The Brattle Group

The Tao of The Smart Grid

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August 24, 2011

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Outline

- Defining the smart grid
- AMI deployment
- Objections to AMI deployment
- Deployment of dynamic pricing
- Objections to dynamic pricing
- Sizing up the national
- Assessing utility-level costs and benefits
- Smart charging of plug-in vehicles

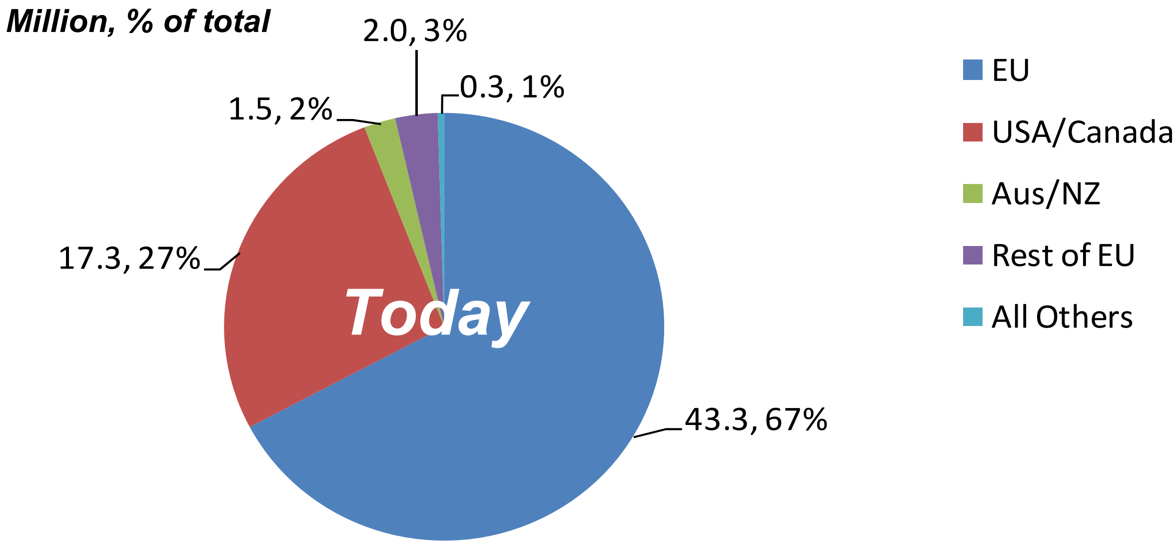
DEFINING THE SMART GRID

Some call it grid modernization

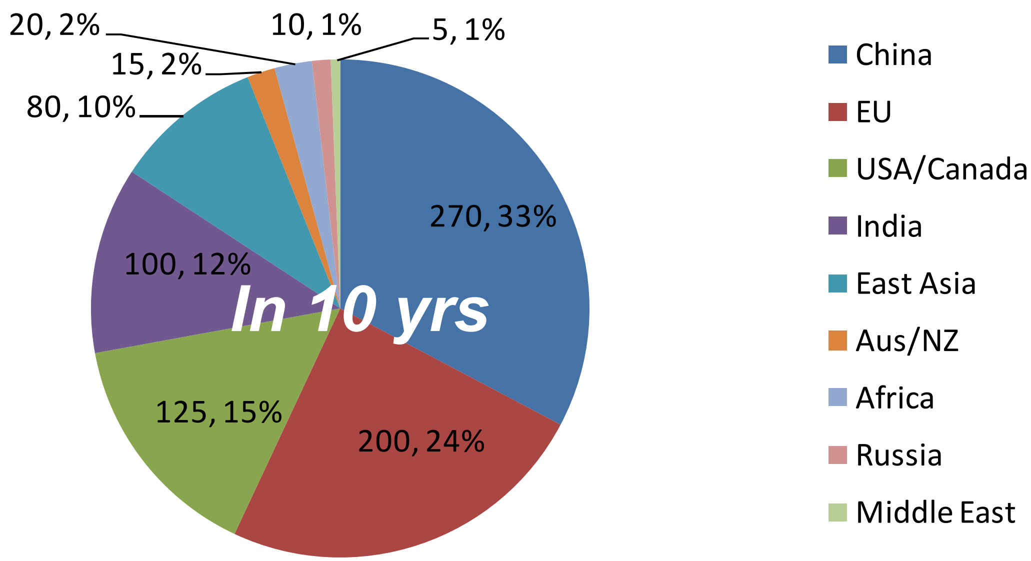
- The smart grid involves the introduction of digital technologies to the entire value chain for electricity that extends from the power plant to the customer
- The smart grid senses problems along the electric pathway before they arise and allows wiser use of energy by customers through two-way communication technologies
- Today, we are going to focus on the customer-facing side of the smart grid and use the following definition
  - Smart Grid = AMI + Demand Response + Dynamic Pricing + Distributed Energy Resources + Plug-in Electric Vehicles

AMI DEPLOYMENT

Smart meters are being deployed globally, as predicted by eMeter

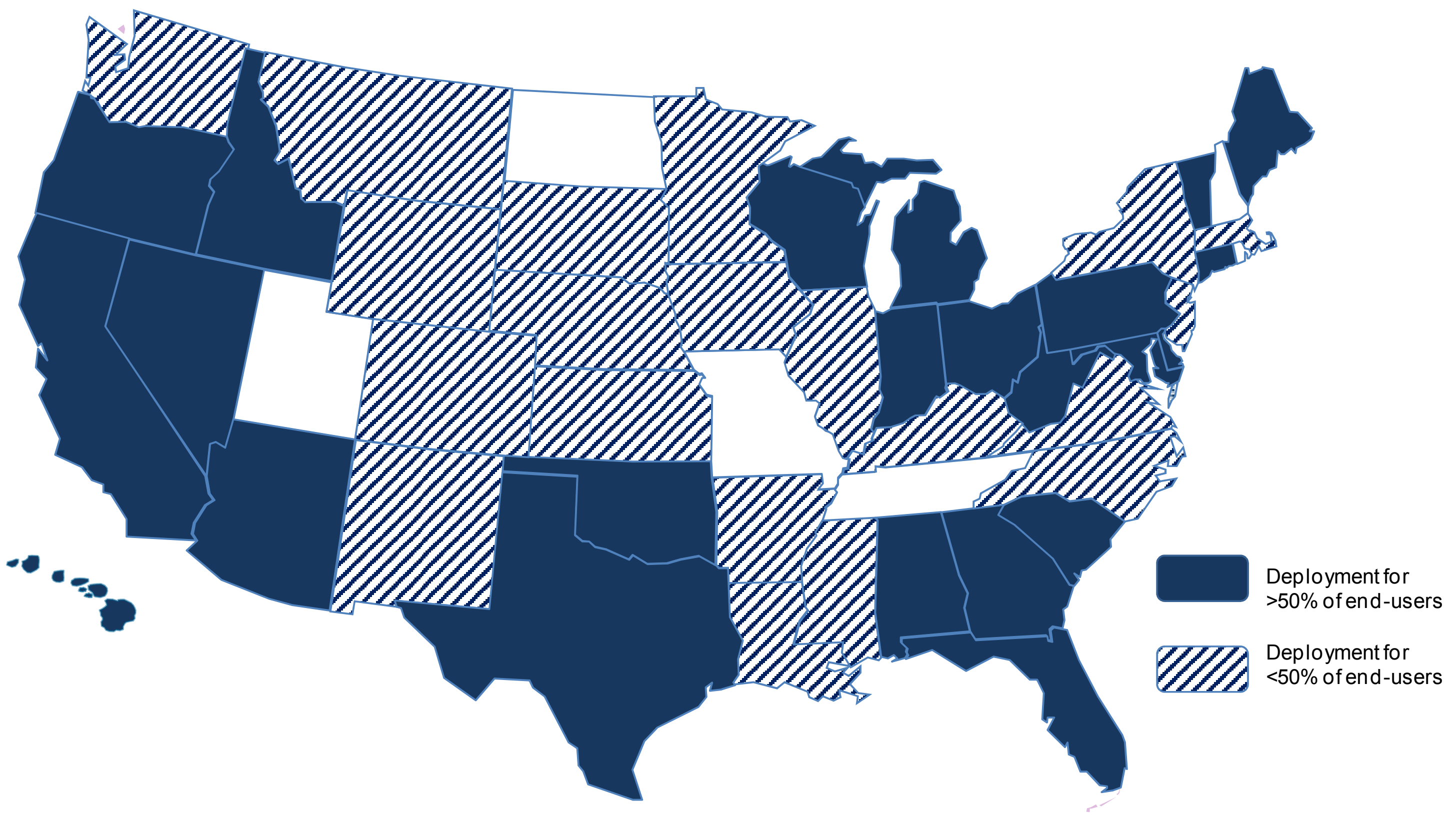


Over 64 million Smart Meters now in Place Worldwide



Over 825 million Smart Meters expected Worldwide in 10 years

Deployment is also underway in the US



(IEE, September 2010 - update underway)

US deployment, as predicted by Greentech Media

- In a few areas of the country, such as California and Texas, smart meters are almost fully deployed
- As of August 2011, approximately 22 million smart meters had been deployed in the U.S.
- It is likely that the number will rise threefold by 2015, representing approximately 50 percent of all US households.
- By the end of this decade, smart meters may be deployed to almost all US households

OBJECTIONS TO AMI DEPLOYMENT

Four main objections

- Adverse health effects
- Loss of privacy
- Compromise of cyber security
- Higher costs

All four objections are brought out in this strident video

- More than 300,000 hits since it came out
- The speaker, Jerry Day, comes across as the credible uncle next door
  – http://www.youtube.com/watch?feature=player_embedded&v=8JNFr_j6kdI
- Similar views have been expressed in recent white papers from AARP and NASUCA

For a rejoinder, check out these two videos

- Highlights from the consumers symposium at Connectivity Week in Santa Clara
  - http://www.youtube.com/watch?v=alXZFiRjwOM
- PowerCents dynamic pricing pilots (Washington, DC)
  - http://www.youtube.com/watch?v=Z6Tsky2xmW8&feature=related

