The Brattle Group

# Experimental Design Considerations in Evaluating the Smart Grid

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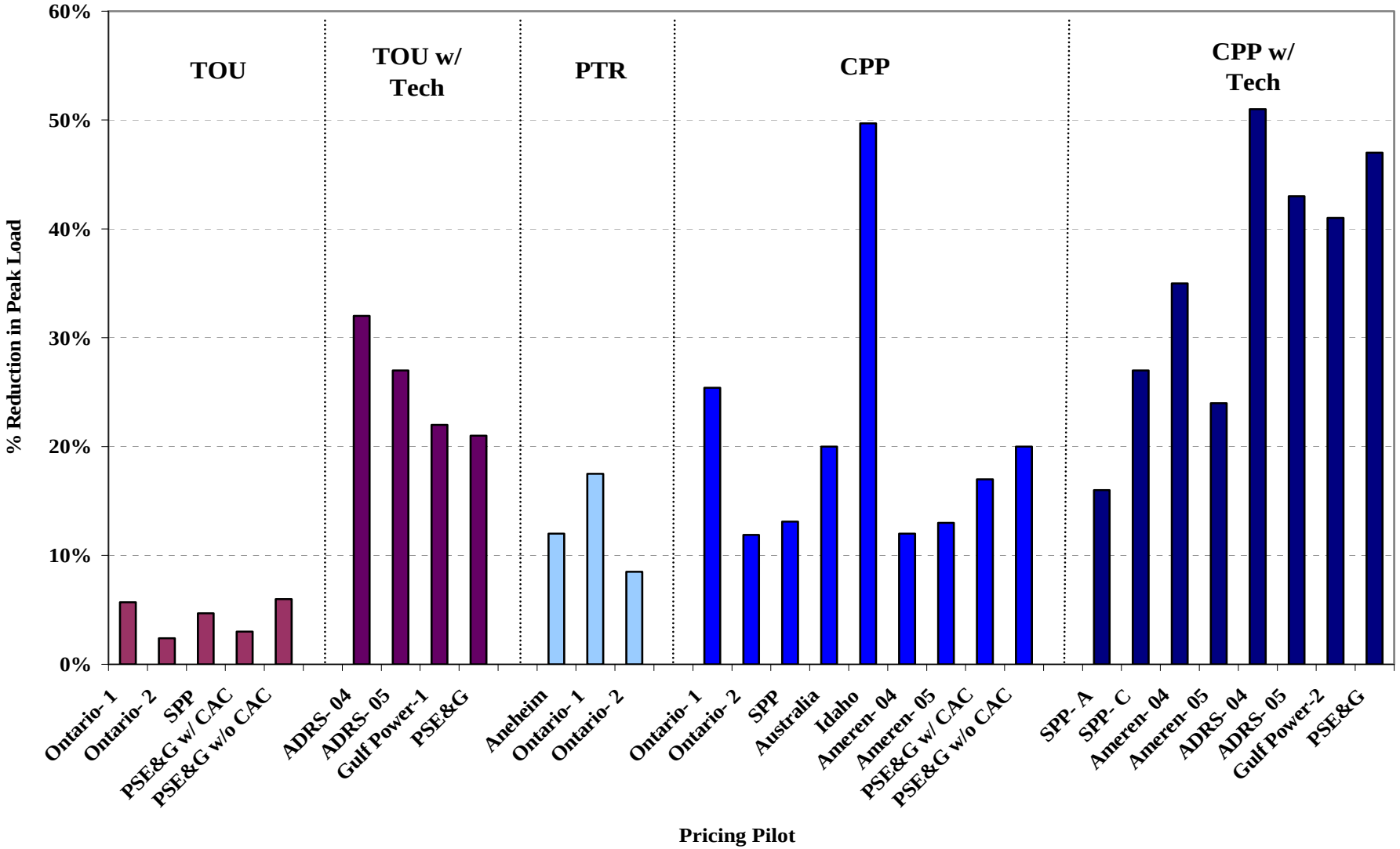
# Results from 17 dynamic pricing experiments conducted in U.S. and elsewhere provide a consistent message



# Do customers exhibit demand response?

YES, according to the evidence from the 17 pricing experiments that have been carried out in U.S. and elsewhere.

