EXH. AF-1T
DOCKETS UE-22___/UG-22___
2022 PSE GENERAL RATE CASE
WITNESS: AHMAD FARUQUI

BEFORE THE
WASHINGTON UTILITIES AND TRANSPORTATION COMMISSION

WASHINGTON UTILITIES AND TRANSPORTATION COMMISSION, Complainant, v. PUGET SOUND ENERGY, Respondent.	Docket UE-22____ Docket UG-22____

PREFILED DIRECT TESTIMONY (NONCONFIDENTIAL) OF

AHMAD FARUQUI

ON BEHALF OF PUGET SOUND ENERGY

JANUARY 31, 2022

PUGET SOUND ENERGY

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I. INTRODUCTION

Q. Please state your name, business address, and position with Puget Sound Energy.

A. My name is Ahmad Faruqui. My business address is 415 Mission Street, Suite 5010, San Francisco, CA, 94105. I am a Principal with The Brattle Group, a consulting firm.

Q. Have you prepared an exhibit describing your education, relevant employment experience, and other professional qualifications?

A. Yes. An exhibit describing my education and relevant employment experience is provided as Exh. AF-2.

Q. Please summarize the purpose of this prefiled direct testimony.

A. I will describe the objectives of a time-varying rates pilot that Puget Sound Energy ("PSE" or "Company") is proposing to carry out over a two-year period beginning in 2023. I will describe the time-of-use ("TOU") rates that will be tested in the pilot. I will describe the consultative process that was used in developing the TOU rates and benchmark the rates against best industry practices. I will then describe the pilot design and benchmark it against best industry practices. Finally, I will describe the Evaluation, Measurement and Verification ("EM&V") process that will be used to evaluate the TOU rates and also benchmark them against best industry practices.

Q. What role did you play in designing the PSE time-varying rates pilot?

A. My team and I assisted PSE in all stages of pilot development, from identifying and developing the rates to designing the pilot and scoping out the EM&V plan. My colleague Dr. Sanem Sergici and I have worked very closely with the PSE team during this time period, and formally engaged with a group of stakeholders through three collaborative meetings organized by PSE.

Q. What is the objective of PSE's time-varying rates pilot?

A. Time-varying rates are designed to lower system costs by providing customers a price signal that encourages them to lower their monthly energy bills by reducing consumption during the peak period and building it in the off-peak period. Well designed and marketed time-varying rates represent a win-win opportunity for the utility and its customers. Additionally, they can help reduce carbon emissions. PSE's pilot is designed to put this hypothesis to the test by placing representative groups of customers on various time-varying rates. The pilot will address the issues of equity and accessibility and help determine the extent to which time-varying rates promote the integration of variable renewable energy resources into the grid.

Q. What time-varying rates will be tested in the pilot?

A. The pilot will test TOU rates, peak-time rebates that are offered in conjunction with TOU rates, and TOU rates focused on customers who drive electric vehicles ("EV"). Separate treatment cells will be included in the pilot for four customer segments: 1) non-low income residential customers, 2) low income customers, 3) all residential customers, and 4) small business customers, as shown in Figure 1 below.

Figure 1: Proposed Treatment Groups in the pilot

Rate	Non-Low-Income Residential	Low Income Residential	All Residential	Small Business
TOU	√	√	N/A	N/A
TOU+PTR[1]	√	√	N/A	√
Three-period TOU (EV)	N/A	N/A	√	N/A

Q. What customer classes will be included in the pilot?

A. As noted above, residential and small and medium-sized businesses will be included in the pilot. Low income customers will be offered the same rates as non-low income customers, but they will be offered varying levels of discounts on their total bill. For details, please see the testimony of PSE witness Birud Jhaveri, Exh. BDJ-1T.

[1] Peak Time Rebate ("PTR").

Q. What time-varying rates are being tested in other pilots that you are familiar with?

A. Other pilots test critical-peak pricing rates, variable peak pricing rates, and real-time pricing rates that do not include demand charges. Some pilots have also tested time-varying demand charges. However, most of them test TOU rates of the type being proposed in the PSE pilot.

Q. How do the rates in PSE's pilot compare with those in other pilots?

A. They compare very favorably in several metrics, including (a) the opportunity to save money by having a significant discount during the off-peak period, (b) the duration and placement of the peak period, (c) the inclusion of a three-period rate for customers who drive EVs, and (d) the inclusion of a peak-time rebate, which introduces a dynamic element into the rate design.

II. PSE UNDERTOOK A DATA-DRIVEN APPROACH TO DEVELOP RATE DESIGNS

Q. Please describe your design approach.

A. Our data-driven design approach is based on widely accepted principles of scientific experiments, ensuring that the pilot results would have both internal and external validity. Internal validity means that a cause and effect relationship can be established between the time-varying rates being offered and the load shape and energy conservation impacts being observed. External validity means that the results will be generalizable to the population of interest.

In addition, the rates that PSE proposes reflect several design considerations, including cost reflectivity, potential savings in peak demand, customer acceptance, and bill savings.

Q. What are the major steps involved in designing time-varying rates?

A. Designing time-varying rates ("TVR") is an iterative process with at least four major steps. The first is to establish whether seasonal and diurnal patterns exist for energy usage and power prices, and if they do, to determine what the profiles are. The next step is to design the rates for the specific TVRs using historical system and cost data, taking into account the pilot's objectives as well as other important rate design principles. The third step is to determine load impacts of the proposed rates. The final step estimates the bill impacts of the new rates, adjusting as needed. Each of these steps is explained in detail below.