DEPLOYMENT OF DYNAMIC PRICING

Recent trends

- Pilots are being carried out in North America, Europe and Australia
- Commissions in the District of Columbia and Maryland have ruled favorably on dynamic pricing
- A recent survey of AMI business cases indicates that about half embody dynamic pricing in some form
- Another survey has revealed that dynamic pricing is one of the top five issues on the minds of utility executives
- The federal government has invested more than $4 billion in pilot and demonstration projects involving the smart grid, some of which involve dynamic pricing

OBJECTIONS TO DYNAMIC PRICING

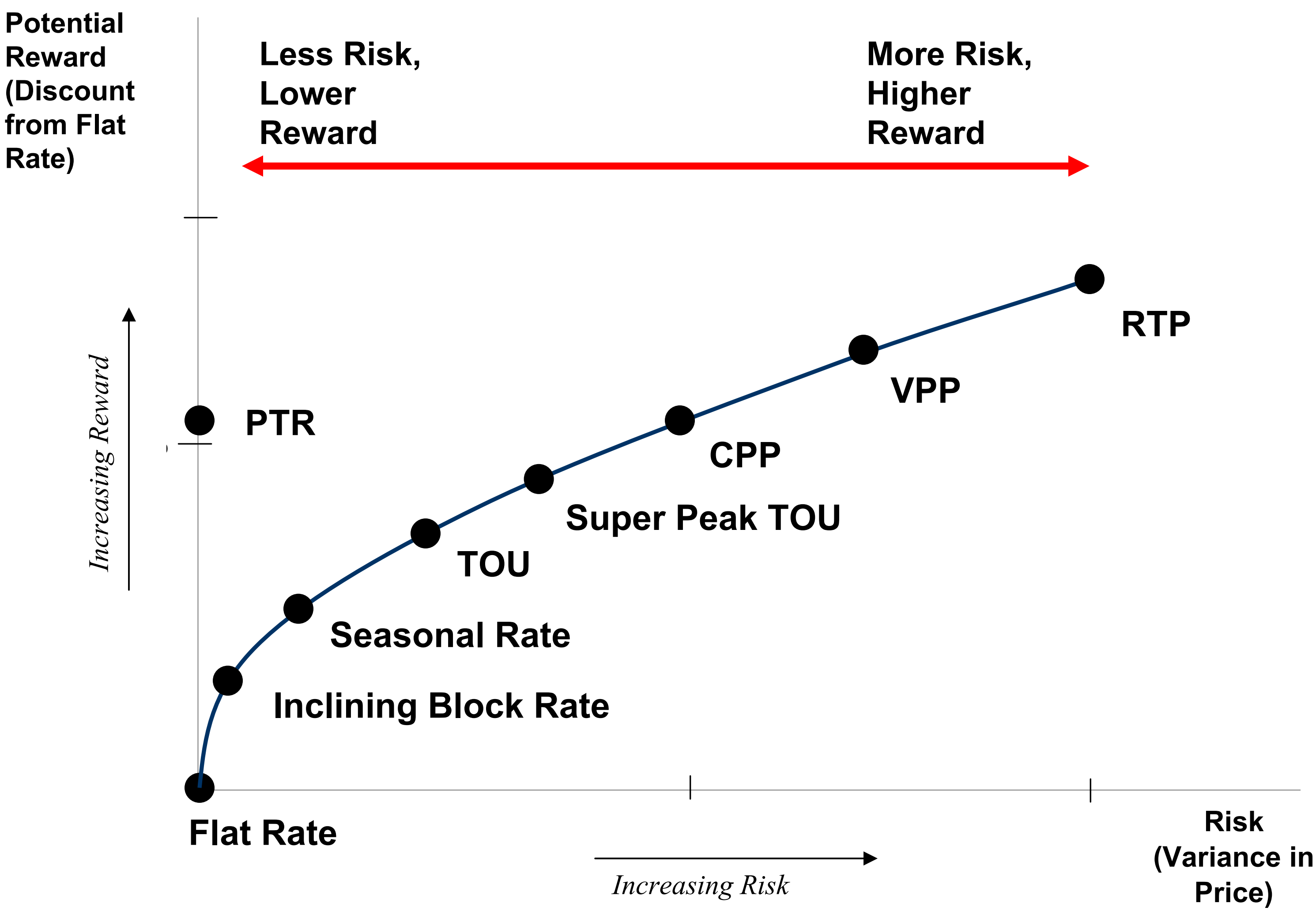
Commonly voiced concerns

- Dynamic pricing is punitive because customers cannot respond to higher prices since electricity is a necessity
  - Unlike other goods and services sold in the marketplace, demand for electricity is not price responsive
- Dynamic pricing will be injurious to the well-being of low income customers, senior citizens and people with disabilities

Mark Toney, Executive Director of TURN

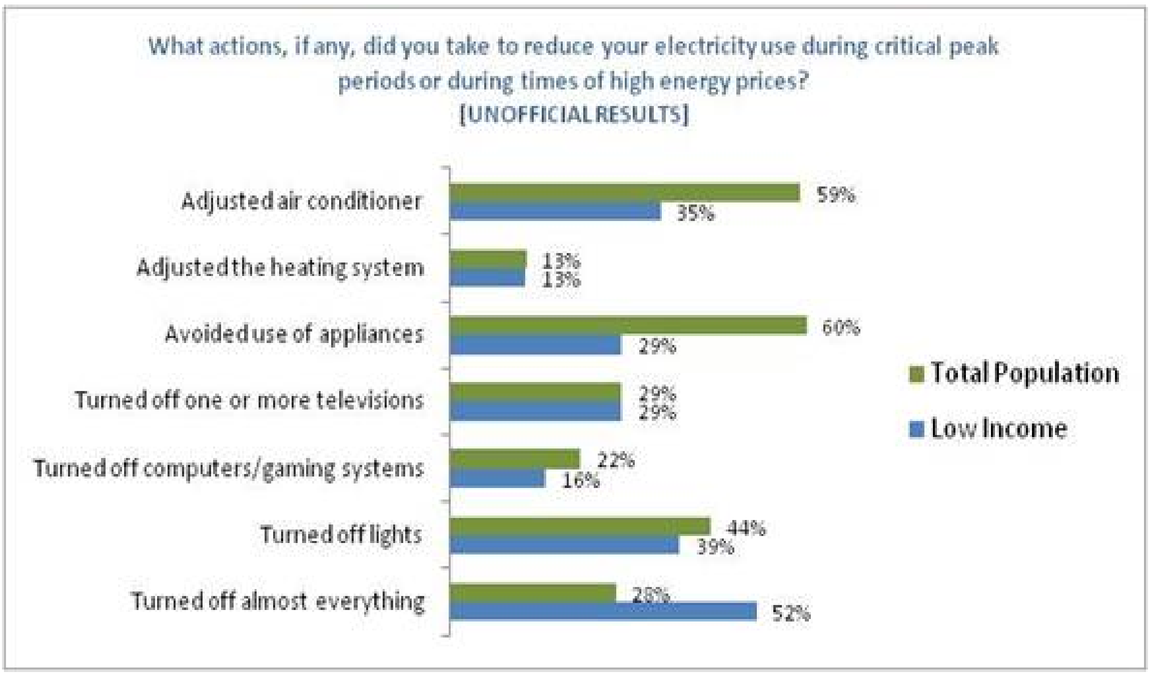
- He voiced all these concerns at an event sponsored by the Kellogg Alumni Association in San Francisco earlier this year
- You can watch the conversation at this link:http://www.vimeo.com/20206833.
- Similar views have been expressed by Barbara Alexander, Nancy Brockway and others

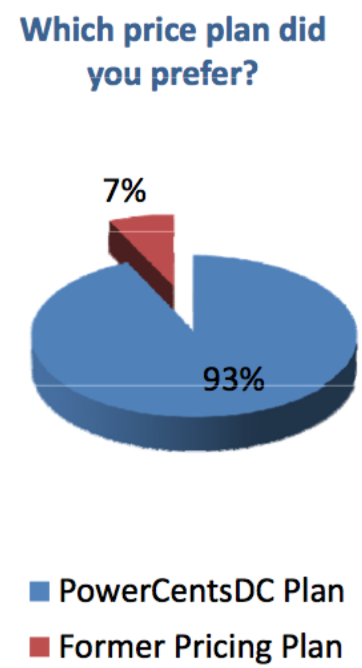
But dynamic pricing is about choice



It empowers consumers to change their behavior, if they want to

- Significant portion of low-income household budget (16%)* provides incentive
- Manageable adjustments and high customer satisfaction





