Dynamic Pricing & Demand Response

PRESENTED TO
IPU's Annual Regulatory Studies Program:
The Fundamentals Course
Lansing, Michigan

PRESENTED BY
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August 11, 2016
Agenda

Benefits of dynamic pricing

Barriers to dynamic pricing and seven myths debunked

Results of experimental roll-outs: case study #1 at BGE

Results of full-scale roll-outs: case study #2 in Ontario

Opt-in vs. opt-out: case study #3 at SMUD
Benefits of Dynamic Pricing
In the U.S., We Lose $10 Billion Each Year Due to Flat Rate Pricing

33% of the nation’s 114 million households are on smart meters

But only 1% are on time-based rates
  - And only 1% of these are on dynamic pricing rates

That prevents us from harnessing the benefits of universal dynamic pricing
  - $7B/year in lower energy costs
  - $3B/year in reduced cross-subsidies
Seven Myths Stand in the Way
The Seven Myths about Dynamic Pricing

Myth #1: Customers don’t respond to dynamic pricing

Myth #2: Customer response does not vary with the magnitude of the price signal

Myth #3: Enabling technologies don’t boost demand response

Myth #4: Customer response does not persist over time

Myth #5: Dynamic pricing will hurt low-income customers

Myth #6: Customers have never encountered dynamic pricing

Myth #7: Customers don’t want dynamic pricing
Myth #1: Customers Don’t Respond to Dynamic Pricing

Because results vary widely, some conclude that we have learned nothing about customer response.

60% of the Tests Have Produced Peak Reductions of 10% or Greater

Grouping Results by Tariff Design Helps Explain Some of the Variation in Impacts

Myth #2: Customer Response Does Not Vary with the Magnitude of the Price Signal

Not only do customers respond, but the magnitude of their response varies with the price incentive. The higher the incentive, the greater their demand response.

To study this relationship between price incentive and peak energy reduction, we have estimated the Arc of Price Responsiveness. The Arc is based on 212 time-varying pricing treatments from around the world.
We Plot Demand Response against the Peak to Off-Peak Price Ratio

TOU Impacts (price only)

Dynamic Pricing Impacts (price only)

Notes: Chart includes 67 data points from TOU pricing treatments without enabling technology.
The Arc was specified considering all 235 time-varying pricing treatments including CPP, VPP, PTR, and TOU.
Myth #3: Enabling Technologies Don’t Boost Demand Response

The data shows that enabling technologies boost price responsiveness

TOU Impacts

Dynamic Pricing Impacts

Notes: Chart includes 67 data points from TOU pricing treatments without enabling technology and 30 data points with enabling technology.

Notes: Chart includes 68 data points from dynamic pricing treatments without enabling technology and 70 data points with enabling technology.
Myth #4: Customer Response Does Not Persist Over Time

We observe that customer response has persisted in long-lived pilots
- Over two years in California, Oklahoma and Washington, DC
- Over four years in Maryland

Full-scale TOU programs have been in place for decades
- The French tempo tariff, a day-specific peak and off-peak rate, goes back to 1965
- Arizona’s TOU rates go back to 1980
Myth #5: Dynamic Pricing Will Hurt Low-Income Customers

Nearly 80% of low income customers are paying more under flat rates
Low Income Customers Are Price Responsive, So They Will Save More with Dynamic Pricing

Note: For the PepcoDC pilot, the average residential response excludes low income customers that qualify for the RAD program.
Myth #6: Customers Have Never Encountered Dynamic Pricing

Consumers experience dynamic pricing in everyday purchases

In the 1990s, Robert Cross highlighted the trend toward setting prices dynamically to maximize profit*

Today, dynamic prices are used by a variety of capital-intensive industries such as airlines, hotels, rental car firms, and railroads

Since 2009, tickets for San Francisco Giants baseball games have varied according to the value of the game

Myth #7: Customers Don’t Want Dynamic Pricing

In Connecticut Light and Power’s Plan-it Wise pilot, post-pilot surveys and focus groups were carried out to examine how customers felt about their participation in the pilot. Residential customers who participated in the survey had an overall satisfaction rating of 5.1 out of a possible 6, with 92 percent saying they would participate again.

