The Brattle Group

Using dynamic pricing to strengthen your AMI business cases

Ahmad Faruqui, Ph. D.

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A framework for quantifying costs and benefits

- Identify and measure costs
  - Deploying advanced metering infrastructure (AMI)
    - Meters
    - Two-communication links
    - Billing systems
  - Offering dynamic pricing signals
    - Marketing costs
    - Program administration costs
- Identify and measure benefits
  - Operational benefits of AMI
  - Demand response (DR) benefits of dynamic pricing
- Develop a net present value

Quantifying DR benefits

- Primary benefits
  - Quantity of DR (MW) * Value of avoided MW
- Quantity of DR
  - kW reduction per customer * Number of participating customers
- Value of avoided load
  - Cost of peaking capacity net of energy revenues
- Secondary benefits
  - Reduction in wholesale prices
  - Enhanced reliability
  - Environmental improvement

As a “wise man” once said ….

- You will encounter several known unknowns
  - Don’t let point estimates deceive you
  - Develop ranges and probabilities

- And you will encounter a few unknown unknowns!
  - Do some scenario planning
  - Stay flexible and adapt to changing realities

Will customers exhibit demand response?

- Yes
  - More than two dozen experiments that have been carried out over the past three decades in Europe and North America
  - Most of these involved time-of-use (TOU) rates but a few involved dynamic pricing
  - Key findings
    - Not every customer will respond
    - Some will respond marginally
    - Some will respond a lot

The Electricity Council of London ran a pioneering TOU experiment in the early 1970s

- It placed 3,600 customers on a TOU rate
- Experimental prices were revenue neutral with prices that prevailed then in Britain
- However, by the time the experiment ended three years later, the experimental prices were half as high as prevailing prices
- Jim Boggis, Study Director, concluded:
  - With the aid of hindsight, the experiment might have been better directed to a more primitive problem. What are the price elasticities and cross elasticities of electricity demand by time of day, day of week and season of year?

The US FEA/DOE ran 16 TOU pricing experiments in the late 1970s; five had strong designs

Experiment	Length of peak periods (hours)	Number of test rates	Max. price ratio	Intermediate pricing period: Weekday	Intermediate pricing period: Weekend	Shoulder or peak price during some weekend hours	Sample size
1. North Carolina	8,10	13	6.2/1	X	X	X	600
2. Connecticut	4	1	16/1	X	X	X	391
3. Los Angeles	3,6,9,12	17	9/1			X	1268
4. Southern California	10	8	9/1				620
5. Wisconsin	6,9,12	9	8/1				674

The LADWP experiment yielded the most comprehensive results

- Customers reduced on-peak usage and increased off-peak usage in response to the TOD rates
- Own-price and cross-price elasticities were successfully estimated using econometric methods and a quadratic functional form for the demand equations
- TOD rates were found to be cost-effective for all customers using more than 1,100 kWh per month, or all customers with swimming pools using more than 800 kWh per month

EPRI proved that results were consistent across the top five experiments

- The average elasticity of substitution was found to be 0.14, suggesting that a doubling of the peak to off-peak price ratio would lead to a 14% drop in the peak to off-peak kWh consumption ratio
- This was a universal result that was transferable across regions, as seen in the next slide

The elasticity of substitution varied across customers and regions

				Typical appliances except	
Type of climate	No appliances	Typical appliances	All appliances	Does not have air conditioning	Has air conditioning
Cool	0.09	0.12	0.16	0.13	0.11
Typical	0.07	0.14	0.21	0.11	0.16
Hot	0.05	0.15	0.25	0.10	0.21

However, it was the French who pioneered the application of dynamic pricing to households

- EDF introduced the *tempo* tariff in the mid-1990s
- It featured a two-period time-of-use rate that varied across three day types that were color coded as red, white and blue
- Customers were notified about day-types through various means including a multi-colored light bulb and an early version of a personal computer
- Several hundred customers adopted the *tempo* tariff
- Most of these customers saved significant amounts of money by load shifting

