DIRECT TESTIMONY OF AHMAD FARUQUI

On Behalf of Arizona Public Service Company

Docket No. E-01345A-16-0036

June 1, 2016

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I. <u>INTRODUCTION</u>

Q. PLEASE STATE YOUR NAME, JOB TITLE, BUSINESS ADDRESS AND PARTY FOR WHOM YOU ARE FILING TESTIMONY.

A. My name is Ahmad Faruqui. I am a Principal with The Brattle Group. My business address is 201 Mission Street, Suite 2800, San Francisco, California 94105. I am filing testimony on behalf of Arizona Public Service Company (APS or Company).

Q. PLEASE DESCRIBE YOUR PROFESSIONAL BACKGROUND AND EXPERIENCE.

A. I have 40 years of academic, consulting and research experience as an energy economist. During my career, I have advised 135 clients in the energy industry, including utilities, regulatory commissions, government agencies, transmission system operators, private energy companies, equipment manufacturers, and IT companies. Besides the U.S., my clients have been located in Australia, Canada, Chile, Egypt, Hong Kong, Jamaica, Philippines, Saudi Arabia, South Africa, and Vietnam. I have advised them on a wide range of issues including rate design, load forecasting, demand response, energy efficiency, distributed energy resources, cost-benefit analysis of emerging technologies, integration of retail and wholesale markets, and integrated resource planning. I have testified or appeared before several state, provincial and federal regulatory commissions and legislative bodies. I have been an invited speaker at major energy conferences in Africa, Asia, Australia, Europe, North America and South America. Finally, I have authored, co-authored or co-edited more than 150 articles, books, editorials, papers and reports on various facets of energy economics. More details regarding my professional background and experience are set forth in my Statement of Qualifications, included as Attachment AJF-1DR.

Q. WHAT ARE YOUR RESPONSIBILITIES AS A PRINCIPAL WITH THE BRATTLE GROUP?

A. I lead the firm's practice in helping clients understand and manage the changing needs of energy consumers.

Q. HAVE YOU PREVIOUSLY TESTIFIED BEFORE THE ARIZONA CORPORATION COMMISSION (COMMISSION)?

A. Yes. I testified in the UNS Electric rate case on the 18th of March, 2016. I have also spoken at a technical workshop before the Commission on the 20th of March, 2014. My presentation discussed the impact of changing customer energy use patterns on utilities. The workshop was entitled, "In the Matter of the Commission's Inquiry into Potential Impacts to the Current Model Resulting from Innovation and Technological Developments in Generation and Delivery of Energy."[1]

II. OVERVIEW AND ORGANIZATION OF TESTIMONY

Q. WHAT IS THE PURPOSE OF YOUR DIRECT TESTIMONY IN THIS PROCEEDING?

A. The purpose of my direct testimony is to comment on the merits of APS's proposal to make demand charges a standard rate feature of the residential rate. The scope of my testimony is focused on the structure, advantages, and rationale for three-part rates. I do not address the specific prices that are being proposed or other rate options that have been proposed.

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[1] Docket No. E-00000J-13-0375, Substantive Workshop No. 1(a) Special Open Meeting, March 20, 2014.

Q. PLEASE SUMMARIZE YOUR TESTIMONY.

A. My testimony begins with a discussion of ratemaking principles and the necessity of replacing two-part rates with three-part rates. An overriding principle of electric rate design is that of cost causation, i.e., the structure of rates should follow the structure of costs. For a variety of reasons, the standard residential rate design in the United States has not followed this basic precept. A very large share of utility costs is fixed. Of the remainder, some vary with peak demand and some vary with energy consumption. Yet most of the fixed and demand-driven costs are recovered through volumetric rates (expressed in cents/kWh). It is possible that in response to rising energy prices, some customers might reduce the volume of electricity they consume but not reduce the demand they place on the grid, since they never see a price for demand. Consequently, much of the fixed costs required to meet their demand would go unpaid. The net result is that cost-causers would not pay for all of the costs they create. Those unrecovered costs would be shifted to customers who use more volume, creating inequities and cross subsidies between customers.

The cost shift from lower load factor customers to higher load factor customers is a structural inefficiency that can be ameliorated through a rate design that includes three parts: a fixed charge, a demand charge, and a volumetric charge. With a three-part rate design, customers would more efficiently use the electric grid in a way that would also reduce the cost shift. In addition, demand rates would provide a price signal that would incentivize the introduction of technologies that reduce demand. If policy-makers wish to encourage innovative distributed technologies, demand rates offer an efficient and equitable method of doing so.

Q. HOW IS YOUR TESTIMONY ORGANIZED?

A. My testimony is organized into several sections. Section III reviews the principles of rate design and the advantages of three-part rates. Section IV summarizes APS's rate design proposal and evaluates the proposal in light of the generally accepted ratemaking principles and the opportunities offered by three-part rates. Section V concludes the testimony.

Q. ARE YOU SPONSORING ANY ATTACHMENTS TO YOUR TESTIMONY?

A. Yes, I sponsor the following attachments to my testimony:

- Attachment AJF-1DR: Statement of Qualifications
- Attachment AJF-2DR: Summary of Residential Demand Rates
- Attachment AJF-3DR: Illustrative Example of Cross-Subsidy

III. PRINCIPLES OF RATE DESIGN

Q. PLEASE PROVIDE A HISTORICAL PERSPECTIVE ON THE THEORY OF ELECTRIC RATE DESIGN.

A. The principles that guide electric rate design have evolved over time. Many authorities have contributed to their development, beginning with the legendary British rate engineer John Hopkinson in the late 1800's.[2] Hopkinson introduced demand charges into electricity rates. Subsequently, Henry L. Doherty proposed a three-part tariff, consisting of a fixed service charge, a demand charge and an energy charge.[3] The demand charge was based on the maximum level of demand which occurred during the

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[2] John R. Hopkinson, "On the Cost of Electricity Supply," *Transactions of the Junior Engineering Society*, Vol. 3, No. 1 (1892), pp.1-14

[3] Henry L. Doherty, *Equitable, Uniform and Competitive Rates,* Proceedings of the National Electric Light Association (1900), pp.291-321

billing period. Some versions of the three-part tariff also feature seasonal or time-of-use (TOU) variation corresponding to the variations in the costs of energy supply.[4]

In the decades that followed, a number of British, French and U.S. economists and engineers made further enhancements to the original three-part rate design.[5] In 1961, Professor James C. Bonbright coalesced their thinking in his canon, *Principles of Public Utility Rates*,[6] which was reissued in its second edition in 1988.[7] Some of these ideas were further expanded upon by Professor Alfred Kahn in his treatise, *The Economics of Regulation*.[8]

Q. WHAT ARE THE GENERALLY ACCEPTED RATE DESIGN PRINCIPLES?

A. In the first edition of his text, Bonbright propounded eight principles which were expanded into ten principles in the second edition. These are almost universally cited in rate proceedings throughout the U.S. and are often used as a foundation for designing rates. For ease of exposition, I have grouped these into five core principles:

1. Economic Efficiency. The price of electricity should convey to the customer the cost of producing it, ensuring that resources consumed in the production and delivery of electricity are not wasted. If the price is set equal to the cost of providing a kWh, customers who value the kWh more than the cost of producing it will use the kWh and customers who value the kWh less will not. This will encourage the development and adoption of energy technologies that are capable