Q. Before you provide more information on the rate design analysis and results, please comment on PSE's pilot development and stakeholder engagement process.

A. PSE designed the TVR pilot in truly collaborative fashion with a group of stakeholders, including Staff of the Washington Utilities and Transportation Commission, the Public Counsel Unit of the Washington Attorney General's Office, the Northwest Energy Coalition, Sierra Club, among many others. Please see Exh. AF-3 for a complete list of stakeholders involved in the collaborative series.

The stakeholder engagement effort took place over several months with three formal touch points in the form of three collaboratives. The first collaborative, which took place in May 2021, provided stakeholders with the project background, objectives, and time-varying rate design options that were under consideration. In addition, the collaborative provided an overview of TVR experience and lessons learned from jurisdictions across the globe. The second collaborative took place in August 2021, focusing on the results of the focus group study that PSE commissioned. For a more detailed discussion of the collaboration process, please see the testimony of PSE witness William T. Einstein, Exh. WTE-1T.

Copies of presentations made at the three collaboratives, including the focus group study results, are provided as Exh. AF-4, Exh. AF-5, and Exh. AF-6. Please note that materials contained in the presentations were used to inform the discussion at the time and have been updated since. Data and information included in this testimony reflect the Company's final proposal. PSE also presented the rate design analysis results and preliminary rate design recommendations. Based on feedback from stakeholders, PSE refined and presented the rate design elements for all treatment groups in the third collaborative in September 2021. During this meeting, PSE also discussed the pilot design approach as well as plans for evaluation, measurement, and verification.

Throughout the development of the pilot, the PSE and Brattle team committed to an open process, inviting and incorporating feedback from stakeholders whenever appropriate. Indeed, multiple stakeholder groups offered valuable comments and feedback that helped improve the pilot design.

Q. What are some important considerations for determining pricing seasons and peak/off-peak windows?

A. The existence of seasonal and diurnal energy usage and power price patterns would indicate that there are opportunities for PSE to manage electricity consumption during peak periods through appropriate price signals. When designing the pricing seasons and the peak/off-peak windows, it is important to capture significant seasonal differences to the noticeable changes in loads and costs exist across the year (to the extent that they exist). The peak window should capture the hours in which the system experiences high load or incurs high marginal costs. Importantly, the peak window should offer a reasonable opportunity for customers to respond to price signals by changing their energy consumption behavior. Customers may not be able to act quickly enough to respond to a peak period that is too short (less than three hours). On the other hand, a peak period that is too long may cause customers unnecessary inconvenience, lowering the likelihood of enrollment, the response rate, and positive customer experience.

Q. How did you define PSE's pricing seasons for this pilot?

A. Peak and off-peak windows and season definitions were determined based on PSE's historic load profiles and marginal energy prices. Specifically, the pilot relies on three sets of data:

1. PSE's historical gross system load in 2018.
2. PSE's historical gross system load in 2019.
3. PSE's projected gross system load in 2025 (from the 2021 Integrated Resource Plan).

Our analysis of PSE's 2018 hourly gross system load data reveals the following patterns:

- The average hourly system load profiles for November through February (weekdays only) exhibit bimodal peak pattern, with a more pronounced evening peak. System load averages are highest in December through February, corresponding to PSE's winter months.
- March, April, and October load profiles also feature bimodal peaks, though the morning peak is more pronounced.
- The shoulder months (May, June, and September) display mostly flat load. System load averages are lowest in these months.
- July and August contain significant evening peaks.

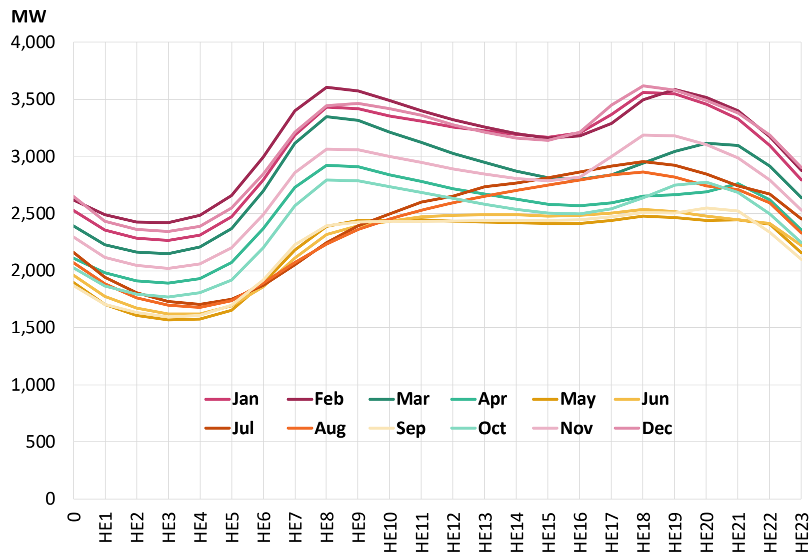
Figure 2 below shows detailed results. Analysis using 2019 data shows the same four patterns.

