Electricity Demand Response

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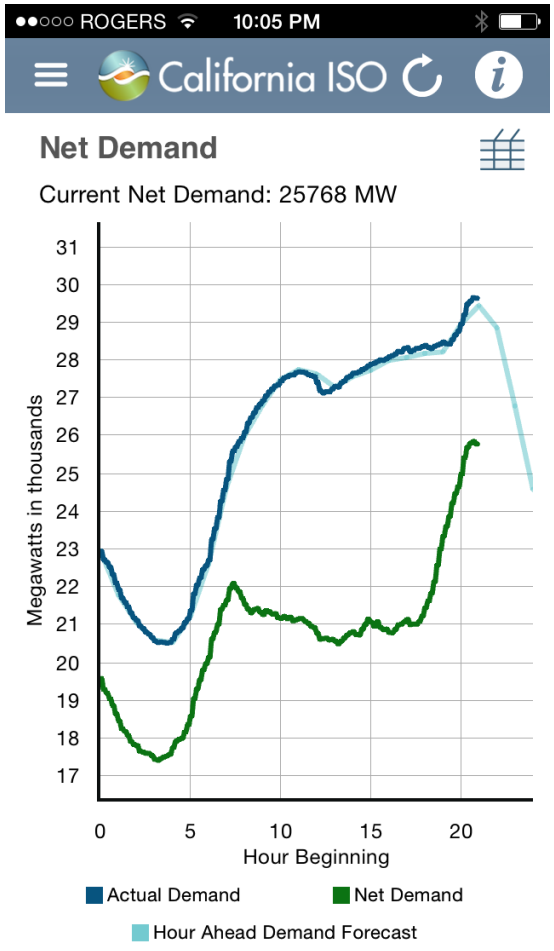
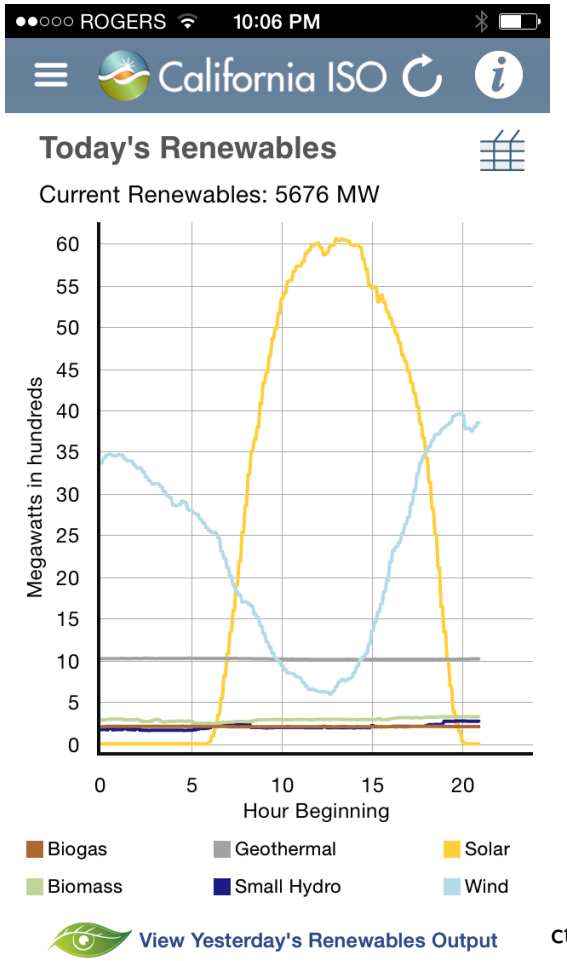
Renewables and demand response

Outline

- Review intermittency challenges from renewables
- Potential role of demand response programs
- Evidence
  - Prices
  - "Behavioural" interventions
  - Automation
- Implications
- Areas in need of research

