generators were charging prices higher than their observed marginal costs, but that they had not taken full advantage of the inelastic demand to raise prices to levels predicted by the estimated models.[7] The estimated demand equation yielded price coefficients that indicated demand was almost twice as sensitive to price on winter weekdays. The price coefficients implied price elasticities of approximately -0.1. This indicates that after restructuring in Britain demand was inelastic. These estimates are not comparable to the U.S. data discussed above because Wolfram's data pertains to a daily demand curve.

Lo, McDonald and Le (1990) developed a model for estimating the appropriate time-of-day tariff for managing peak load, in the context of the deregulated UK electricity market.[8] Implicit in their models were elasticities of demand derived from other studies. Their review of previous literature on the UK system concluded that price elasticities of demand were relatively elastic in the long run and relatively price inelastic in the short run, with values ranging from -0.13 to -1.14 for short run and -1.12 to -1.89 for long run. These estimates are similar to the estimates in Bohi's survey, except for the higher estimate of the short run price elasticity.

ELECTRICITY SUPPLY ELASTICITIES

Current Supply Elasticity Estimates

Supply elasticities, per se, do not exist in a regulated retail electricity market. Prices are set beforehand in a regulatory proceeding, and utilities must supply all retail power demanded at the price paid by their franchise customers. Thus, utilities are required to buy or build the power, reliability, ancillary services and transmission necessary to meet retail demand.

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7 Wolfram, Catherine, "Measuring Duopoly Power in the British Electricity Spot Market," presented at Electricity Industry Restructuring: A Research Conference, University of California Energy Institute, March 1996.

8 Lo, K.L., J.R. McDonald and T.Q. Le, "Time-of-day Electricity Pricing Incorporating Elasticity for Load Management Purposes," *Electrical Power and Energy Systems*, v. 13, no. 4, p. 230-239, 1991.

Supply elasticities currently exist in the Western wholesale markets, where utilities and marketers compete to sell their "excess" generation in order to garner contributions to margin for shareholders or for native load customers. Short-term supply does expand as price increases; higher cost thermal units can be turned on or ramped up and generation from further away can pay the transmission charges. In today's market there is a huge band of fossil-fueled generation with very similar costs, so that in the absence of transmission constraints, out-of-state supply of surplus energy is very elastic. Whenever there are transmission constraints, a price increase cannot increase the availability of energy from areas on the other side of the constraint.

A countervailing force in the wholesale market is the role played by hydropower. Availability of very cheap power can swing by a factor of three, depending on which parts of the hydro-producing West are in wet, average or dry conditions. Because the western fossil-based system was built to complement the hydro system, supply elasticities are more volatile and weather-related than might be expected.

Changes in Supply Elasticities Due to Restructuring

Given that FERC open transmission access policies and the creation of an ISO will reduce transmission access constraints, supply elasticities should be higher in the long run. The incentives for operating existing generation will be more market-driven. Also, as a result of emerging direct access, retail customers will be able to participate in the market.

This will not occur overnight. During the transition period, the operation of the competitive transition charge (CTC) may reduce the supply elasticities for power plants that the utilities continue to own. If market prices for energy decrease, the utilities would have less incentive to reduce output at their power plants because they need only cover their variable costs. When the CTC is completed and generators rely on market-based prices or long-term contracts, they will be at risk for the full cost of generation. In the long-term, without guaranteed cost recovery from the CTC or the PBR for the life of a unit, we expect the amount of total generation will shrink. Uncompetitive units will be retired.

Even in a restructured world, some units may not be subject to supply elasticity. Units which are designated as "must-run" will have minimum performance requirements and, as a quid pro quo, cost recovery through a performance-based rate. Even if the market prices fall below operation and maintenance costs, owners of "must-run" generation may have no incentive to reduce output or to cease operating the power plants.

As a result of restructuring, the scope of existing markets would change, and new markets would emerge. Markets will emerge for ancillary services, and the current separate prices for firm and non-firm energy will be replaced. Bilateral contracts, contracts for differences and futures markets will emerge. These will supplement the pool market which includes only day-ahead and hour-ahead deals and the ISO real-time and ancillary services markets. As compared to a pool without these markets, the financial instruments will increase supply elasticities by reducing the investors' risks.

As long as this is a high capital cost industry, we expect generation supply from new resources not to be very elastic compared to other forms of commerce. Long lead times and investors' risk mean that the entry of new generation in response to price increases will be gradual. There will also be public pressures not to let prices rise above current real levels. Only if prices rise substantially above such levels is generation supply expected to be very elastic. If prices do rise, the market response is more complicated than just adding generation. Investments in transmission upgrades or energy efficiency are equally feasible options.[9] Competition among suppliers in retail markets may stimulate new smaller supply options. This should increase the price elasticity of electricity supplies. The extent of such options will depend on the future funding of financing electricity research and development.