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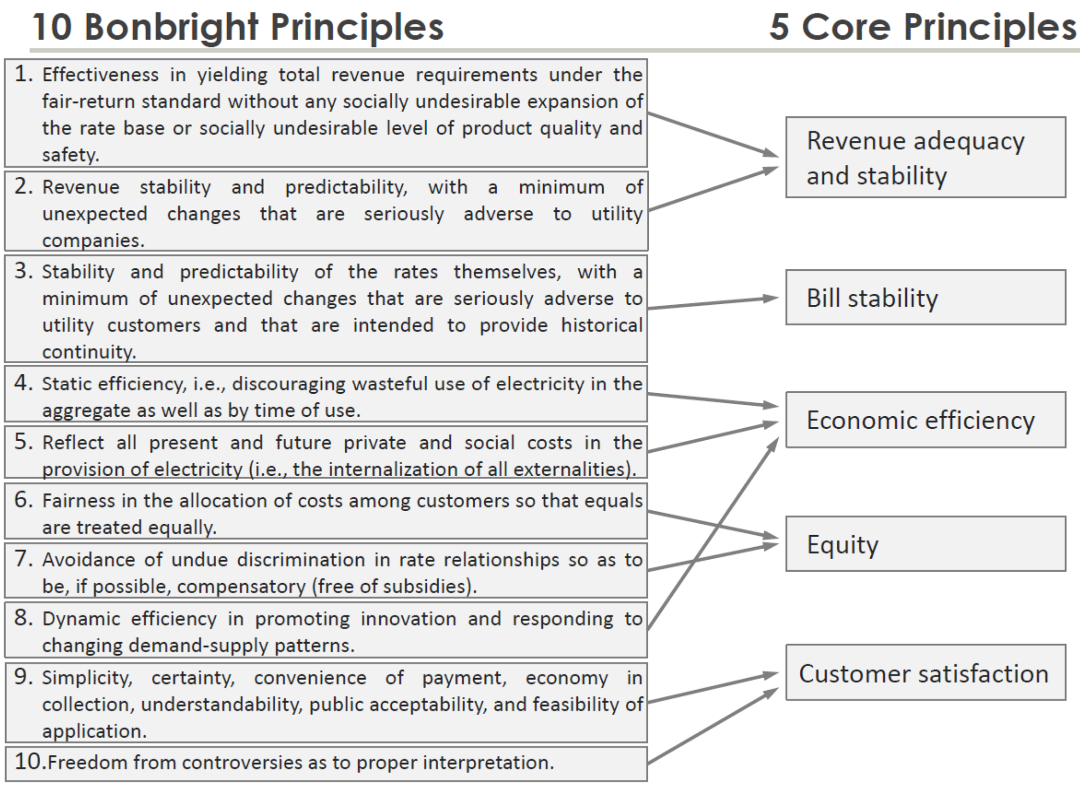
[4] *See*, for example, Michael Veall, "Industrial Electricity Demand and the Hopkinson Rate: An Application of the Extreme Value Distribution," *Bell Journal of Economics*, Vol. 14, Issue No. 2 (1983).
[5] The most notable names include Maurice Allais, Marcel Boiteux, Douglas J. Bolton, Ronald Coase, Jules Dupuit, Harold Hotelling, Henrik Houthakker, W. Arthur Lewis, I. M. D. Little, James Meade, Peter Steiner and Ralph Turvey.
[6] James C. Bonbright, *Principles of Public Utility Rates*, (Columbia University Press: 1961) 1st Edition.
[7] James C. Bonbright, Albert L. Danielsen, and David R. Kamerschen, *Principles of Public Utility Rates,* 2nd ed. (Arlington, VA: Public Utility Reports, 1988).
[8] Alfred Kahn, *The Economics of Regulation: Principles and Institutions*, rev. ed. (MIT Press, June 1988).

of providing the most valuable services to the power grid, and thus the greatest benefit to electric customers as a whole.

2. Equity. There should be no unintentional subsidies between customer types. A classic example of the violation of this principle occurs under flat rate pricing structures (*i.e.*, cents/kWh). Since customers have different load profiles, "peaky" customers, who use more electricity when it is most expensive, are subsidized by less "peaky" customers who overpay for cheaper off-peak electricity. Note that equity is not the same as social justice, which is related to inequities in socioeconomic status rather than cost. The pursuit of one is not necessarily the pursuit of the other, and vice versa.
3. Revenue adequacy and stability. Rates should recover the authorized revenues of the utility and should promote revenue stability. Theoretically, all rate designs can be implemented to be revenue neutral within a class, but this would require perfect foresight of the future. Changing technologies and customer behaviors make load forecasting more difficult and increase the risk of the utility either under-recovering or over-recovering costs when rates are not cost reflective.
4. Bill stability. Customer bills should be stable and predictable while striking a balance with the other ratemaking principles. Rates that are not cost reflective will tend to be less stable over time, since both costs and loads are changing over time. For example, if fixed infrastructure costs are spread over a certain number of kWh's in Year 1, and the number of kWh's halves in Year 2, then the price per kWh in Year 2 will double even though there is no change in the underlying infrastructure cost of the utility.

Customer satisfaction. Rates should enhance customer satisfaction. Because most residential customers devote relatively little time to reading their electric bills, rates need to be relatively simple so that customers can understand them and perhaps respond to the rates by modifying their energy use patterns. Giving customers meaningful cost-reflective rate choices helps enhance customer satisfaction. Figure 1 illustrates my grouping of Bonbright's original ten principles.

Figure 1: Deriving the Five Core Principles of Rate Design



Q. DID PROFESSOR BONBRIGHT DISCUSS THE CONCEPT OF COST CAUSATION IN DESIGNING RATES?

A. Yes. In the first edition, an entire chapter is devoted to this topic. It is entitled: "Cost of Service as the Basic Standard of Reasonableness." In the chapter, he states: "One standard of reasonable rates can fairly be said to outrank all others in the importance attached to it by experts and public opinion alike – the standard of cost of service, often qualified by the stipulation that the relevant cost is necessary cost or cost reasonably or prudently incurred."[9] Later, he states that "The first support for the cost-price standard is concerned with the consumer-rationing function when performed under the principle of consumer sovereignty."[10] He also cites another benefit of the cost-price standard when he says that "an individual with a given income who decides to draw upon the producer, and hence on society, for a supply of public utility services should be made to 'account' for this draft by the surrender of a cost-equivalent opportunity to use his cash income for the purchase of other things."[11] Later in Chapter XVI, where he discusses the "criteria of a sound rate structure," he says that a purely volumetric rate assumes that the total cost of the utility varies directly with the changes in the kWh output of energy. He calls this "a grossly false assumption" and says such a rate "violates the most widely accepted canon of fair pricing, the principle of service at cost." Later, while discussing the Hopkinson rate, he says that such a "rate distinguishes between the two most important cost functions of an electric-utility system: between those costs that vary with changes in the system's output of energy, and those costs that vary with plant capacity and hence with the maximum demands on the system (and subsystems) that the company must be prepared to meet in planning its construction program."[12]

Q. PLEASE DISCUSS FURTHER HOW THE CONCEPT OF COST CAUSATION FLOWS OUT OF THE BONBRIGHT PRINCIPLES.

A. The Bonbright principles of economic efficiency and equity in particular embody the concept of cost causation. Economic efficiency is achieved by having cost-reflective prices. This ensures that products are only consumed by those customers who value them at more than they cost to produce. Pricing below cost is wasteful because

[9] James C. Bonbright, *Principles of Public Utility Rates*, (Columbia University Press: 1961) 1st Edition, Chapter IV, p. 67.
[10] Op. cit., p. 69.
[11] Op. cit., p. 70.
[12] Op. cit., p. 310.

customers will purchase and consume products that they would not choose to consume if faced with the full cost. Similarly, pricing above cost is wasteful because customers who would get a net benefit from consuming the product at its cost of production lose out on that benefit. Respecting the equity principle requires that the tariff's design not result in unintended cross-subsidies between customers. This differs from a public policy that seeks to intentionally subsidize certain customers through the tariff. Prices that are cost reflective minimize unintentional subsidies.

Q. GIVEN BONBRIGHT'S EMPHASIS ON COST CAUSATION, WHY DOES HIS FIFTH PRINCIPLE CALL FOR REFLECTING SOCIAL COSTS (OR EXTERNALITIES) IN ELECTRIC RATES?

A. Each of Professor Bonbright's principles should be read in conjunction with the others. Reading a single principle in isolation from the others ensures that it will be taken out of context, resulting in a misleading use of his rate design philosophy. The cost of service is Professor Bonbright's *basic standard* for designing rates, and it is clear from his writings that above all, rates should be cost-based. This is easily squared with the principle of reflecting social costs in the provision of electricity. If a price has been assigned to a certain externality, in other words, if it has been internalized, and that price is part of the utility's cost structure, then it is economically efficient to reflect the price of that externality in rates for all customers. However, it would violate the core principles of ratemaking if only certain customers or technologies were charged or compensated for their impact on those externalities. For instance, compensating owners of only one specific technology for reductions in emissions would lead to inefficient levels of investment in that technology when there may be other options which, if similarly compensated, would provide even greater environmental benefits. All technologies and customers should be on a level playing field when developing residential rate design.

Q. WHAT IS THE STANDARD RATE STRUCTURE FOR RESIDENTIAL CUSTOMERS?

A. The standard rate structure for residential customers in much of the U.S. consists of two parts, a monthly service charge and a volumetric (kilowatt-hour, or kWh) energy charge. Most of the revenue is collected from the volumetric charge. The monthly service charge does not come close to reflecting the full amount of the fixed costs that are incurred in keeping a customer connected to the grid.

Q. DOES THE COLLECTION OF REVENUES ON A VOLUMETRIC BASIS ALIGN WITH THE ACTUAL NATURE OF UTILITY COSTS?

A. No. The collection of utility revenues through volumetric charges does not comport with the underlying cost structure of providing electricity to customers. Most of the costs do not vary with the volume of electricity that is produced and delivered to the customer, but do vary with peak demand. And some are absolutely fixed, varying neither with energy consumed or peak demand.

It is well known that in order to provide electricity to a customer, a utility must bear – directly or indirectly – costs related to energy, generation, transmission, distribution, metering, and customer service. Generation energy costs vary with kWh electricity consumption. But generation capacity costs do not; they vary with system peak demand. Similarly, transmission costs also vary with system peak demand while distribution and transmission costs vary with maximum demand that is local to the customer and to the neighborhood in which the customer resides. Metering, billing, customer care, and other connection/hookup costs are a fixed cost per each customer of a particular class. Some of these costs vary across time. Generation costs will vary from hour to hour depending on the marginal generation source. Distribution and transmission networks, while used year round, are generally sized to meet class and system peak demand, respectively.