Challenges: expected intermittency





Source: CAISO

Challenges: unexpected intermittency

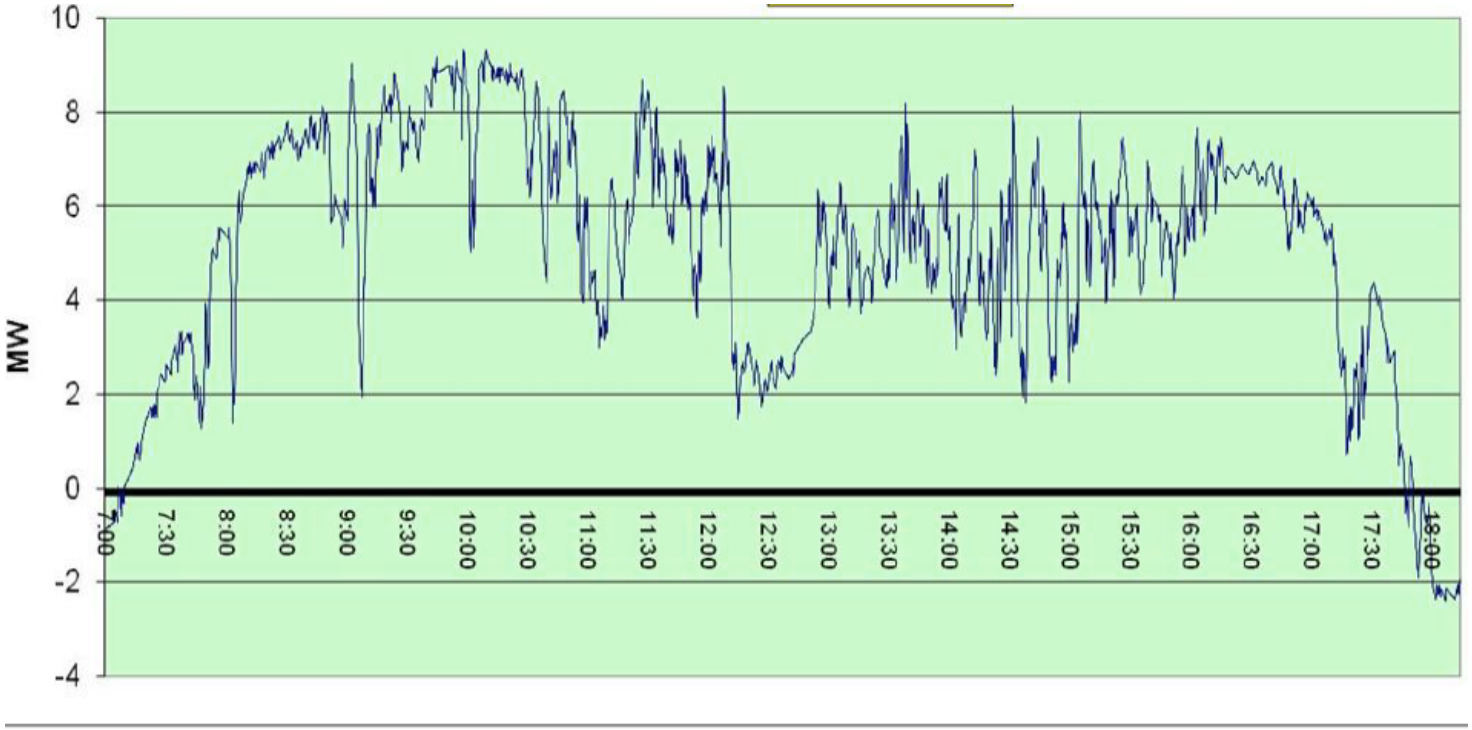
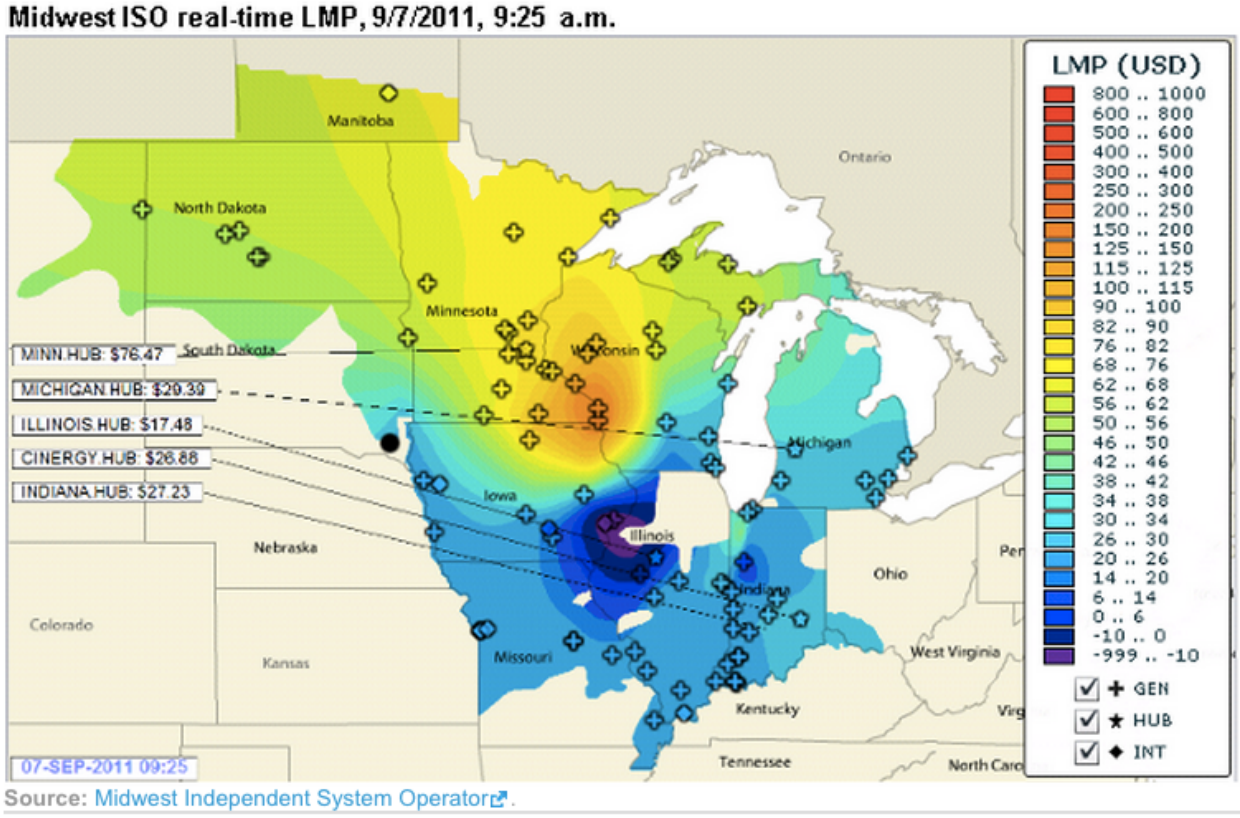


