Residential Response to Critical Peak Events of Electricity: Green Mountain Power Experience

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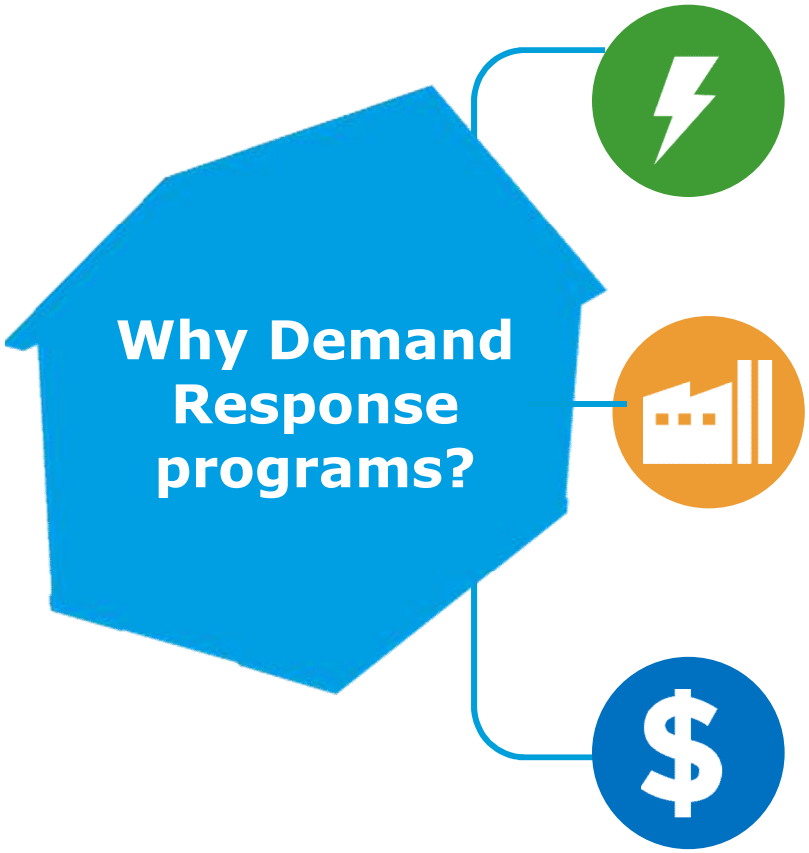
Motivation:



Properties of electricity markets

- Non-storability of electricity
- Dynamic electricity demand

Demand response (DR) programs can reduce the peak electricity demand by encouraging customers reduce their consumption.

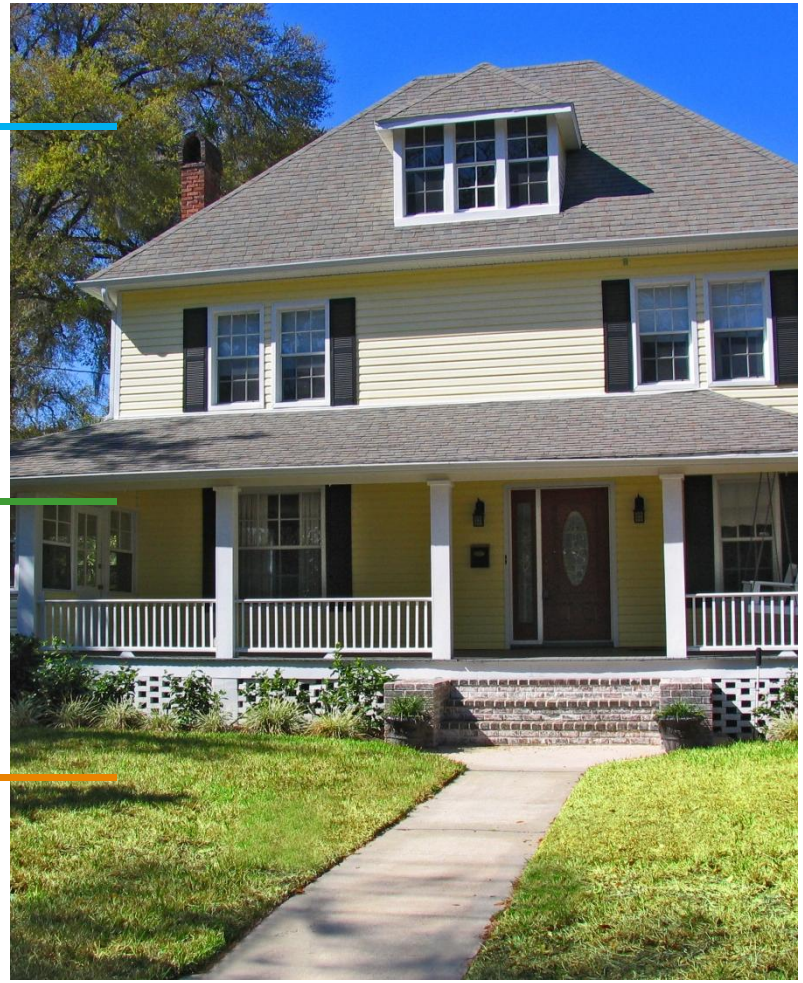
Besides increasing electric grid reliability, DR programs also benefit utility companies by minimizing the need of building new infrastructure