Puget Sound Energy ran a TOU pricing pilot in 2001/02

- It featured several hundred thousand customers on a *mild* TOU rate where peak prices were 15% higher than the average rate and off-peak prices were 15% lower
- Even then, month-after-month, customers lowered peak usage by about 5 percent
  - Usage reductions were higher in the winter months
- However, the cost of the meters and billing systems was higher than the value of reduced load and the program was discontinued
- Since the experiment involved only a single TOU rate, it did not yield price elasticities
  - Impacts were difficult to predict for other TOU rates

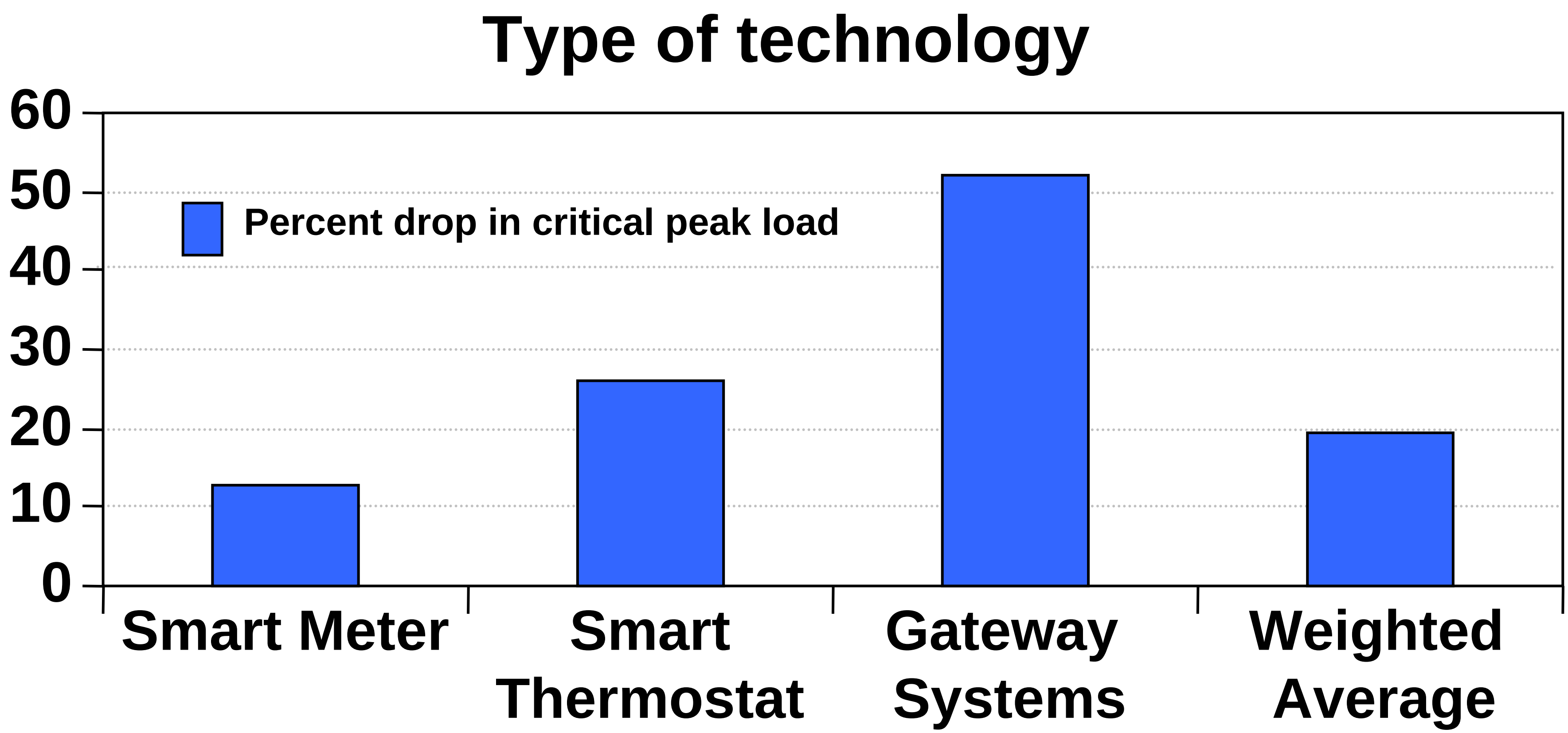
California created a Working Group to study the issue