In addition to historical system load data, the Brattle Group examined future system load profile using forecast data from the 2021 Integrated Resource Plan ("IRP"). PSE does not expect the system load profile to change dramatically in the next several years. In 2025, system load is forecasted to be substantially higher between November and March relative to the rest of the year. Similar to previous years, the highest system peak load is forecasted to take place in the winter. Figure 2 and Figure 3 below show detailed results for PSE's 2018 and 2025 system load profiles.

Finally, we observe that in 2018 and 2019, all top 20 peak load days occurred in the months of December to March.

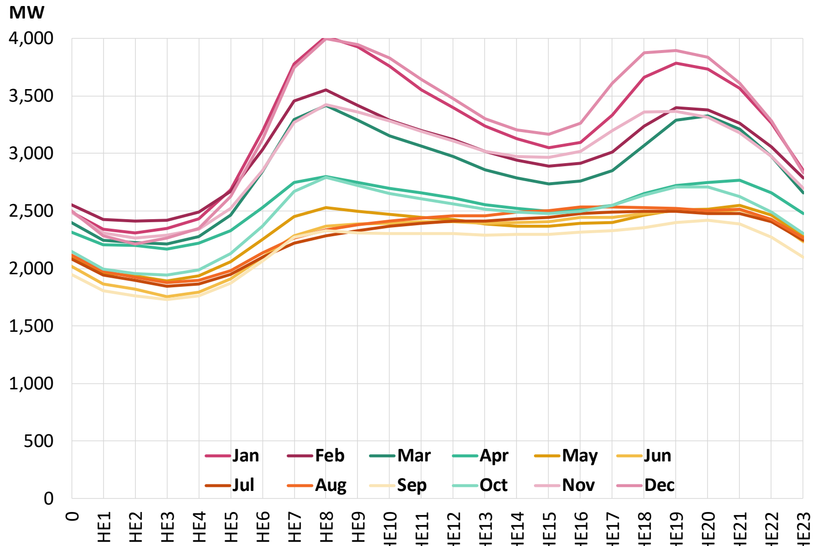
Based on our analysis of both historical and forecast system load, the Company's current definition for winter, which is from October through March, is still valid.[2]

Figure 2: 2018 Weekday-Only System Gross Load Averages



[2] One can make the case for a longer winter (October through April) or a shorter winter definition (November through March). Using PSE's existing definition for winter in this pilot can help avoid confusion and simplifies the implementation process.

Figure 3: Forecasted 2025 Weekday-Only System Gross Load Averages



Q. Did you consider other data sources to validate these results?

A. Yes. Besides gross system load, we also analyzed net system load and system marginal cost data for seasonal patterns. Net load is intended to represent the load to be served after accounting for non-dispatchable generation and market purchases or sales. It is defined as gross load minus the amount of non-dispatchable energy generation, which includes wind, solar, and run-of-river hydropower generation.[3] Net load is an important metric for power system with a high share of variable renewable energy generation, separating the portion of load that is served by must-take, must-sell, and zero short-run marginal cost resources from the remaining load. As such, net load tends to correlate with the system

[3] Here, we also factor in long-term firm sales and purchases, which are contractual obligations that PSE has to meet. Specifically, Net Load = Gross System Load – Non-Dispatchable Generation – Long-Term Purchase + Long-Term Sales

marginal energy costs, and the definition for pricing season and peak window should accordingly reflect net load patterns.

In addition to net load, we also analyzed PSE's marginal cost data. As PSE's power system relies significantly on hydropower resources, we used wholesale power prices at Mid-Columbia trading hub ("Mid-C") as a proxy for system marginal cost.

Q. Please explain your findings from the net load and marginal cost data analyses.

A. Our analysis of net load data confirms the trends that we observed using gross system load data. Net load profiles for November through March feature a pronounced morning peak and evening peak. Forecast hourly generation data for 2025 indicates a starker contrast in net load between these winter months and the rest of the year. Compared to 2018, the former's double peak profiles in 2025 becomes more noticeable, pulling away from the latter.

While gross load and net load data both indicate a flat profile for the summer months, Mid-C power price data shows a peak in the late afternoon. This spike is driven by a handful of high-priced days, which coincided with periods when the Pacific Northwest region experienced extreme weather events such as intense heat waves. See the testimony of PSE witness Kyle C. Stewart, Exh. KCS-1CT, for details about increased regional peak demand during the summer months.

Q. Please describe your approach to determining pricing periods.

A. As described above, one of the primary goals of the pilot is to reduce costs to serve customers by improving capacity utilization, encouraging economic conservation, and peak shaving. The time varying rates will be designed to incentivize customers to reduce peak load and shift usage from high-cost hours to low-cost hours. Therefore, we analyze both system load data and price data to determine the TVR periods. We did this in two steps:

- First, we conducted a cluster analysis on hourly system load (both gross load and net load) and hourly system cost at the monthly and daily levels for both winter and non-winter weekdays.[4]
- Second, we evaluated Mid-C prices to gauge the correlation between high-load hours and high-priced hours.

Q. What are your cluster analysis results?

A. Results from our cluster analysis suggest a daily peak of nine hours in the winter: five hours in the morning (HE7-11) and four hours in the evening (HE18-21) (see Figure 4 below).[5] This is consistent with descriptive statistics results, which show that the peak hours of the top 20 load days tend to occur in the morning (HE8-HE9) and in the evening (HE18-21).

[4] Please see Exh. AF-4 for more information on cluster analysis.
[5] These correspond to 6AM to 11AM and 5PM to 9PM, respectively.