Key Research Questions

What is the impact of time-varying electricity rates and information technology on residential average hourly kW usage in time periods surrounding critical peak events?

Are changes in hourly electricity consumption persistent?

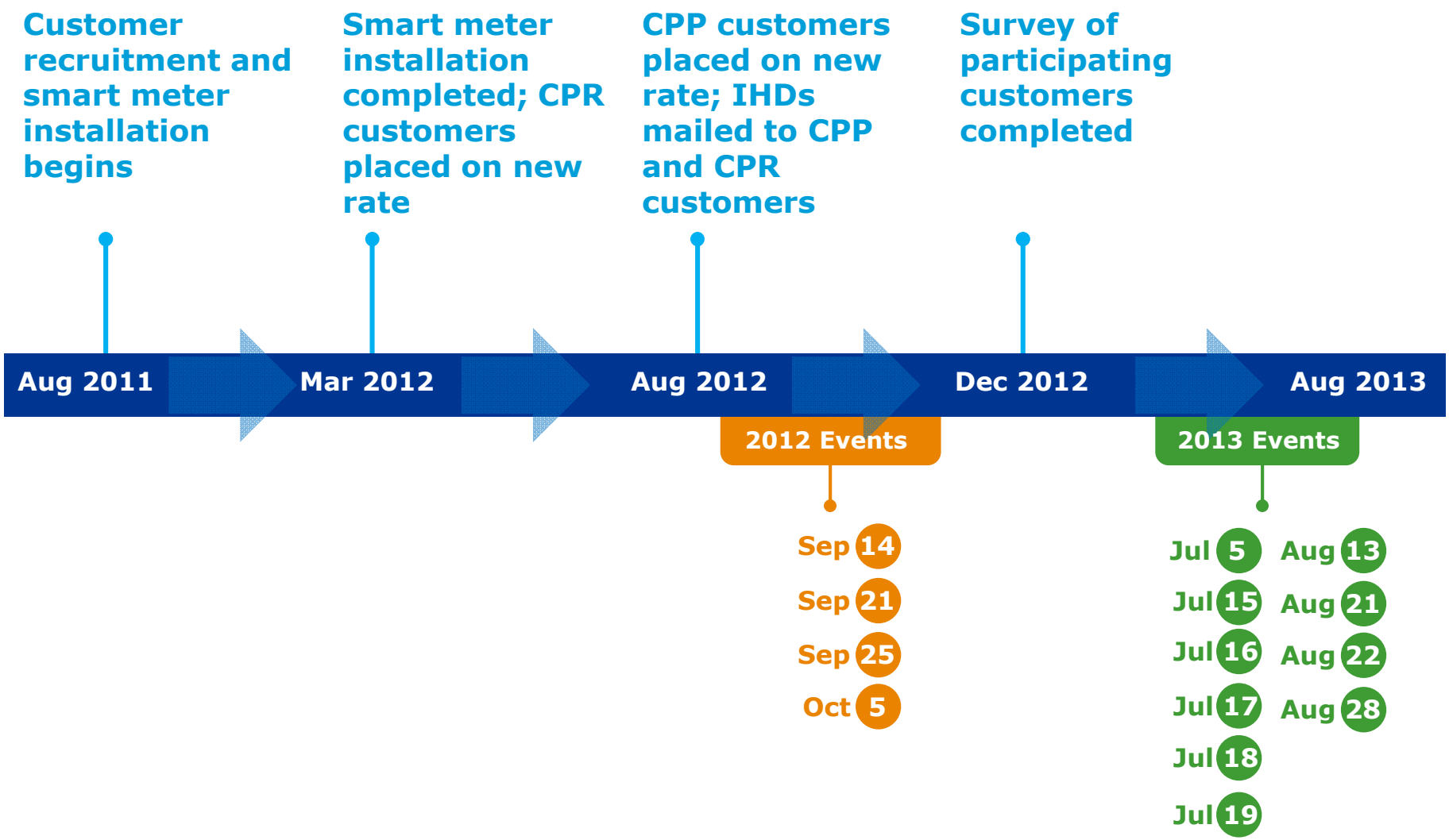
Does the presence of information technology induce changes in monthly electricity?