Customers showed similarly high levels of satisfaction with pilots at Consumers Energy, Baltimore Gas and Electric, Hydro One and California utilities.
Customers Are Not Inconvenienced by Time-Varying Pricing

Related to the myth that customers do not want dynamic pricing is the idea that customers will have to resort to extreme measures to save money on dynamic rates, such as getting up at 2 AM to do the laundry.

In a recent survey of customers who participated in the Hydro One TOU pilot, only 4 percent found the changes in their daily activities to be inconvenient.

Most customers value the opportunity to save money by making small adjustments in their energy consumption schedules.
Results of Experimental Roll-outs
Baltimore Gas & Electric’s Smart Energy Pricing (SEP) Pilot

Scientifically valid sample design and M&V method

Continued for four consecutive summers (2008-2011)

- The Brattle Group carried out the impact evaluation for each of the summers and analyzed whether price-responsiveness persists over time

More than 11 different treatments tested over the course of four years with nearly 950 treatment customers at its height

Yielded invaluable information for the design of BGE’s full-scale pricing program
# SEP Pilot Tested 11 Treatments Over the Course of Four Years

<table>
<thead>
<tr>
<th>Treatment</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
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<tr>
<td><strong>Peak Time Rebate (Price Only)</strong></td>
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<tr>
<td><strong>Peak Time Rebate + Energy Orb</strong></td>
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<tr>
<td><strong>Peak Time Rebate + Energy Orb + AC Switch</strong></td>
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<tr>
<td><strong>Peak Time Rebate + Energy Orb + Smart Thermostat</strong></td>
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<tr>
<td><strong>Peak Time Rebate + Smart Thermostat</strong></td>
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<tr>
<td><strong>Dynamic Peak Price (DPP)</strong>*</td>
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<tr>
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<tr>
<td><strong>Peak Time Rebate + Change in Event Window</strong></td>
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<td>X</td>
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<tr>
<td><strong>Peak Time Rebate + In Home Display/Portal</strong></td>
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<tr>
<td><strong>Peak Time Rebate + Legacy DLC Program</strong></td>
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<tr>
<td><strong>Legacy DLC Program</strong></td>
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<td><strong>Control Group</strong></td>
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</table>
Findings Informed BGE’s Full Scale Deployment of Dynamic Pricing

Customers were responsive to the price signals

- Customers responded similarly to the CPP and PTR rates
- Elasticity of substitution ranged from 0.100 to 0.149 (depending on weather conditions)
- The peak impacts ranged from 23 to 34 percent at a 10:1 price ratio (depending on the weather)
- Daily price elasticity was estimated at -0.05

Customers who were on the price-only treatment for four years showed persistence in their price responsiveness

BGE rolled out opt-out PTR rates to 315,000 customers in the summer of 2013

- 82% of the customers engaged
Northeast Utilities (Connecticut Light & Power) Pilot

The Plan-it Wise Energy Program (PWEP) began to call critical peak days in June 1, 2009 and ran through August 31, 2009

- The pre-treatment period covered May 2009
- 10 event days were called during the pilot period

Around 2,200 residential and small C&I customers were exposed to time-varying rates during the pilot period

- 1,114 residential and 1,123 small C&I customers were enrolled in the program as of August 2009

Summer 2009 was a relatively mild summer
NU Tested the Impact of Different Rate Structures in Conjunction with Several Different Technologies

PWEP tested three different rate structures with two levels of prices for each, yielding a total of six different price levels:

- Time-of-Use (TOU)
  - Low and High levels were tested

- Peak Time Pricing (PTP)
  - Low and High levels were tested

- Peak Time Rebate (PTR)
  - Low and High levels were tested
NU Also Tested the Effectiveness of Several Different Technologies in the Pilot

Technologies tested in the pilot program include:

- Smart thermostat
- A/C switch
- Energy orb
- In-home display (IHD)

The effectiveness of the technologies were tested by enabling certain customers with one of these technology options and comparing their load profiles with those of other customers who did not have these enabling technologies.
Demand Response Impact Summary, Residential LO
Demand Response Impact Summary, Residential HI

Critical Peak Hour Impact (% of original consumption)