Figure 4: Cluster Analysis Results (Hour Ending)

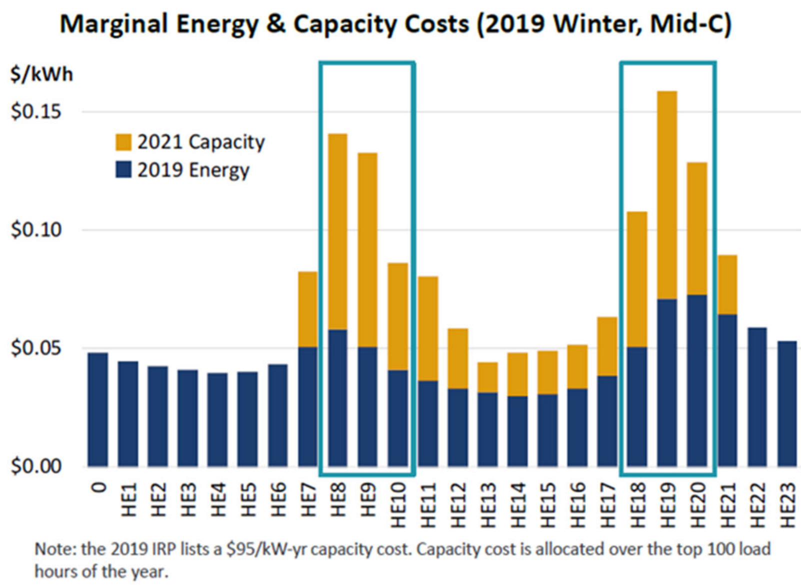
	Gross Load	Net Load	Mid-C
2018			
Winter	7-11, 18-21	7-11, 18-20	8, 18-22
Non-Winter	13-21	12-21	18-21
2019			
Winter	7-11, 18-21	7-11, 18-21	19-20
Non-Winter	14-21	13-21	19-21

While the identified peak window captures the system peak hours, the 9-hour peak may be too long based on our experience with similar pilots in other jurisdictions and can negatively affect customer enrollment and experience. Therefore, we next explored whether the correlation between high-load hours and high-priced hours exists, and whether such correlation may help narrow the peak window.

Q. How did you narrow the peak windows?

A. First, we constructed the Mid-C winter (October-March) and non-winter average hourly prices. These price patterns suggest a narrower peak windows (HE7-9 and HE 19-21 for winter, and HE 19-21 for non-winter). Next, we spread the generation capacity costs as determined in the IRP ($95/kW-year) across the top 100 load hours (which all occurred in the winter months), and overlaid these costs on top of the Mid-C prices. Doing so narrows the winter peak window even further, to HE8-10 and HE18-20 (or 7-10AM and 5-8PM) for the winter months (see Figure 5 below).

Figure 5: Marginal Energy and Capacity Costs (2019 Winter, Mid-C)



Q. Please summarize your findings and recommendations.

A. Our analysis shows that PSE's system experiences the highest gross load in the winter months (October through March), confirming that PSE is a winter-peaking system. In these months, a dual-peak profile is evident across all three metrics: gross load, net load, and Mid-C power prices. System loads in summer and shoulder months are relatively flat (or have slight evening peaks), though in recent years, Mid-C prices exhibit prominent peak spikes in the summer months, coinciding with periods of intense heat waves. Going forward, effects of climate change will become more pronounced in the region, and extreme heat waves may recur with higher frequency. Consequently, year-round TVRs may serve as a tool to help manage system peak loads and peak power prices. See the testimony of

Kyle Stewart, Exh. KCS-1CT, for risks associated with increased summer price volatility.

Results from our cluster analysis indicate that a peak period may last as long as nine hours. Mapping the capacity cost during the top load hours onto Mid-C prices results in a shorter, six-hour peak window for the winter months and a three-hour peak window for the non-winter months. Together, this design adjustment should make the rate more appealing for customers. Figure 6, below, summarizes the proposed definition for pricing season and peak windows for the TVR pilot.

Figure 6: Proposed definition for Pricing season and Peak Windows

Season	Peak Period	Off-peak Period
Winter (October- March)	HE 8-10 and HE 18-20 on weekdays	All other hours, weekends and holidays
Non-Winter (April – September)	HE 18-20 on weekdays	All other hours, weekends and holidays

Q. What design elements did you consider when developing the TVR program that targets customers who own electric vehicles?

A. We kept the following considerations in mind when designing the three-period TOU rate that targets customers with EVs:

- The three-period TOU rate has the same peak periods (7AM-10AM and 5PM-8PM) as other TVR programs instead of the longer window, to make the rate more customer-friendly.
- The super off-peak period (when price is lowest) should occur when the system is least constrained. This translates to a super off-peak period

between 11PM-7AM, every day of the week. The daily super off-peak period allows customers to take advantage of low rates by scheduling automatic charging every night.

- Weekends only involve super off-peak and off-peak windows. Because the rates apply to the whole house, this design offers customer a break on weekends.

Q. How did you calculate the rates for each TVR program?

A. At a high level, we began with PSE's 2021 embedded cost study results for Residential and Small Business classes. The total costs of service for each rate class is made up of four different functions: Generation, Transmission, Distribution, and Customer. Because PSE does not have a marginal cost of service study at this time, we used the marginal costs to assess the marginal generation capacity and energy costs (namely Mid-C power prices), and embedded costs for Transmission and Distribution costs.