GMP Pilot Study

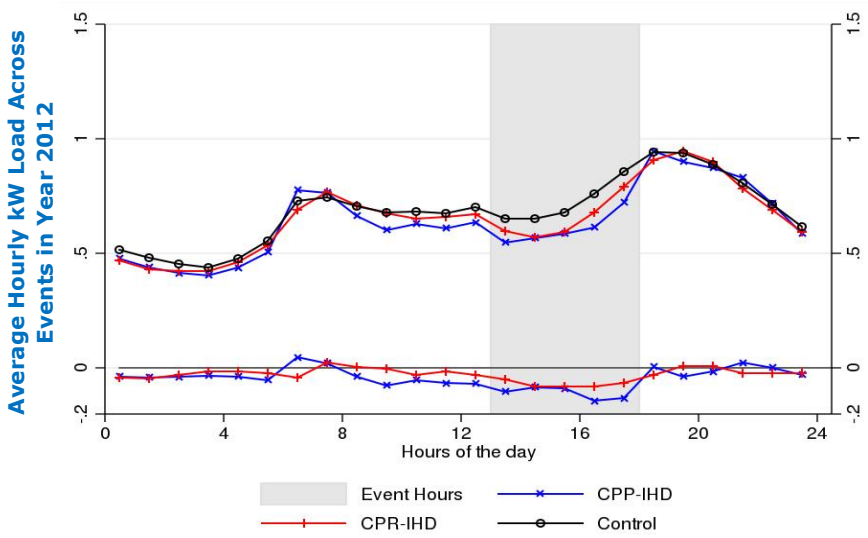
- Two time-based rates – critical peak pricing **(CPP)** and critical peak rebate **(CPR)** – coupled with in-home display **(IHD)** equipment
- **Single-home residents** of Rutland, VT area
- **Two-step approach** for participant selection
- **2107** participants separated into four treatment groups and a control group resulting in **23 million** hourly load observations for the two-year study

Timeline of the pilot study



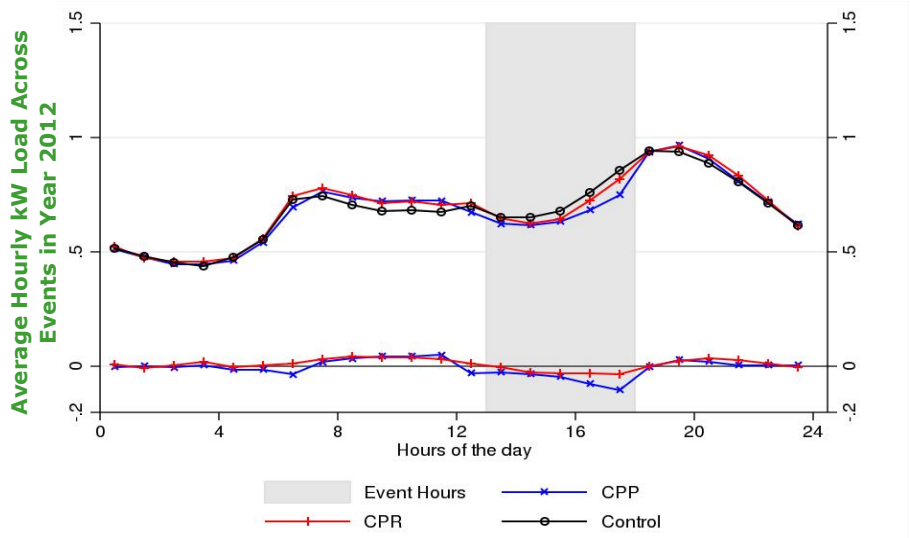
Average hourly load during CPP events – 2012

IHD Groups



The graph around x- axis represents average hourly kW difference between treatment and control groups

