Zen and the Art of Rate Design

A Meditation on Time-Varying Rates (TVR)

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So, why the reference to Zen?

- Zen is characterized by the use of *koans*, which are brief paradoxical statements whose mastery is essential to meditation

- Once the monks have been so trained, they abandon their ultimate dependence on reason and are forced into gaining sudden intuitive enlightenment

A disclaimer

- *I have been searching for the optimal rate design since I started working for EPRI in July 1979. This search did not end when I retired from Brattle because I found it was impossible to retire from economics.*
- *In 1989, I signed on to a TOU rate and have been on some type of TOU rate ever since; for a few years, I was also on a CPP rate paired with direct load control of my central a/c.*
- *In 2016, I did a whole house energy upgrade*
  - *https://www.latimes.com/opinion/livable-city/la-ol-solar-power-energy-efficiency-20160315-story.html*
- *In 2019, I bought an EV and later installed solar+storage*
  - https://pv-magazine-usa.com/2022/05/26/the-making-of-a-clean-energy-prosumer-part-one/
  - https://pv-magazine-usa.com/2022/05/27/the-making-of-a-clean-energy-prosumer-part-two/

1. What is the regulatory framework that governs rate design?

- Rates should be based on cost of service
  - Cost of service studies can be based on marginal cost of embedded (average cost)
  - Most utilities use embedded cost
- Rates should be customer friendly
  - Extensive market research including focus groups, surveys, and conjoint analysis should be undertaken to make sure customers will understand the rates and know how to respond to them
  - Rates should be designed to minimize adverse impact on customers
  - It may be useful to offer bill protection for the first year
- Rates should recover utility revenues
  - Decoupling or some type of lost revenue adjustment mechanism should be in place

Controversies are intrinsic to rate design – its both art and science, with a fair bit of politics thrown into the mix

There's never been any lack of interest in the subject of electricity tariffs. Like all charges upon the consumer, they are an unfailing source of annoyance to those who pay, and an argument among those who levy them… There is general agreement that appropriate tariffs are essential to any rapid development of electricity supply and there is complete disagreement as to what constitutes an appropriate tariff.

- *D. J. Bolton, Cost and Tariffs in Electricity Supply,* Chapman & Hall, UK, 1938

2. How do TVRs fit into the broad picture of rate design?

The most common rate design is a flat volumetric rate with a modest fixed charge

- The national average for the volumetric rate is around 15 cents/kWh
- The national median for a fixed charge is around $11/month

Popular rate designs include inclining block rates and declining block rates

Several utilities also offer demand charges

- They may be based on coincident or non-coincident peak demand, which is measured in kW

TVRs have been around for a long time but are finally gaining traction

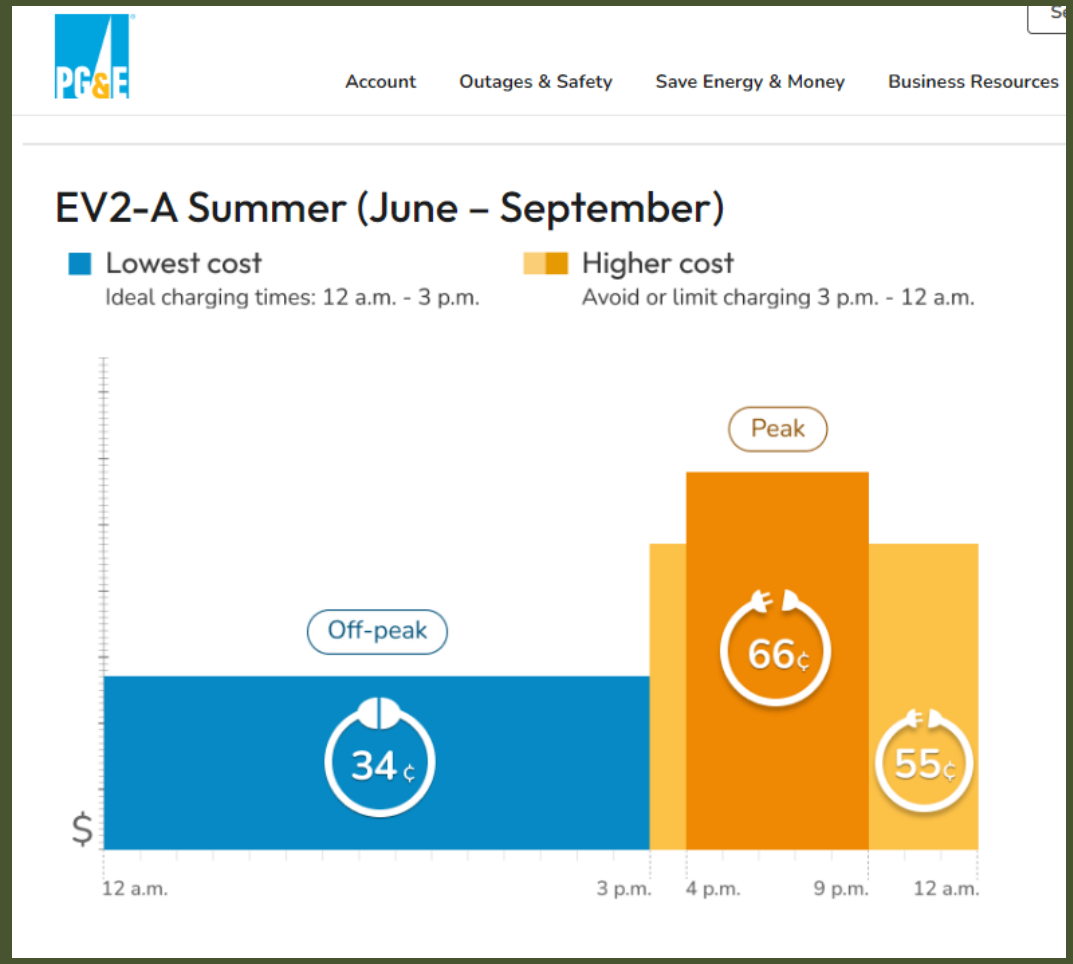
3. What exactly are TVRs?