For Residential TOU rate, we first calculated the winter and non-winter peak rates to reflect the generation capacity, transmission, distribution, and energy costs. We then allocated the remaining costs (net of revenue from peak hours and revenue from fixed charges) equally across the off-peak periods, solving for the corresponding rates. This method ensures revenue neutrality.

To design the TOU+PTR rate, we first developed the critical peak pricing ("CPP") rate. This is because CPP and PTR are mirror images of each other. We assumed 15 winter peak events and five non-winter peak events per year on the basis that PSE is winter peaking, but prices also spike in the non-winter months, mostly due to extreme weather. We calculated a critical peak rate by allocating generation capacity cost across the event hours.[6] We also applied an adjustment factor by multiplying the generation capacity cost by 70 percent to acknowledge that demand response availability may be less than that of a peaker plant.[7]

After determining this critical peak rate, we calculated the rebate amount that would give the customers same incentive for load shifting. The PTR rate should reflect the customer's opportunity cost for consuming electricity during critical peak events. In other words, the rebate amount should account for the fact that the customer avoids paying by not consuming electricity. For instance, if the electricity price during the critical peak is $1 per kWh, and the retail rate is $0.10 per kWh, the equivalent amount of rebate should be $0.90 per kWh. We adopted this method for TOU+PTR rate schedules both Residential and Small Business customers. Peak and off-peak rates are calculated in the same manner as in the TOU method.

Finally, we designed the three-period TOU rate (targeting customers with EVs) using a method similar to the two-period TOU rate. Like the two-period TOU rate, this rate is also revenue neutral, meaning that it collects the same amount of revenue for the class, before any load shifting.

[6] PSE may call an "event" during periods of supply constraints to induce demand response. Under CPP, the per kWh rate is higher during the event hours. Under PTR, customers earn a rebate for reducing their electricity consumption relative to their baseline.
[7] This amounts to a 30 percent derate, which is a reasonable number for jurisdictions with limited experience with DR programs.

Q. What are the results?

A. Results are shown in Figure 7, below. Strong price signals exist across all four rate designs. For the residential TOU rate, the peak/off-peak price ratio is about 5 to one in winter months, and 2.8 to one for non-winter months. The three-period TOU rate has an even stronger price signal, with a 7.5 to one price ratio for the winter months. The TOU+PTR rates feature similarly strong price signals: about 8.4 to one and 8.9 to one for the residential customers and the small business customers, respectively. For every kWh reduction during peak events relative to their baseline, customers will receive a rebate of about 50 cents.

Figure 7: Proposed rate designs

		Current Residential Rate	Residential TOU	Residential TOU+PTR	Res. Three-Period TOU	Small C&I TOU + PTR
Customer Charge	$/mo	$7.49	$7.49	$7.49	$7.49	$10.39
Current Rate						
<=600 kWh	$/kWh	0.09				
>600 kWh	$/kWh	0.11				
TOU Charges						
Winter						
On-Peak	$/kWh		$0.31	$0.18	$0.30	$0.18
Off-Peak	$/kWh		$0.06	$0.08	$0.08	$0.07
Super Off-Peak	$/kWh		-	-	$0.04	-
Non-Winter						
On-Peak	$/kWh		$0.17	$0.17	$0.14	$0.17
Off-Peak	$/kWh		$0.06	$0.08	$0.06	$0.07
Super Off-Peak	$/kWh		-	-	$0.04	-
Full Year						
Peak Time Rebate	$/kWh		-	$0.48	-	$0.48
On-Peak : Off-Peak Ratios						
Winter			5.2 : 1	2.3 : 1	7.5 : 1.9 : 1	2.4 : 1
Non-Winter			2.8 : 1	2.2 : 1	3.6 : 1.5 : 1	2.3 : 1
PTR:Off-Peak (Winter)			-	8.4 : 1	-	8.9 : 1

Q. How do PSE's proposed TVRs and their design elements compare to those offered elsewhere in the country?

A. The key features of PSE's proposed TVRs are in line with the TVR programs offered across the country, especially with the most recent wave of TVR pilots that incorporated lessons learned from previous experiments and deployments. For instance, of the 303 U.S. utilities that offer TOU rates, the overwhelming majority of them (74 percent) have two periods.[8] Only two rates in the survey have more than three periods. Likewise, a large majority (71 percent) of the TOU rates have a price ratio of at least two to one, the minimum level to induce any meaningful customer behavior changes. Similarly, peak periods tend to last for six or fewer hours. TOU rates with peak periods of twelve hours or longer are legacy TOU programs, which have been offered for many years but have low enrollment rates.

Time-varying rates that target EV customers are relatively newer. Of the 27 TOU rates for EV customers surveyed, we find that the price ratios varied from 1.2:1 to 15:1. The median price ratios for summer and winter rates with three or more periods are 3.7 and 2.5, respectively.[9]

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[8] 2018 EIA Form 861.

[9] *See* http://files.brattle.com/files/14717_the_state_of_residential_ev_electric_rates_10-15-2018.pdf

Q. Given the proposed rate designs, what level of peak impacts are you expecting?

A. The level of peak demand reduction corresponds with the peak to off-peak price ratio: the higher the price ratio, the higher the peak impact.[10] However, the price responsiveness increases at a decreasing rate as the price ratio increases. Using Brattle's Arcturus database and the load impact model, we estimated the average customer response to the new rates. For a residential customer with Residential TOU rate, the peak impact on a winter day can be as high as 10.9 percent. The full results are shown below in Figure 8. It is important to note that the most of the data in the Arcturus database is from summer-peaking utilities as the winter peaking utility experience with TVRs has been more limited. However, most recent evidence from Hydro Quebec, a winter peaking utility, is quite encouraging and consistent with those from summer peaking utilities.