Q. HOW SHOULD THESE COSTS TRANSLATE INTO RATES?

A. According to the notion of cost causation, the rate structure should reflect the nature of the costs. To address the deficiencies of current two-part rates, I support the institution of a three-part rate design, consisting of a fixed monthly service charge, a demand charge, and a volumetric charge. The fixed charge should be designed to cover the fixed costs such as metering, billing, and customer care. Sometimes it also covers the cost of the line drop and the associated transformer. The demand charge should be designed to cover demand-driven costs, such as transmission, distribution, and generation capacity. It is typically applied to the individual customer's maximum demand, either during a defined on-peak period, or regardless of time of occurrence, or based on a combination of the two. While the concept of demand is instantaneous, in implementation demand is usually measured over 15-minute, 30-minute or 60-minute intervals. The energy charge covers the cost of the fuels that are used to generate electricity, as well as power grid operations and maintenance (O&M). The demand charge and the energy charge might vary with the time of use of electricity and have different seasonal and/or peak/off-peak charges. Such three-part rates align the rate design with costs, a fundamental tenet of rate design.

Q. WHAT IS THE CONSEQUENCE OF DEMAND-RELATED COSTS BEING COLLECTED THROUGH VOLUMETRIC RATES?

A. This mismatch between cost structure and rate structure creates an inevitable and indisputable cost shift from customers with lower load factors (i.e., high peak demand relative to total electricity consumption) to customers with higher load factors. Customers might reduce their load factor if, for instance, they install rooftop solar. With a lower load factor, customers paying for electricity under a flat volumetric rate design will reduce their bill without providing a proportionate reduction in system costs.

Inevitably, customers with high (i.e., beneficial) load factors who are paying for electric service under a volumetric rate design wind up paying more for comparable service.

To illustrate this point, I have created a simplified example with "Utility X" to show how two-part rates create cross-subsidies between customer classes. Utility X is authorized to collect $120 million in revenue per year from the 100,000 households in its service area. There are three types of households: low usage households consume 500 kWh/month, standard usage households consume 1,000 kWh/month and high usage households consume 1,500 kWh/month. This is shown in Table 1.

Table 1: Characteristics of Utility X

Input	Value	Units
Revenue Requirement	120,000,000	($/year)
Households	100,000	(households)
<u>Average Usage</u>		
Low-users	500	(kWh/mo)
Standard-users	1,000	(kWh/mo)
High-users	1,500	(kWh/mo)

Utility X collects its revenue requirement from customers with a two-part rate. Under its two-part rate, the utility collects ten percent of its revenue requirement with a fixed charge and ninety percent with a variable energy charge. However, the structure of Utility X's costs differs from its revenues. Fixed costs account for 25 percent of Utility X's total costs, variable energy costs account for 25 percent, and demand-related costs account for 50 percent. Table 2 summarizes this common misalignment of costs and rates.[13]

[13] Low-usage customers' demand is assumed to be 3 kW, standard-usage demand is assumed to be 5 kW, and high-usage demand is assumed to be 7 kW. These illustrative assumptions can be modified in the Microsoft Excel model, which has been provided as Attachment AJF-3DR.

Table 2: Revenue and Cost Structure for Utility X (per Customer)

	Revenue Structure	Cost Structure	Rate	Cost
Fixed	10%	25%	$10 / mo	$75 / mo
Variable	90%	25%	$0.09 / kWh	$0.025 / kWh
Demand	0%	50%	-	$10.00 / kW

Table 3 illustrates how Utility X's two-part rate structure can create a cross-subsidy when households vary in consumptive use. In this example, low-usage customers are subsidized by high-usage customers. Low-usage customers benefit from a cross-subsidy because the revenue from their low monthly usage does not balance with the fixed costs and demand-related costs required to serve them. As a result, the high-usage customers in this example are on the hook for the subsidies to low-usage customers.

Table 3: Illustration of Cross-Subsidization Under a Two-Part Rate

Customer Class	Monthly Usage (kWh)	Demand (kW)	Fixed ($/mo)	Variable ($/mo)	Demand ($/mo)	Monthly Bill ($/mo)	Yearly Bill ($/yr)	Number of Households	Total to Utility ($/yr)
Standard household	**1,000**	**5.00**						**33,333**	
Revenue			10	90	-	100	1,200		40,000,000
Cost			25	25	50	100	1,200		40,000,000
Over (Under) Payment			(15)	65	(50)	-	-		-
Low-usage household	**500**	**3.00**						**33,333**	
Revenue			10	45	-	55	660		22,000,000
Cost			25	13	30	68	810		27,000,000
Over (Under) Payment			(15)	33	(30)	**(13)**	(150)		**(5,000,000)**
High-usage household	**1,500**	**7.00**						**33,333**	
Revenue			10	135	-	145	1,740		58,000,000
Cost			25	38	70	133	1,590		53,000,000
Over (Under) Payment			(15)	98	(70)	**13**	150		**5,000,000**
Total			**(45)**	**195**	**(150)**	**-**	**-**	**100,000**	**120,000,000**

I have provided this illustrative cross-subsidy model as Attachment AJF-3DR, which also includes details on how cross-subsidization can be alleviated by appropriately matching Utility X's rates with its cost of service.

Q. DID PROFESSOR BONBRIGHT SUPPORT THE USE OF THREE-PART RATES?

A. Yes. Professor Bonbright opposed largely volumetric rates since they treat "the total cost of the business as if it varied directly with changes in in the kilowatt-hour output of energy – a grossly false assumption – it violates the most widely accepted canon of fair pricing, the principle of service at cost."[14]

According to his widely cited text, Professor Bonbright believed that three-part rates mirrored the structure of utility costs and cited their widespread deployment to medium and large commercial and industrial rates.[15] In support of three-part rates, Bonbright cites an earlier text by the British engineer D. J. Bolton,[16] who states:

> "More accurate costing has shown that, on the average, only one-quarter of the total costs of electricity supply are represented by coal[17] or items proportional to energy, while three-quarters are represented by fixed costs or items proportional to power, etc. If therefore only one rate is to be levied it would appear more logical to charge for power and neglect the energy, were it not for certain practical difficulties of which the following are two. In the first place the effective power demand on the system made by any particular consumer is extremely difficult to estimate, and is very different from the individual maximum demand metered at the consumer's terminals. Secondly, a purely power tariff would probably lead to a waste of energy to a greater extent than a purely energy tariff leads to waste of power."[18]

Of course, with the arrival of smart meters, customer demand at times of system and distribution peak can be accurately recorded. And the choice is no longer a binary one of imposing either a demand-only rate or an energy-only rate. The time is ripe for

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[14] James C. Bonbright, Albert L. Danielsen and David R. Kamerschen, Principles of Public Utility Rates, Second Edition, Public Utility Reports, Inc., 1988, p. 397.
[15] James C. Bonbright, *Principles of Public Utility Rates*, Columbia University Press, 1961.
[16] Bonbright says that "On many technical issues, no American treatise on electric utility rates can equal that by the distinguished British rate engineer D. J. Bolton." Page 289, n. 3.
[17] Coal was the dominant fuel for generating electricity in the United Kingdom in 1938 when the book was first published.
[18] D. J. Bolton, *Costs and Tariffs in Electricity Supply*, Chapman & Hall Ltd., 1951, p. 59.

deploying a three-part pricing structure that better reflects the cost of providing electric services in the APS service territory.

Interestingly, when Bonbright discusses a two-part rate structure, he is referring to what he characterizes as "the two most important cost functions of an electric-utility system"[19] -- demand and energy charges. When he moves into a discussion of three-part rate structures, he adds truly fixed charges, customer charges, to the two-part rate concept. Beginning on page 346, three-part rates are discussed extensively in the Bonbright canon.[20]

Q. HOW HAS THE PRINCIPLE OF COST CAUSATION AND THREE-PART RATES BEEN APPLIED IN PRACTICE?

A. Many commercial and industrial (C&I) customers across the U.S. are served under three-part rate structures. Indeed, it can be said that those structures have been the norm for these customer classes for decades in much of the U.S.

In Arizona, for instance, other than a couple of small electric cooperatives, all utilities for which I was able to find rate information utilize demand charges for some or all of their C&I customers.[21] In fact, many U.S. utilities offer these rates on a mandatory basis to their large C&I customers and a few, such as PacifiCorp's Utah service territory and Duke Energy's North Carolina service territory, offer them on a mandatory basis to even their smaller C&I customers.

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[19] Bonbright, p. 310.

[20] Bonbright, second edition, page 401, credits Doherty with extending the Hopkinson two-part rate into a three part rate. Henry L. Doherty, "Equitable, Uniform and Competitive Rates," Proceedings of the National Electric Light Association, 1900, pp. 291-321.

[21] The small utilities without demand charges are Columbus Electric Cooperative and Graham County Electric Cooperative. Both utilities sell less than 200,000 MWh of electricity per year.