Source:PowerCentsDC Pilot Data

*Cornell study on low-income households

Dynamic pricing encourages technological innovation

Web portal

Source: http://news.lehsys.com/2009/06/google-power-meter-energy

Programmable communicating thermostat

Source: http://www.zigbee.org/Products/CertifiedProducts/ZigBeeSmartEnergy.aspx

In-home display

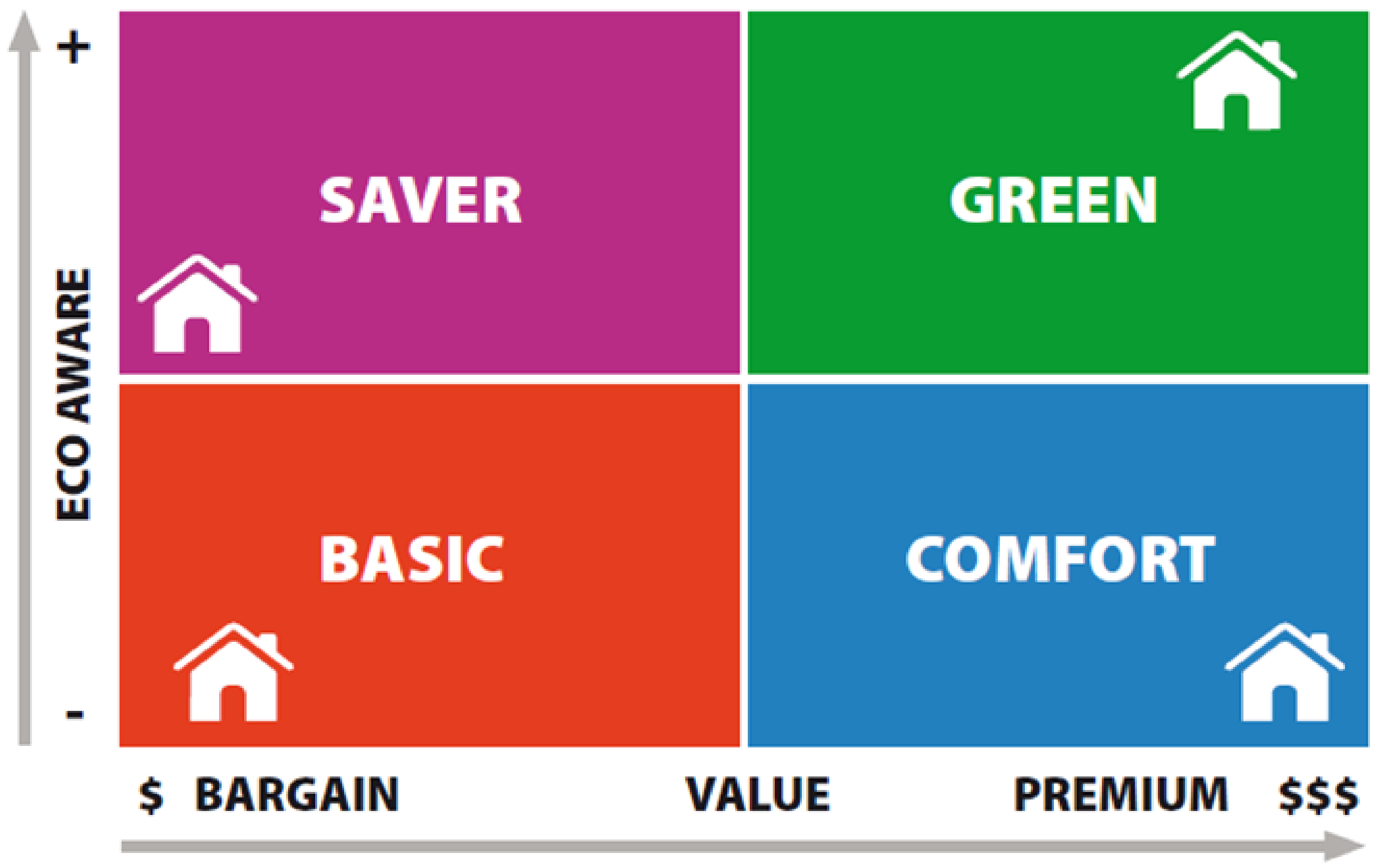
Source: http://www.prlog.org/10527353-aztechs-in-home-display-achieves-zigbee-certification.html

Home area network

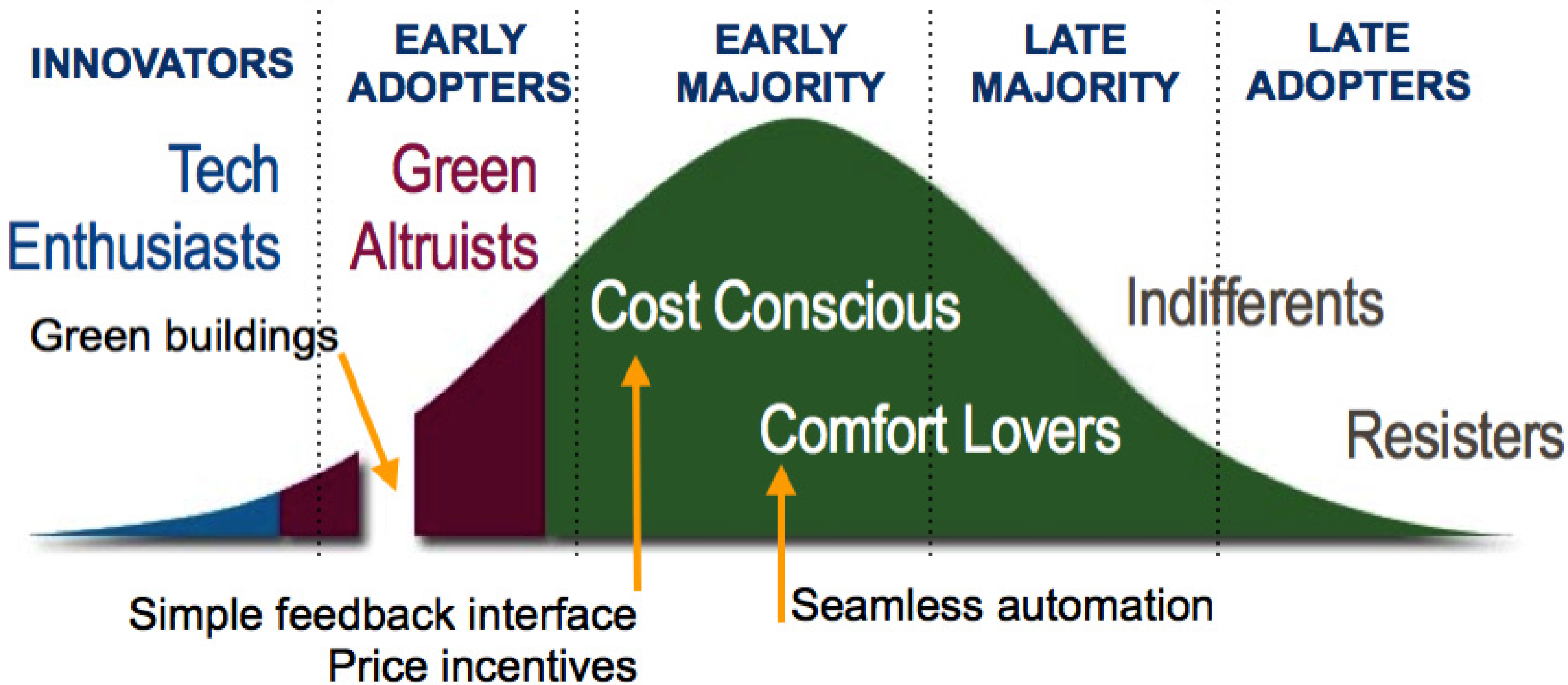
Source: http://www.cisco.com/web/consumer/products/hem.html#~consumers

Source: http://www.examiner.com/city-hall-in-louisville/ge-to-make-new-smart-washers-and-dryers-louisville