[10] Ahmad Faruqui, Sanem Sergici, and Cody Warner, "Arcturus 2.0: A meta-analysis of time-varying rates for electricity," The Electricity Journal, Volume 30, Issue 10, December 2017, pp. 64-72. https://www.sciencedirect.com/science/article/abs/pii/S1040619017302750.

Figure 8: Expected Peak Reduction Impacts for the Proposed TVR Programs

Rate	Season	Ratio (P:OP)	Estimated Peak Demand Reduction
Residential TOU	Winter	5.2:1	10.9%
	Non-winter	2.8:1	6.8%
Residential TOU+PTR	Winter	2.3:1	5.5%
	Non-Winter	2.2:1	5.2%
	Event day	8.4:1	11.0%
Residential Three-Period TOU (EV)	Winter	7.5:1	12.6%
	Non-winter	3.6:1	11.9%
Small C&I TOU+PTR	Winter	2.4:1	5.8%
	Non-Winter	2.3:1	5.5%
	Event day	8.9:1	11.3%

Q. Did you examine whether the proposed time varying rates will lead to lower bills for customers?

A. Yes. Because the proposed time-varying rates are revenue neutral, the average customer should not experience a change in their bill. Whether and to what extent a given customer saves money by transitioning to one of the new time-varying rates depends on a number of factors. Chiefly among them are the customer's load profile and their willingness to modify electricity usage patterns. If a residential customer uses proportionately less electricity during peak times, moving from PSE's current rate to the proposed TOU rate will lead to bill savings even if the customer does not change their usage patterns. On the other hand, the customer will experience a bill increase if they consume proportionately more electricity during peak hours. Most customers can lower their bills by shifting energy usage away from peak periods.

To evaluate the impact of the proposed rates on residential customer's bills, we calculated the monthly bills under the current inclining block rates, the proposed TVR before price response, and the proposed TVR after price response. Analysis using randomly sampled AMI data for 18,000 residential customers shows that with no demand response (no action taken), 44 percent of customers will pay less after switching to TOU rates (savings of about $6 per month), and 56 percent of customers will pay more (bill increase of $4 per month). As expected, the average monthly bill per customer per month does not change. With price response, 64 percent of customers will experience lower bills. For the sample as a whole, the average monthly bill per customer is about $3 lower.

III. PSE DESIGNED ITS DEPLOYMENT PLAN ACCORDING TO SCIENTIFICALLY VALID METHODS AND INDUSTRY BEST PRACTICES

Q. How did you determine the required sample size for each of the pilot treatments?

A. We undertook statistical power calculations to determine the minimum sample size required for each of the pilot treatments. This is a necessary step in every scientifically valid pilot to verify that sample size is large enough to detect statistically significant impacts. There are several variables that go into these calculations such as the acceptable level of significance, granularity of the data, homogeneity of the customers, and the minimum detectable impact ("MDI") one will need to quantify in the study. As the MDI increases (e.g., expected impact from the pilot is 10 percent versus 5 percent), the required sample size for a statistically significant measurement decreases. See Exh. AF-6 for a more detailed discussion on the sample size determination.

Q. How did you determine the required sample size for each of the pilot treatments?

A. Acknowledging the higher uncertainty in the expected peak impacts (or MDI in the context of statistical calculations) in winter peaking systems, we undertook the sample size calculations twice. The first set of results used the expected peak impacts from Arcturus as presented in Figure 8, and the second set of results used the 50 percent of the expected Arcturus impacts as the MDI in the calculations. The reason for running the 50 percent adjustment case is to compute a "conservative/high sample size" that would certify a sufficient sample for the measurements if the impacts from the pilot are less than those predicted by Arcturus. By reviewing the results from these two sets of results, we proposed the sample sizes in Figure 9 below.

Figure 9: Proposed Treatment and Control Sample Sizes

	Rate	Low Case	High Case	Recommended Treatment Sample Size Target	Recommended Control Sample Size Target
Residential	TOU	500	1,700	1,000	1,000
	TOU+PTR	750	3,000	1,500	1,500
	Three-Period TOU	250	600	500	500
Low Income	TOU	500	1,700	1,000	1,000
	TOU+PTR	750	3,000	1,500	1,500
Small C&I	TOU+PTR	1,800	7,000	2,000	2,000
	TOTAL			**7,500**	**7,500**

Q. How will customers be enrolled in the pilot?

A. Customers will be enrolled in the pilot on an opt-in basis. Opt-in is currently PSE's preferred strategy for full deployment in the future, and to the extent possible, the pilot design should mirror the full deployment enrollment approach in order to maximize useful insights from the experiment and to maximize external validity.

Q. What design and analysis methods are you proposing for the pilot?

A. We propose to use a quasi-experimental approach to select pilot participants. At a high level, PSE will offer the opportunity to participate in the pilot to customers who are selected randomly. Customers in a control group (no treatment) can be drawn from the customer population pool and matched with customers in the treatment group based on how similar they are to each other.[11] The effects of TVR (e.g., amount of electricity that a customer reduces during peak hours) can be determined by comparing the performance of the customer in the treatment group against that of the customer in the control group.