Q. HAVE THREE-PART RATES BEEN OFFERED TO RESIDENTIAL CUSTOMERS IN OTHER U.S. JURISDICTIONS?

A. Yes. There are at least 20 utilities in 14 states that offer a three-part rate to residential customers, including APS, which has almost 120,000 of its customers on a three-part rate. In most cases, the rates are available to all customers on an opt-in basis. In the case of Salt River Project (SRP), a three-part rate is mandatory for all residential customers who choose to install a new grid-connected DG PV system.[22] All residential customers of Mid-Carolina Electric Cooperative and Butler Rural Electric Cooperative also face a mandatory demand charge.

Q. WHAT HAS PREVENTED THREE-PART RATES FROM BEING MORE BROADLY DEPLOYED TO RESIDENTIAL CUSTOMERS?

A. Until recently, metering technology for residential customers has been a significant technological hurdle. The traditional electromechanical meters that were installed in most homes only measured the customer's cumulative electricity consumption and not the customer's demand. Without the ability to meter demand, utilities could not cost-effectively offer three-part rates to these customers. Advances in metering technology have changed this situation.

Q. HOW HAVE ADVANCES IN METERING TECHNOLOGY CHANGED THE UTILITY'S ABILITY TO OFFER THREE-PART RATES?

A. With the deployment of automated meters (sometimes also referred to as advanced metering infrastructure, or AMI), consumption can be recorded in intervals of an hour or less. This allows the utility to collect the consumption data necessary to incorporate demand charges into rates. It has removed a large barrier to the wider dissemination of

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[22] SRP website: http://www.srpnet.com/prices/home/customergenerated.aspx.

cost-reflective rates to residential customers. Given these technological developments, rate structures for residential customers should be changed.

Q. SHOULD UTILITIES OFFER THREE-PART RATES TO RESIDENTIAL CUSTOMERS?

A. Yes. The timing is propitious for making cost-reflective three-part rates the standard offering for all residential customers. These rates will recover costs from customers in an equitable manner by more accurately charging customers for their use of the power grid. A more cost-reflective rate will also encourage the adoption of emerging energy technologies and changes in energy consumption behavior that will lead to more efficient use of power grid infrastructure and resources.

Q. HOW WOULD A THREE-PART RATE ENCOURAGE THE ADOPTION OF EMERGING ENERGY TECHNOLOGIES?

A. By providing customers with a price signal that includes a component for demand, a three-part rate would encourage the adoption of technologies that are designed to smooth out a customer's load profile. Behind-the-meter battery storage, for example, could be used to release electricity during hours of high electricity demand and store electricity during hours of low electricity demand. Load control technologies, such as programmable communicating thermostats, demand limiters, and digital controls built into smart appliances, could also help customers manage their electricity demand. If a customer took service under a three-part rate, the use of battery storage, or other demand-reducing technologies, would reduce the customer's bill. This reduction in the customer's bill is an economic value that forms the basis of the price signal created by three-part rates.

In the same vein, introducing a demand charge and reducing the volumetric charge would decrease the economic attractiveness of energy technologies that cannot provide energy savings during those peak hours when the energy reductions are most valuable to the system. This simply means that the three-part rate structure is encouraging adoption of those technologies that are most beneficial to the power grid and to customers. It is important to take this broader view of energy technologies to avoid overstating the importance of one particular option that may not be the most beneficial.

Q. ASIDE FROM TRANSMITTING PRICE SIGNALS THAT ENCOURAGE TECHNOLOGICAL INNOVATION, WOULD THREE-PART RATES PROVIDE OTHER BENEFITS TO RESIDENTIAL CUSTOMERS?

A. Three-part rates will incentivize customers to smooth their energy consumption profile – and therefore reduce their electricity bills - even if they are not equipped with enabling technologies. There is a widespread misperception that customers do not respond to changing electricity prices. This is contradicted by empirical evidence derived from more than 40 pilots and full-scale rate deployments involving over 200 innovative rate offerings over roughly the past dozen years. The pilots have found that customers can and do respond to new price signals by changing their energy consumption pattern.[23]

Further, there is evidence that customers respond not just to changes in the rate structure generally, but specifically to demand charges. The following studies arrived at this conclusion after careful empirical analysis:

- Caves, D., Christensen, L., Herriges, J., 1984. "Modeling alternative residential peak-load electricity rate structures." *J. Econometrics*. Vol 24, Issue 3, 249-268.

[23] Some of these studies are summarized in Ahmad Faruqui and Sanem Sergici, "Arcturus: International Evidence on Dynamic Pricing," *The Electricity Journal*, (August/September 2013). Similar results were obtained from an earlier generation of 14 pricing pilots that were funded in the late seventies and early eighties by the U.S. Federal Energy Administration (later part of the Department of Energy). *See* Ahmad Faruqui and Bob Malko, "The Residential Demand for Electricity by Time-of-Use: A Survey of Twelve Experiments with Peak Load Pricing," *Energy*, Vol. 8, No. 10, (1983).

- Stokke, A., Doorman, G., Ericson, T., 2009, January. "An Analysis of a Demand Charge Electricity Grid Tariff in the Residential Sector," Discussion Paper 574, Statistics Norway Research Department.
- Taylor, Thomas N., 1982. "Time-of-Day Pricing with a Demand Charge: Three-Year Results for a Summer Peak." Award Papers in Public Utility Economics and Regulation. Institute of Public Utilities, Michigan State University, East Lansing, Michigan.
- Taylor, T., Schwartz, P., 1986, April. "A residential demand charge: evidence from the Duke Power time-of-day pricing experiment." *Energy Journal*. (2), 135–151.

Q. IS THERE ANY SPECIFIC EVIDENCE THAT APS CUSTOMERS WILL RESPOND TO DEMAND CHARGES?

A. Yes. As described in APS witness Miessner's direct testimony in this proceeding, 60 percent of a sample of APS's customers on a three-part rate reduced their demand after switching to the three-part rate, with those who actively manage their demand achieving demand savings of 9 percent to 20 percent or more.

IV. <u>APS'S RATE PROPOSAL</u>

Q. WHAT IS THE DESIGN OF APS'S CURRENT RATES FOR RESIDENTIAL CUSTOMERS?

A. APS currently offers five rate options to residential customers, one of which includes a demand charge.[24] The rate options are described briefly as follows:

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[24] APS also has a frozen residential rate option that is a three-part rate with a demand charge and an on-peak TOU period of 9:00 a.m. to 9:00 p.m. However, this rate is not open to new enrollment. APS offers some pilot rates with limited enrollment as well.

- Standard Rate: Two-part rate with a four-tiered inclining block volumetric charge in the summer and a flat volumetric charge in the winter.
- Time Advantage (7 p.m. to noon): Two-part rate with a two-period TOU volumetric charge with prices that vary seasonally.
- Combined Advantage (7 p.m. to noon): Three-part rate with a demand charge and a two-period TOU volumetric charge. Prices in the TOU charge and the demand charge vary seasonally. The demand charge is based on maximum demand during the billing cycle as measured only during the peak period.
- Time Advantage Super Peak (7 p.m. to noon): Two-part rate with a three-period TOU volumetric charge with prices that vary seasonally. The super peak period is constrained to a three-hour window (3 p.m. to 6 p.m.) during a subset of summer months (June, July, and August).
- Critical Peak Pricing: This is a rider that can be combined with the Standard Rate described above. Customers experience a higher price during a five-hour period (2 p.m. to 7 p.m.) on between six and 18 days of the year. In return, customers receive a significant rate discount during all other hours for the months of June through September.

Q. HAVE YOU REVIEWED HOW APS IS PROPOSING TO REDESIGN ITS RESIDENTIAL RATES?

A. Yes. APS is proposing several changes to its residential rate offerings. Most notably, it is proposing to make demand charges the standard feature of all rates offered to residential customers, with the exception of a subset of small usage customers who will have the option to choose a rate that does not include a demand charge. The peak period will be redefined to start at 3 p.m. and end at 8 p.m. for each of the offerings.

Q. WHAT IS YOUR VIEW OF THE EXPERIENCE THAT APS HAS HAD WITH RESIDENTIAL DEMAND CHARGES UP TO THIS POINT?

A. APS has the most highly subscribed residential three-part rate in the U.S., with almost 120,000 customers on its Combined Advantage tariff. This represents more than 10 percent of its residential customer base and over 20 percent of its residential energy sales. When new rate designs are introduced on a voluntary basis, they rarely achieve enrollment levels in excess of 10 percent.[25] Considering that APS has been offering its three-part rate on a voluntary basis among several other rate options, and considering that enrollment in the three-part rate has grown significantly over the past several years, this is a very strong indication that APS's customers are interested in and prepared for rates with demand charges.

Q. DO YOU AGREE WITH APS'S PROPOSAL TO MAKE DEMAND CHARGES A STANDARD RATE FOR RESIDENTIAL CUSTOMERS?

A. Yes. For the reasons I discussed previously in this testimony, the introduction of a cost-based demand charge is a significant and necessary improvement over two-part rate offerings. About 120,000 APS customers have shown a preference for receiving their electric service on a three-part rate. There is no reason why a demand charge cannot be included in the standard rate for residential customers.