Customer segments have varying degrees of environmental and price sensitivity

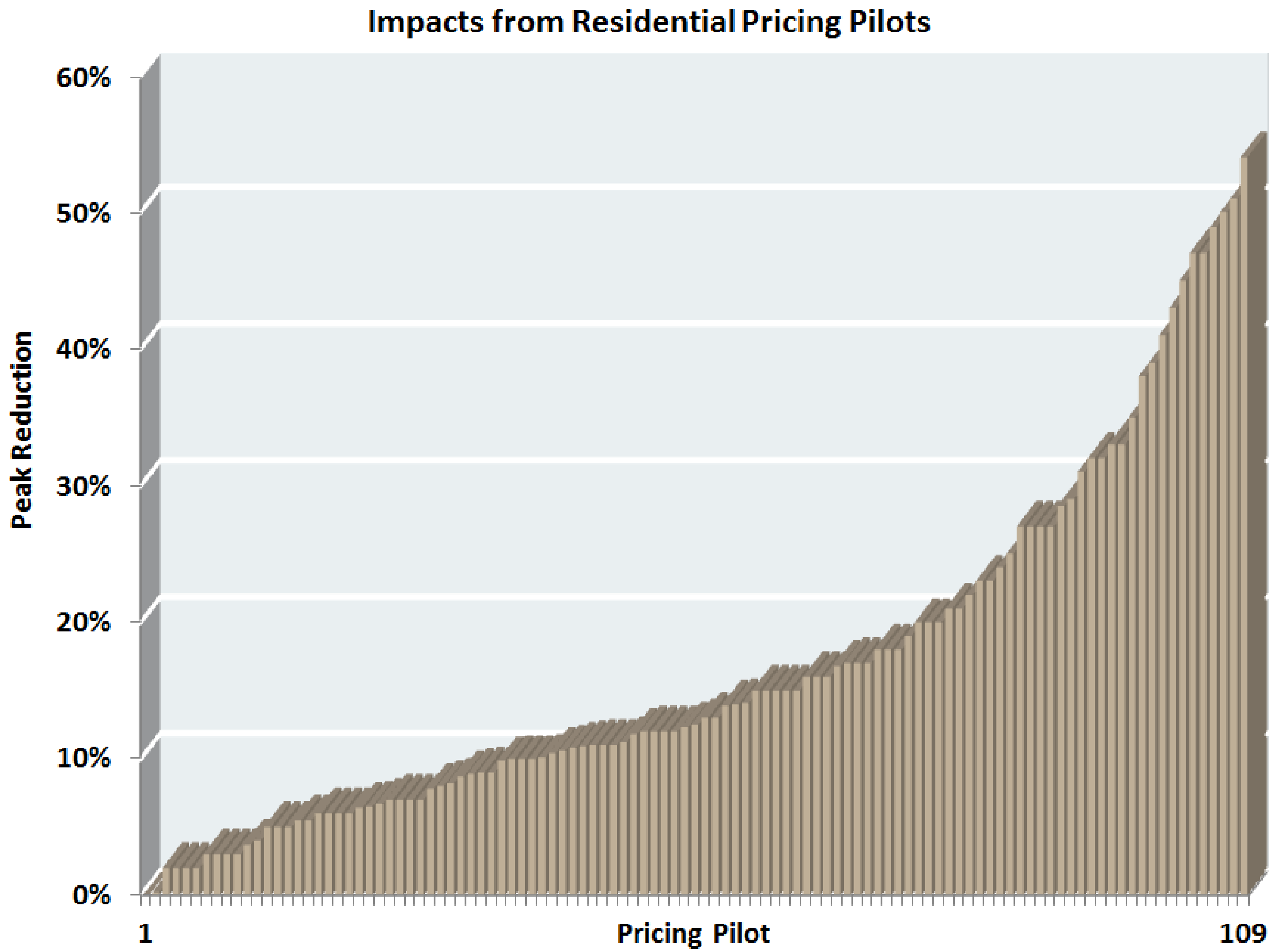


Residential Trigger Points Differ

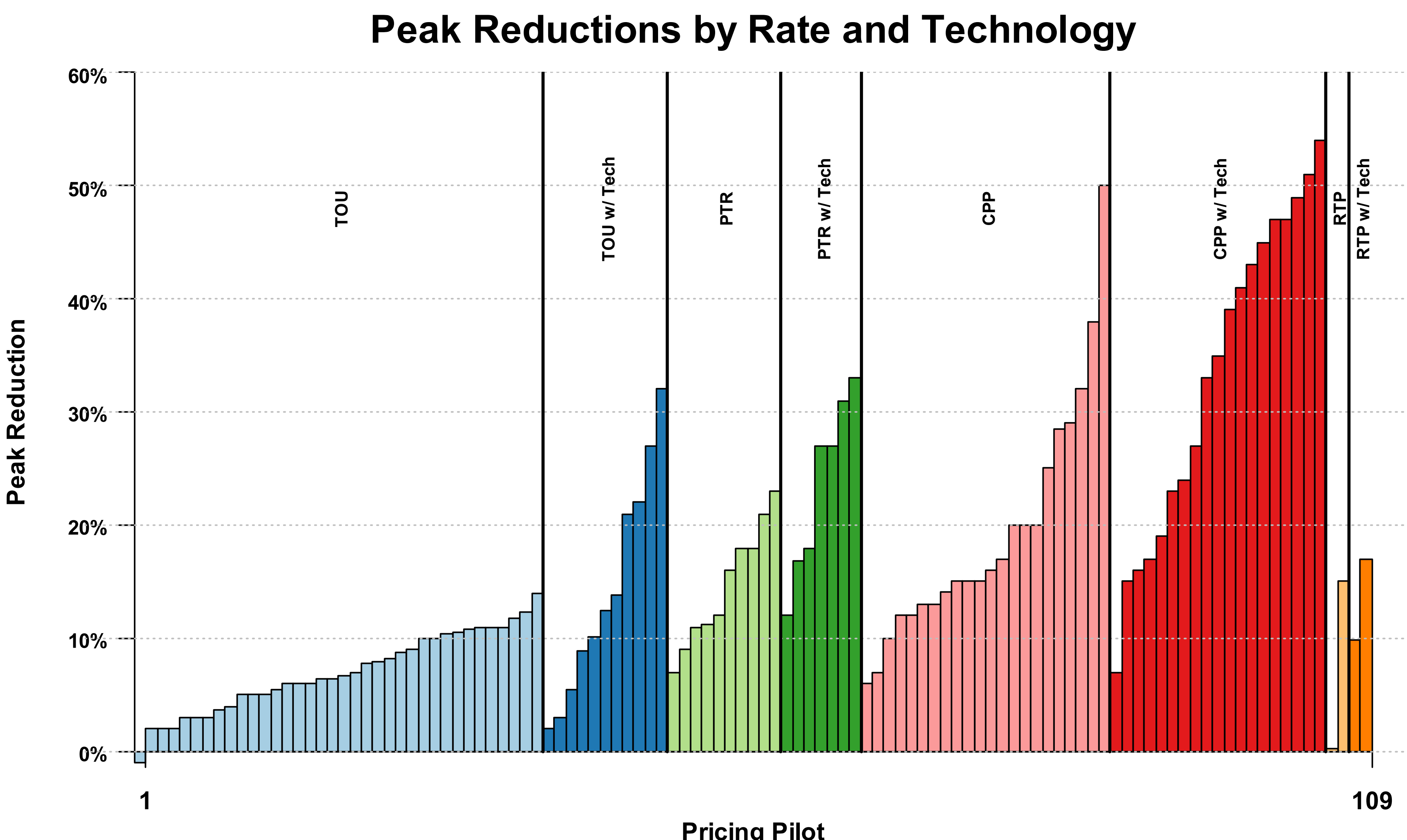


Source: NAP Communications Umbrella Action Guide, page 11

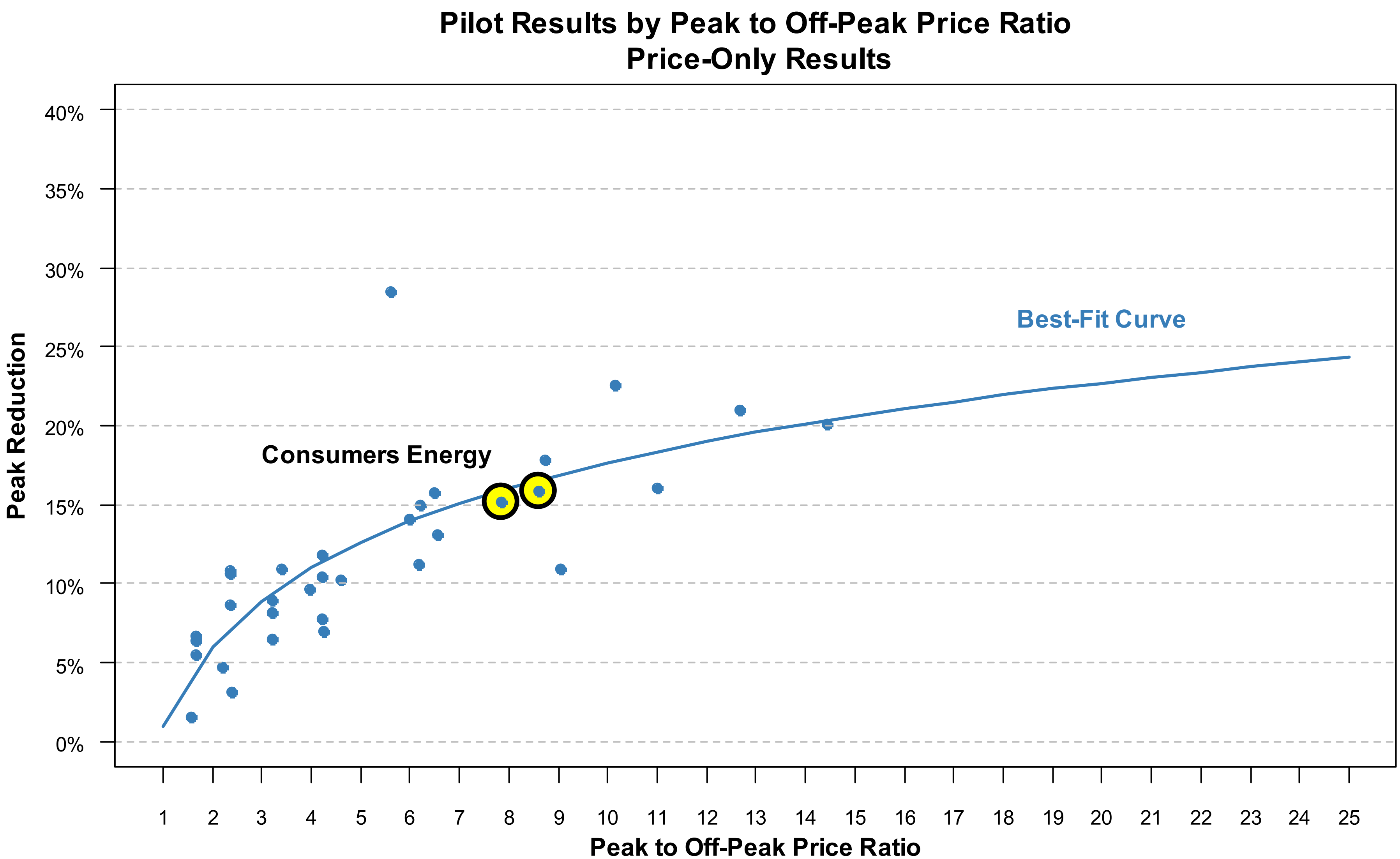
There is a "Great Wall" of evidence on consumer behavior, coming from 109 tests with dynamic pricing