Customer Type

- 25.0%
- 20.0%
- 15.0%
- 10.0%
- 5.0%
0.0%
-5.0%
-10.0%
-15.0%
-20.0%
-25.0%

TOU
TOU ORB
TOU TECH
PTR
PTR ORB
PTR TECH
PTP
PTP ORB
PTP TECH

-10.9%
-10.9%
-17.8%
-16.1%
-23.3%
-3.1%
-3.1%
-3.1%
-25.0%
-20.0%
-15.0%
-10.0%
-5.0%
0.0%

Average Customer

-16.1%
-16.1%
-17.8%

-23.3%

PWEP Results—Residential Customers

- **TOU** customers reduced their critical peak period usage by **1.6 to 3.1** percent
- **PTR** customers reduced their critical peak period usage by **7.0 to 17.8** percent
- **PTP** customers reduced their critical peak period usage by **10.2 to 23.3** percent
- **Presence of ORB or IHDs** does not have a statistically significant incremental effect for any of the PTP, PTR, and TOU groups
- **Presence of A/C switch or thermostat** increases the impacts for PTP and PTR groups whereas it does not have a statistically significant incremental effect for the TOU group
- As a result of the programs, **total monthly consumption increases** by about 0.2 percent for the PTP program and **decreases** by about 0.2 percent for PTR and TOU programs
Consumers Energy’s Dynamic Pricing Pilot (“Personal Power Plan” or PPP) Took Place in the Summer of 2010

It began on July 2010 and ran through September 2010

- Six event days were called during the pilot (treatment) period
- The pre-treatment period covered May and June 2010

Around 600 customers were placed on dynamic pricing or informational treatments during this period

- The pilot also involved two distinct control groups
  - One group was uninformed of the pilot (GCON) ~ 230 customers
  - The other was informed of the pilot (RCON) ~ 90 customers
Consumers Energy Ran a Personal Power Plan Pilot in 2010

<table>
<thead>
<tr>
<th></th>
<th>TREATMENT</th>
<th>TOTAL</th>
<th>CONTROL</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>RCPP</td>
<td>RCPP_TECH</td>
<td>RCPR</td>
</tr>
<tr>
<td>PRE-TREATMENT</td>
<td>122</td>
<td>98</td>
<td>152</td>
</tr>
<tr>
<td>TREATMENT</td>
<td>122</td>
<td>98</td>
<td>152</td>
</tr>
</tbody>
</table>

Note: The counts are restricted to the active customers as of September 01, 2010.
PPP Tested the Impact of Dynamic Prices and Information in Conjunction with an Enabling Technology

PPP tested two different dynamic pricing structures:
- Critical peak pricing treatment (RCPP)
- Critical peak rebate treatment (RCPR)

PPP tested the role of information in changing the usage behavior of the customers
- Informational treatment (RPIO)

PPP also tested the effectiveness of an intelligent communicating thermostat (ICT) in boosting the impacts from prices or information alone
- CPP and ICT treatment (RCPP_TECH)
- Informational and ICT treatment (RPIO_TECH)
Estimation of Demand Equations

In order to predict consumption under new rate designs, we estimate a constant elasticity of substitution (CES) demand system that consists of two equations:

- Substitution Equation models changes in load shape caused by changing peak-to-off peak prices
- Daily Equation models changes in average daily consumption caused by changing average daily prices

Using elasticities estimated by this system of two equations, we predict consumption by rate period

- The price differential between the mid-peak and off-peak periods is very small. For that reason, we combined the mid-peak and off-peak periods into one period
Summary of the Price Elasticities from the Pricing Treatments

The results showed that the substitution elasticities for RCPP, RCPP_Tech, and RCPR customers were not statistically distinguishable from each other

- In other pilots, the substitution elasticities were higher for the customers with enabling technologies. This result did not hold in the PPP pilot. This could be as a result of ease of central air-conditioning (CAC) control overrides presented to the customers in the PPP pilot.

- The similarity of the substitution elasticities for the CPP and CPR treatments was also observed in the BGE’s SEP 2008 pilot but not in the Connecticut Light & Power (CL&P) and Pepco pilots.