Q. HOW DOES APS'S PROPOSED DEMAND CHARGE COMPARE TO THAT OF OTHER RESIDENTIAL THREE-PART RATE OFFERINGS?

A. The residential rate offerings of other U.S. utilities provide precedent for each of the elements in APS's proposed demand charge. For instance, APS is proposing to measure

[25] For information on residential demand response program participation, *see* FERC reports on advanced metering and demand response: http://www.ferc.gov/industries/electric/indus-act/demand-response/dem-res-adv-metering.asp.

average demand over a 60-minute interval. Five of the residential three-part rates offered by U.S. utilities measure demand over a 60-minute interval. Table 4 below summarizes each element of APS's proposal and identifies the number of residential demand rate offerings in the U.S that include this element. Further information about all of the residential demand charge offerings in the U.S. that I have identified is provided in Attachment AJF-2DR.

Table 4: Features of APS's Proposed Three-Part Rate Offering

Features of APS's Proposed Three-Part Rate Offering	Number of Rates Offered by Other U.S. Utilities that Share this Characteristic
Seasonal variation in demand charge	12
Includes time-varying energy charge	7
Demand measured during peak period	6
60-minute demand measurement interval	5
Universal demand charge	4

Note: The features listed for APS are elements of at least one of its proposed three-part rate offerings.

Q. ARE APS'S PROPOSED THREE-PART RATES CONSISTENT WITH THE RATEMAKING PRINCIPLE OF EQUITY AND FAIRNESS?

A. Yes. Each customer imposes costs on the system, some of which are fixed and the rest of which are demand-driven and energy-driven. Under purely volumetric tariffs, customers with high demand, but low monthly consumption, would not be paying their fair share of the cost of maintaining, upgrading, and expanding the utility's generation, transmission and distribution system. Instead, lower-demand customers would be covering the deficit and paying more than their fair share. Each of APS's proposed three-part rates more closely match demand, fixed, and variable costs with demand, fixed, and variable charges and will reduce this inequity so that all customers will pay their fair share of the costs associated with the generation of electricity, its delivery through utility's transmission and distribution system, and customer service.

Q. ARE APS'S PROPOSED THREE-PART RATES CONSISTENT WITH THE RATEMAKING PRINCIPLE OF ECONOMIC EFFICIENCY?

A. Yes. As I discussed previously, the cost-based price signals in the three-part rates proposed by APS provide customers with the financial incentive to make investments in technologies or otherwise change their behavior in ways that are most beneficial to the system. Technologies and behaviors that reduce a customer's demand should ultimately lead to a more efficient use of the grid, reduced costs, and lower bills.

A careful reading of the text by Bonbright suggests that, when he discusses efficiency, he means economic efficiency in the broad sense of the term and not just energy efficiency. The attainment of economic efficiency requires that resources are used in the least wasteful way possible. If a product is being consumed by someone who values that product at less than it costs to produce, then that consumption is wasteful and society would be better off on aggregate redeploying those resources elsewhere. In a decentralized market economy, prices are used to guide efficient resource use. Thus if a good is priced correctly, consumers who value it at less than its cost will not purchase it and an efficient outcome is achieved. In discussions about electricity consumption, the conversation often focuses on just one dimension of economic efficiency – energy conservation, which entails reducing the amount of electricity consumed. However there are other dimensions, where electricity consumption may be very inefficient, such as in demand. If capacity is essentially given away for free, then customers, who may place a very low value on capacity, will consume it, even if its cost to society (ultimately them and other customers) is very high.

Q. ARE APS'S PROPOSED THREE-PART RATES CONSISTENT WITH THE RATEMAKING PRINCIPLE OF CUSTOMER SATISFACTION?

A. Yes. APS is proposing to offer a diverse portfolio of rate options to residential customers. Having a meaningful choice of cost-based pricing products is a benefit to customers.

Q. ARE APS'S PROPOSED THREE-PART RATES CONSISTENT WITH THE RATEMAKING PRINCIPLE OF BILL STABILITY?

A. For the residential class as a whole, there will be no change in electric bills. That would also be true for customers whose load profile is similar to that of the class average. Customers whose load factors are higher than the class average will experience lower bills. Customers whose load factor is worse than the class average, because they have been subsidized for years by the customers whose load factor was higher than the class average, will experience higher bills, since the change in rates will remove that subsidy. However, they will have an opportunity to lower their bills by reducing their demand. And that would also be true for customers who are automatically seeing lower bills. They will have an opportunity to further lower their bills by reducing their demand.

Q. ARE APS'S PROPOSED THREE-PART RATES CONSISTENT WITH THE RATEMAKING PRINCIPLE OF REVENUE ADEQUACY AND STABILITY?

A. Yes. The introduction of a three-part rate will not change the utility's revenues. A properly designed three-part rate will be revenue neutral for the class as a whole and therefore collect the same revenue as the otherwise applicable two-part rates. The main reason for moving to three-part rates is the ability to more accurately recover costs from those customers who are imposing costs on the system, and to provide customers with an incentive to consume electricity in a more efficient manner.

While Professor Bonbright says that rates should be stable and predictable, he does not say that rate structures should remain frozen in time. In the U.S., there is an ineluctable movement towards cost-reflective rates brought about by the rollout of AMI and by the increased availability and customer adoption of a wide range of digital end-use technologies such as smart appliances, smart thermostats, home energy management systems, battery storage systems, electric vehicles and rooftop solar panels. APS's three-part rate proposal is designed to provide stability in this new environment.

V. CONCLUSION

Q. WHAT ARE YOUR CONCLUSIONS ABOUT APS'S THREE-PART RATE DESIGN PROPOSALS?

A. APS has put forward a cost-based three-part rate proposal that is consistent with the Bonbright principles. I support the Company's plan to make this the standard rate for all its residential customers (with an exception for small consumers of electricity). The two-part rate which is presently employed by APS, and throughout the industry, is inefficient, inequitable and unsustainable. It must give way to three-part rates. Not only are two-part rates ineffective at providing the proper pricing signals, they do not facilitate the integration of distributed energy resources with the grid, nor do they stimulate the deployment of other innovative technologies such as customer-situated battery storage and plug-in electric vehicles. In addition, they only provide customers at most two ways of reducing their bills, by reducing or shifting energy consumption. With three-part rates, customers would have up to three ways in which to lower their bills: by reducing demand, by reducing energy consumption, or by moving consumption or demand or both from peak to off-peak periods.

Q. DOES THIS CONCLUDE YOUR TESTIMONY?

A. Yes, it does.

BEFORE THE ARIZONA CORPORATION COMMISSION

Arizona Public Service Company

Docket No. E-01345A-16-0036

PREPARED DIRECT TESTIMONY OF

AHMAD FARUQUI

Attachment AJF-1DR: Statement of Qualifications

Dr. Ahmad Faruqui is an economist with 40 years of academic, consulting and research experience in the efficient use of energy. He has assisted clients in the conceptualization, design, analysis, and evaluation of a wide range of programs related to advanced metering infrastructure, conservation voltage reduction, combined heat and power, demand charges, distributed energy resources, dynamic pricing, demand response, energy efficiency and newly emerging technologies, such as plug-in electric vehicles, rooftop solar, and distributed generation. He has provided regulatory support and testimony in proceedings related to these issues in 34 states, the District of Columbia and Canada.

Two of Dr. Faruqui's dynamic experiments have won professional awards, and he was named one of the world's Top 100 experts on the smart grid by Greentech Media.

He has consulted with more than 135 energy organizations around the globe and testified or appeared before a dozen state and provincial commissions and legislative bodies in the United States and Canada. He has also advised the Alberta Utilities Commission, the Edison Electric Institute, the Electric Power Research Institute, FERC, the Institute for Electric Efficiency, the Ontario Energy Board, the Saudi Electricity and Co-Generation Regulatory Authority, and the World Bank. His research on the energy behavior of consumers has been cited in Business Week, The Economist, Forbes, National Geographic, The New York Times, Fortune, the San Francisco Chronicle, the San Jose Mercury News, the Wall Street Journal, The Times (London) and USA Today. He has appeared on Fox Business News, National Public Radio and Voice of America.

Dr. Faruqui is the author, co-author or co-editor of four books and more than 150 articles, papers, and reports on efficient energy use. He has published in peer-reviewed journals such as Energy Economics, Energy Journal, Energy Efficiency, and the Journal of Regulatory Economics and trade journals such as The Electricity Journal and the Public Utilities Fortnightly. He has taught economics at San Jose State University, the University of California at Davis and the University of Karachi. He holds a an M.A. in agricultural economics and a Ph. D. in economics from The University of California at Davis, where he was a Regents Fellow, and B.A. and M.A. degrees in economics from The University of Karachi, where he was awarded the Rashid Minhas Gold Medal in economics and the Government of Pakistan Overseas Scholarship.