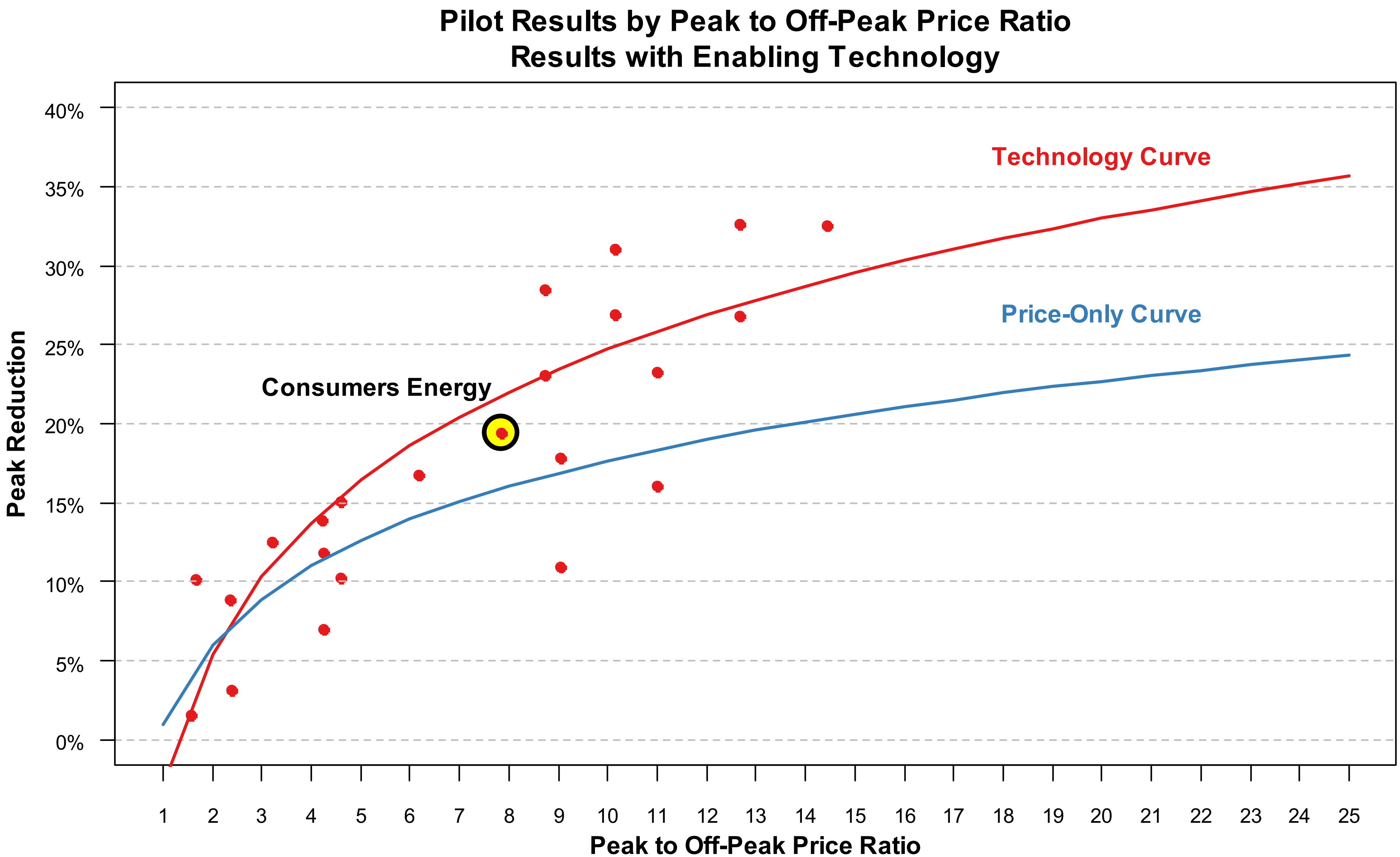
When filtered by rate and technology, the impacts yield a "Manhattan Skyline"



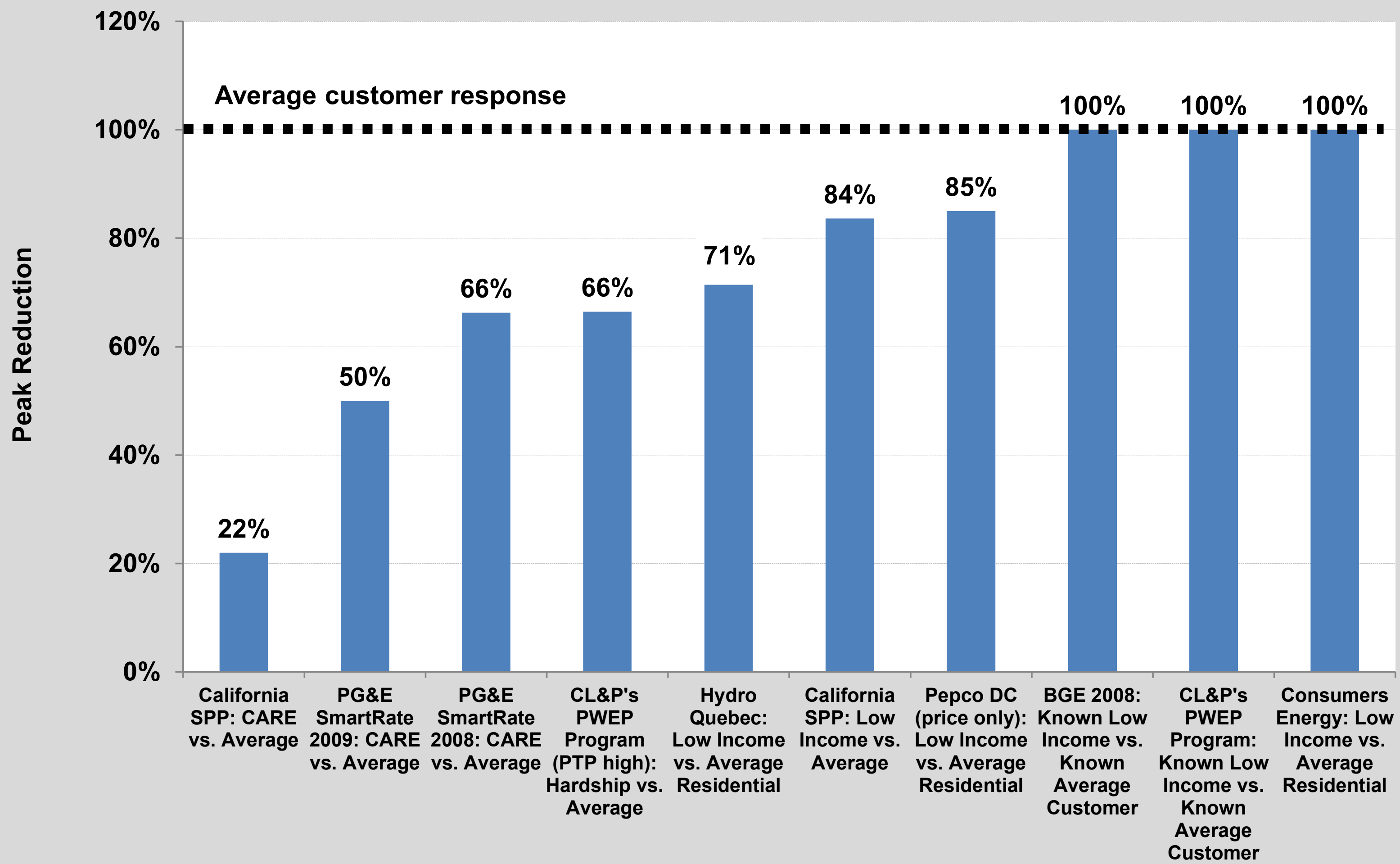
The best-designed pilots allow us to infer the "Arc of Price Responsiveness"



In most cases, the inclusion of enabling technology boosts price responsiveness



Even low income customers respond



Note: For the PepcoDC pilot, the average residential response excludes low income customers that qualify for the RAD program

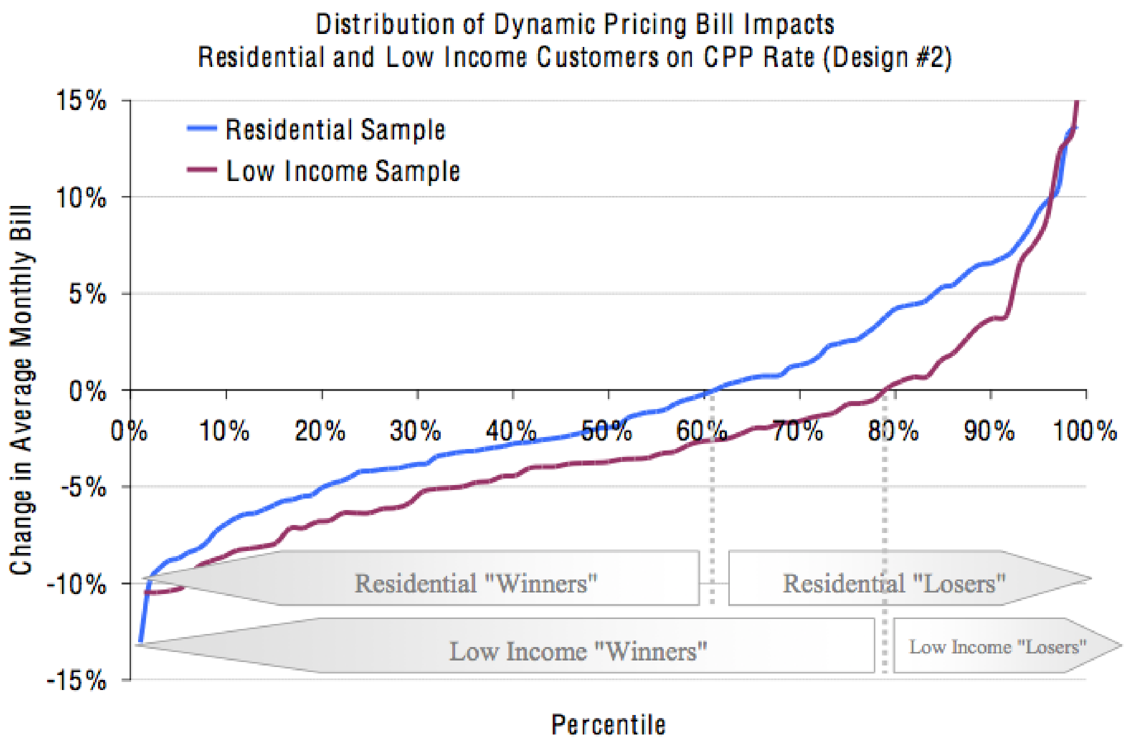
Fairness is a matter of how we look at the issues

Photo by Marshall Cetlin

Without dynamic pricing, frugal people with small homes subsidize consumers who are casual about their energy use during high peak hours.