- The energy crisis caused in part by the lack of demand response
- The CPUC initiated a proceeding on demand response, dynamic pricing and advanced metering
  - But no one knew whether customers would respond to dynamic pricing by a sufficient margin to offset the costs of AMI
- A preliminary cost-benefit analysis for PG&E revealed that the NPV of benefits could be as low as -$500 million or as high as $1,500 million, given that the price elasticity could be as low as -0.1 or as high as -0.3

This led to a statewide pricing pilot (SPP), "the mother of all experiments"

- It involved two state commissions, three investor-owned utilities, numerous intervenors *and yes*, 2,500 residential and small commercial and industrial customers over 2003-05
- On average, residential customers dropped peak loads on critical days by 13 percent
  - Critical period rates were five times higher than average rates
- Customers with central air-conditioning (CAC) dropped loads by 16 percent while those without CAC dropped loads by 8 percent
- 30% of the customers accounted for 80% of the impact
  - Not every customer has to respond for dynamic pricing to have a significant impact on system loads

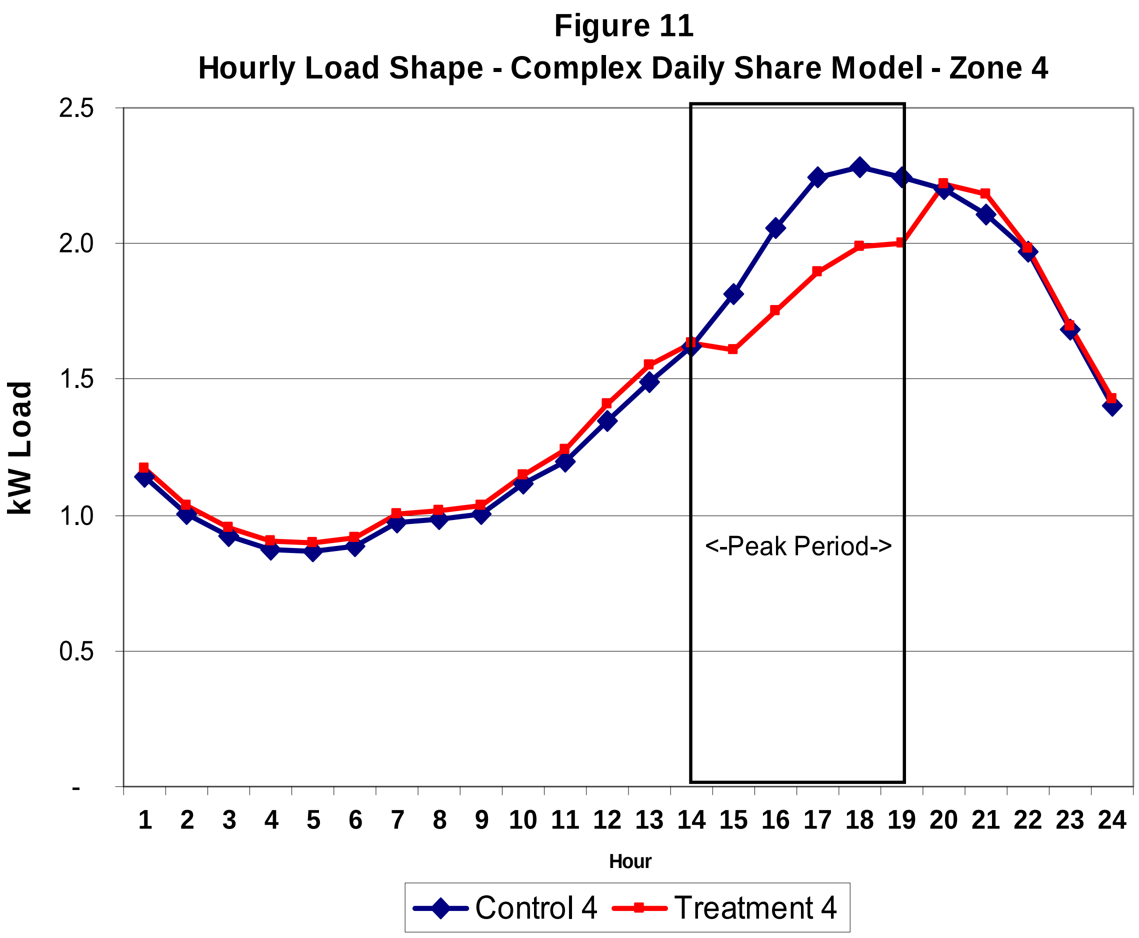
In the SPP, enabling technologies boosted the drop in critical peak loads