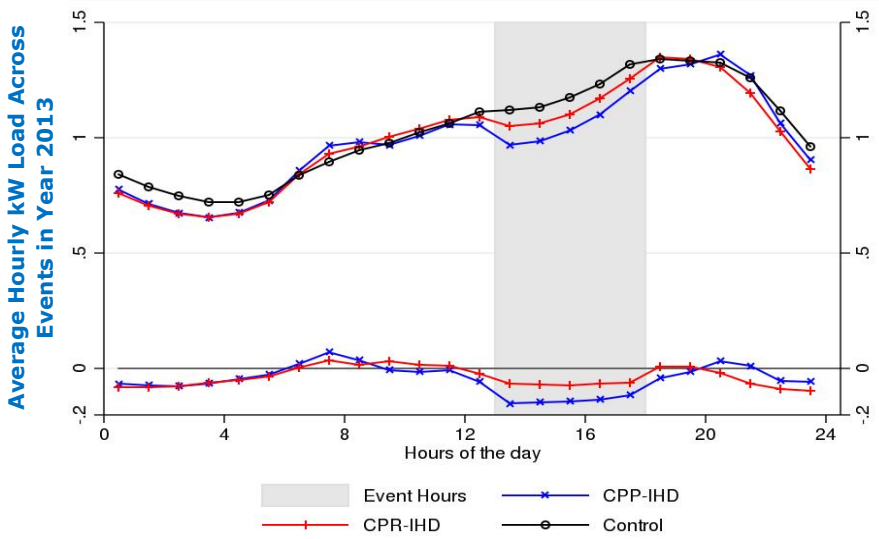
Non IHD Groups



The graph around x- axis represents average hourly kW difference between treatment and control groups

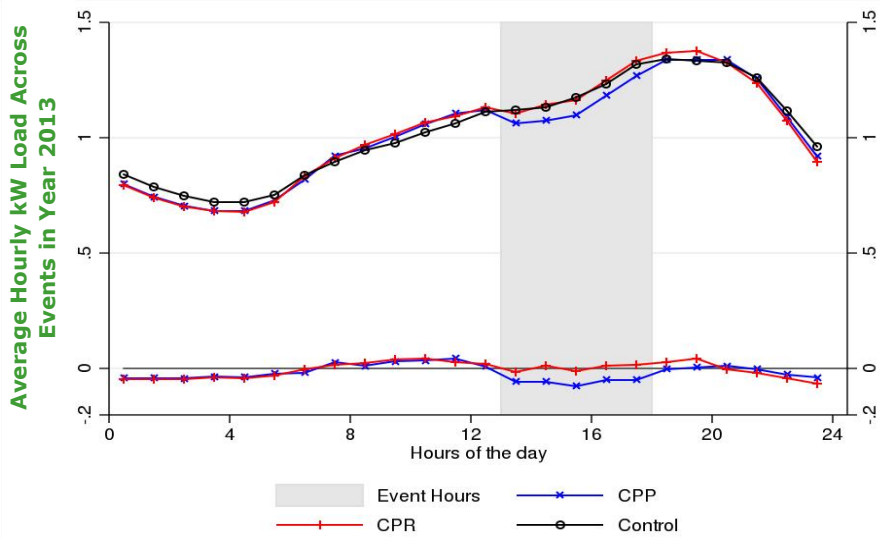
Average hourly load during CPP events – 2013

IHD Groups



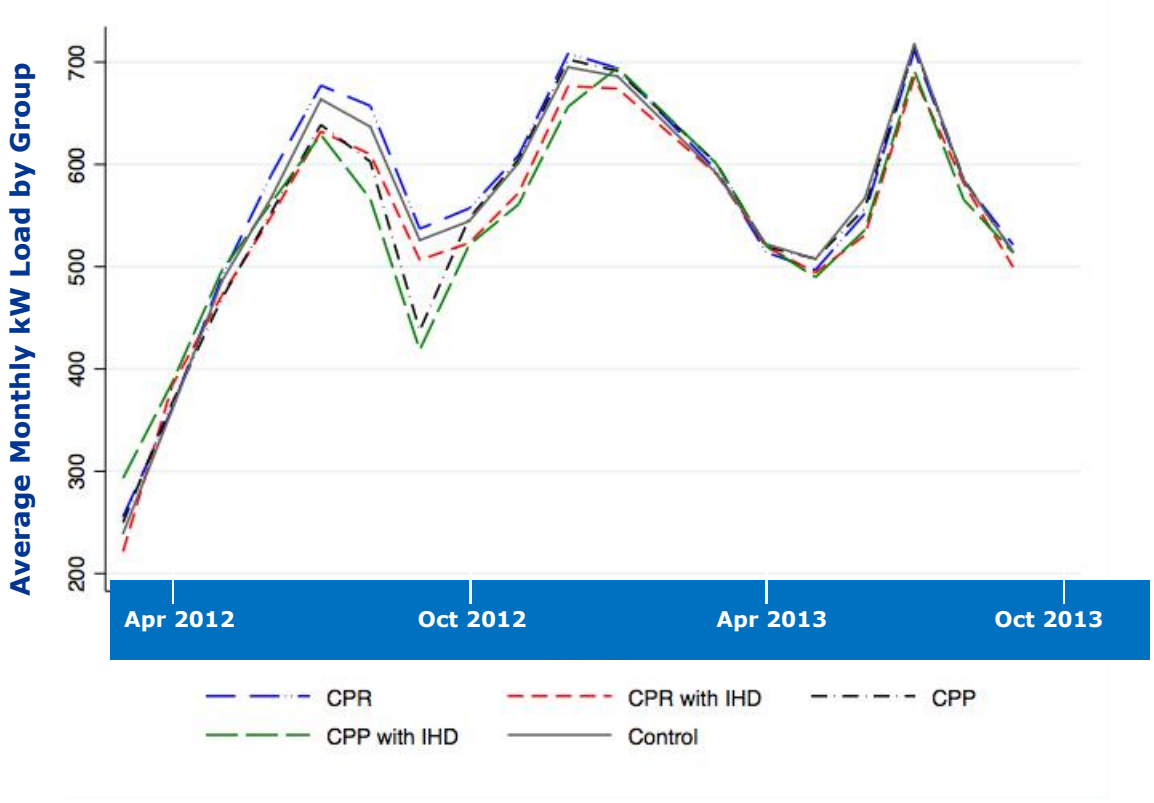
The graph around x- axis represents average hourly kW difference between treatment and control groups

