PRISM
Simulating the Impact of Demand Charges in the Absence of Empirical Data

CENTER FOR RESEARCH IN REGULATED INDUSTRIES
30th Annual Western Conference

PRESENTED BY:
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June 30, 2017
Agenda

Why implement demand charges?

Why simulate impacts?

How does the PRISM model work?
What are demand charges?

Demand charges efficiently allocate energy costs

- Customers are charged for their impact on system capacity costs
- Demand charges can be revenue neutral
- Demand charges can be tailored to a utility’s needs
New Interest in Demand Charges

- Smart meters have made three-part rates possible
- The need for three-part rates is increasingly apparent
  - Slower sales growth
  - Strained capacity limitations
  - Distributed generation growth
Predicting Impacts

- Pilots
  - Accurate, expensive, & time-consuming
- Prior Demand Studies
  - Limited sample:

<table>
<thead>
<tr>
<th>Study</th>
<th>Location</th>
<th>Utility</th>
<th>Year(s)</th>
<th># of participants</th>
<th>Monthly demand charge ($/kW)</th>
<th>Energy charge (cents/kWh)</th>
<th>Fixed charge ($/month)</th>
<th>Timing of demand measurement</th>
<th>Interval of demand measurement</th>
<th>Peak period</th>
<th>Estimated avg reduction in peak period consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Norway</td>
<td>Istad Nett AS</td>
<td>2006</td>
<td>443</td>
<td>10.28</td>
<td>3.4</td>
<td>12.10</td>
<td>Peak coincident</td>
<td>60 mins</td>
<td>7 am to 4 pm</td>
<td>5%</td>
</tr>
<tr>
<td>2</td>
<td>North Carolina</td>
<td>Duke Power</td>
<td>1978 - 1983</td>
<td>178</td>
<td>10.80</td>
<td>6.4</td>
<td>35.49</td>
<td>Peak coincident</td>
<td>30 mins</td>
<td>1 pm to 7 pm</td>
<td>17%</td>
</tr>
<tr>
<td>3</td>
<td>Wisconsin</td>
<td>Wisconsin Public Service</td>
<td>1977-1978</td>
<td>40</td>
<td>10.13</td>
<td>5.8</td>
<td>0.00</td>
<td>Peak coincident</td>
<td>15 mins</td>
<td>8 am to 5 pm</td>
<td>29%</td>
</tr>
</tbody>
</table>
Predicting Impacts (continued)

- We can rely on pilots for time-varying rates
  - The Arc of Price Responsiveness
    - Over 60 residential pilots catalogued
    - Includes TOU, CPP, VPP, and PTR pilots

Note: Chart includes 67 data points from TOU pricing treatments without enabling technology. The Arc was specified considering all 230 time-varying pricing treatments including CPP, VPP, PTR, and TOU.
PRISM Overview

- PRISM has evolved over time
  - Originally only for time-varying rates, now demand charges as well
  - Originally specific to California
- Applicable to aggregate load shape or individual customers
- There are three PRISM models
  - PRISM Yellow: time-varying charges
  - PRISM Blue: demand charges
  - PRISM Green: IBR
PRISM Yellow and PRISM Blue

- These models have identical methodology, except for an additional calculation in PRISM Blue
  - PRISM Blue maps demand charges into peak charges per kWh

\[
\text{Mapped Demand Charge (\$/kWh)} = \frac{\text{Demand Charge (\$)}}{\text{Peak Usage (kWh)}}
\]
Customers react to the price change in two ways

Part 1: customers react to the change in their daily (total) price of electricity.

- PRISM models this change using a daily elasticity ($\varepsilon_D$)

$$\text{Energy}_1 = \text{Energy}_0 \times \frac{\text{Price}_{\text{Daily}1}}{\text{Price}_{\text{Daily}0}}^{\varepsilon_D}$$
Part 2: customers react to the peak-to-off-peak ratio

- We calculate each customer’s new all-in energy charges

\[
Price_{Peak} = \frac{Fixed \ Charge}{Energy_{Peak}} + Volumetric \ Charge_{Peak}
\]

\[
Price_{Off \ Peak} = \frac{Fixed \ Charge}{Energy_{Off \ Peak}} + Volumetric \ Charge_{Off \ Peak}
\]

- We then calculate the customer’s shift from peak to off-peak usage using \( \varepsilon_{CES} \), the constant elasticity of substitution
**Sample Application: North Star Electric**

We model the following rates:

<table>
<thead>
<tr>
<th></th>
<th>Current Pricing</th>
<th>Time of Use Pricing</th>
<th>Demand Charge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Customer Charge ($/month)</td>
<td>$10.00</td>
<td>$10.00</td>
<td>$10.00</td>
</tr>
<tr>
<td>Volumetric Charge ($/kWh)</td>
<td>$0.10</td>
<td></td>
<td>$0.06</td>
</tr>
<tr>
<td>Peak (4PM - 8PM)</td>
<td></td>
<td>$0.27</td>
<td></td>
</tr>
<tr>
<td>Off-Peak</td>
<td></td>
<td>$0.07</td>
<td></td>
</tr>
<tr>
<td>Demand Charge ($/kW)</td>
<td></td>
<td></td>
<td>$10.00</td>
</tr>
</tbody>
</table>
**Sample Application: Customers**

We model the rates for the following customers:

<table>
<thead>
<tr>
<th>Sample Usage Patterns</th>
<th>Peak Usage</th>
<th>Off-Peak Usage</th>
<th>Total Usage</th>
<th>Demand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Customer A</td>
<td>80</td>
<td>300</td>
<td>380</td>
<td>3</td>
</tr>
<tr>
<td>Customer B</td>
<td>150</td>
<td>850</td>
<td>1000</td>
<td>4</td>
</tr>
<tr>
<td>Customer C</td>
<td>250</td>
<td>2250</td>
<td>2500</td>
<td>7</td>
</tr>
</tbody>
</table>
Sample Application: New Charges

<table>
<thead>
<tr>
<th>Customer</th>
<th>Current Rate</th>
<th>Time-of-Use</th>
<th>Demand Charge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Customer A</td>
<td>$48.00</td>
<td>$52.60</td>
<td>$62.80</td>
</tr>
<tr>
<td>Customer B</td>
<td>$110.00</td>
<td>$110.00</td>
<td>$110.00</td>
</tr>
<tr>
<td>Customer C</td>
<td>$260.00</td>
<td>$235.00</td>
<td>$230.00</td>
</tr>
</tbody>
</table>
Sample Application: Customer A

<table>
<thead>
<tr>
<th>Customer A</th>
<th>Current Rate</th>
<th>Time-of-Use</th>
<th>Demand Charge</th>
<th>Time-of-Use % Change</th>
<th>Demand Charge % Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Usage</td>
<td>380</td>
<td>379</td>
<td>376</td>
<td>-0.4%</td>
<td>-1.1%</td>
</tr>
<tr>
<td>Peak Usage</td>
<td>80</td>
<td>73</td>
<td></td>
<td>-9.1%</td>
<td></td>
</tr>
<tr>
<td>Demand</td>
<td>3.0</td>
<td>2.6</td>
<td></td>
<td></td>
<td>-13.8%</td>
</tr>
</tbody>
</table>

*Demand is measured in kW, all else in kWh.
## Sample Application: Customer B

<table>
<thead>
<tr>
<th>Customer B</th>
<th>Current Rate</th>
<th>Time-of-Use</th>
<th>Demand Charge</th>
<th>Time-of-Use % Change</th>
<th>Demand Charge % Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Usage</td>
<td>1,000</td>
<td>1,000</td>
<td>1,000</td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
<tr>
<td>Peak Usage</td>
<td>150</td>
<td>134</td>
<td>-10.4%</td>
<td>0.0%</td>
<td></td>
</tr>
<tr>
<td>Demand</td>
<td>4.0</td>
<td>3.5</td>
<td>-12.9%</td>
<td>0.0%</td>
<td></td>
</tr>
</tbody>
</table>

*Demand is measured in kW, all else in kWh.*
## Sample Application: Customer C

<table>
<thead>
<tr>
<th>Customer C</th>
<th>Current Rate</th>
<th>Time-of-Use</th>
<th>Demand</th>
<th>Time-of-Use % Change</th>
<th>Demand Charge % Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Usage</td>
<td>2,500</td>
<td>2,511</td>
<td>2,513</td>
<td>0.4%</td>
<td>0.5%</td>
</tr>
<tr>
<td>Peak Usage</td>
<td>250</td>
<td>222</td>
<td></td>
<td>-11.0%</td>
<td></td>
</tr>
<tr>
<td>Demand</td>
<td>7.0</td>
<td>6.0</td>
<td></td>
<td></td>
<td>-14.0%</td>
</tr>
</tbody>
</table>

*Demand is measured in kW, all else in kWh.*
Utility Application

- In 2016, we worked with Xcel Energy to predict the impact of a proposed combination residential demand/time-of-use structure.
  - Over 200 customers
  - Revenue-neutrality adjustments
  - Predicted summer peak usage reduction of 11.6%
  - Predicted summer total usage increase of 0.7%
Conclusion

- The PRISM model is a flexible tool for predicting residential response to demand-based rate structures.

- Limitations
  - Only as accurate as the elasticity inputs
    - Elasticity varies by region
  - Not as accurate as a pilot
Appendix: PRISM Methodology Equations

\[
\frac{kWh}{hr_{\sigma_1}} = \frac{h \times kWh/hr_1}{\ln\left(\frac{kWh}{hr_{\rho_0}}\right) + \varepsilon_{CES}\left(\ln\left(\frac{P_{\rho_1}}{P_{\sigma_1}}\right) - \ln\left(\frac{P_{\rho_0}}{P_{\sigma_0}}\right)\right)}
\]

\[
kWh/hr_{\rho_1} = e^{\ln\left(\frac{kWh}{hr_{\rho_0}}\right) + \varepsilon_{CES}\left(\ln\left(\frac{P_{\rho_1}}{P_{\sigma_1}}\right) - \ln\left(\frac{P_{\rho_0}}{P_{\sigma_0}}\right)\right)} \times kWh/hr_{\sigma_1}
\]
Presenter Information

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Angela Gunn is a senior research analyst in The Brattle Group’s San Francisco office. She has worked with economic experts to support testimony on topics such as ratemaking, water allocation, and the economic impacts of energy infrastructure. Ms. Gunn holds a B.A. in Economics from Pomona College and will be pursuing a Ph.D. in Applied Economics at the Wharton School of the University of Pennsylvania in Fall 2017.

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