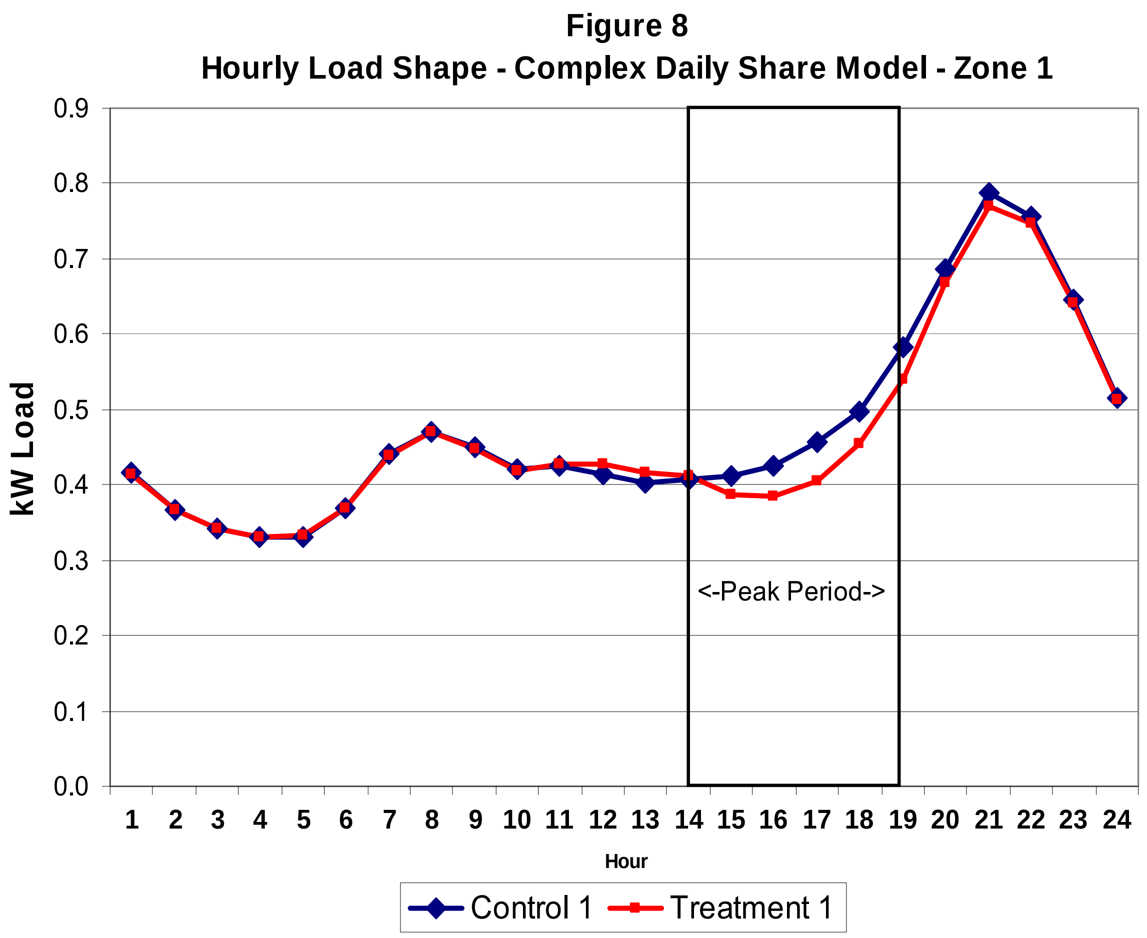
This demand response satisfies the CPUC's "resource adequacy" requirements