Non IHD Groups



The graph around x- axis represents average hourly kW difference between treatment and control groups

Average Monthly Energy Consumption by groups



Peak load analysis – Randomized Control Treatment

$$(1)\quad y_{it} = \beta_i + \beta_1 Temp_t + \beta_2 \sum_j DT_{ji} + \beta_3^{DB} DB_t + \beta_3^{DE} DE_t + \beta_3^{DA} DA_t + \beta_4^{DB} \sum_j DT_{ji} * DB_t + \beta_4^{DE} \sum_j DT_{ji} * DE_t + \beta_4^{DA} \sum_j DT_{ji} * DA_t + \varepsilon_{it}$$

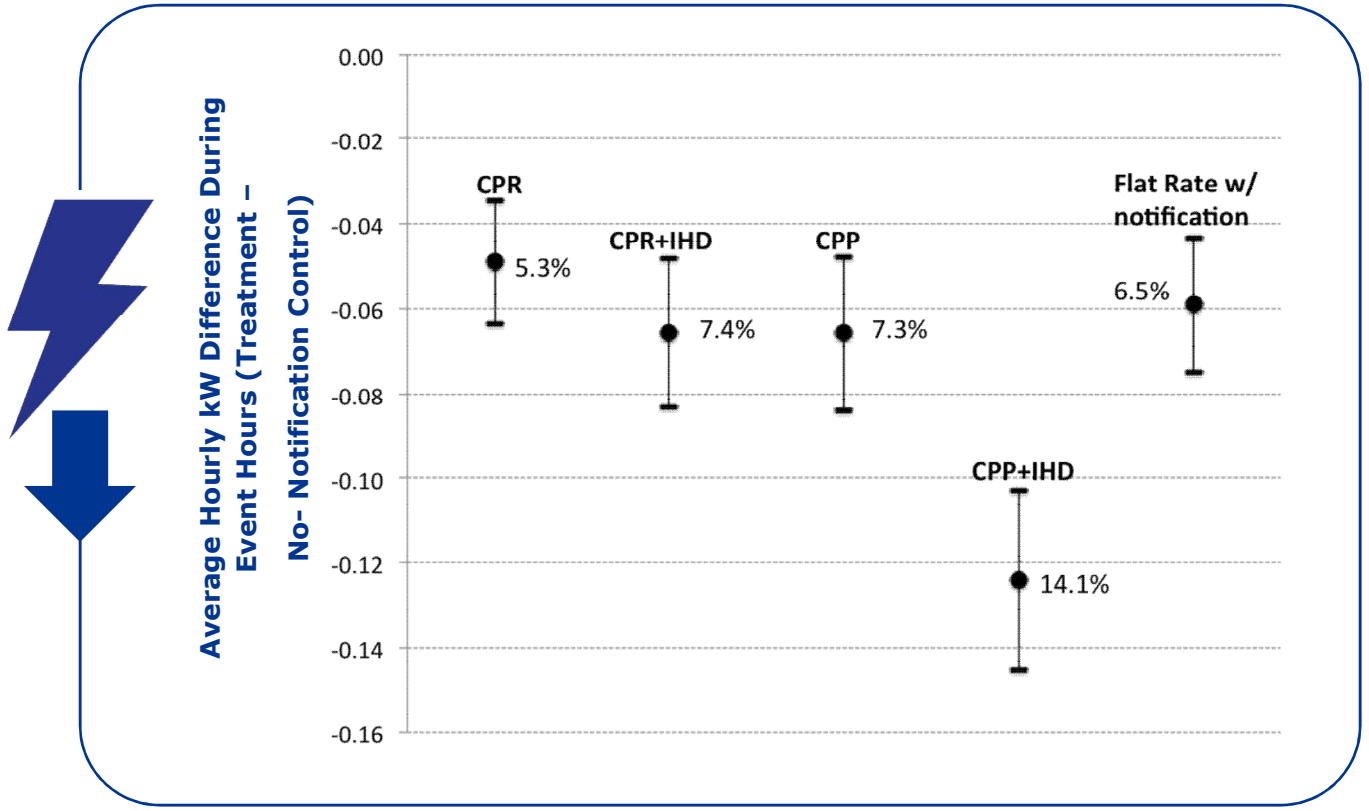
where y is the residents' hourly electricity consumption.