AREAS OF EXPERTISE

- *Innovative pricing.* He has identified, designed and analyzed the efficiency and equity benefits of introducing innovative pricing designs such as three-part rates, including fixed monthly charges, demand charges and time-varying energy charges; dynamic pricing rates, including critical peak pricing, variable peak pricing and real-time pricing; time-of-use pricing; and inclining block rates.
- *Rate design.* He has helped design forward-looking programs and services that exploit recent advances in rate design and digital technologies in order to lower customer bills and improve utility earnings while lowering the carbon footprint and preserving system reliability.
- *Cost-benefit analysis of advanced metering infrastructure*. He has assessed the feasibility of introducing smart meters and other devices, such as programmable communicating thermostats that promote demand response, into the energy marketplace, in addition to new appliances, buildings, and industrial processes that improve energy efficiency.
- *Demand forecasting and weather normalization.* He has pioneered the use of a wide variety of models for forecasting product demand in the near-, medium-, and long-term, using econometric, time series, and engineering methods. These models have been used to bid into energy procurement auctions, plan capacity additions, design customer-side programs, and weather normalize sales.
- *Customer choice*. He has developed methods for surveying customers in order to elicit their preferences for alternative energy products and alternative energy suppliers. These methods have been used to predict the market size of these products and to estimate the market share of specific suppliers.
- *Hedging, risk management, and market design*. He has helped design a wide range of financial products that help customers and utilities cope with the unique opportunities and challenges posed by a competitive market for electricity. He conducted a widely-cited market simulation to show that real-time pricing of electricity could have saved Californians millions of dollars during the Energy Crisis by lowering peak demands and prices in the wholesale market.
- *Competitive business strategy*. He has helped clients develop and implement competitive marketing strategies by drawing on his knowledge of the energy needs

of end-use customers, their values and decision-making practices, and their competitive options. He has helped companies reshape and transform their marketing organization and reposition themselves for a competitive marketplace. He has also helped government-owned entities in the developing world prepare for privatization by benchmarking their planning, retailing, and distribution processes against industry best practices, and suggesting improvements by specifying quantitative metrics and follow-up procedures.

- *Design and evaluation of marketing programs.* He has helped generate ideas for new products and services, identified successful design characteristics through customer surveys and focus groups, and test marketed new concepts through pilots and experiments.
- *Expert witness.* He has testified or appeared before state commissions in Arizona, Arkansas, California, Colorado, Connecticut, Delaware, the District of Columbia, Illinois, Indiana, Iowa, Kansas, Michigan, Maryland, Minnesota, Nevada, New Mexico, Ohio, Oklahoma, Ontario (Canada), Pennsylvania and Texas. He has assisted clients in submitting testimony in Georgia. He has presented to the California Energy Commission, the California Senate, the Congressional Office of Technology Assessment, the Kentucky Commission, the Minnesota Department of Commerce, the Minnesota Senate, the Missouri Public Service Commission, and the Electricity Pricing Collaborative in the state of Washington. In addition, he has led a variety of professional seminars and workshops on public utility economics around the world and taught economics at the university level.

EXPERIENCE

Innovative Pricing

- **Report examining the costs and benefits of dynamic pricing in the Australian energy market.** For the Australian Energy Market Commission (AEMC), developed a report that reviews the various forms of dynamic pricing, such as time-of-use pricing, critical peak pricing, peak time rebates, and real time pricing, for a variety of performance metrics including economic efficiency, equity, bill risk, revenue risk, and risk to vulnerable customers. It also discusses ways in which dynamic pricing can be rolled out in Australia to raise load factors and lower average energy costs for all consumers without harming vulnerable consumers, such as those with low incomes or medical conditions requiring the use of electricity.

- **Whitepaper on emerging issues in innovative pricing.** For the Regulatory Assistance Project (RAP), developed a whitepaper on emerging issues and best practices in innovative rate design and deployment. The paper includes an overview of AMI-enabled electricity pricing options, recommendations for designing the rates and conducting experimental pilots, an overview of recent pilots, full-deployment case studies, and a blueprint for rolling out innovative rate designs. The paper's audience is international regulators in regions that are exploring the potential benefits of smart metering and innovative pricing.
- **Assessing the full benefits of real-time pricing.** For two large Midwestern utilities, assessed and, where possible, quantified the potential benefits of the existing residential real-time pricing (RTP) rate offering. The analysis included not only "conventional" benefits such as avoided resource costs, but under the direction of the state regulator was expanded to include harder-to-quantify benefits such as improvements to national security and customer service.
- **Pricing and Technology Pilot Design and Impact Evaluation for Connecticut Light & Power (CL&P).** Designed the Plan-It Wise Energy pilot for all classes of customers and subsequently evaluated the Plan-It Wise Energy program (PWEP) in the summer of 2009. PWEP tested the impacts of CPP, PTR, and time of use (TOU) rates on the consumption behaviors of residential and small commercial and industrial customers.
- **Dynamic Pricing Pilot Design and Impact Evaluation: Baltimore Gas & Electric.** Designed and evaluated the Smart Energy Pricing (SEP) pilot, which ran for four years from 2008 to 2011. The pilot tested a variety of rate designs including critical peak pricing and peak time rebates on residential customer consumption patterns. In addition, the pilot tested the impacts of smart thermostats and the Energy Orb.
- **Impact Evaluation of a Residential Dynamic Pricing Experiment: Consumers Energy (Michigan).** Designed the pilot and carried out an impact evaluation with the purpose of measuring the impact of critical peak pricing (CPP) and peak time rebates (PTR) on residential customer consumption patterns. The pilot also

tested the influence of switches that remotely adjust the duty cycle of central air conditioners.

- **Impact Simulation of Ameren Illinois Utilities' Power Smart Pricing Program.** Simulated the potential demand response of residential customers enrolled to real- time prices. Results of this simulation were presented to the Midwest ISO's Supply Adequacy Working Group (SAWG) to explore alternative ways of introducing price responsive demand in the region.
- **The Case for Dynamic Pricing: Demand Response Research Center.** Led a project involving the California Public Utilities Commission, the California Energy Commission, the state's three investor-owned utilities, and other stakeholders in the rate design process. Identified key issues and barriers associated with the development of time-based rates. Revisited the fundamental objectives of rate design, including efficiency and equity, with a special emphasis on meeting the state's strongly-articulated needs for demand response and energy efficiency. Developed a score-card for evaluating competing rate designs and applied it to a set of illustrative rates that were created for four customer classes using actual utility data. The work was reviewed by a national peer-review panel.
- **Developed a Customer Price Response Model: Consolidated Edison**. Specified, estimated, tested, and validated a large-scale model that analyzes the response of some 2,000 large commercial customers to rising steam prices. The model includes a module for analyzing conservation behavior, another module for forecasting fuel switching behavior, and a module for forecasting sales and peak demand
- **Design and Impact Evaluation of the Statewide Pricing Pilot: Three California Utilities.** Working with a consortium of California's three investor-owned utilities to design a statewide pricing pilot to test the efficacy of dynamic pricing options for mass-market customers. The pilot was designed using scientific principles of experimental design and measured changes in usage induced by dynamic pricing for over 2,500 residential and small commercial and industrial customers. The impact evaluation was carried out using state-of-the-art econometric models. Information from the pilot was used by all three utilities in their business cases for advanced metering infrastructure (AMI). The project was

conducted through a public process involving the state's two regulatory commissions, the power agency, and several other parties.

- **Economics of Dynamic Pricing: Two California Utilities.** Reviewed a wide range of dynamic pricing options for mass-market customers. Conducted an initial cost-effectiveness analysis and updated the analysis with new estimates of avoided costs and results from a survey of customers that yielded estimates of likely participation rates.
- **Economics of Time-of-Use Pricing: A Pacific Northwest Utility.** This utility ran the nation's largest time-of-use pricing pilot program. Assessed the cost-effectiveness of alternative pricing options from a variety of different perspectives. Options included a standard three-part time-of-use rate and a quasi-real time variant where the prices vary by day. Worked with the client in developing a regulatory strategy. Worked later with a collaborative to analyze the program's economics under a variety of scenarios of the market environment.
- **Economics of Dynamic Pricing Options for Mass Market Customers – Client: A Multi-State Utility.** Identified a variety of pricing options suited to meet the needs of mass-market customers, and assessed their cost-effectiveness. Options included standard three-part time-of-use rates, critical peak pricing, and extreme-day pricing. Developed plans for implementing a pilot program to obtain primary data on customer acceptance and load shifting potential. Worked with the client in developing a regulatory strategy.
- **Real-Time Pricing in California – Client: California Energy Commission.** Surveyed the national experience with real-time pricing of electricity, directed at large power customers. Identified lessons learned and reviewed the reasons why California was unable to implement real-time pricing. Catalogued the barriers to implementing real-time pricing in California, and developed a program of research for mitigating the impacts of these barriers.
- **Market-Based Pricing of Electricity – Client: A Large Southern Utility.** Reviewed pricing methodologies in a variety of competitive industries including airlines, beverages, and automobiles. Recommended a path that could be used to transition from a regulated utility environment to an open market environment featuring customer choice in both wholesale and retail markets. Held a series of seminars for senior management and their staffs on the new methodologies.