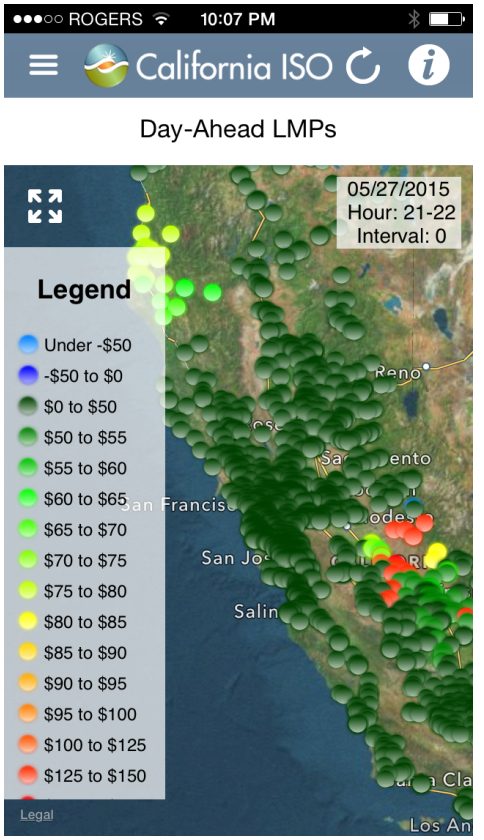
Figure 2.12: PV Plant output on a partly-cloudy day (Sampling time 10 seconds)

Source: NERC 2009

Challenges: nodal scarcity



May 27, 2015 day-ahead prices in CA



Source: CAISO

Challenges

Implications: 3 possible solutions

- Adjust "local" supply
  - Day-ahead (predictable)
  - Regulation and spinning reserves (unexpected)
  - Storage?
- Import from adjacent markets
  - Subject to transmission constraints and timeliness of resource availability
- Curtail demand
  - Demand response initiatives
  - **This is the *focus of my talk***

Options for demand response

Three main types of interventions

- Time-varying prices
- "Behavioral" interventions
  - E.g. moral suasion
- Automation
  - Curtailment contracts
  - Voluntarily response to high prices

- What has been tested?
- What have we learned?