$Temp$ includes three weather related hourly

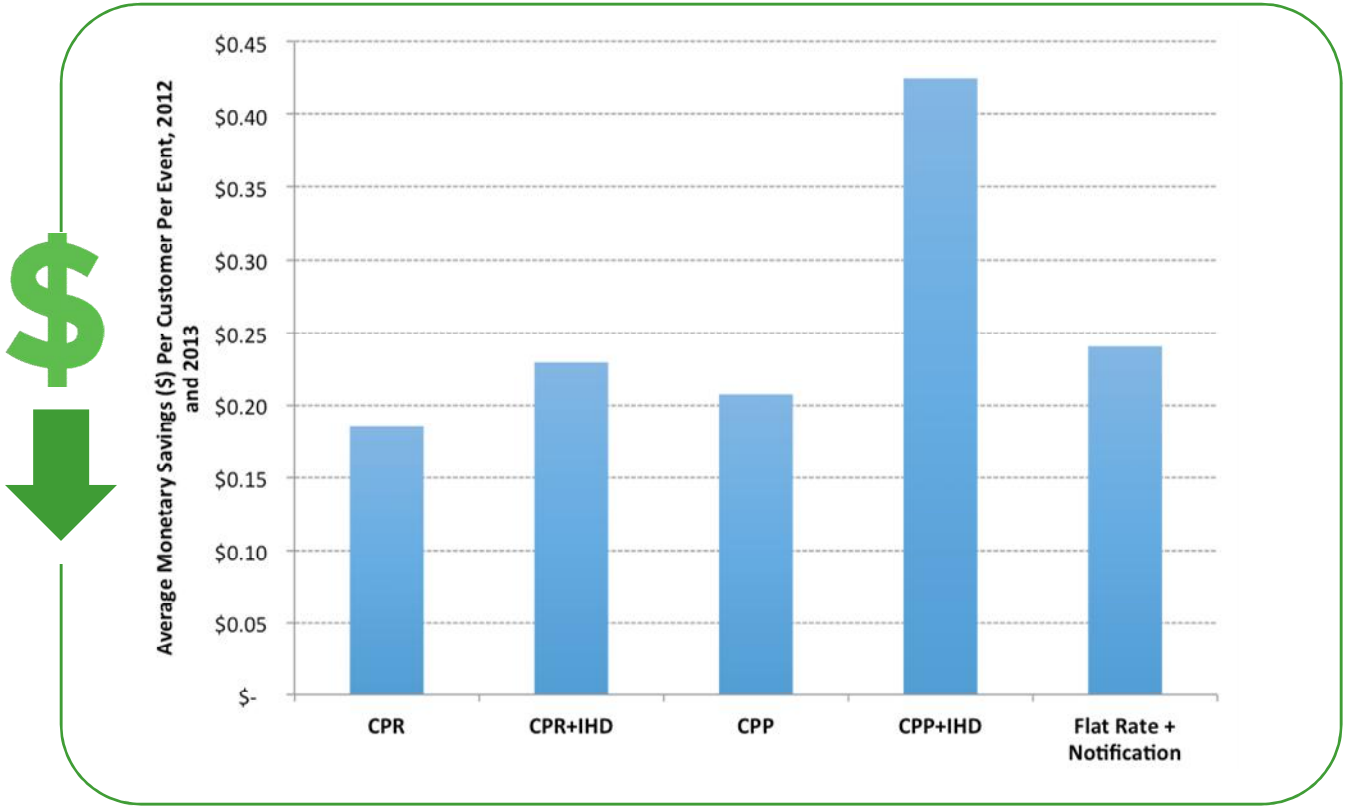
DT indicates different treatment groups.

DB, DE, and DA are three binary variables denoting hours surrounding critical peak event – before, during, and after the event.