Most are instant winners

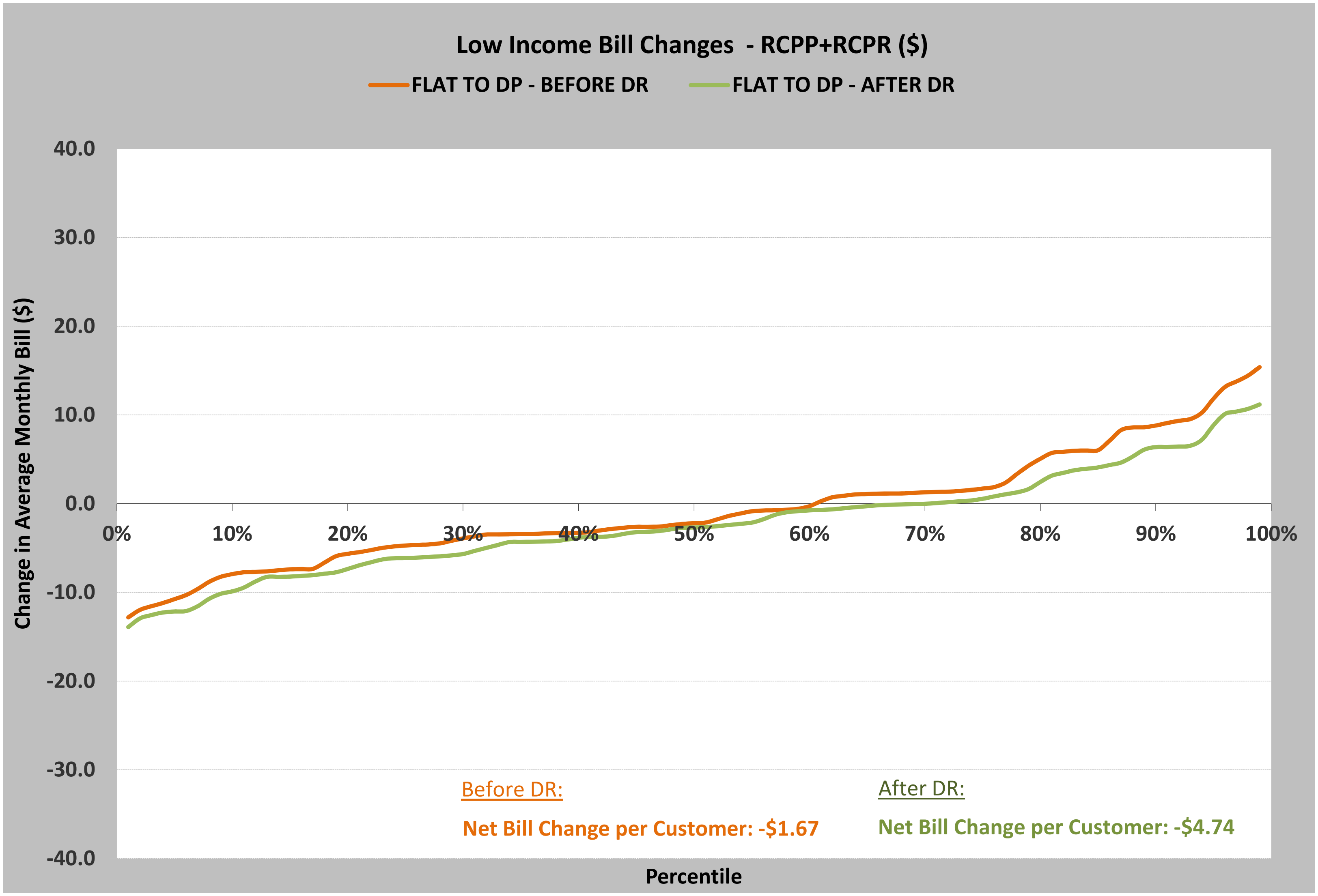
Most low-income households benefit without changing behavior, even if they stay at home all day. All receive advantages of better reliability and lower operating costs.



Opportunity to win via simple behavior changes.

Protections can be kept in place for medically frail.

The Consumers Energy pilot shows that many low income customers benefit even without demand response



SIZING UP THE NATIONAL BENEFITS

The smart grid provides numerous opportunities to promote wise energy use

- Over the next two decades, 2011-2030, we are likely to see the wide-scale deployment of advanced metering infrastructure (AMI), demand response (DR) through dynamic pricing and associated enabling technologies, and energy efficiency (EE)
- Over the following two decades, 2031-2050, we are likely to additionally see the wide-scale deployment of distributed energy resources (DER) and plug-in hybrid vehicles (PHEVs)
- We have quantified the national benefits, using the *iGrid 1.0* software

The 49 dimensions of the smart grid

7 Value Streams

- AMI
- DR (dynamic pricing)
- DR (enabling technology)
- EE (in home displays)
- EE (continuous building commissioning)
- DER
- PHEV

7 Performance Metrics

- Metering costs
- Generation capacity costs
- T&D costs
- Energy costs
- System reliability
- Carbon emissions
- Gasoline costs

We use two forecast horizons for established technologies and leading-edge technologies

Established Technologies: 2010 - 2030

- **AMI** – Will be the IT backbone of the smart grid
- **DR** – Time-based pricing and automating technologies can be offered once AMI is deployed
- **EE** – iGrid measures added EE benefits over and above traditional EE measures and programs enabled by the SG (e.g. information displays)

Leading-Edge Technologies: 2010 - 2050

- **DER** – downstream solar, wind, storage, and other resources are already entering, but the smart grid will improve their economics via time-differentiated prices and customer or utility "dispatch"
- **PHEV** – with the SG, PHEV charging can be better controlled and both G2V and V2G benefits realized

The national landscape

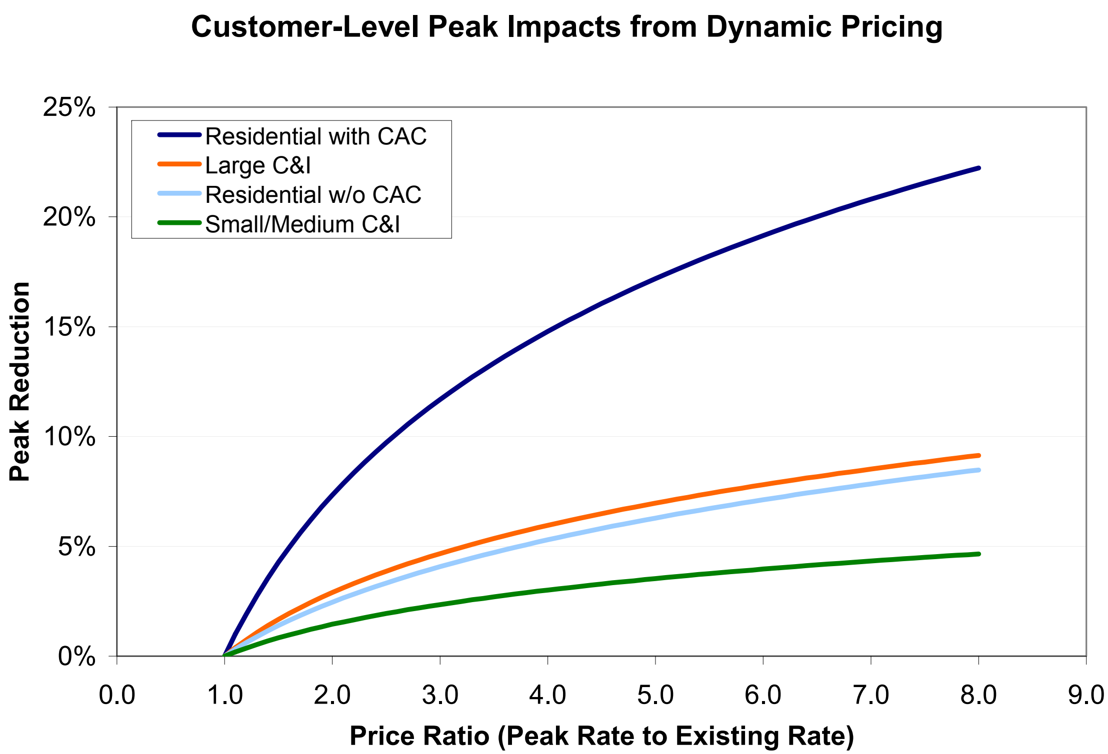
- Number of electric customers
  - 124.7 million residential customers
  - 18.2 million small/medium commercial and industrial customers
  - 0.2 million large commercial and industrial customers
- Peak demand of 761 GW
  - Energy sales of 3.9 million GWh per year

The direct value of AMI is from avoided meter reading costs

- Deployment is assumed to vary by customer class and occurs during the next five years
- Annual meter O&M cost estimates vary by customer type
  - Residential: $15 per customer per year
  - C&I: $30 per customer per year
- Over the forecast horizon, this will yield savings of $32.7 billion in avoided costs (present value)

AMI will also enable several other smart grid applications which are not quantified here

The smart grid will enable dynamic pricing of electricity and lower peak demands



- Peak impacts are a function of the dynamic rate and central a/c (CAC) saturation:
  - 8.0 price ratio
  - 60% CAC saturation
- A conservation effect due to pricing is also accounted for:
  - 1% residential, 0% C&I
- Residential and C&I participation rate of 25%

Multiplying the class participation rate into the average customer impacts gives the system impact

Automating technologies enhance effect of dynamic pricing

- Automating technologies lead to additional impacts that are incremental to those from dynamic pricing
- 30% of residential customers and 40% of C&I customers participating in dynamic pricing are equipped with these automating technologies

Increase in Dynamic Pricing Impacts due to Automating Technology

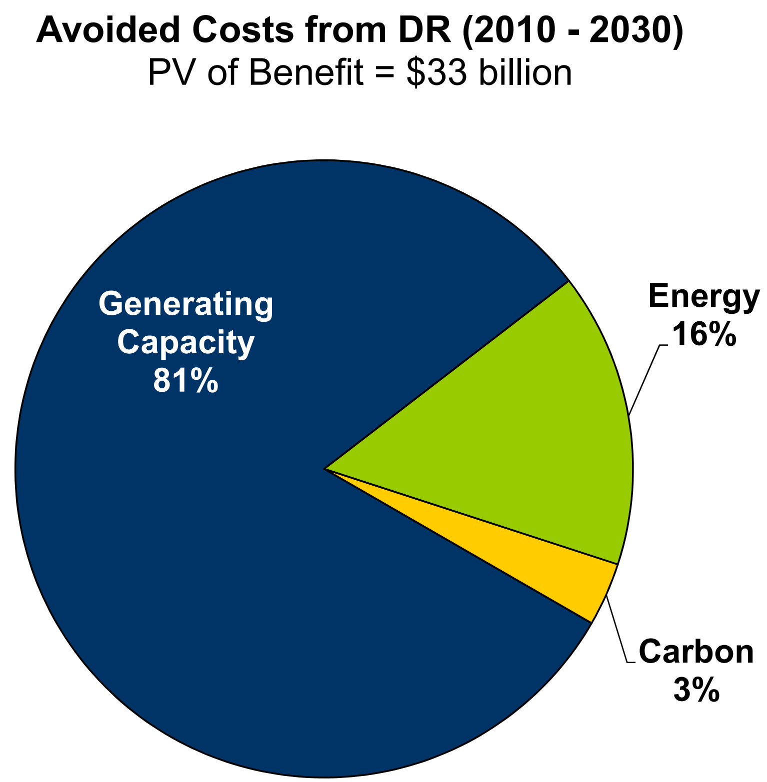
	Residential	Small/Medium C&I	Large C&I
PCT	60%	100%	N/A
Auto DR	N/A	N/A	90%
Gateway	150%	160%	N/A