Warning: almost everything we know relates to residential consumers

Main source

Jessoe, Rapson & Smith (forthcoming), "Utilization and Customer Behavior: Smart Choices for the Smart Grid", *International Handbook of Smart Grid Development*

An aside on methodologies

Many methods allow us to retrieve credible estimates DR intervention effects

- Randomized controlled trial
  - Recruit sample
  - Randomize into control and treatment groups
- Randomized encouragement design
  - When it is infeasible or undesirable to exclude from participation
  - Randomly encourage a subset of the population to participate
  - Compare encouraged and non-encouraged to retrieve treatment effect
- Regression discontinuity design
  - Many interventions are triggered by crossing a threshold

Goals: transparency, credibility, fairness.

Time-varying prices

Several flavours, which differ in timeliness and granularity

- Time-of-use pricing (TOU)
  - Peak and off-peak periods and prices set months in advance
  - E.g. $0.20/kWh from noon-8pm on weekdays; $0.10/kWh all other hours
  - Captures *at most* 6-13% of variability in wholesale market prices
- Critical-peak pricing (CPP)
  - Steep price increases for a small number of hours
  - Finite number of CPP "events" each season
  - Customers notified shortly before the event
- Real-time pricing (RTP)
  - Prices vary with high frequency to reflect wholesale market fluctuations

Very few (<5%) of customers in US are on TVP (mostly TOU)

Requires smart meters

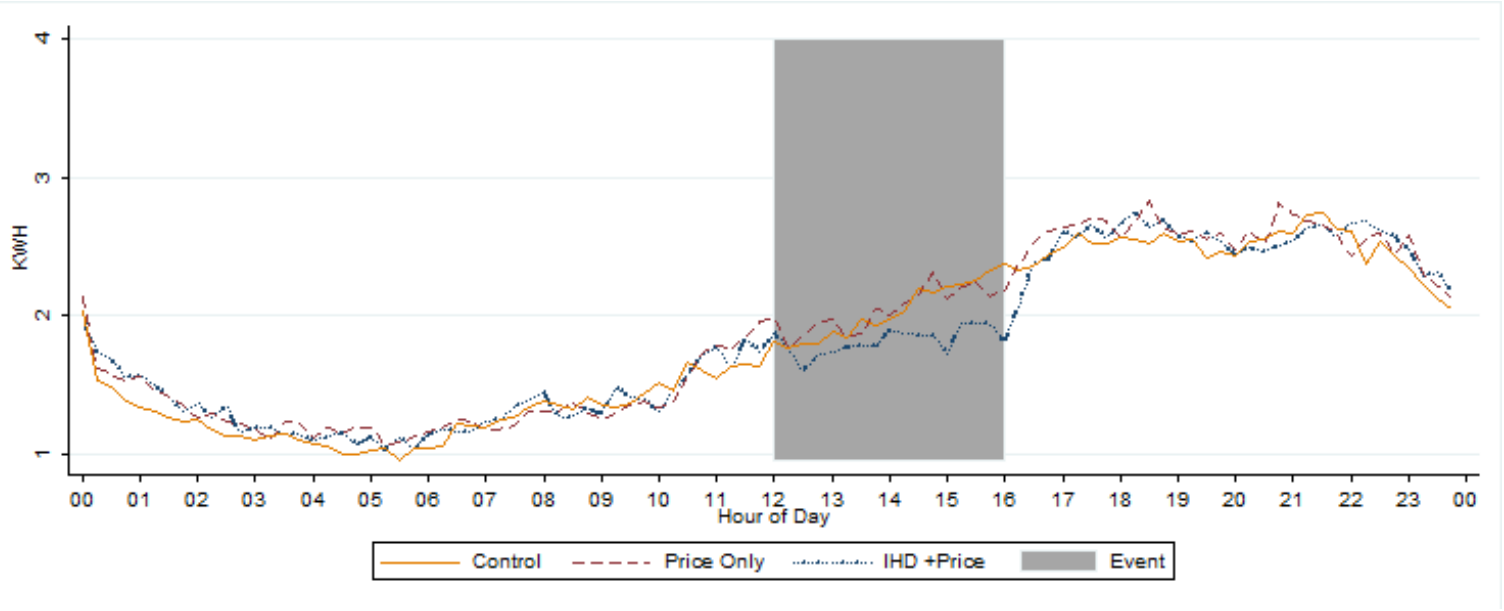
Time-varying prices

Evidence

- In general, consumers respond to prices
  - 10% increase in flat-rate prices leads to ~1% decrease in energy use
- TOU produces mixed results (small to insignificant effects)
  - Peak/off-peak gradient matters
  - Likely undermined by weak incentives and inattention
- CPP is much more effective
  - Several studies find large demand reductions during CPP events
  - Effects much larger (2-3x) when accompanied by information displays
- RTP: much less evidence
  - One study shows conservation response to high prices, with no load shifting