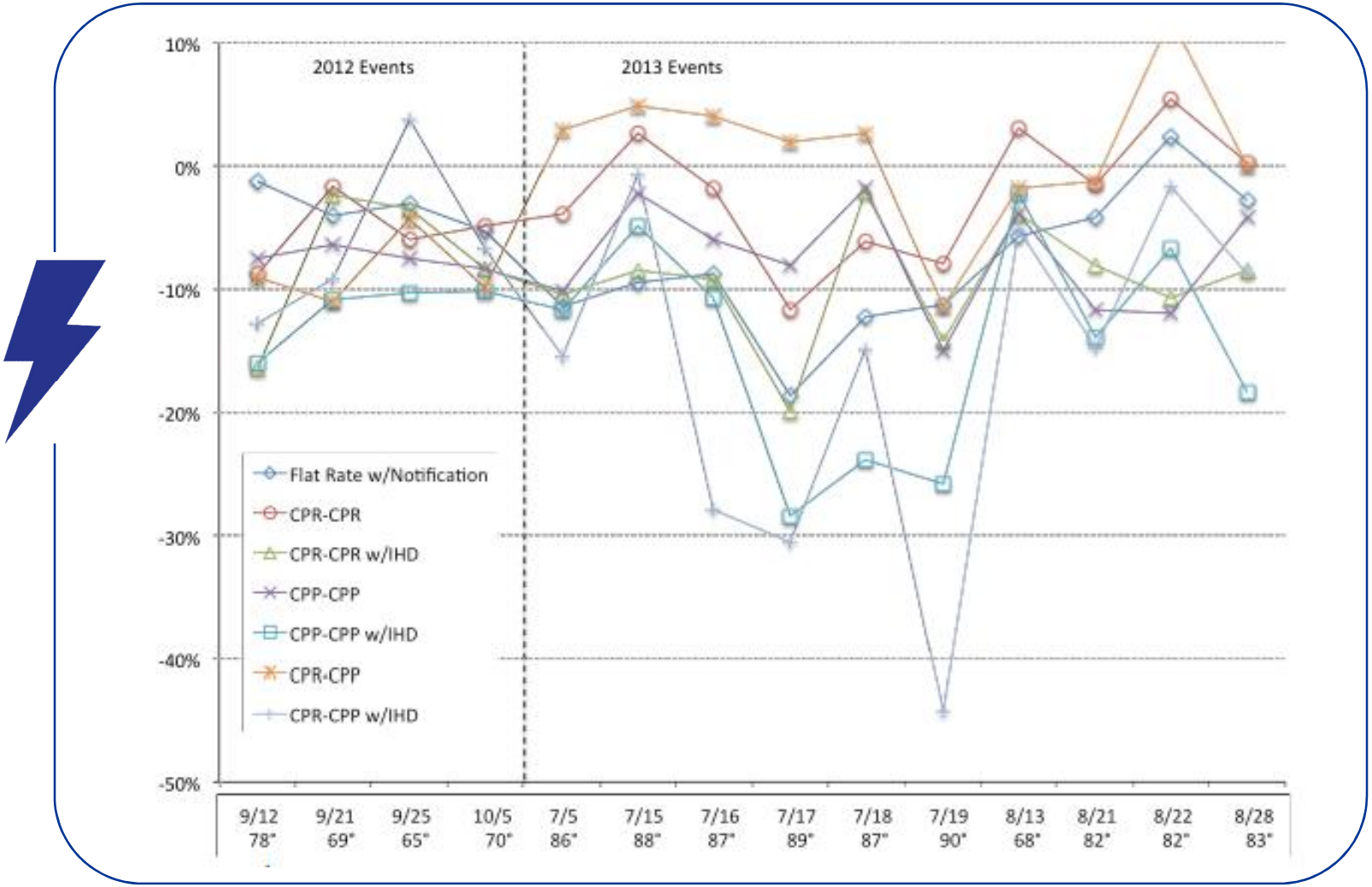
Average Peak Load Reduction by Treatment Group



Average Monetary Savings ($) per Customer per Event



Persistence Analysis by Treatment groups



Impact of IHD technology in monthly electricity usage (kW)

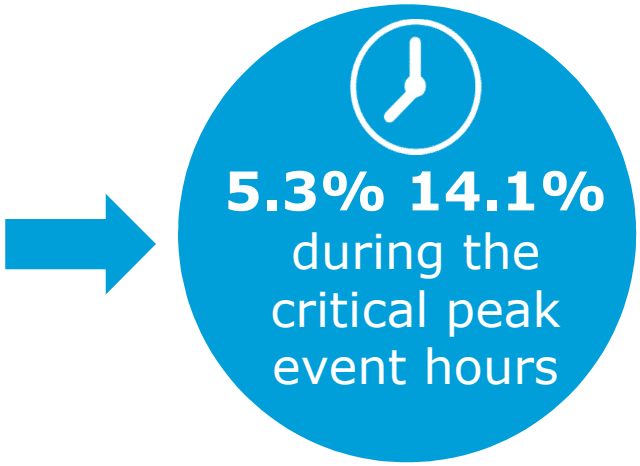
$$y_{im} = \theta_i + \theta_m + \theta_1 W_m + \theta_2 IHD + \varepsilon_{im}$$