**The magnitude of price response depends on several factors:**

- magnitude of the price increase
- presence of central air conditioning
- availability of enabling technologies

**Across the range of experiments studied:**

- TOU rates induce a drop in peak demand that ranges between three to six percent
- CPP tariffs lead to a drop in peak demand of 13 to 20 percent
- CPP tariffs accompanied with enabling technologies lead to a drop in peak demand in the 27 to 44 percent range.

# Can you borrow results from other pilots?

In the near term, you can borrow results from other pilots to do an initial cost-benefit analysis

- But sooner or later, you will wish to do your own pilot
  - How should you design the experiment sample?
  - 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?

# 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 other experiments

**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 the scientific principles of good design**

# The principles of good experimental design

## Internal validity

1. A true cause-effect relationship should be established within the experiment
   - Need to determine what the participants would have done absent the treatment
     - Through a control group representing the "but-for" world
     - Without a control group, any conclusion will be overshadowed with doubt about spurious correlation
   - Need to isolate the impacts of confounding factors
     - Through controlling for the effects of weather, economy, etc.
     - Measuring the load profiles of both control and treatment customers before as well as during the treatment

# The pre-requisites of internal validity

2. Sufficient number of control and treatment customers to ensure precise statistical measurement and to improve the signal-to-noise ratio

3. Customers should be selected and assigned to the control and treatment groups using a sampling strategy consistent with the ultimate deployment strategy

4. Data on the socio-demographic characteristics should also be compiled

# Internal validity – (Cont'd)

5. Multiple treatments are required to construct a model of customer price response

6. Customer should be encouraged to stay in the pilot as long as possible

7. Appreciation payments, if any, should be handled appropriately
   - Toward the end of the pilot
   - Unrelated to the level of monthly usage

# External validity

Are the experimental findings applicable outside of the pilot test to the population at large?

- Need to identify the ultimate deployment strategy as this will inform the sampling strategy drawing control and treatment groups in the pilot
- Full-scale deployment scenarios should be clearly identified
  - Universal deployment
  - Default deployment with opt-out provisions
  - Optional deployment with opt-in provisions
- The pilot should then mimic these deployment scenarios

# 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) $T_2 - C_2$

# Most common problems in pilot design

1. No control group with pre-treatment measurement
   - Cannot measure cause-effect relationship, and ceases to be a valid experiment
2. Control group without pre-treatment measurement
   - Cannot eliminate the effects of weather and other "confounding" variables
   - Cannot determine whether treatment and control groups are balanced
3. No control group and no pre-treatment measurement
   - Will yield the poorest results
4. Non-comparable control group
   - Becomes a quasi-experiment
5. Non-random sampling methods
   - Cannot generalize the results to the population

# Common problems in pilot design (Cont'd)

6. Insufficient sample size by treatment
   - Leads to statistically-imprecise estimates
7. Compensatory payments to participants during the pilot
   - Leads to biased estimates
8. Hawthorne effect
   - Leads to biased estimates
9. Testing two objectives in one pilot
   - If something goes wrong in the testing of one objective, the other objective may be compromised as well

# Well designed rates produce significant peak reductions and high levels of customer acceptance

**Features of well designed rates**

- Revenue neutrality
- Short Peak period
- Strong Price Signals
- Rates that reflect system costs
- Opportunity for significant bill savings
- Simplicity

# Customer education plays an important role in a well-designed experiment

**Good customer education should accompany good rate design features**

- Customer education can
  - Set realistic expectations about likely benefits
  - Inform them what they need to do in order to benefit
  - Inform them what they don't need to do
  - Help them understand their energy bill

# Additional reading

- Ahmad Faruqui and Sanem Sergici, "Household Response to Dynamic Pricing: A Survey of Seventeen Pricing Experiments," (November 13, 2008). Available at SSRN: http://ssrn.com/abstract=1134132
- Robert Earle and Ahmad Faruqui, "Impacts of the Smart Grid on Utilities," 25th Annual NAESCO Conference, Los Angeles, October 28, 2008.
- Ahmad Faruqui, "Creating Value through Demand Response," DOE Smart Grid e-forum, Roslyn, Virginia, October 23, 2008.
- Ahmad Faruqui, "Will the Smart Grid Promote Wise Energy Choices?" Illinois Smart Grid Initiative, Chicago, August 5, 2008.