Rate designs in which the price of electricity varies by time of day and across seasons of the year

The basic and most popular TVRs are “static” rate designs in which the price by period and the periods are set in advance

The more advanced TVRs are dynamic in which the price may be known in advance but when it will be called is unknown

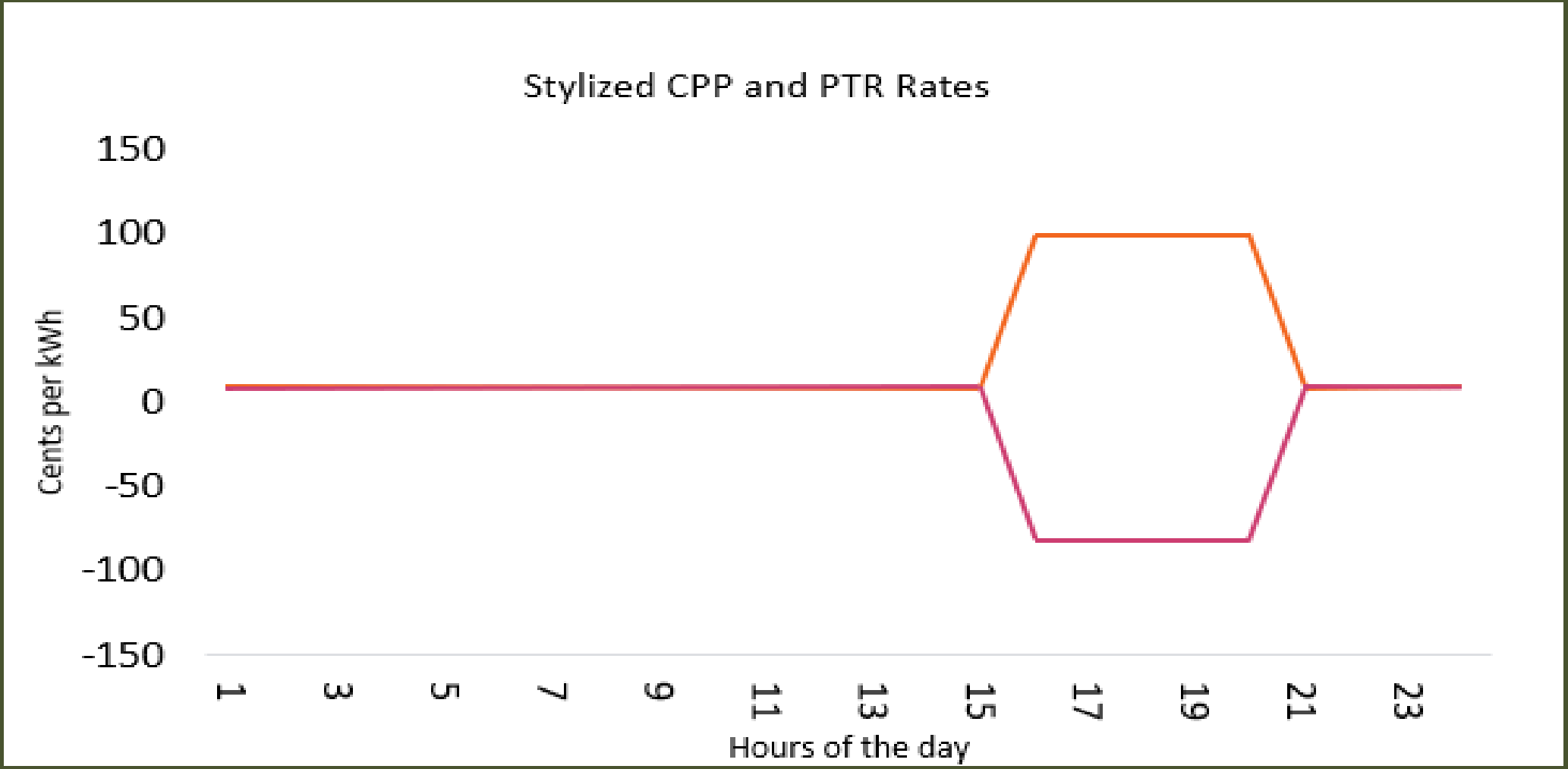
In the most advanced TVRs, neither the price nor when it will be called are known in advance



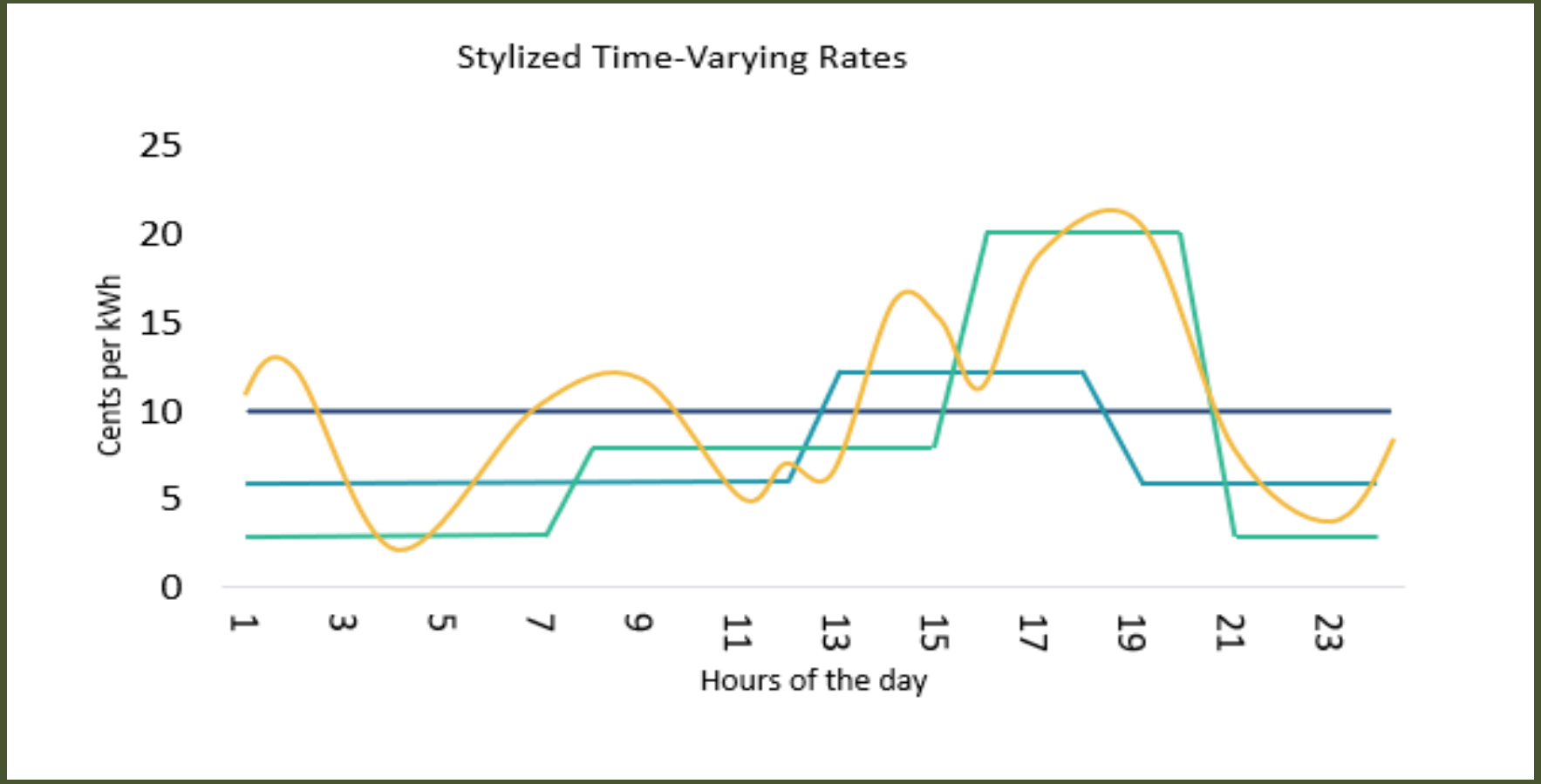
TVRs span a wide spectrum of rate designs