Assumptions based on review of multiple pilots including the California Statewide Pricing Pilot as well as research from LBNL

Avoided capacity requirements dominate the demand response benefits

Assumptions:

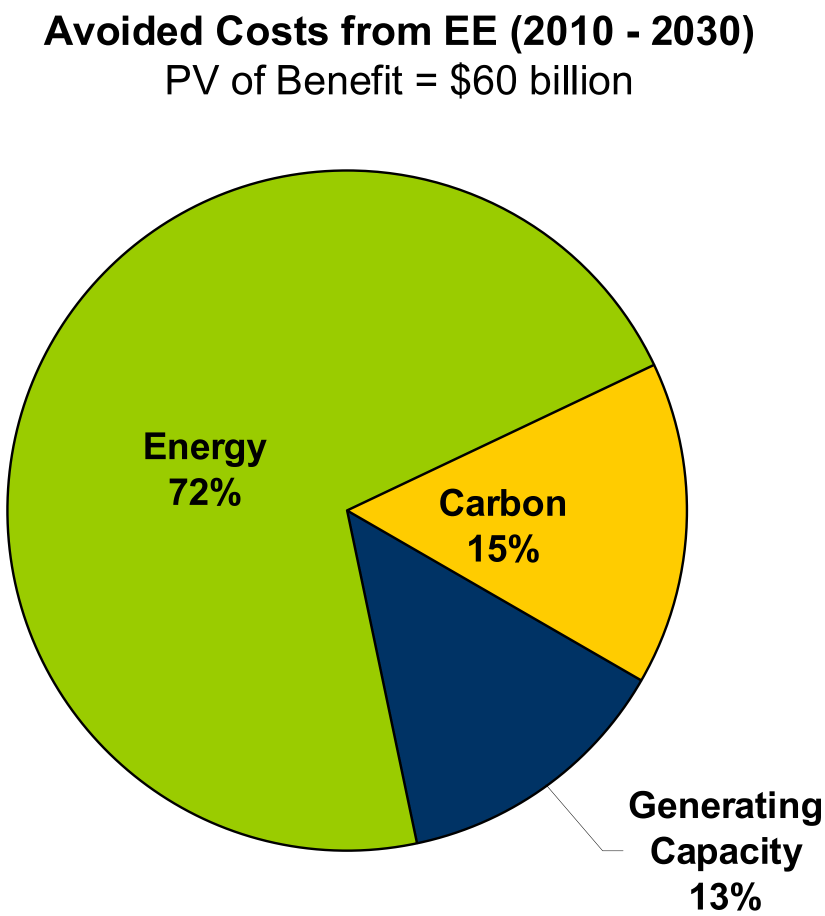
- Avoided capacity = $75 kW-year
- Avoided Energy = $100/MWh
- Carbon price = $25/metric ton of CO2



- System peak reduction is 3.4% by 2030
- Annual CO2 reduction is 5 million metric tons by 2030

Avoided energy costs dominate the energy efficiency benefits

- System peak reduction is 1.5% by 2030
- Annual sales reduction is 1.4% by 2030
- Annual CO2 reduction is 61 million metric tons by 2030



US smart grid benefits add up to $121 billion (not counting DERs and PEVs)

Smart Grid Valuation Summary, 2010 - 2030
Present Value of Avoided Costs, Millions of $

	Meter O&M	Generating Capacity	Energy from Electricity*	Energy from Gasoline	Carbon	Reliability	Total
AMI	$32,747	$0	$0	$0	$0	$0	**$32,747**
DR (Dynamic Pricing)	$0	$15,729	$2,951	$0	$635	$0	**$19,315**
DR (Enabling Technology)	$0	$6,939	$1,359	$0	$292	$0	**$8,590**
EE (IHDs)	$0	$3,534	$22,703	$0	$4,883	$0	**$31,120**
EE (Building Commissioning)	$0	$4,443	$20,267	$0	$4,359	$0	**$29,069**
Total without PHEVs and DERs	**$32,747**	**$30,645**	**$47,280**	**$0**	**$10,169**	**$0**	**$120,841**

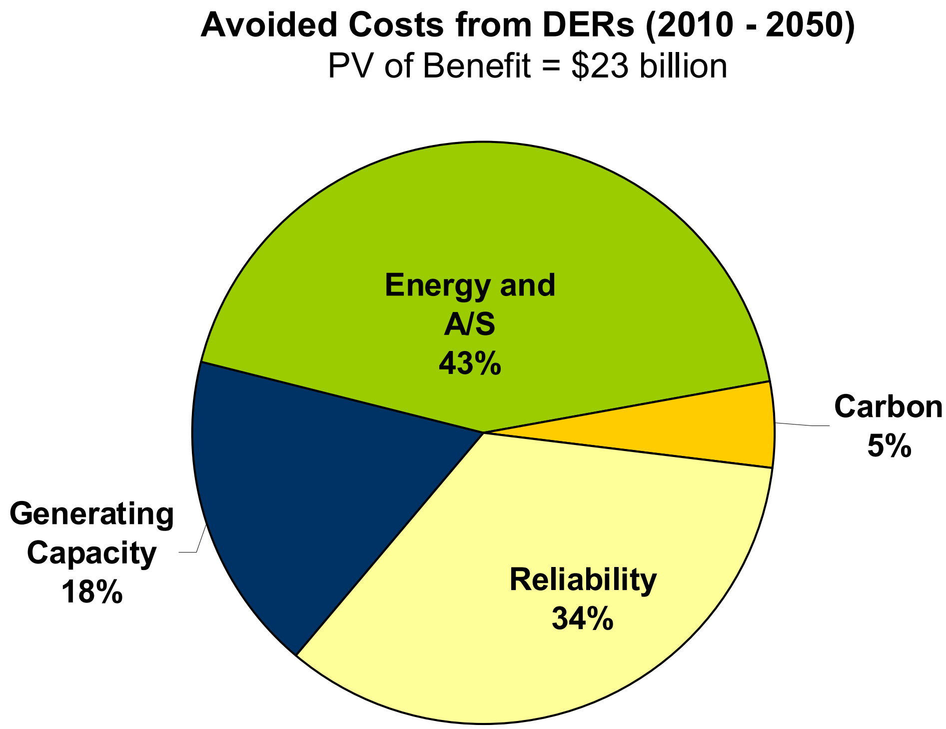
* Also includes value of ancillary services for DERs

Energy and ancillary services of DERs dominate the benefits, followed by reliability

Assumed value of lost load to average device owner:

- $5/kW-year for residential
- $100/kW-year for Small and Medium C&I
- $83/kW-year for Large C&I

- System peak reduction is 3.1% by 2050
- Increase in wind generation is 3.3% by 2050
- 200 minutes of outage per customer are eliminated
- Annual CO2 reduction is 34 million metric tons by 2050



All together, US benefits of the smart grid add up to $397 billion

Smart Grid Valuation Summary, 2010 - 2050
Present Value of Avoided Costs, Millions of $

	Meter O&M	Generating Capacity	Energy from Electricity*	Energy from Gasoline	Carbon	Reliability	Total
AMI	$44,618	$0	$0	$0	$0	$0	**$44,618**
DR (Dynamic Pricing)	$0	$25,080	$4,644	$0	$999	$0	**$30,723**
DR (Enabling Technology)	$0	$11,064	$2,139	$0	$460	$0	**$13,663**
EE (IHDs)	$0	$6,086	$38,559	$0	$8,294	$0	**$52,939**
EE (Building Commissioning)	$0	$7,869	$35,396	$0	$7,613	$0	**$50,878**
DERs	$0	$4,191	$10,088	$0	$1,113	$8,019	**$23,411**
Total without PHEVs	$44,618	$54,290	$90,828	$0	$18,479	$8,019	**$216,233**
PHEVs	$0	-$5,740	-$112,118	$297,418	$1,626	$0	**$181,185**
Grand Total	**$44,618**	**$48,549**	**-$21,290**	**$297,418**	**$20,105**	**$8,019**	**$397,418**

* Also includes value of ancillary services for DERs

Note, PHEV benefits begin to accrue in 2011,
although they are not shown in the two-decade benefits table

ASSESSING UTILITY-LEVEL COSTS AND BENEFITS

Smart meters will create several "Day One" benefits

- Smart meters will significantly enhance the customer's transactional experience with the grid, enabling her to see the following
  - Bill-to-Date, Web Presentment, High Bill Analysis, Move-in/Move Out Enhancements, and so on.
  - Voluntary prepay plans and electronic payments from mobile phone outside of normal business hours
  - Security notifications in case of emergencies, storms, etc.
  - Faster repair and priority recovery for vulnerable residents (after hospitals and first responders)
- However, these benefits are difficult to quantify