- Responses held constant across two and three consecutive critical days
  - So they are likely to stay constant in a real heat wave
- Responses did not degrade during the second summer
  - The load impact is not a novelty that wears off
  - This finding is consistent with results from the earlier 16 experiments, some of which lasted for 3 years
  - It is also consistent with customer responses observed by Arizona Public Service, Gulf Power and the Salt River Project

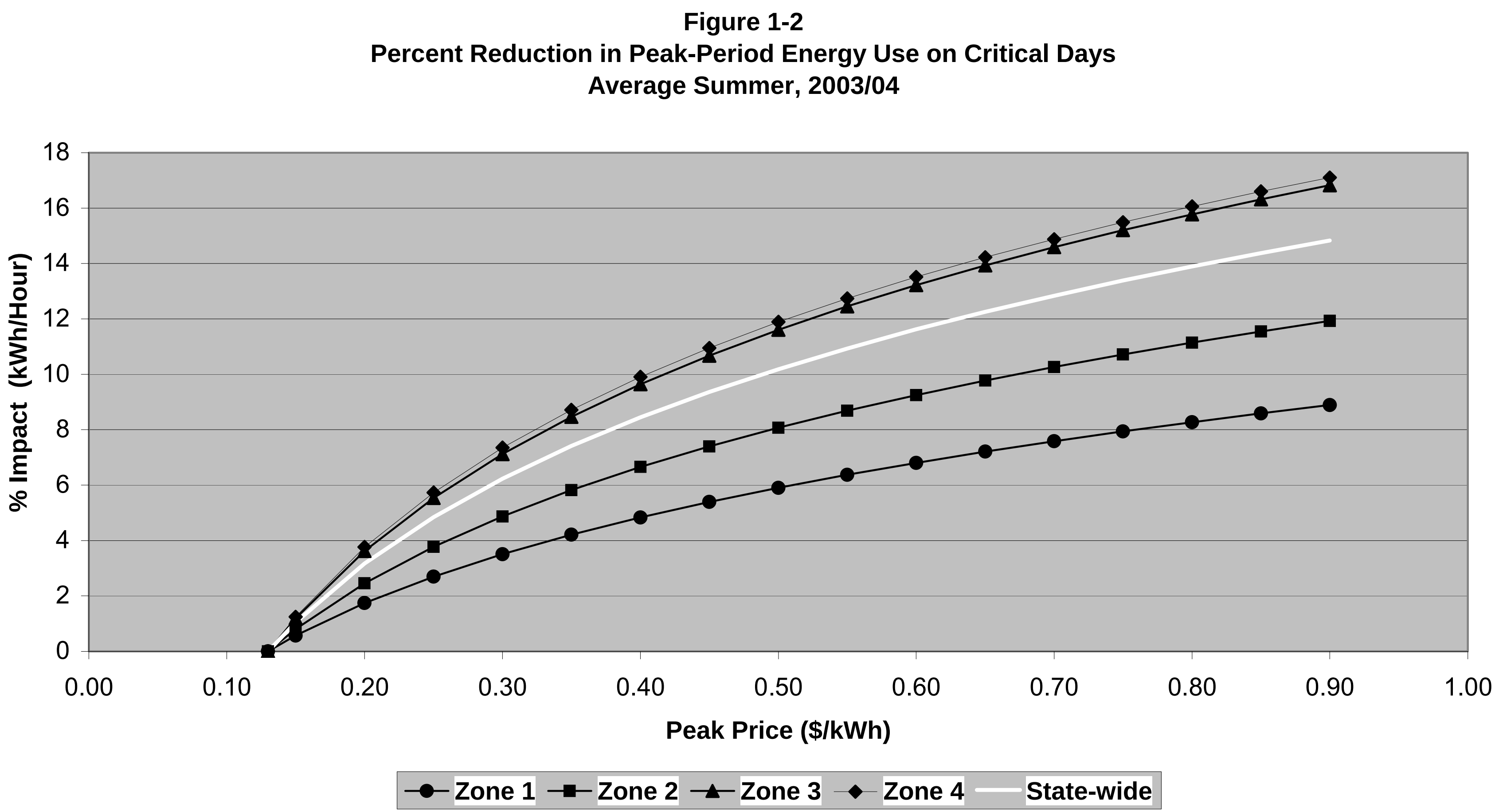
Dynamic prices have a substantial impact in a hot climate such as the Central Valley's