Rate	Definition
1- Time-of-Use (TOU)	The day is divided into peak and off-peak time periods. Prices are higher during the peak period hours to reflect the higher cost of supplying energy during that period
2- Critical Peak Pricing (CPP)	Customers pay higher prices during critical events when system costs are highest or when the power grid is severely stressed
3- Peak Time Rebates (PTR)	Customers are paid for load reductions on critical days, estimated relative to a forecast of what the customer would have otherwise consumed (their "baseline")
4- Variable Peak Pricing (VPP)	During alternative peak days, customers pay a rate that varies by day to reflect dynamic variations in the cost of electricity
5- Real-Time Pricing (RTP)	Customers pay prices that vary by the hour to reflect the actual cost of electricity
6- Two-part Real-Time Pricing (2-part RTP)	Customer's current rate applies to a baseline level of consumption. A second, marginal cost based, price applies to deviations from the baseline consumption
7- Three-part Rates (3-part Rates)	In addition to volumetric energy charge and fixed charge, customers are also charged based on peak demand, typically measured over a span of 15, 30, or 60 minutes
8- Fixed Bill with Incentives	Customers pay a fixed monthly bill accompanied with tools for lowering the bill (such as incentives for lowering peak usage)

Critical-peak pricing (CPP) and peak-time rebates (PTR) are mirror images



Real-time pricing are the most unpredictable TVRs



4. What are the guidelines for designing TVRs?

Well designed TOU rates should reflect the cost of service

They may contain 2 or 3 pricing periods

In a 3-period rate, make sure that the mid-peak period rate equals or is slightly less than the standard rate

The rates may vary across weekdays and weekends

They may also vary seasonally

They may be static or dynamic

If dynamic, they may provide a “critical peak” pricing signal or a “peak time” rebate

They may be offered on an opt-in or opt-out basis and, in rare cases, on a mandatory basis

https://energycentral.com/c/um/should-time-use-rates-be-made-standard-tariff

The latest utility to provide opt-out TVRs is PSEG Long Island NY

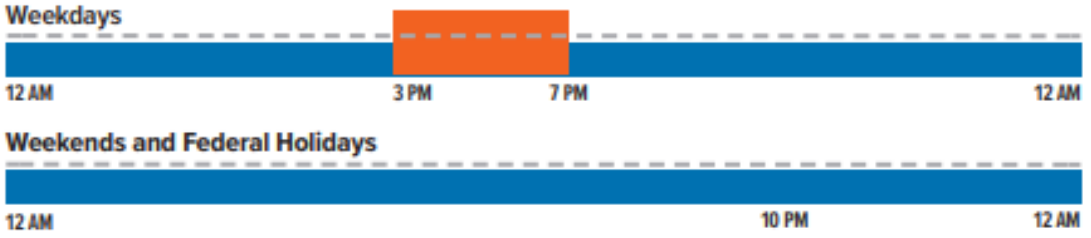
"Time-of-Day" Rates

Effective January 1, 2024, Rate 194 is the standard residential rate. That rate along with optional Rate 195, are Time-of-Day (TOD) rates. Off-Peak Rates offer a discount from Rate 180, 88% of the year. See page 5 for more.

Rate 194: Residential, Time-of-Day, Off-Peak

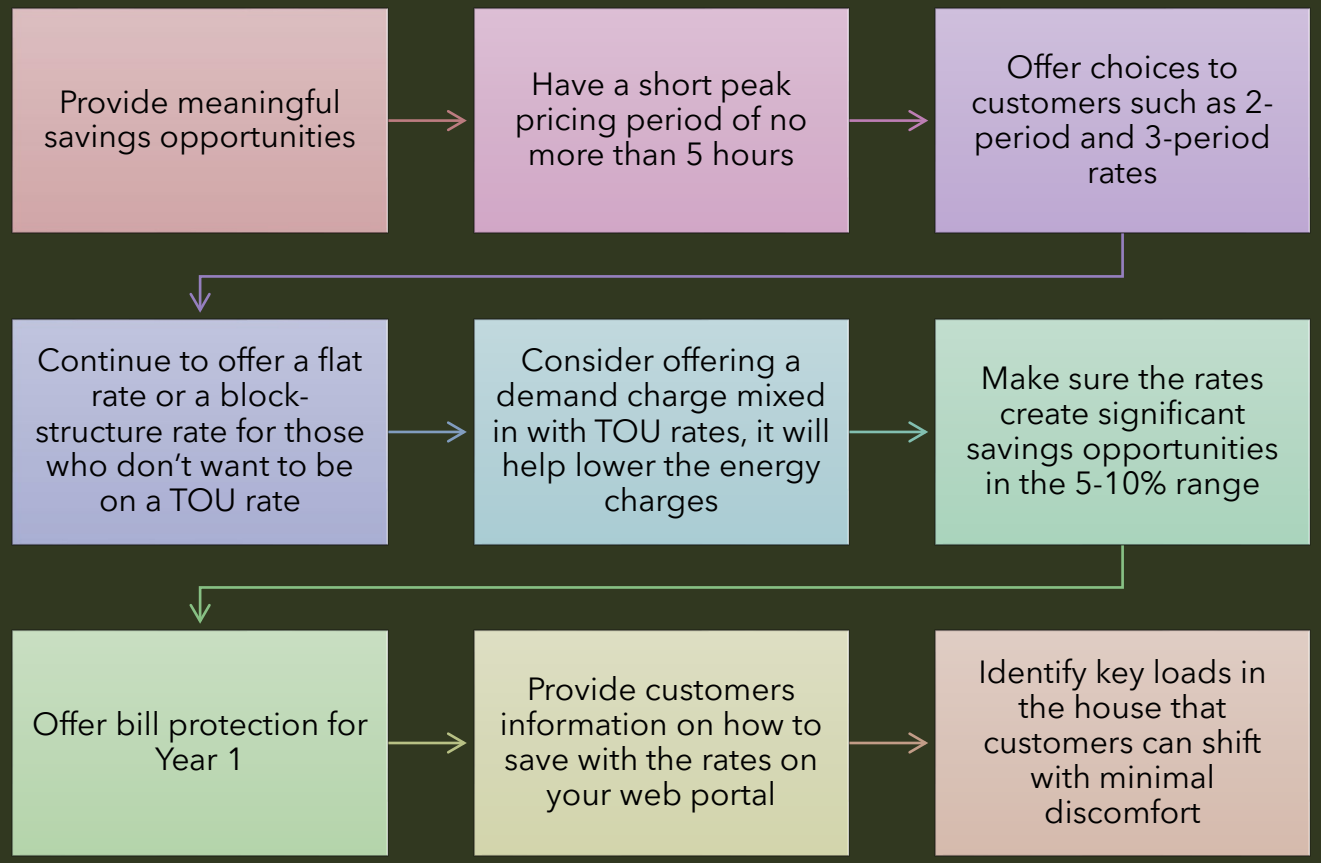
Time Period	June - Sept.	Oct. - May
Daily Service Charge: (Per Day)	$0.5100	$0.5100
Off-Peak - All hours outside Peak hours		
Delivery Charge: per kWh	$0.0999	$0.0848
Power Supply Charge: 87.73% (summer)/87.61% (non-summer) of monthly published rate		
Peak - 3 PM - 7 PM Weekdays (except federal holidays)		
Delivery Charge: per kWh	$0.2025	$0.1722
Power Supply Charge: 175.45% (summer)/175.23% (non-summer) of monthly published rate		