Time-varying prices

Example: randomized experiment in CT (Jessoe & Rapson 2014)



- CPP price: $0.70/kWh
- Treatment effects on treated
  - 7% price-only
  - 22% price+IHD
- Advance notice matters
  - Little response when given 30-min notice

Behavioural interventions

Interventions

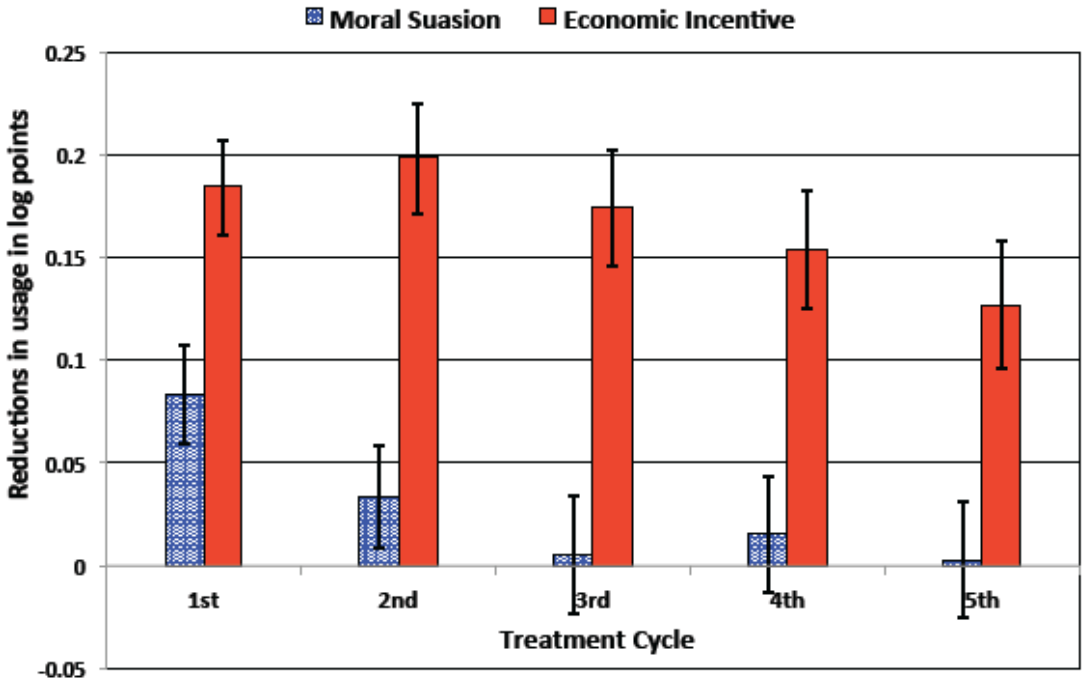
- Moral suasion
  - Appeal to pro-social instincts when requesting conservation during peak hours

Common, but generally deployed for overall energy conservation (not targeted DR)

- Social norms
  - Compare customer's usage to neighbours' usage
- Goal setting
- Games/competitions
- etc.

Moral suasion

Evidence (Ito, Ida and Tanaka WP)