- **Tools for Electricity Pricing – Client: Consortium of Several U.S. and Foreign Utilities.** Developed Product Mix, a software package that uses modern finance theory and econometrics to establish a profit-maximizing menu of pricing products. The products range from the traditional fixed-price product to time-of-use prices to hourly real-time prices, and also include products that can hedge customers' risks based on financial derivatives. Outputs include market share, gross revenues, and profits by product and provider. The calculations are performed using probabilistic simulation, and results are provided as means and standard deviations. Additional results include delta and gamma parameters that can be used for corporate risk management. The software relies on a database of customer load response to various pricing options called StatsBank. This database was created by metering the hourly loads of about one thousand commercial and industrial customers in the United States and the United Kingdom.

- **Risk-Based Pricing – Client: Midwestern Utility.** Developed and tested new pricing products for this utility that allowed it to offer risk management services to its customers. One of the products dealt with weather risk; another one dealt with risk that real-time prices might peak on a day when the customer does not find it economically viable to cut back operations.

Demand Response

- **National Action Plan for Demand Response: Federal Energy Regulatory Commission.** Led a consulting team developing a national action plan for demand response (DR). The national action plan outlined the steps that need to be taken in order to maximize the amount of cost-effective DR that can be implemented. The final document was filed with U.S. Congress in June 2010.

- **National Assessment of Demand Response Potential: Federal Energy Regulatory Commission.** Led a team of consultants to assess the economic and achievable potential for demand response programs on a state-by-state basis. The assessment was filed with the U.S. Congress in 2009, as required by the Energy Independence and Security Act of 2007.

- **Evaluation of the Demand Response Benefits of Advanced Metering Infrastructure: Mid-Atlantic Utility.** Conducted a comprehensive assessment of the benefits of advanced metering infrastructure (AMI) by developing dynamic pricing rates that are enabled by AMI. The analysis focused on customers in the residential class and commercial and industrial customers under 600 kW load.

- **Estimation of Demand Response Impacts: Major California Utility.** Worked with the staff of this electric utility in designing dynamic pricing options for residential and small commercial and industrial customers. These options were designed to promote demand response during critical peak days. The analysis supported the utility's advanced metering infrastructure (AMI) filing with the California Public Utilities Commission. Subsequently, the commission unanimously approved a $1.7 billion plan for rolling out nine million electric and gas meters based in part on this project work.

Smart Grid Strategy

- **Development of a smart grid investment roadmap for Vietnamese utilities.** For the five Vietnamese power corporations, developed a roadmap to guide future smart grid investment decisions. The report identified and described the various smart grid investment options, established objectives for smart grid deployment, presented a multi-phase approach to deploying the smart grid, and provided preliminary recommendations regarding the best investment opportunities. Also presented relevant case studies and an assessment of the current state of the Vietnamese power grid. The project involved in-country meetings as well as a stakeholder workshop that was conducted by Brattle staff.
- **Cost-Benefit Analysis of the Smart Grid: Rocky Mountain Utility.** Reviewed the leading studies on the economics of the smart grid and used the findings to assess the likely cost-effectiveness of deploying the smart grid in one geographical location.
- **Modeling benefits of smart grid deployment strategies.** Developed a model for assessing benefits of smart grid deployment strategies over a long-term (e.g., 20-year) forecast horizon. The model, called iGrid, is used to evaluate seven distinct smart grid programs and technologies (e.g., dynamic pricing, energy storage, PHEVs) against seven key metrics of value (e.g., avoided resource costs, improved reliability).
- **Smart grid strategy in Canada.** The Alberta Utilities Commission (AUC) was charged with responding to a Smart Grid Inquiry issued by the provincial

government. Advised the AUC on the smart grid, and what impacts it might have in Alberta.

- **Smart grid deployment analysis for collaborative of utilities.** Adapted the iGrid modeling tool to meet the needs of a collaborative of utilities in the southern U.S. In addition to quantifying the benefits of smart grid programs and technologies (e.g., advanced metering infrastructure deployment and direct load control), the model was used to estimate the costs of installing and implementing each of the smart grid programs and technologies.
- **Development of a smart grid cost-benefit analysis framework.** For the Electric Power Research Institute (EPRI) and the U.S. DOE, contributed to the development of an approach for assessing the costs and benefits of the DOE's smart grid demonstration programs.
- **Analysis of the benefits of increased access to energy consumption information.** For a large technology firm, assessed market opportunities for providing customers with increased access to real time information regarding their energy consumption patterns. The analysis includes an assessment of deployments of information display technologies and analysis of the potential benefits that are created by deploying these technologies.
- **Developing a plan for integrated smart grid systems.** For a large California utility, helped to develop applications for funding for a project to demonstrate how an integrated smart grid system (including customer-facing technologies) would operate and provide benefits.

Demand Forecasting

- **Comprehensive Review of Load Forecasting Methodology: PJM Interconnection.** Conducted a comprehensive review of models for forecasting peak demand and re-estimated new models to validate recommendations. Individual models were developed for 18 transmission zones as well as a model for the RTO system.
- **Analyzed Downward Trend: Western Utility.** We conducted a strategic review of why sales had been lower than forecast in a year when economic activity had been brisk. We developed a forecasting model for identifying what had caused the drop in sales and its results were used in an executive presentation to the

utility's board of directors. We also developed a time series model for more accurately forecasting sales in the near term and this model is now being used for revenue forecasting and budgetary planning.

- **Analyzed Why Models are Under-Forecasting: Southwestern Utility.** Reviewed the entire suite of load forecasting models, including models for forecasting aggregate system peak demand, electricity consumption per customer by sector and the number of customers by sector. We ran a variety of forecasting experiments to assess both the ex-ante and ex-post accuracy of the models and made several recommendations to senior management.
- **U.S. Demand Forecast: Edison Electric Institute.** For the U.S. as a whole, we developed a base case forecast and several alternative case forecasts of electric energy consumption by end use and sector. We subsequently developed forecasts that were based on EPRI's system of end-use forecasting models. The project was done in close coordination with several utilities and some of the results were published in book form.
- **Developed Models for Forecasting Hourly Loads: Merchant Generation and Trading Company.** Using primary data on customer loads, weather conditions, and economic activity, developed models for forecasting hourly loads for residential, commercial, and industrial customers for three utilities in a Midwestern state. The information was used to develop bids into an auction for supplying basic generation services.
- **Gas Demand Forecasting System – Client: A Leading Gas Marketing and Trading Company, Texas.** Developed a system for gas nominations for a leading gas marketing company that operated in 23 local distribution company service areas. The system made week-ahead and month-ahead forecasts using advanced forecasting methods. Its objective was to improve the marketing company's profitability by minimizing penalties associated with forecasting errors.

Demand Side Management

- **The Economics of Biofuels.** For a western utility that is facing stringent renewable portfolio standards and that is heavily dependent on imported fossil fuels, carried out a systematic assessment of the technical and economic ability of biofuels to replace fossil fuels.

- **Assessment of Demand-Side Management and Rate Design Options: Large Middle Eastern Electric Utility.** Prepared an assessment of demand-side management and rate design options for the four operating areas and six market segments. Quantified the potential gains in economic efficiency that would result from such options and identified high priority programs for pilot testing and implementation. Held workshops and seminars for senior management, managers, and staff to explain the methodology, data, results, and policy implications.
- **Likely Future Impact of Demand-Side Programs on Carbon Emissions – Client: The Keystone Center.** As part of the Keystone Dialogue on Climate Change, developed scenarios of future demand-side program impacts, and assessed the impact of these programs on carbon emissions. The analysis was carried out at the national level for the U.S. economy, and involved a bottom-up approach involving many different types of programs including dynamic pricing, energy efficiency, and traditional load management.
- **Sustaining Energy Efficiency Services in a Restructured Market – Client: Southern California Edison.** Helped in the development of a regulatory strategy for implementing energy efficiency strategies in a restructured marketplace. Identified the various players that are likely to operate in a competitive market, such as third-party energy service companies (ESCOS) and utility affiliates. Assessed their objectives, strengths, and weaknesses and recommended a strategy for the client's adoption. This strategy allowed the client to participate in the new market place, contribute to public policy objectives, and not lose market share to new entrants. This strategy has been embraced by a coalition of several organizations involved in the California PUC's working group on public purpose programs.
- **Organizational Assessments of Capability for Energy Efficiency – Client: U.S. Agency for International Development, Cairo, Egypt.** Conducted in-depth interviews with senior executives of several energy organizations, including utilities, government agencies, and ministries to determine their goals and capabilities for implementing programs to improve energy end-use efficiency in Egypt. The interviews probed the likely future role of these organizations in a privatized energy market, and were designed to help develop U.S. AID's future funding agenda.

- **Enhancing Profitability Through Energy Efficiency Services – Client: Jamaica Public Service Company.** Developed a plan for enhancing utility profitability by providing financial incentives to the client utility, and presented it for review and discussion to the utility's senior management and Jamaica's new Office of Utility Regulation. Developed regulatory procedures and legislative language to support the implementation of the plan. Conducted training sessions for the staff of the utility and the regulatory body.