Power Supply Charge adjusts monthly based on energy market prices. Current price can be found online at **psegliny.com/rates**

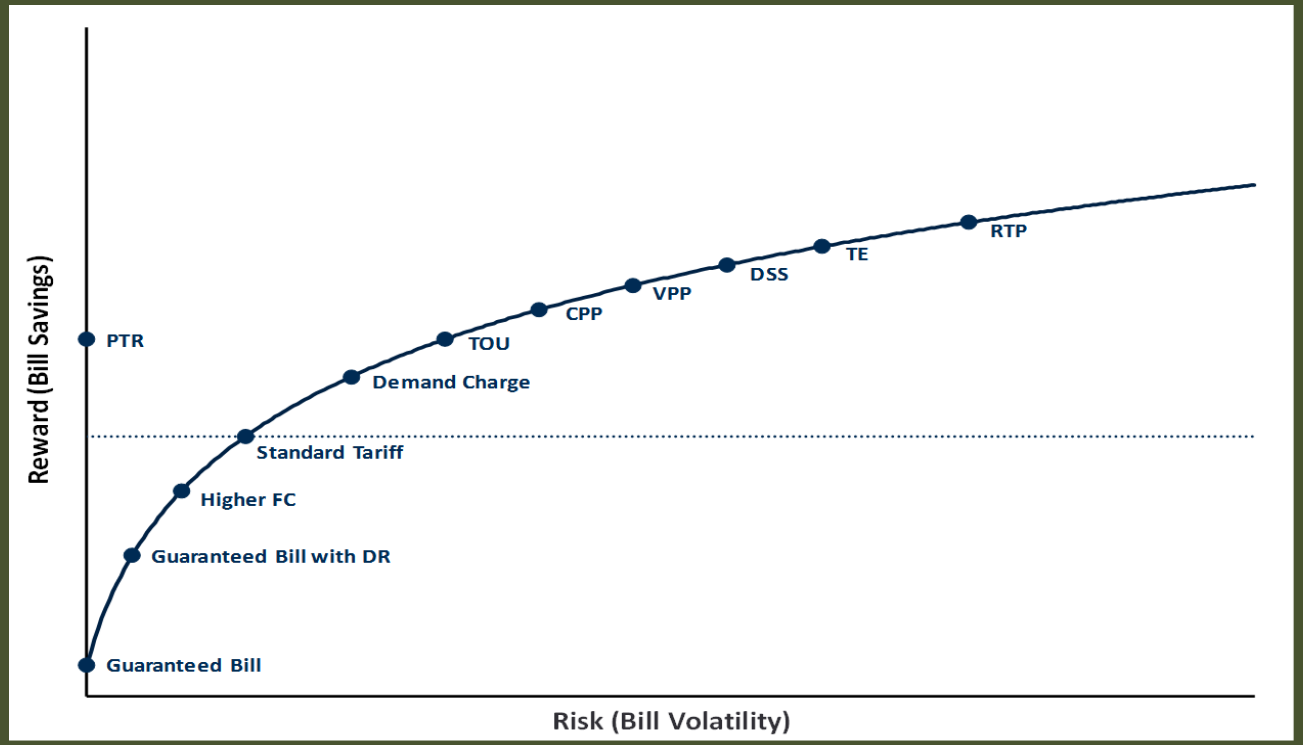


What price ratios should be offered on an opt-out (default) basis? Between 2:1 and 3:1 is the ideal range.

5. What *should you do* with TVRs?



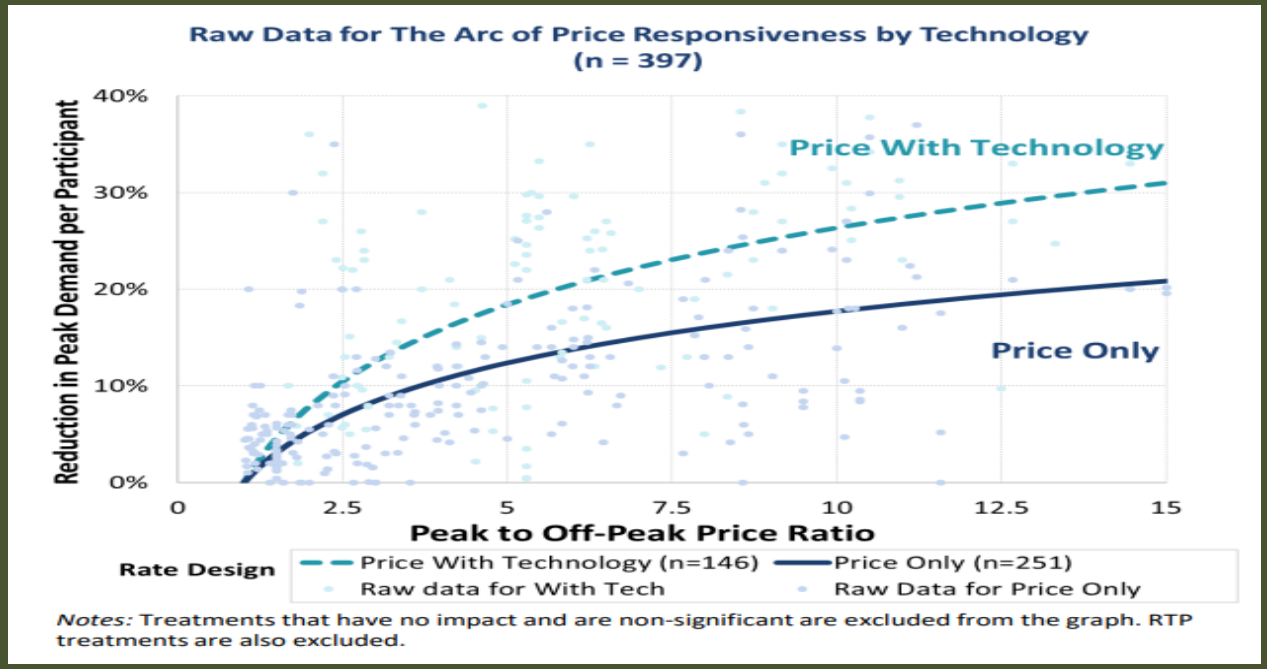
Offer customers a choice of rate designs that map out an "efficient pricing frontier"



What have we learned after conducting scores of pilots with TVRs?