Future supply elasticity is dependent on a number of decisions being made about the structure of the new market. For example, in markets with local transmission constraints, supply elasticities will initially be very low. Current plans call for such markets to be largely supplied by power plants subject to "must-run" constraints, thus unable to change their output in response to price changes. Over time, it is hoped that reliability or voltage support services of these power plants will be unbundled from the energy production of these power plants. Ancillary services could be provided in whole or in part by demand-side bidding, by local transmission upgrades, or by building new power plants within areas of transmission constraints. Therefore, the energy production from existing power plants would no longer be "must-run" and would become more responsive to price changes.

Another example comes from ancillary services. Staff's preliminary analysis suggests that PG&E may find that a principal value of its hydro is for spinning reserve rather than for energy sales. The use of hydro for spinning reserve implies a low supply elasticity for spinning reserves. But, hydro is a multi-use resource with many competing demands and PG&E's hydro operations could largely reflect incentives from the planned performance based ratemaking. to be filed at the CPUC this summer.

Research on Elasticities

The University of California Energy Institute (UCEI) is currently doing a market power analysis under contract with the Commission[10] which uses estimates of demand and supply elasticities. UCEI will analyze the fringe firms' supply elasticities in the spot markets under restructuring. The fringe firms are those which have little or no influence on prices and take prices as given, as opposed to dominant firms which may have some influence on price and do not take prices as given. UCEI is considering using a range of market demand elasticities at the end user level. The UCEI contract will use estimates of elasticities of demand for dominant firms to project the extent of market power.

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9 See also Robert Grow's June 18, 1996 ***ER 96 Testimony On Incentives For New Generation*** .

10 Results will be available in November 1996.

CONCLUSION

During the transition to the competitive market, changes in the price elasticity of demand and supply are likely to be small. In the longer term, competition may increase the price elasticity of both demand and supply. Existing estimates of the long run price elasticity of demand already suggest much greater responsiveness to a change in price, in contrast to the short run. Competition is likely to increase substitutes available to consumers. If deregulation in other industries is a good guidepost, competition will create entirely new goods that cannot be imagined now. Few observers of telecommunications could have predicted the availability of call forwarding, caller identification or cellular phones. It seems plausible that restructuring of electricity will have similar effects with respect to demand and supply.

With respect to supply, restructuring will change the scope of existing markets and new markets would emerge. Given that FERC open transmission access and the creation of an ISO will reduce transmission access constraints, supply elasticities should be higher in the long run. The incentives for operating existing generating units will be more market-driven. However, generation supply from new resources would not be very elastic compared with other forms of commerce. Long lead times and investors' risk mean that the entry of new generation in response to price increases will continue to be gradual.

Witness Qualifications
for
BRANDT STEVENS

EDUCATION

Ph.D., Economics, University of California Riverside, 1982
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PROFESSIONAL EXPERIENCE

Dr. Stevens has been employed by the California Energy Commission since 1989. He has been a contributing author to the Fuels Report and the California Transportation Energy Analysis Report. Dr. Stevens is a member of several professional associations. His research has been published in journals such as the *Journal of Environmental Economics and Management*, *Energy Economics* and *Resource and Energy Economics*. In addition, he has been a manuscript reviewer for journals, including a recent manuscript review for *Contemporary Economic Policy*.

Prior to employment at the Energy Commission, Dr. Stevens held a faculty appointment at Illinois State University in Normal, Illinois.

Witness Qualifications
for
LIONEL LERNER

I am currently (since December 1, 1994) an Electric Generation System Program Specialist I. Previously, I developed assumptions and methods for the capacity expansion and demand conformance processes. My major responsibility is analyzing electricity restructuring issues including market power in deregulated portions of the electricity industry. I also analyze Federal legislation affecting these processes, including the National Energy Policy Act (NEPACT). Prior to this, I was the Commission expert on municipal utility need conformance, and did economic impact analyses for technologies. I did socioeconomic analyses for conservation program EIRs, including EIR on load management standards.

Before coming to the Energy Commission, I reviewed the work of district economist at the Department of Water Resources, and was project manager for a statewide input-output model.

I hold a Ph.D. degree in Political Economy from Johns Hopkins University, Baltimore, Maryland, and an M.A. degree in Economics from the University of Chicago.