Our proposed "random sampling with a matched control group" approach preserves the random element in the "randomized controlled trial" ("RCT") approach and involves lower recruitment costs compared to the "randomized encouragement design" ("RED") approach.

Q. Please explain the differences among these different approaches.

A. Often used in the drug development context, the RCT is a statistically rigorous method, randomly assigning recruited customers into the treatment and control groups. This approach was deployed in early TVR pilots (including California's statewide pricing pilot in 2003), but it has become less common because of

[11] This process is accomplished through a statistical method called "propensity score matching", where statistical analysis is used to identify variables that are most closely correlated with enrollment in the pilot. A propensity score (probability to participate) is computed for the treatment group and the control group. For each customer in the treatment group, the propensity score is used to identify and assign their counterpart in the control group.

potentially adverse impacts on customer satisfaction.[12] In RED designs, the utility randomly invites customers to participate in the treatment group, and customers can decide whether to receive treatment. The Sacramento Municipal Utility District SmartPricing Pilot and the Ontario RPP pilots followed this approach. RED preserves the random element and does not negatively affect the customer experience. However, it requires a much larger sample size relative to the RCT to isolate the true impact of the treatment, increasing implementation costs.

Because of its relative advantages, many of the recent wave of TVR pilots have used the random sampling with matched control group design. For example, the Alectra Advantage Power Pricing Pilot (conducted in 2017), Maryland's PC44 TOU pilot (2019), PowerPath DC Pepco Residential TOU pilot (2020), and Every Missouri TOU pilot (2021), all used this approach.

Q. How will customers be recruited?

A. As explained above, customers in the treatment group will be recruited from several waves of randomly selected group of eligible customers. The selected customers will receive recruitment materials from PSE, and they can choose to participate by completing a pre-launch survey. The survey confirms eligibility and collects relevant socio-demographic data for subsequent analysis. PSE's recruitment team will continue with this wave-based deployment until the recruitment targets or enrollment caps are reached. Based on previous studies, we

[12] For example, customers may be recruited and their participation is subsequently denied or delayed because the experiment's requirements are already met. This may lead to customer experience issues.

expect that no more than five percent of contacted customers will join the pilot. Customers in the control group will be chosen from a group of customers who are not approached for the pilot.

Q. Will PSE offer participating customers bill protection?

A. The Company is not planning to offer bill protection to customers participating in the pilot for three reasons. First, bill protection may not be available for customers participating in the eventual full-scale deployment. As discussed above, the pilot's design elements should mirror those of the full deployment to the extent possible to ensure that findings from the pilot will be externally valid. Second, bill protection may obscure the true customer response because by knowing that their (lack of) response would not affect the monthly bills, some customers in the pilot may not change their behaviors as they would in the absence of bill protection. As a result, bill protection may "dilute" customer response to price signals. Finally, low-income participants in the pilot will still be eligible for PSE's low-income discounts and programs, which will mitigate any bill increase that these participants may experience.

Q. How long will the pilot last?

A. The pilot is proposed to run over a period of two years.

Q. When will PSE initiate the pilot?

A. PSE plans to prepare for the pilot launch once it receives the Commission's approval. We understand that PSE is planning for a launch date in around late 2023.

Q. Did PSE develop an EM&V approach for the pilot?

A. Yes. We helped PSE develop a high-level EM&V approach for the measurement and verification of the pilot impacts. PSE is also planning to submit a more detailed EM&V plan after the approval of the pilot.

Q. What are PSE's planned EM&V activities throughout the two-year pilot?

A. A comprehensive approach to EM&V allows PSE to maximize its experience from the pilot and use these learnings for a successful broader scale roll-out in the future. PSE currently plans for four distinct EM&V activities: 1) Load impact evaluation after the first year of the pilot; 2) Load impact evaluation after the second year of the pilot; 3) Process evaluation after the second year of the pilot, and 4) Customer surveys before, during, and at the conclusion of the pilot.

Q. What are the major building blocks of load impact evaluation?

A. The experimental design of each pilot dictates the optimal approach for load impact evaluation. Pilots designed with control groups typically rely on one of the following statistical analysis techniques: the differences-in-differences (ANOVA or ANCOVA), panel regressions (fixed-effects or random-effects), or individual customer regressions. The first step is to decide on the evaluation approach given the experimental design (in PSE's case, randomized sampling with matched control group). The second step is to identify load impact metrics to be quantified (peak, mid-peak, off-peak impacts, average daily conservation impact, etc.). The third step is to consider and estimate alternative models and select the one that leads to the most robust results for reporting out the metrics. The last step is to quantify customers' overall price responsiveness in the form of price elasticities that would allow predicting impacts for prices other than those tested in the pilot.

Q. What is your proposed load impact evaluation approach for PSE?

A. We propose that PSE's TVP Pilot Program is evaluated using an "ex-post load impact" analysis. This analysis is the central piece of a load-impact evaluation effort. The main goal of this analysis is to estimate the percentage reduction in peak demand and the percentage reduction in overall usage in response to the time-varying prices. This is generally straightforward to estimate with econometric methods.

In addition, it is also quite valuable to estimate price elasticities in pilot studies to understand customers' underlying responsiveness to different price ratios. We recommend that PSE make reasonable efforts to estimate these elasticities at the end of the second year of the pilot.