Advanced Technology Assessment

- **Competitive Energy and Environmental Technologies – Clients: Consortium of clients, led by Southern California Edison, Included the Los Angeles Department of Water and Power and the California Energy Commission**. Developed a new approach to segmenting the market for electrotechnologies, relying on factors such as type of industry, type of process and end use application, and size of product. Developed a user-friendly system for assessing the competitiveness of a wide range of electric and gas-fired technologies in more than 100 four-digit SIC code manufacturing industries and 20 commercial businesses. The system includes a database on more than 200 end-use technologies, and a model of customer decision making.
- **Market Infrastructure of Energy Efficient Technologies – Client: EPRI.** Reviewed the market infrastructure of five key end-use technologies, and identified ways in which the infrastructure could be improved to increase the penetration of these technologies. Data was obtained through telephone interviews with equipment manufacturers, engineering firms, contractors, and end-use customers.

TESTIMONY

Arizona

Testimony before the Arizona Corporation Commission on behalf of Arizona Public Service Company, in the matter of the Application for UNS Electric, Inc. for the Establishment of Just and Reasonable Rates and Charges Designed to Realize a Reasonable Rate of Return on the Fair Value of the Properties of UNS Electric, Inc. Devoted to the its Operations Throughout the State of Arizona, and for Related Approvals, Docket No. E-04204A-15-0142, December 9, 2015.

California

Rebuttal Testimony before the Public Utilities Commission of the State of California, Pacific Gas and Electric Company Joint Utilities on Demand Elasticity and Conservation Impacts of Investor-Owned Utility Proposals, in the Matter of Rulemaking 12-06-013, October 17, 2014.

Testimony before the Public Utilities Commission of the State of California on behalf of Pacific Gas and Electric Company on rate relief, Docket No. A.10-03-014, summer 2010.

Testimony before the Public Utilities Commission of the State of California, on behalf of Southern California Edison, Edison SmartConnect™ Deployment Funding and Cost Recovery, exhibit SCE-4, July 31, 2007.

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Delaware

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Kansas

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Ohio

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Texas

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BEFORE THE ARIZONA CORPORATION COMMISSION

Arizona Public Service Company

Docket No. E-01345A-16-0036

PREPARED DIRECT TESTIMONY OF

AHMAD FARUQUI

Attachment AJF-2DR: Summary of Residential Three-Part Tariffs

Summary of Residential Three-Part Tariffs

#	Utility	Utility Ownership	State	Residential Customers Served	Fixed charge ($/month)	Demand Charge ($/kW-month) Summer	Demand Charge ($/kW-month) Winter	Timing of demand measurement	Demand interval	Combined with Energy TOU?	Applicable Residential Customer Segment	Mandatory or Voluntary
[1]	Alabama Power	Investor Owned	AL	1,241,998	14.50	1.50	1.50	Any time	15 min	Yes	All	Voluntary
[2]	Alaska Electric Light and Power	Investor Owned	AK	13,968	11.49	6.72	11.11	Any time	Unknown	No	All	Voluntary
[3]	Arizona Public Service	Investor Owned	AZ	1,019,292	16.96	13.50	9.30	Peak Coincident	60 min	Yes	All	Voluntary
[4]	Black Hills Power	Investor Owned	SD	54,617	13.00	8.10	8.10	Any time	15 min	No	All	Voluntary
[5]	Black Hills Power	Investor Owned	WY	2,153	15.50	8.25	8.25	Any time	15 min	No	All	Voluntary
[6]	Butler Rural Electric Cooperative	Cooperative	KS	7,000	25.00	5.00	5.00	Any time	60 min	No	All	Mandatory
[7]	City of Fort Collins Utilities	Municipal	CO	60,464	5.37	2.50	2.50	Any time	Unknown	No	All	Voluntary
[8]	City of Kinston	Municipal	NC	9,776	14.95	9.35	9.35	Peak Coincident	15 min	No	All	Voluntary
[9]	City of Longmont	Municipal	CO	34,697	15.40	5.75	5.75	Any time	15 min	No	All	Voluntary
[10]	Dakota Electric Association	Cooperative	MN	94,924	12.00	14.70	11.10	Any time	15 min	No	All	Voluntary
[11]	Dominion	Investor Owned	NC	101,158	16.39	8.25	4.83	Peak Coincident	30 min	Yes	All	Voluntary
[12]	Dominion	Investor Owned	VA	2,105,500	12.00	5.68	3.95	Peak Coincident	30 min	Yes	All	Voluntary
[13]	Duke Energy Carolinas, LLC	Investor Owned	NC	1,608,151	13.38	7.77	3.88	Peak Coincident	30 min	Yes	All	Voluntary
[14]	Duke Energy Carolinas, LLC	Investor Owned	SC	460,178	9.93	8.15	4.00	Peak Coincident	30 min	Yes	All	Voluntary
[15]	Fort Morgan	Municipal	CO	5,273	6.13	10.22	10.22	Unknown	Unknown	No	All	Voluntary
[16]	Georgia Power	Investor Owned	GA	2,072,622	10.00	6.64	6.64	Any time	30 min	Yes	All	Voluntary
[17]	Mid-Carolina Electric Cooperative	Cooperative	SC	55,000	24.00	12.00	12.00	Any time	60 min	No	All	Mandatory
[18]	Midwest Energy Inc	Cooperative	KS	29,951	22.00	6.40	6.40	Any time	15 min	No	All	Voluntary
[19]	Otter Tail Power Company	Investor Owned	MN	47,699	16.00	6.08	5.11	Any time	60 min	No	All	Voluntary
[20]	Otter Tail Power Company	Investor Owned	ND	44,910	18.38	6.52	2.63	Any time	60 min	No	All	Voluntary
[21]	Otter Tail Power Company	Investor Owned	SD	8,648	13.00	7.05	5.93	Any time	60 min	No	All	Voluntary
[22]	Salt River Project	Political Subdivision	AZ	891,668	32.44 or 45.44	9.59 to 34.19	3.41 to 9.37	Peak Coincident	30 min	Yes	DG only	Mandatory
[23]	Swanton Village Electric Department	Municipal	VT	3,208	26.57	6.77	6.77	Any time	Unknown	No	All	Mandatory
[24]	Westar Energy	Investor Owned	KS	700,000	16.50	6.78	2.09	Any time	30 min	No	All	Voluntary
[25]	Xcel Energy (PSCo)	Investor Owned	CO	1,182,093	12.25	8.57	6.59	Any time	15 min	No	All	Voluntary

Sources: Utility tariffs as of April 2016, and "Form EIA-861 2013 data files, EIA_861_Retail_Sales_2013.xls" (for Utility ownership and Residential Customers Served columns).

Notes:

Peak periods are applicable from Monday through Friday excluding holidays. For some utilities, the monthly fixed charge has been calculated by multiplying a daily charge by 30.5.

[2]: Mandatory if customer consumes more than 5,000 kWh per month for three consecutive months or has a recorded peak demand of 20 KW for three consecutive months.

[3]: The monthly fixed charge is a daily basic service charge multiplied by 30.5 days.

[4]-[5]: Black Hills also offers an optional time-of-use rate that includes both energy and demand charges for customers owning demand controllers.

[12]: Demand charge is the sum of the distribution demand charge and the generation demand charge. The distribution demand charge is $1.612/kW and the generation demand charge is $4.070/kW for the summer and $2.334/kW for the winter.

[15]: The timing of demand measurement and the demand interval are not explicitly identified in the publicly available information we have reviewed.

[18]: The demand charge is based on the greater of the highest average 15 minute kW demand measured during the period for which the bill is rendered, and 80% of the average 15 minute maximum demand for the last three summer months.

[19]-[21]: Demand is measured as the maximum winter demand for the most recent 12 months. New customers have an assumed demand of 3 kW for their first year. Fixed charge for MN is customer charge per month plus facilities charge per month. Fixed charge for ND and SD is just customer charge per month.

[22]: Customers below 200 amps pay a fixed charge of $32.55 per month and customers above 200 amps pay $45.44 per month. Demand charges vary across three seasons: Winter, Summer (May, June, September, and October), and On-Peak Summer (July and August). The summer demand charges shown here apply for the On-Peak Summer period. The (on-peak) summer demand charge is $9.59 for up to 3kW of demand, 17.82 for the next 7kW, and 34.19 for over 10kW. The winter demand charge is $3.41 for up to 3kW, 5.46 for the next 7kW, and $9.37 over 10kW. The utility is experimentally offering the rate plan to a limited number of non-DG customers.

[23]: The demand charge is based on the greater of the measured demand for the current month and 85% of the highest recorded demand established during the preceding eleven months. The rate is mandatory for all residential customers with monthly consumption equal to or greater than 1,800 kWh, measured on a rolling 12 month average basis.

BEFORE THE ARIZONA CORPORATION COMMISSION

Arizona Public Service Company

Docket No. E-01345A-16-0036

PREPARED DIRECT TESTIMONY OF

AHMAD FARUQUI

Attachment AJF-3DR: Illustrative Example of Cross-Subsidy

The cross-subsidy illustrative model is provided separately in a Microsoft Excel file titled “Cross-Subsidy Model.xls.”