The daily elasticities for the RCPP and RCPR customers were not statistically significant, whereas the daily elasticity is large and statistically significant for the RCPP_Tech customers.
Summary of the Impacts from the Pilot Treatments

On the critical event days:
- The RCPP customers reduced their peak usage by 15.2%
- The RCPP_Tech customers reduced their peak usage by 19.4%
- The RCPR customers reduced their peak usage by 15.9%
- The RPIO customers reduced their peak usage by 5.8%
- The RPIO_Tech customers reduced their peak usage by 5.8%

On the non-event days:
- The RCPP customers reduced their peak usage by 5.0%
- The RCPP_Tech customers reduced their peak usage by 3.9%
- The RCPR customers reduced their peak usage by 7.8%

On a monthly basis:
- The RCPP and RCPR customers did not change their monthly usage
- The RCPP_Tech customers increased their monthly usage by 0.8%
Peak Demand Impacts Across the PPP Treatments

Critical Peak Hour Impact (% of original consumption)

-15.2%
-15.9%
-5.8%
-5.8%
-19.4%
-22.5%
-20.0%
-17.5%
-15.0%
-12.5%
-10.0%
-7.5%
-5.0%
-2.5%
0.0%

Customer Type

Average Customer

RCPP
RCPP_TECH
RCPR
RPIO
RPIO_TECH
Load Profile on a Proxy Event Day Before and After Demand Response
Results of Full-Scale Roll-Outs
Residential Dynamic Pricing Is Transitioning to a New Phase: Full-scale Deployment

Several utilities are achieving significant participation through aggressive opt-in programs
- Time-of-use (TOU) rates at APS and SRP in Arizona
- Variable peak pricing (VPP) at OG&E in Oklahoma

Others are rolling out default programs for the mass market
- Pepco in Delaware and Maryland
- BGE in Maryland
- Sacramento Municipal Utility District (SMUD) in California
- The Province of Ontario, Canada
Case Study #2: Ontario’s Residential TOU Program

Besides Italy, Ontario is the only region in the world to deploy Time-of-Use (TOU) rates for generation charges to all customers who stay with regulated supply.

TOU rates were deployed in Ontario to incentivize customers to curtail electricity usage during the peak period and possibly to reduce overall electricity usage.

The Brattle Group was retained by Ontario Power Authority to undertake the impact evolution of the TOU program.

- Three year assignment; the 1st Year Impact Evaluation results are presented here, the 2nd year study is underway.
TOU Rates In Ontario

Note: The prices above are commodity only, this study uses the all-in prices that customers actually face
Institutional Background

Ontario has 70+ Local Distribution Companies (LDCs)
- The Regulated Price Plan (RPP) offers TOU rates on a default basis
- Customers can opt-out of RPP by contracting with a retailer

Smart Metering Initiative announced by provincial government in 2004 required the LDCs required to
- Roll out smart meters by 2010
- Deploy TOU rates by 2012
- Migrate smart meter data to a centralized Meter Data Management and Repository (MDM/R) before TOU
Timing, Data and Challenges

For example: Central Region Rollout Schedule - Residential

- Dotted line: AMI customers in sample before TOU
- Solid line: AMI customers in sample on TOU

total number of AMI customers in sample before TOU

total number of AMI customers in sample on TOU
About the Study

Three year effort to measure load shifting and conservation impacts of TOU by calendar year

- All Impact Reports on IESO website

Examine three seasons and two customer classes

- Summer, Winter and IESO Evaluation Peak
- Residential and general service

Today’s Results from Study Year 3

- Includes 8 LDCs
- Constitute more than 50% of Ontario electricity accounts.
Methodology

Use Generalized Addilog Demand System to measure impacts
- Structural Model—allows out of sample predictions
- Allows for substitution elasticities to vary between periods

Impacts calculated separately for each of four Ontario sub-regions
- Impacts allowed to vary by socio-demographic factors

Reweight regional impacts using census characteristics to obtain representative regional impacts

Province-wide impacts are calculated by weighting the regional impacts by regional customer count shares
Results

There is significant evidence of load shifting across all regions and years

- Reduction in usage in the peak period, some reduction in the mid-peak
- Increase in usage in the off-peak periods

The load shifting model parameters are generally well-behaved and have magnitudes that have been observed in other pilots