Q. Please describe your proposed approach for the load impact evaluation of the TOU rates.

A. For all the TOU treatments tested in the pilot, we propose the use of a panel data estimation with control group and pre-treatment data. We propose the use of a fixed effects regression, which accounts for the impact of unobservable time-invariant variables and prevents them from biasing the estimates. This regression will be estimated by season and account for the impact of all other factors besides the TOU rate. This analysis will determine the peak demand reductions and overall conservation impact demonstrated by the treatment customers.

Q. What are metrics that will result from the TOU load impact analysis?

A. It is possible to develop various metrics from the estimations, but there are several metrics that are key to understanding the outcome of the pilot. These metrics are as follows:

- Change in the average peak period demand;
- Change in the average off-peak period demand;
- Change in the average usage level;
- Bill distribution impacts by season for treatment and control group customers;
- Analysis of peak demand and usage impacts by customer segments to the extent sufficient data is available;
- Own/daily price elasticity, if applicable;
- Inter-period substitution elasticity, if applicable.

Once the models are estimated, it is possible to run the models on different sub-samples to generate other metrics of interest.

Q. Please describe your proposed approach for the load impact evaluation of the PTR rates.

A. For the PTR tested in the TVP pilot, we propose a within-subject panel data estimation using only the treatment period data on treatment customers. More specifically, this fixed effects regression will be estimated between event days and all non-event days for the treatment customers. Another variation is to only use "comparable" non-event days instead of all non-event days for control purposes. Comparable non-event days can be determined by choosing the days with most similar weather conditions to the event-days. Model specifications are flexible in that it is possible to estimate average impacts for individual peak hours by event day, or average peak impacts on average event day.

Q. What are metrics that will result from the PTR load impact analysis?

A. Like the metrics for the TOU load impact analysis, PTR analysis will require a number of metrics to be developed to gauge the price responsiveness of the PTR customers. These metrics are:

- Average peak demand impact on all event days;
- Peak demand impacts by event day;
- Persistence of impacts for consecutive event days;

- Analysis of event day peak impacts by customer segments to the extent sufficient data is available;
- Bill distribution impacts by season for treatment customers;
- Own/daily price elasticity, if applicable;
- Inter-period substitution elasticity, if applicable.

Q. What data will be necessary to undertake the TOU and PTR load impact analyses?

A. Load impact analysis will require the collection of various data elements to undertake the control group matching analysis, load impact analysis and bill impact analysis. Figure 10 below presents these data requirements.

Figure 10: Data Requirements for Load Impact Analysis

Category	Data Requirement
1- Control group matching analysis	• Hourly and monthly consumption data for the recruitment and set-aside control group samples, ideally extending one year before the start of the pilot • Customer participation data on PSE programs • Electric heating status, dwelling type, income status and geographical identifier for each residential customer • Business Type, business size, operation hours, and geographical identifier for each commercial customer
2- Load impact analysis	• Hourly usage data for each of the treatment and control customers ideally extending one year before the start of the pilot • Hourly usage data for each of the treatment and control customers during the treatment period • Effective pilot start date for each treatment customer • All in rates for standard rates and TOU tariff • Weather data based on relevant weather station(s) that are in the closest geographical proximity to the treatment and control group customers • Each treatment and control customer's participation in utility programs • For treatment customers leaving the program, the date they left the program
3- Bill impact analysis	• Monthly bills for treatment and control customers, ideally extending one year before the start of the pilot • Monthly bills for treatment and control customers during the pilot period

Q. Is PSE also planning to undertake a process evaluation as part of their EM&V efforts?

A. Yes. PSE is planning to undertake a process evaluation at the end of the pilot that consists of an assessment of the implementation of the program, with the goal of producing better and more cost-effective programs in the future. Process evaluation is typically conducted by surveying or soliciting feedback from the various groups involved in the pilot program, including both participants, implementers and administrators of the program. It can be thought of as a comprehensive documentation of the operational side of the pilot, supported by data and statistics, when possible. Data collected during this process include, but are not limited to, the following:

- Customer recruitment and outreach (pre-treatment survey);
- Customer acceptance and interest in treatment (post-treatment survey);
- Understanding the reasons for non-participation and attrition;
- Quality control practices;
- Time, schedule and budget management;
- Lessons learned;
- Project resource constraints and staff training;
- In-field and back-office challenges with implementation.

IV. CONCLUSION

Q. What do you conclude about PSE's time-varying rates pilot proposal?

A. PSE has undertaken a rigorous, data-driven approach to develop rate designs that aim to reduce system costs, offer customer options to manage their energy bills and accommodate their lifestyles, and help to achieve PSE's 100 percent carbon-free goals. The key design elements proposed in the pilot are based on scientifically valid methods and are consistent with industry best practices. In addition, the rate development process involved extensive stakeholder outreach, consisting of a series of three collaboratives and multiple individual stakeholder conversations. Comments and feedback on various aspects of the rate design from stakeholders were carefully considered and factored in the final design. The proposed pilot will provide valuable insight into PSE customers' ability and willingness to dynamically respond to price signals, shifting load away from system peaks. PSE's proposal is a vital step in its journey to modernize its energy system to deliver reliable, affordable, and clean electricity to its customers.

Q. Does this conclude your testimony?

A. Yes.