They produce an impact even in a mild climate such as San Francisco's



The SPP results have been codified into a pricing impact simulation model (PRISM)



California's utilities have used the SPP results to develop AMI business cases

- PG&E's $1.7 billion AMI filing was unanimously approved by the CPUC last July
  - Almost 90% of the benefits come from operational savings
  - The utility projects more than 500 MW of demand response by 2011, assuming that about a third of its customers with central air conditioning will adopt dynamic pricing tariffs
  - It is proceeding to deploy five million electric and four million gas meters
- SDG&E's AMI filing is awaiting a CPUC decision
- SCE has filed a Phase I feasibility report
  - It plans to file an application later this year

Can you make use of the SPP results?

- Yes, once you adjust the “initial conditions” in the PRISM software to match the conditions of their service area:
  - Existing rate design
  - Existing load shape
  - Saturation of central air conditioning
  - Weather conditions
- You can then enter a variety of time-varying designs and estimate likely load response to each of them
- This information can be used to carry out a *preliminary* cost-benefit analysis
  - We are currently doing this for a mid-Atlantic utility
- A definitive assessment may require that you conduct your own pilot (more on this later)

You can use this information to comply with EPACT 2005

- Estimate benefits and costs over the project lifetime and derive the NPV of net benefits
- Analysis should factor in key uncertainties dealing with impact per customer, number of participants, avoided costs and AMI costs
- Analysis should factor in multiple perspectives
  - Total resource cost
  - Participant
  - Utility
  - Society

The total resource cost (TRC) perspective

- Develop a dynamic pricing rate and estimate its impact per customer
  - Ball park estimate: 10-30 percent per customer
- Identify the number of participating customers
  - Ball park estimate: 10 – 30 percent of the target market
- Compute aggregate DR impact
  - Ball park estimate: 1 to 9 percent of peak demand
- Estimate value of avoided costs
  - Ball park estimate of capacity costs: $52 – 85 /kW-yr
  - Factor in energy costs
  - Factor in changes in air emissions
- Combine the last two to come up with an NPV of benefits and compare it with the NPV of costs

The customer perspective

- Customer benefits
  - Bill savings
  - Recruitment or participation incentives
  - Enhanced awareness about energy usage
  - Better control of energy costs
  - Improved air quality
  - Faster power restoration after an outage
- Customer costs
  - Cost of metering
  - Loss of privacy