There are some unexpected, positive and significant elasticities in the conservation models, likely due to insufficient data history and little price variation
Residential Summer Load Shifting Across All Periods for Ontario

Province-Level Load Shifting Summer Residential

* Period 6 was mid-peak before May 2011
Note: Black bars indicate 95% confidence intervals for the impact
Residential TOU Peak Period Impacts Across Regions

Summer TOU Peak Period (11am – 5pm)
Residential Load Shifting Results

Note: Black bars indicate 95% confidence intervals for the impact
Ontario Residential TOU Impacts Compared to TOU Pilots from Around the Globe

All of the data points shown in blue above, are currently drawn from TOU pilot studies, not full scale rollouts like the OPA.
Ontario Residential TOU Impacts Compared to TOU Pilots from Around the Globe

All of the data points shown in blue above, are currently drawn from TOU pilot studies, not full scale rollouts like the OPA.

Close-up of Ontario Residential TOU Summer Impacts Compared to TOU Pilots from Around the World
Residential Substitution Elasticities Compared to Pilot Studies Elsewhere*

* The Ontario TOU rollout was system wide, not a pilot

Residential Substitution Elasticities Compared to Other Pilots
(Summer TOU Peak Period)
Residential Winter Load Shifting Across All Periods for Ontario

Provincial Winter Load Shifting for Residential

* Period 6 was peak before May 2011

Note: Black bars indicate 95% confidence intervals for the impact
Annual Residential Conservation Impacts by Region

We did not find any evidence of residential conservation due to the rollout of TOU rates

- There is very little variation in average prices over time

Residential TOU and Non-TOU Prices 2010-2014
Conclusions from the Ontario deployment

By 2012, the province of Ontario had switched nearly 95% of residential customers to default TOU

We exploit variations in the timing of the rollout as well as the existence of non-TOU retail customers to estimate the load shifting and conservation impacts of TOU

Load shifting impacts are consistent with those found in other studies and relatively consistent across regions in Ontario and study years

We find no evidence of TOU induced conservation
Opt-In vs. Opt-Out Roll-Outs
Should TOU Rates Be Rolled Out as the Default Tariff?

The average TOU enrollment level is 28% under default flat rates. When TOUs are the default, the average enrollment rate rises to 85%.
Dynamic Pricing Enrollment Levels Are Similar to Those of the TOU Offerings

The average dynamic pricing enrollment is 20% under default flat rates and 84% when dynamic prices are the default.
Should We Roll Out Dynamic Pricing as the Default Rate?

In general, there are three types of customers:

Type A customers: Highly interested in TVR (time varying rates)

Type B customers: Somewhat interested in TVR

Type C customers: Not interested in and may be hostile to TVR
We Develop Three Hypotheses for the Impact of a Default Time Varying Rate

**H1: \( A_{\text{impact}} + B_{\text{impact}} = A_{\text{impact}} \)**
- Only Type A customers respond to the TVR, so the impact of the TVR for Type B customers is zero

**H2: \( A_{\text{impact}} + B_{\text{impact}} < A_{\text{impact}} \)**
- There is consumer backlash to the default TVR so that all Type B customers and even some Type A customers opt out

**H3: \( A_{\text{impact}} + B_{\text{impact}} > A_{\text{impact}} \)**
- All Type A customers and some Type B customers respond to the TVR
We Expect that H3 Is the Most Likely Outcome

Overall demand response savings will always be greater under default TVR than a default flat rate, provided the impact for group B is positive.

Participation in TVR Under Different Default Options

- **Default Flat Rate with Opt-In TVR**
  - Under default flat rates, a relatively small number of high impact customers in group A participate in TVR.

- **Default TVR with Opt-In Flat Rate**
  - Under default TVR, a large number of lower impact group B customers participate in TVR in addition to the high impact Group A customers.
Case Study #3: Opt-In vs. Opt-Out at SMUD

A pilot by Sacramento Municipal Utility District tested both opt-in and opt-out rates. By assigning the entire opt-in impact to Type A customers, we can calculate the Type B customers’ impact according to the equation:

\[ \text{Impact}_{A+B} = \text{Impact}_A \times \left( \frac{\text{Share}_A}{\text{Share}_{A+B}} \right) + \text{Impact}_B \times \left( \frac{\text{Share}_B}{\text{Share}_{A+B}} \right) \]

Filling in the values and rearranging, we estimate that Type B customers have an impact of 2% on default TOU rates, one third of the impact of Type A customers.