- More than 60 pilots have been carried out across the globe over the past two decades, including more than 400 pricing treatments
- They have yielded valuable information on how customers respond to TOU rates, with and without enabling technologies and with and without information on how to take advantage of TOU rates
- When I was working at Brattle, we carried out a meta-analysis of the data
  - The resulting model, *Arcturus*, has been updated several times as new results are published
  - "Arcturus 2.0: A meta-analysis of time-varying rates for electricity," with Sanem Sergici and Cody Warner, *The Electricity Journal*, 30:10, December 2017, pp. 64-72. https://www.sciencedirect.com/science/article/pii/S1040619017302750
  - https://www.brattle.com/wp-content/uploads/2023/02/Do-Customers-Respond-to-Time-Varying-Rates-A-Preview-of-Arcturus-3.0.pdf

6. Do customers respond to TVRs? Yes, based on the meta-analysis in *Arcturus*



7. Do customers respond to TVRs in cold climates?

- For a long time, there was a concern that they won't
- However, new evidence from Quebec and Nova Scotia in Canada shows that they do respond
- Check out these references:
  - https://energycentral.com/c/em/does-price-responsive-exist-cold-climates
  - "Does dynamic pricing work in a winter-peaking climate? A case study of Hydro Quebec, with Frederic Pelletier, *The Electricity Journal*, Volume 35, Issue 2, March 2022. https://www.sciencedirect.com/science/article/abs/pii/S1040619022000069
- TOU pricing also works in a hot and humid climate like Florida's
  - "Dynamic Pricing Works in a Hot, Humid Climate," with Neil Lessem and Sanem Sergici, *Public Utilities Fortnightly*, May 2017. https://www.fortnightly.com/fortnightly/2017/05/dynamic-pricing-works-hot-humid-climate

8. The perennial question – should you do your own pilot?

If your customer demographics and climate are unique, you may want to do a pilot to assess customer acceptance and load response

If your rate design is unique and has not been tested elsewhere, you may want to do a pilot

If you do a pilot, make sure the recruitment process mimics the full-scale deployment process – opt-in, opt-out or mandatory

Make sure you have matching control and treatment groups and before and after measurements, as in any good clinical trial of a new "treatment"

Reference: "Bridging the Chasm Between Pilots and Full-scale Deployment of Time-of-Use Rates," with Sanem Sergici and Long Lam, *The Electricity Journal*, Volume 33, Issue 10, December 2020. https://www.sciencedirect.com/science/article/abs/pii/S1040619020301494

TOU rates have been proposed by PSE&G in New Jersey*

- PSE&G has filed an application with the regulatory commission seeking to offer two different TOU rates to its customers on an opt-in basis
- Customers will be provided bill protection in Year 1
- The flat rate will continue to be the standard rate
- One of the TOU rates will be a 2-period rate and is designed to appeal to the typical residential customer
- The other TOU rate is a 3-period rate and is designed to appeal to residential customers who drive an EV
- *I have submitted testimony in the case

The 2-period rate proposed by PSE&G in New Jersey during summer has a 3:1 ratio between peak and off-peak rates

Figure 5 Summary of Proposed Two-Period TOU Rate

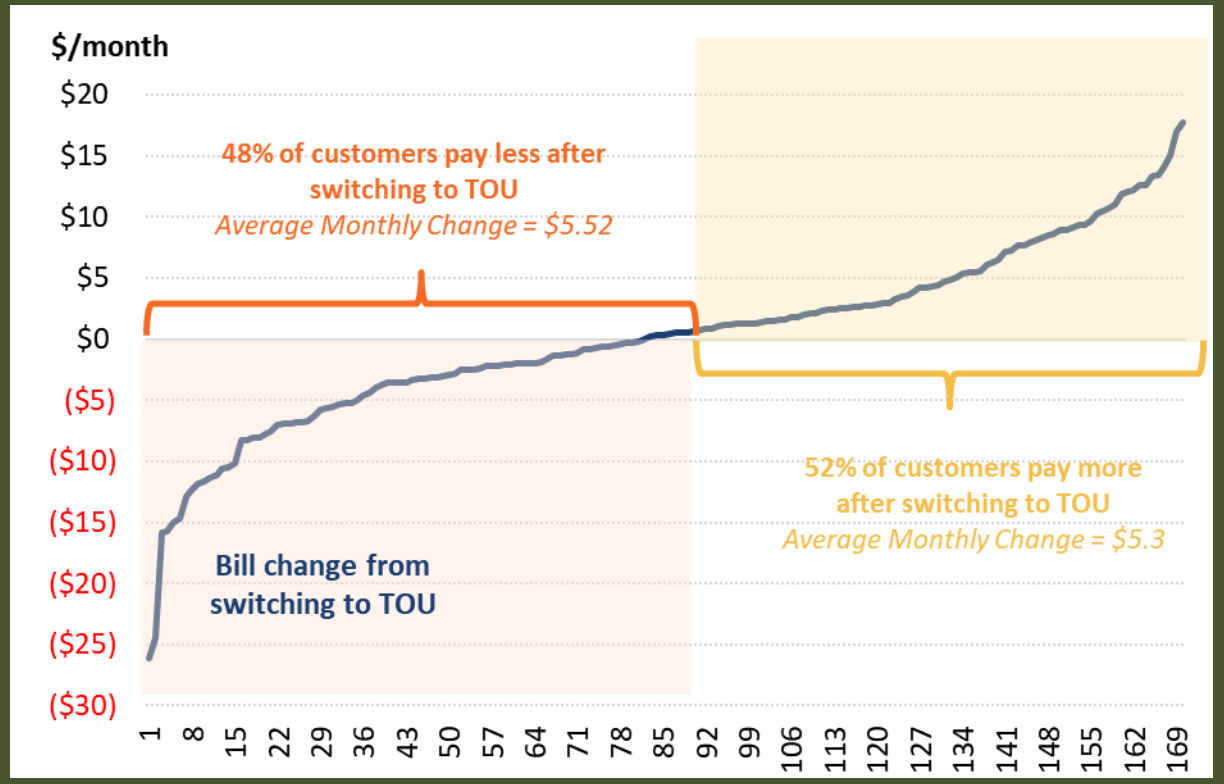
	Two Period TOU			
	Summer		Winter	
	On Peak	Off Peak	On Peak	Off Peak
Generation ($/kWh)	$0.127337	$0.065788	$0.131136	$0.072600
Transmission ($/kWh)	$0.139700	$0.052704	$0.069850	$0.052704
Distribution ($/kWh)	$0.209513	$0.037114	$0.153778	$0.037114
Final Rate ($/kWh)	**$0.476551**	**$0.155605**	**$0.354764**	**$0.162418**
Monthly Charge ($/Month)		$8.05		

The 3-period TOU rate proposed by PSE&G in New Jersey in the summer has a 6.8:1 ratio between the peak and off-peak prices