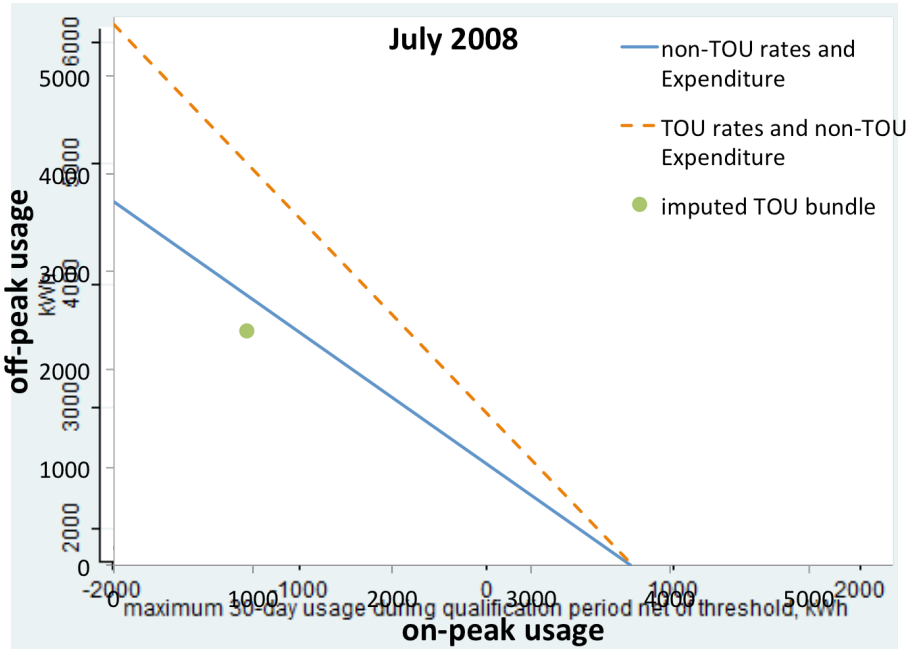


- Setting; Kyoto prefecture 2012-13
- Moral suasion "works", but much less than a large economic incentive
- Effects dissipate with repetition

Rational inattention?

Evidence from Jessoe, Rapson & Smith, 2014

Electricity usage at the TOU threshold



- Households forced onto TOU tariff if monthly usage exceeds a threshold (red)
- TOU rates *lower* than flat rates during *both* peak and off-peak hours during initial rollout
- In response, households *lowered* their electricity use!
- What can explain that?
  - Inattention
  - Intermittent updating
  - Other?

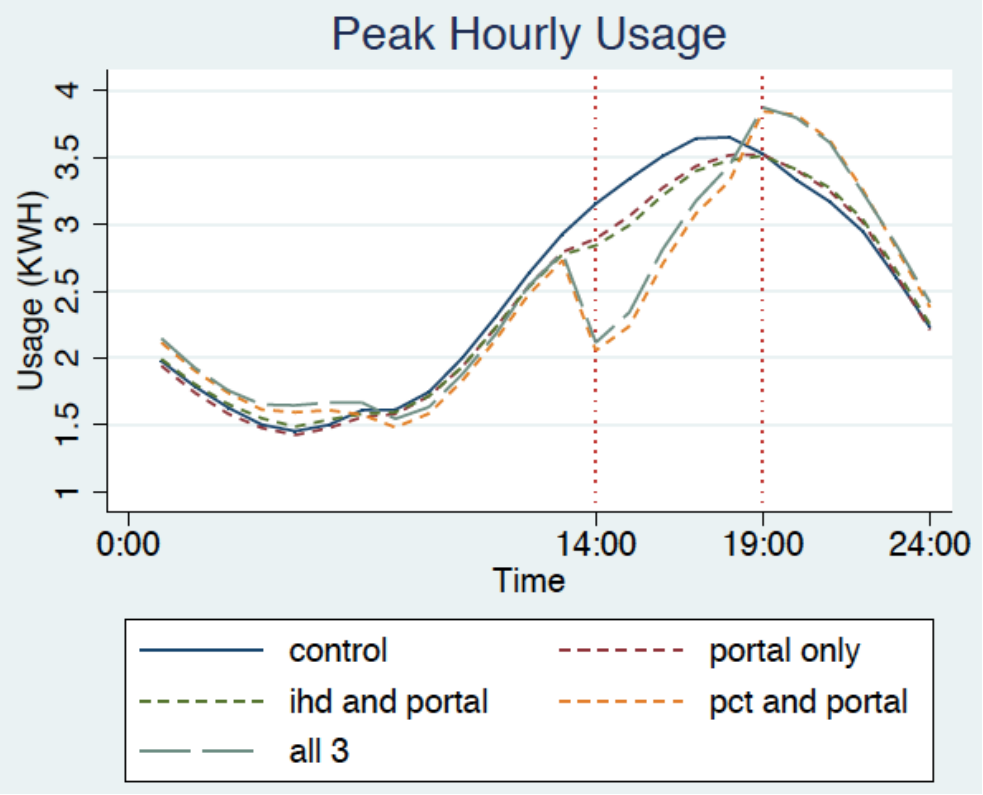
Automation

Two flavours

- "Smart" appliances pre-programmed to respond to prices
  - E.g. Thermostat temperature set point increases by 1-degree C when price rises above $0.30/kWh
- Electric utility enters into a contract allowing it to curtail load
  - Similar technology (smart appliances), but utility discretion
  - E.g. ENERNOC