Other benefits and costs have been quantified in an IEE whitepaper

	Pioneer	Committed	Exploratory	Cautious
Current meter	AMR Operational	AMI in process	All analog	All analog
Direct load control	DLC 1.0 (< 1% customers)	DLC 1.0 (< 1% customers)	DLC 1.0 (< 1% customers)	DLC 1.0 (< 1% customers)
Generation profile	T&D only, all generation purchased (nuclear, gas, hydro)	Mix of generation owned by utility and purchased (hydro, gas, nuclear)	Bulk of generation owned by utility (gas, nuclear, coal)	Bulk of generation owned by utility (coal, nuclear, gas)
Regulatory environment	Approved to proceed	Mandates for SG/RPS	Approved to proceed	Conservative
Climate change attitude	Problem	Serious Problem	Problem	Skepticism
Regional climate	Moderate cold-hot	Fairly temperate	Extreme cold-hot	Temperate-hot
Emphasis on efficiency and conservation	High	High	Low	Low

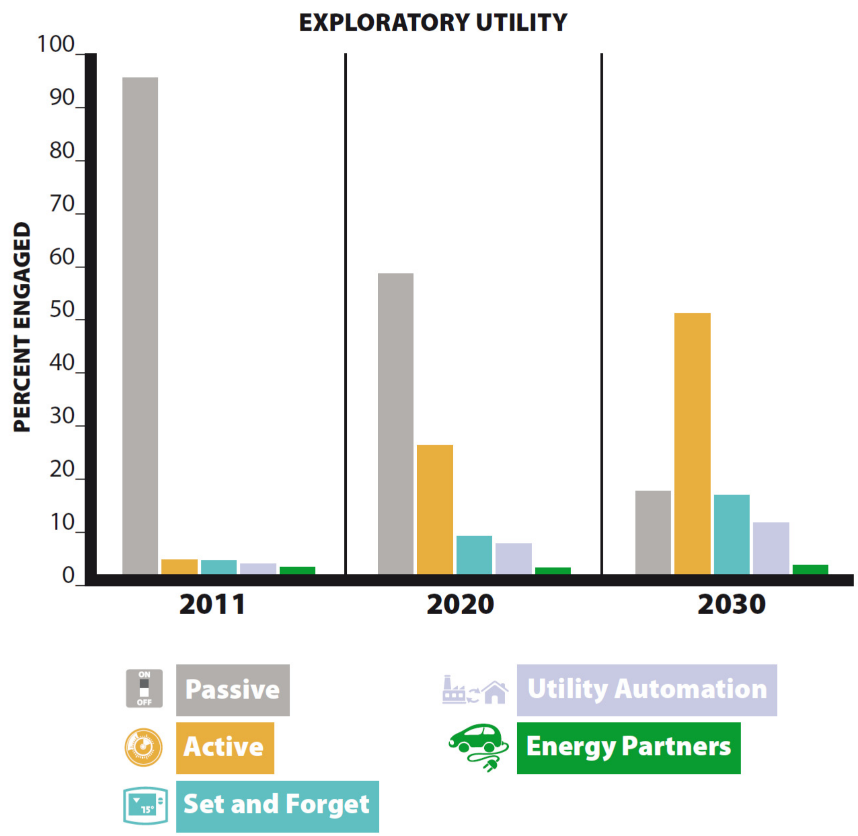
Customers choose their role

	PASSIVE	ACTIVE	SET & FORGET	UTILITY AUTOMATION	ENERGY PARTNERS
BASIC		Display/no display No risk rebate			
COMFORT		Display/no display No risk rebate	Programmable Communicating Thermostat No risk rebate	Direct load control Programmable Communicating Thermostat or Switch No risk rebate	
SAVER		Display/no display No risk rebate	Programmable Communicating Thermostat No risk rebate or Heat wave pricing	Direct load control Programmable Communicating Thermostat or Switch No risk rebate	
GREEN		Display/no display No risk rebate or Heat wave pricing	Programmable Communicating Thermostat Home Energy Management System Heat wave pricing	Direct load control Programmable Communicating Thermostat or Switch No risk rebate	Electric Vehicle Home Energy Management System Time of use rate

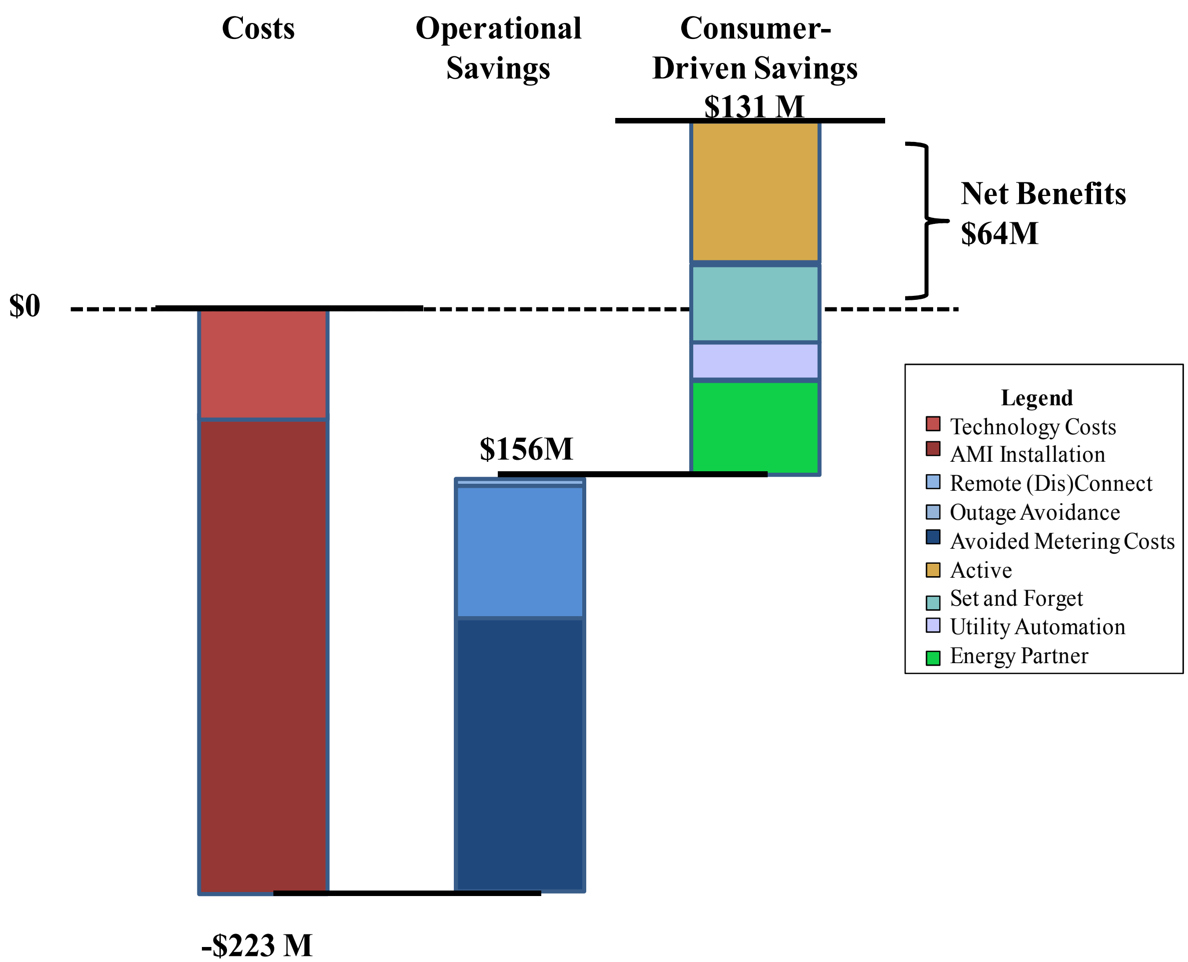
Summary results (using *iGrid 2.0*)

- Assuming a service area of one million households, the total cost for a utility to invest in AMI and associated home energy management technologies ranged from a low of $198 million to a high of $272 million
- The AMI investment produced operational savings (resulting from avoided metering costs, automated outage detection, and remote connections) of between $77 million and $208 million, and customer-driven savings (resulting from energy pricing programs, in-home enabling technologies, and energy information) of between $100 million and $150 million
- The net benefits from investing in AMI ranged from between $21 million and $64 million for the four types of utilities

Exploratory utility – customer engagement migration



Exploratory utility – components of costs and benefits (NPV, $ millions)



SMART CHARGING OF PLUG-IN VEHICLES

In the near term, plug-in vehicles could create a problem for some utilities

- PEVs will initially cluster in neighborhoods that are either green or affluent (or both), seriously straining the distribution system
- Will smart prices enable smart charging, as many have argued?
  - Only if PEV owners are *6* times more price responsive than dynamic pricing customers will 50 percent of the "natural" PEV load shift to off-peak periods
  - They would have to be *20* times more price responsive for 100 percent of the load to be shifted

Is that likely?

- We don’t know but the question can be addressed by designing and executing scientifically designed pilots, just as those that were used to test the impact of dynamic pricing
- The pilots should involve random allocation of customers to treatment and control groups and before-and-after measurements
- A variety of time-of-use rates should be tested

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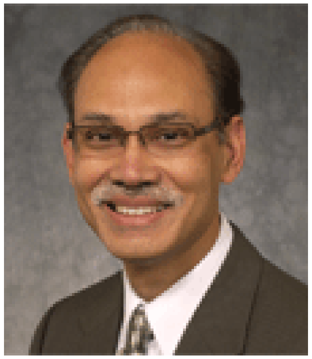
Speaker Bio and Contact Information



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Dr. Ahmad Faruqui has advised utilities in two dozen states on smart grid issues involving the customer and testified before a dozen state and provincial commissions and legislative bodies. He has designed and evaluated some of the best known pilot programs involving dynamic pricing and enabling technologies. The author, co-author or editor of four books and more than 150 articles, papers and reports, he holds a doctoral degree in economics from the University of California at Davis and undergraduate and graduate degrees from the University of Karachi, Pakistan.

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- Cost of Capital
- Demand Forecasting and Weather Normalization
- Demand Response and Energy Efficiency
- Electricity Market Modeling
- Energy Asset Valuation
- Energy Contract Litigation
- Environmental Compliance
- Fuel and Power Procurement
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- Renewables
- Resource Planning
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- Market-Based Rates
- Market Design and Competitive Analysis
- Mergers and Acquisitions
- Transmission

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