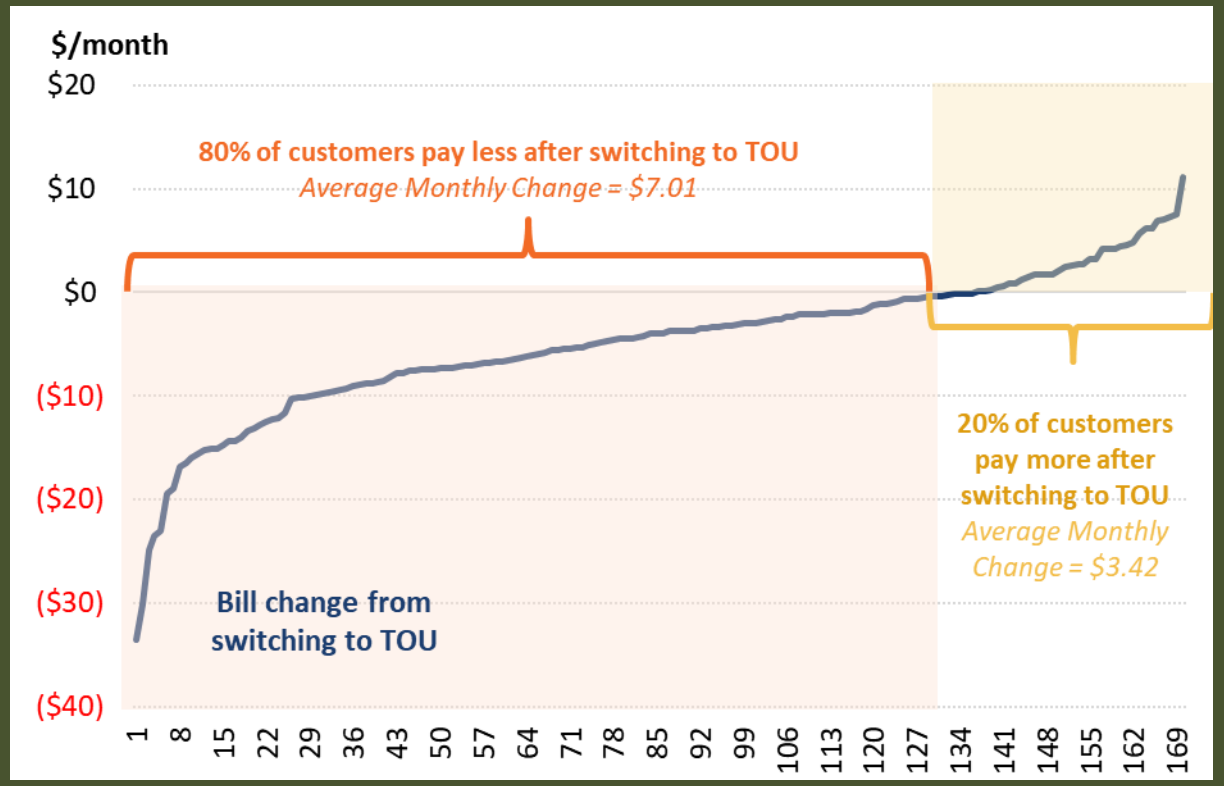
Figure 6 Summary of Proposed Three-Period TOU Rate

	Three Period TOU					
	Summer			Winter		
	On Peak	Mid Peak	Off Peak	On Peak	Mid Peak	Off Peak
Generation ($/kWh)	$0.127337	$0.070636	$0.048759	$0.131136	$0.075768	$0.063677
Transmission ($/kWh)	$0.139700	$0.069850	-	$0.069850	$0.069850	-
Distribution ($/kWh)	$0.209513	$0.042307	$0.021153	$0.153778	$0.042307	$0.021153
Final Rate ($/kWh)	**$0.476551**	**$0.182794**	**$0.069912**	**$0.354764**	**$0.187925**	**$0.084830**
Monthly Charge ($/Month)			$8.05			

Bill impacts of the 3-period rate prior to load shifting



Bill impacts of the 3-period rate with load shifting (source: *Arcturus*)



9. What other questions need to be addressed as you move forward with TVRs?

- What marketing collateral should be used to recruit customers?
- Should bill protection be offered?
- Should enabling technologies be offered to facilitate load shifting?
- Behavioral messaging?
- Bill decomposition?
- A rate choice algorithm on the web portal?

10. What *should you not do* with TVRs?

- Have long peak pricing periods of 12 hours
- Develop default rates with peak to off-peak ratios greater than 3:1
- Have opt-in rates with peak to off-peak ratio less than 1.5:1 – customers will be inconvenienced and save next to nothing
- Forget to reach out to customers and educate them on how best to respond to the rates
- Couch the rate design in arcane, technical jargon
- Forget to engage with stakeholders: customers, trade allies, intervenors and influencers

11. What is the status of TVRs in the US?

- As of 2022, some 13.2 million residential customers **(~10%)** were enrolled on some form of TOU rates in the US.
- In 2021, 363 U.S. utilities offered at least one form of TOU rate to residential customers
  - 327 were simple TOU rates
  - 28 were CPP rates
  - 11 were PTR rates
  - 7 were VPP (multiple CPP)) rates
  - 6 were RTP rates

12. What is the geographical dispersion of TVRs in the US?

- It's largely concentrated in a few states
  - Arizona, California, Colorado, Oklahoma, Maryland, and Michigan
- Default TOU rates are gaining traction with utilities in several states
  - California, Colorado, Michigan, Missouri, New York -- Hawaii and Minnesota may follow
- One utility has mandatory TOU rates
  - Fort Collins in Colorado
- Many utilities offer opt-in TOU rates
  - The enrollment rate is often 1% or less
- In Illinois, both investor-owned utilities offer real-time pricing
  - The enrollment rate is around 1%
- https://energycentral.com/c/um/how-should-time-varying-rates-be-structured-households
- https://energycentral.com/c/um/what-national-landscape-rate-design-context-pricing-electricity

13. What TVRs are being offered in other countries?

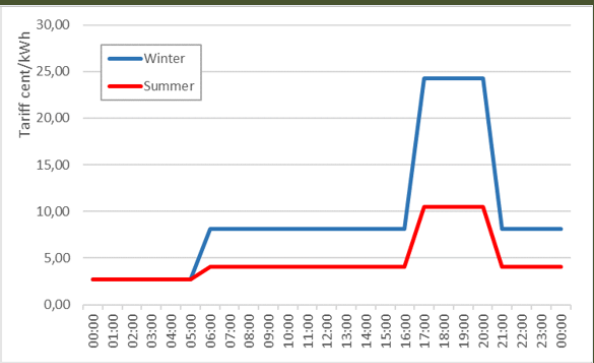
- Time-of-day rates
  - Ontario, Canada – First region in North America to offer default TOU rates
    - "The Impact of Time-of-Use Rates in Ontario," with Neil Lessem, Sanem Sergici, and Dean Mountain, *Public Utilities Fortnightly*, February 2017. https://www.fortnightly.com/fortnightly/2017/02/impact-time-use-rates-ontario
  - Quebec, Canada – Offering CPP and PTR on an opt-in basis
  - Great Britain – Octopus offers a variety of TOU rates targeted at customers with PV panels, batteries, and EVs ; the Economy 7 TOU rate has been available for customers with thermal energy storage for decades
  - Dynamic operating envelopes in Australia (dynamic pricing for exporting energy from PV panels)
    - "Time of Use Rates: An International Perspective," with Cecile Bourbonnais, *Energy Regulation Quarterly*, Volume 8, Issue 2, June 2020. https://www.energyregulationquarterly.ca/articles/time-of-use-rates-an-international-perspectives#sthash.tNurCwB7.IH1irft2.dpbs
- Real-time pricing is gaining traction in a few countries
  - Spain (default tariff)
- Denmark https://energycentral.com/c/em/flexible-demand-denmark-conversation-claus-krog-ekman
- Norway (default tariff) https://energycentral.com/c/em/flexible-demand-norway-conversation-matthias-hofmann

Denmark's approach to tariff design

OPTIMAL RATE DESIGN?