Automation

Evidence 1: Hartman & Bollinger WP

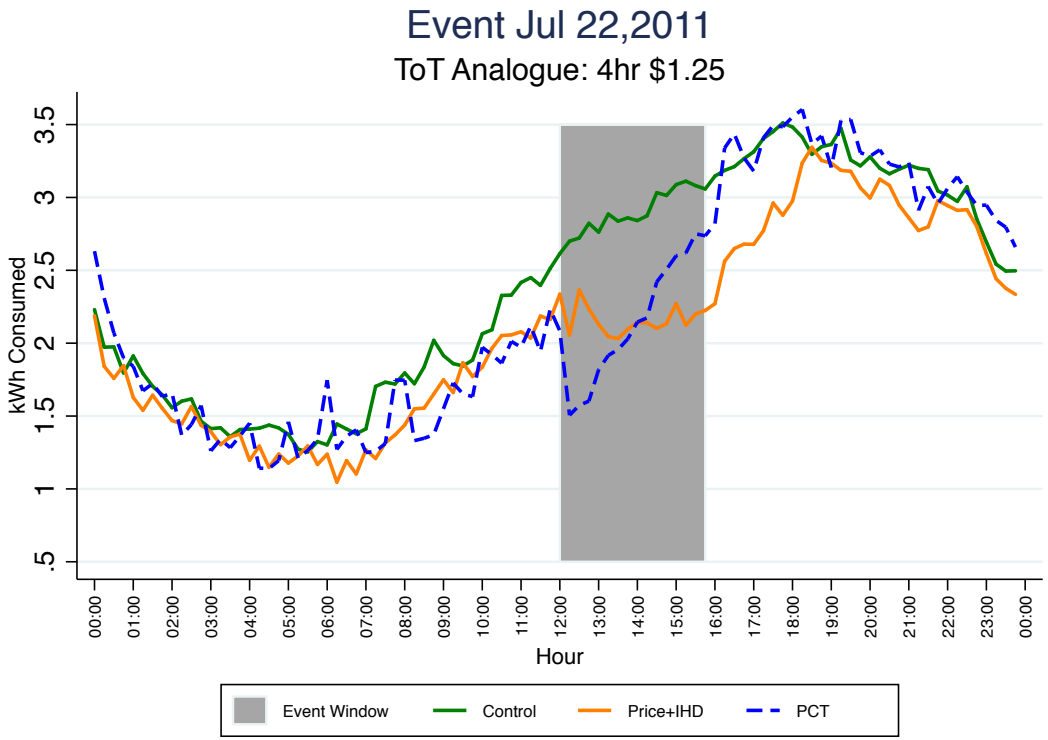


- TOU and CPP prices
  - I think this figure averages across them
- PCT cuts load to AC based on price and temperature

- Sharp effects from automation
- Can influence sharpness by staggering timing of device response (if desired)

Automation

Evidence 1: Jessoe, Miller & Rapson WP



- CPP prices
- PCT adjusts temperature set point up 3 degrees F during price events
- Sharp effects from automation

Summary

What have we learned about consumers?

- Responsive to price
  - Much more responsive to price when informed about usage
- Consumers are poorly informed
- (Rationally) inattentive, potentially intermittent updaters
- Susceptible to behavioural nudges
  - But these dissipate over time
  - These are difficult (but not impossible) to target to certain times

Implications

Demand response take-aways

- Prices and automation well-suited for addressing *expected* intermittency/ ramps
  - Requires smart meter and/or smart appliances/devices
- *Unexpected* intermittency/ramps less amenable to price-only solutions
  - Inattention
  - Coarseness of response
- Automation has clear benefits
  - Overcomes information and attention deficits
  - Social benefits ≠ private benefits
  - Requires investment in smart infrastructure

Research priorities

Where should we focus future research efforts?

- Commercial and industrial sectors
  - Do firms behave as "rational" agents?
- Long-run response to prices/automation
- Effect of compound interventions
  - How do intrinsic and extrinsic triggers interact?
- "Supply curve" of DR and substitutes
  - Private vs social costs of intervention
  - How do they compare to alternatives (e.g. storage)?
- What is the best way to roll out DR programs to the masses?
  - Choice-neutral defaults?
  - Voluntary? Mandatory? Incentive-based?

Thank you

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