### Peak Reductions for SMUD

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<tr>
<th></th>
<th>TOU</th>
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<td>Opt-In TVR</td>
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<td>Enrollment Rate</td>
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<td>Peak Reduction for Participating Customers</td>
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<td>Aggregate Peak Reduction (MW)</td>
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Notes:
Assumed Coincident Demand (MW): 2,000
The Transition
Transitioning to Dynamic Pricing

- **Opt-in Rate**
  - Leave Flat Rate Unchanged
  - Provide Shadow Bills
  - Change Flat Rate
  - Don’t Provide Shadow Bills

- **Opt-out Rate**
  - Offer Two-Part Rate
    - Set First Part Equal to Historic Load Shape
    - Customer Buys First Part as a Forward Market Transaction
    - Offer Bill Protection
    - Don’t Offer Bill Protection
  - Offer Single-Part Rate

**Steps**
- Pilot Dynamic Pricing
- AMI Business Case
- Deploy AMI

**Additional Steps**
- Conduct Measurement and Verification
- Understand Customer Preferences
- Segment the Market
- Create Segment-Specific Messages
- Get the Word Out
- Educate and Answer Questions
Ahmad Faruqui is an economist whose consulting practice is focused on the efficient use of energy. His areas of expertise include rate design, demand response, energy efficiency, distributed energy resources, advanced metering infrastructure, plug-in electric vehicles, energy storage, inter-fuel substitution, combined heat and power, microgrids, and demand forecasting. He has worked for more than a hundred clients on five continents. These include electric and gas utilities, state and federal commissions, independent system operators, government agencies, trade associations, research institutes, and manufacturing companies. Ahmad has testified or appeared before commissions in Alberta (Canada), Arizona, Arkansas, California, Colorado, Connecticut, Delaware, the District of Columbia, FERC, Illinois, Indiana, Kansas, Maryland, Minnesota, Nevada, Ohio, Oklahoma, Ontario (Canada), Pennsylvania, ECRA (Saudi Arabia), and Texas. He has presented to governments in Australia, Egypt, Ireland, the Philippines, Thailand and the United Kingdom and spoken at energy seminars on all six continents. His research on the energy behavior of consumers has been cited in Business Week, The Economist, Forbes, National Geographic, The New York Times, the San Francisco Chronicle, the San Jose Mercury News, the Wall Street Journal and USA Today. He has appeared on Fox Business News, National Public Radio and Voice of America. He is the author, co-author or editor of four books and more than 150 articles, papers and reports on energy matters. His work has appeared 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 holds bachelors and masters degrees from the University of Karachi and a doctorate in economics from The University of California at Davis.

The views expressed in this presentation are strictly those of the presenter(s) and do not necessarily state or reflect the views of The Brattle Group.
References – I

References – II

- Faruqui, Ahmad, Dan Harris and Ryan Hledik. “Unlocking the €53 billion savings from smart meters in the EU: How increasing the adoption of dynamic tariffs could make or break the EU’s smart grid investment.” Energy Policy Volume 38, Issue 10 (October 2010): 6222-6231.
References – III

- Faruqui, Ahmad, Ryan Hledik, and Neil Lessem. “Smart by Default.” Public Utilities Fortnightly (August, 2014). http://www.fortnightly.com/fortnightly/2014/08/smart-default?page=0%2C0&authkey=e5b59c3e26805e2c6b9e469cb9c1855a9b0f18c67bbe7d8d4ca08a8abd39c54d


Videos

Georgetown University’s CSIS. A 90-minute panel session on time-variant pricing. Washington, DC.
https://www.youtube.com/watch?v=0p6ZHaXszRQ

NYU School of Law. A day-long conference on time-variation pricing as part of the REV Proceedings. New York, NY.
http://www.sallan.org/Sallan_In-the-Media/2015/04/rev_agenda_time_variant_p.php

Northwestern University’s Kellogg Alumni Club. A two hour debate on the merits of dynamic pricing. San Francisco, CA.
https://vimeo.com/20206833