Principles for Danish rate design (tariff mode 3.0)

- Cost authenticity / fairness: The single costumer should pay the costs they give rise to in the grid.
- Collectivity: Cost should not depend on "miles of network they use".
- Simplicity
- Options to ensure price signals that create incentives.



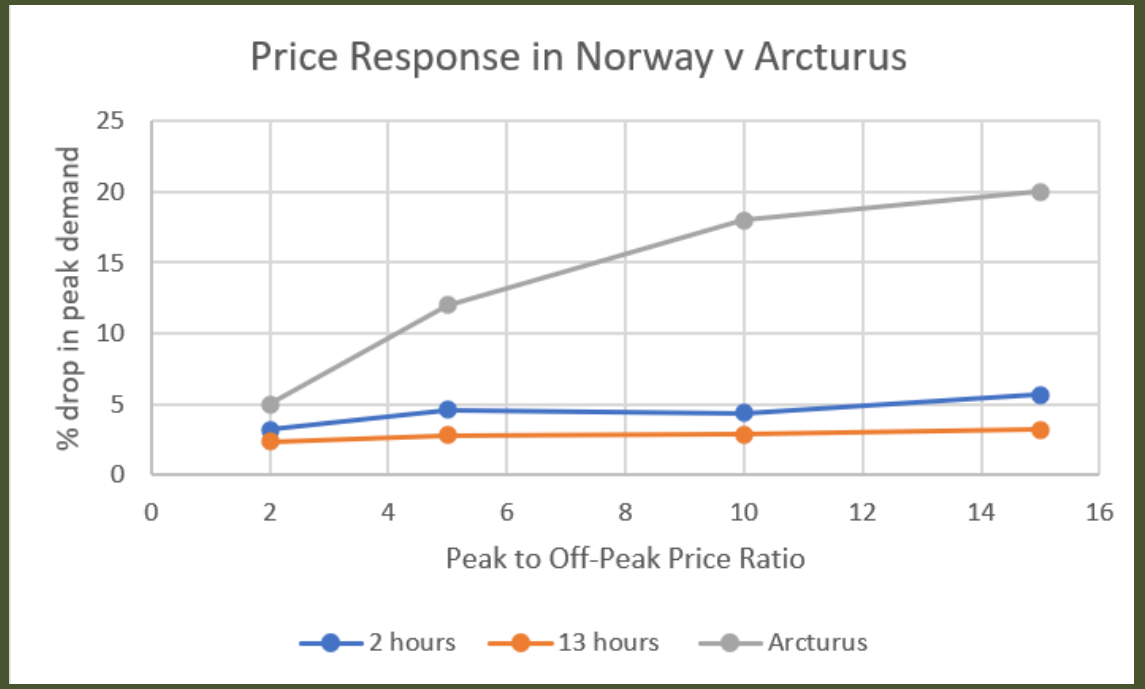
Tarif: Fixed charge + volumetric

Normal household:
Fixed: ~95 USD/year
Volumetric: Variable (3 c/kWh – 24 c/kWh) depending on TOU and season.

CONSULATE GENERAL OF DENMARK Silicon Valley

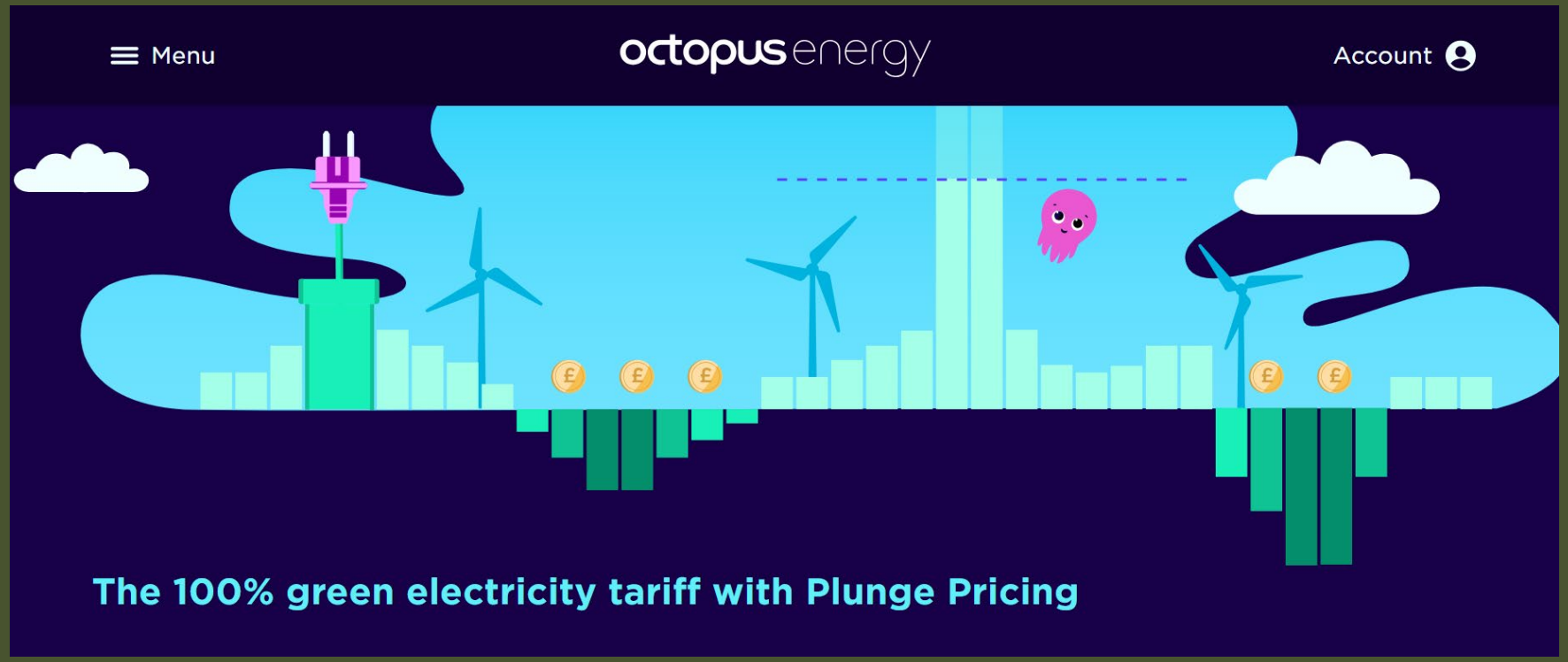
Danish Energy Agency

Price response in Norway to peak-time rebates is much lower than in the Arcturus data base, possibly because all customers are already on real-time pricing