The utility perspective

- Utility benefits
  - Lower energy and capacity costs
  - Reduced air emissions

- Utility costs
  - AMI hardware and software costs
  - Customer recruitment and maintenance costs

Policy issues

- Dealing with conflicts between multiple perspectives, since the program may look attractive from one and unattractive from another
- Deciding on deployment strategy
  - Voluntary (opt-in)
  - Voluntary (opt-out)
  - Mandatory
- Dealing with customer apprehensions about rate hikes and price instability
- Ensuring regulatory acceptance and cost recovery

Obtaining regulatory acceptance *and* cost-recovery

- Regulators want assurance that the program will be cost-effective for society
- They want to make sure that it will not subsidize shareholders at the expense of ratepayers
- They want to ensure that it will not make any ratepayers worse off
- To convince them, you may wish to do your own pilot
  - This will give you direct evidence on customer response
  - It will also help you gauge customer acceptance, design your educational collateral and possibly re-design the rates before going full-scale

Should you do a pilot?

- Probably, since there is much uncertainty about a go/no go decision on AMI/dynamic pricing and not everyone wants to borrow results from California
- How should you proceed?
  - Plan on letting it run for about a year
  - Plan on spending real money on it but no more than the value of information you hope to gain from the pilot
  - If your objective is to estimate customer behavior to dynamic pricing, you will need to do an experiment that follows scientific design principles

What are the essential qualities of an experiment?

Internal Validity

- Can a cause-effect relationship be established within the experiment?

External Validity

- Are the experimental findings applicable to other populations in other settings?

Common errors in experimental design

No control group

- Cannot measure cause-effect relationship, and ceases to be an experiment

No pre-treatment measurement

- Can’t eliminate the effects of weather and other “confounding” variables

Nonrandom sampling methods

- Cannot generalize results

Non-comparable control group

- Becomes a quasi-experiment

Insufficient number of treatments

- Cannot generalize results

Common errors (continued)

Insufficient sample size by treatment

- Leads to statistically-imprecise estimates

Compensatory payments to participants

- Leads to biased estimates

Hawthorne effect

- Leads to biased estimates

Estimating program impacts

	Control Group	Treatment Group
Before Treatment	C_1	T_1
After Treatment	C_2	T_2

I. True Impact Measure = $(T_2 - T_1) - (C_2 - C_1)$

- "Gold standard" for assessing program impacts
- All other variables are held constant
- Random assignment to control or treatment group

II. Alternative Measures of Impact

(1) $T_2 - T_1$
(2) T_2
(3) $T_2 - C_2$

Ongoing pilots that feature dynamic pricing rates

- Ameren, Missouri
- Anaheim, California (rebate program)
- Commonwealth Edison, Illinois (RTP)
- HECO, Hawaii (just TOU)
- Idaho Power, Idaho
- Pepco, District of Columbia
- PSEG, New Jersey
- SMUD, California

What's next?

The future, though imminent, is obscure

Planning your future

- In the near term, you can borrow results from other pilots, such as California's SPP, to do an initial cost-benefit analysis
  - This will take you about four to six weeks
- Later on, you may wish to do your own pilot
  - Should it be an experiment, with control and treatment groups, random selection and random assignment?
  - What types of rates should you test in the pilot?
  - Should you also bundle some enabling technologies with the rates?
  - Would it be useful to also test some pure information treatments?

Additional reading

- Ahmad Faruqui, “2050: A pricing odyssey,” *The Electricity Journal*, October 2006
- Robert Earle and Ahmad Faruqui, “Toward a new paradigm for valuing demand response,” *The Electricity Journal*, May 2006
- Ahmad Faruqui and Stephen S. George, “Pushing the envelope on rate design,” *The Electricity Journal*, March 2006
- Ahmad Faruqui and Stephen S. George, “Quantifying customer response to dynamic pricing,” *The Electricity Journal*, May 2005