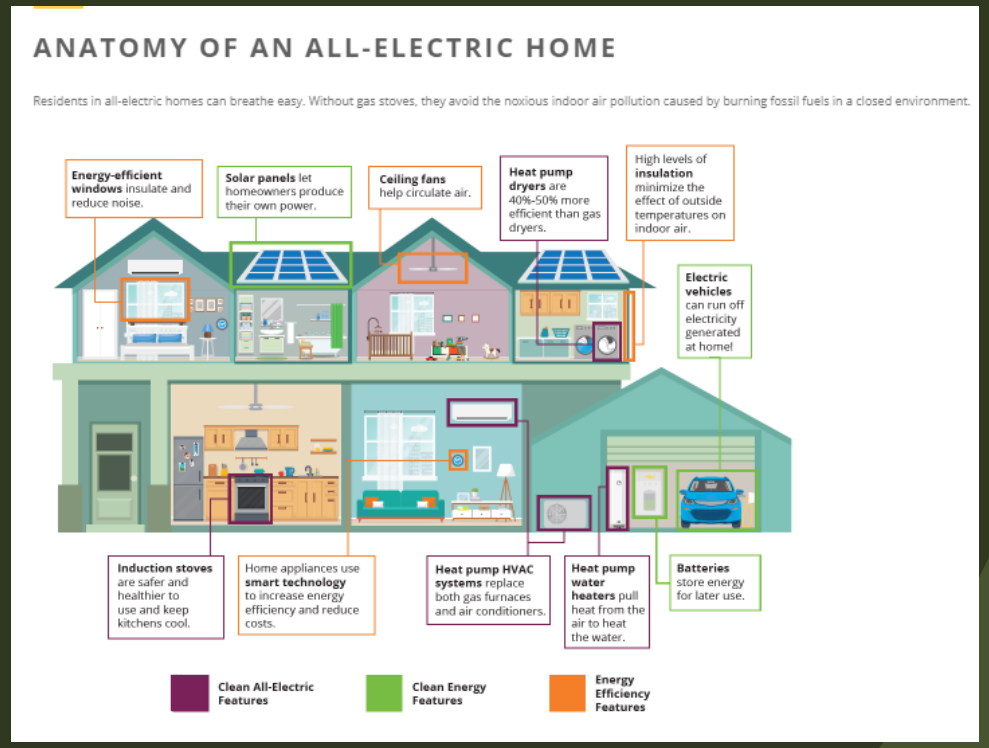


Octopus Energy' Agile Tariff in Great Britain

- Agile prices **can spike up to 100 p/kWh any time** - although a typical household in Winter '22-'23 paid around 35 p/kWh average.
- This tariff is best suited to customers who can shift large amounts of their energy use to avoid these expensive peaks, often by using smart home technologies like solar and batteries.



14. What will the customer of the future look like?



- More and more customers will have green tastes and diverse lifestyles
- Customers will have new digital technologies that will draw them toward TOU rates
  - Heat pumps
  - Smart thermostats
  - Electric clothes dryers
  - Induction stoves
  - Dishwashers with timers
  - Electric vehicles (EVs)
  - Photovoltaic panels (PVs)
  - Battery energy storage systems (BESS)

15. Can TVRs help lower the operating costs of electrification?

- TOU rates can encourage consumers with solar panels -- *prosumers* -- to pair them with batteries – becoming *prosumagers* -- and avoid straining the grid during the peak period
- TOU rates will lower the cost of charging EV's
- TOU rates *may* help lower the operating costs of running heat pumps
    - *If and when* heat pumps are widely deployed, customers could lower their bills by preheating their homes during the off-peak hours in the winter and precooling their homes during the off-peak hours in the summer

16. Are TVRs a panacea?

- While TOU rates have been the backbone of my career since I started working on them in 1979, they are NOT a panacea
  - Yes, they can reduce peak loads arising from HVAC systems and EV charging, build off peak loads to make the best use of solar energy, and help customers lower their bills
  - But they cannot offset the impact of rising electric rates on customer bills
- Most customers just spend a few minutes a year thinking about their electric bills
  - https://energycentral.com/c/cc/do-customers-understand-their-bills
- On some customers, TOU rates cast an Orwellian shadow
  - *Load Management = Lifestyle Management*
- Thus, go in with low expectations when offering TOU rates to customers and be prepared to be pleasantly surprised
  - "Ten lessons in rate design: A Meditation," *The Electricity Journal*, Volume 35, Issue 10, December 2022. https://www.sciencedirect.com/science/article/abs/pii/S104061902200149X

The 16 Questions – A Recap

1. What is the regulatory framework that governs rate design?
2. How do TVRs fit into the broad picture of rate design?
3. What exactly are TVRs?
4. What are the guidelines for designing TVRs?
5. What *should you do* with TVRs?
6. Do customers respond to TVRs?
7. Do customers respond to TVRs in cold climates?
8. The perennial question – should you do your own pilot?
9. What other questions need to be addressed as you move forward with TVRs?
10. What *should you not do* with TVRs?
11. What is the status of TVRs rates in the US?
12. What is the geographical dispersion of TVRs in the US?
13. What TVRs are being offered in other countries?
14. What will the customer of the future look like?
15. Can TVRs help lower the operating costs of electrification?
16. Are TVRs a panacea?

What the Monk said

- As I entered the hallowed precincts of the temple, a voice rang out: *I have no faith in regulatory bodies calculating and imposing the "correct" TOU tariff, although to be honest I don't believe there is such a thing. I do not see the economy as in equilibrium, with an optimal tariff, but rather as a discovery process, in which different retail suppliers will try out different tariffs to see which customers prefer.*

Biography

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- Dr. Faruqui has 45 years of consulting, teaching and research experience in rate design, load flexibility, energy efficiency, demand response, distributed energy resources, demand forecasting, decarbonization, and electrification. He has worked for over 150 clients on 5 continents and testified or appeared nearly 100 times before regulatory bodies, governments, and legislative councils on 6 continents.
- He has authored or coauthored more than 100 papers in peer-reviewed and trade journals and co-edited books on industrial structural change, customer choice, and electricity pricing. His work has been cited in *Bloomberg, Business Week, The Economist*, and *Forbes*, and in *Los Angeles Times*, *Mercury News*, *San Francisco Chronicle*, *The New York Times* and the *Washington Post*. He has appeared on NPR and Fox Business News.
- Dr. Faruqui has taught economics at San Jose State, UC Davis and the University of Karachi and delivered guest lectures at Carnegie Mellon, Harvard, Idaho, MIT, New York, Northwestern, Rutgers, San Francisco, Stanford, and UC Berkeley. He holds an MA in Agriculture Economics and a PhD in Economics from UC Davis, and a BA and an MA in Economics from the University of Karachi, Pakistan.