Independent Variables	*Year 1 (2012)*	*Year 2 (2013)*
Average monthly cooling degree hours	-37.402**	45.924**
	(17.591)	(19.250)
Average monthly heat index (F)	9.558***	5.086
	(2.714)	(3.558)
Customers with IHD	-34.616***	-12.707**
	(9.240)	(6.264)
Number of observations	*22,313*	*19,490*
Adjusted R2	*0.072*	*0.218*
Month-fixed effects	*Yes*	*Yes*

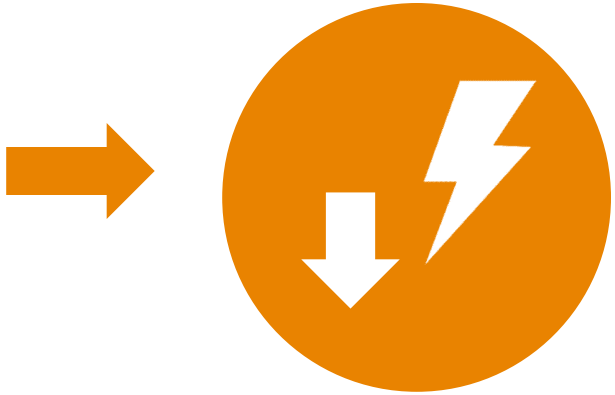
*note: *** p<0.01, ** p<0.05, * p<0.1*

Take away from the pilot study

CPP and **CPR** treatments did induce demand reductions during critical peak periods. Econometric results suggest peak load reduction of 5.3 – 14.1 percent during the critical peak event hours.



One of the interesting findings is that a simple notification of **critical peak events** can be as effective as some types of rate treatments.



Take away from the pilot study

IHD equipped participants' monthly energy consumption is **2.0 – 5.3%** lower than the monthly energy usage of **non-IHD customers.**

Rate and information treatments used in the pilot study did not induce persistent and consistent response across multiple events. Rate/Information treatments alone will not be successful in reducing peak load as desired.

Image source: http://www.edmi-meters.co.uk/chameleon-in-home-display/

Thank you.

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SAFER, SMARTER, GREENER

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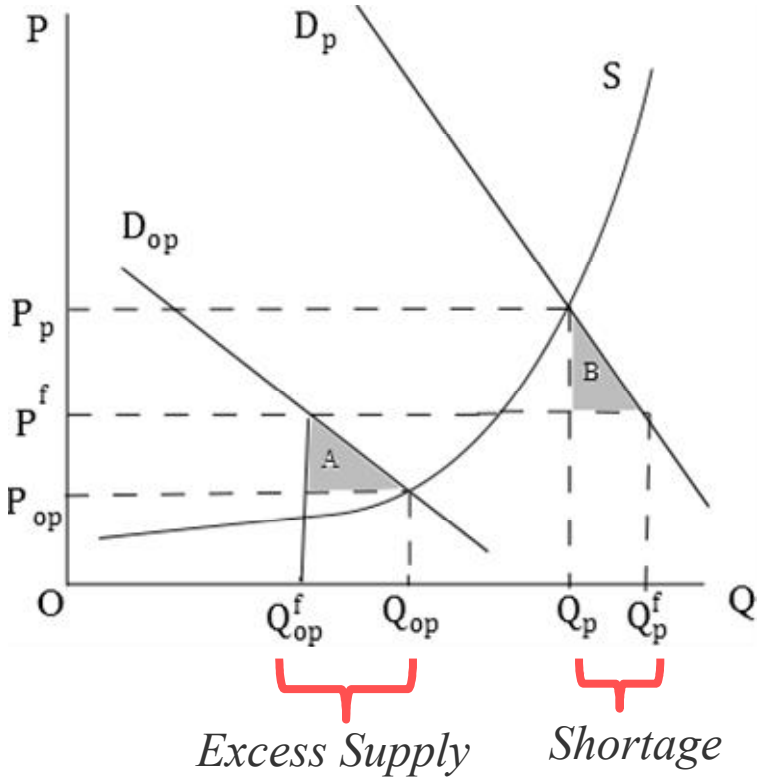
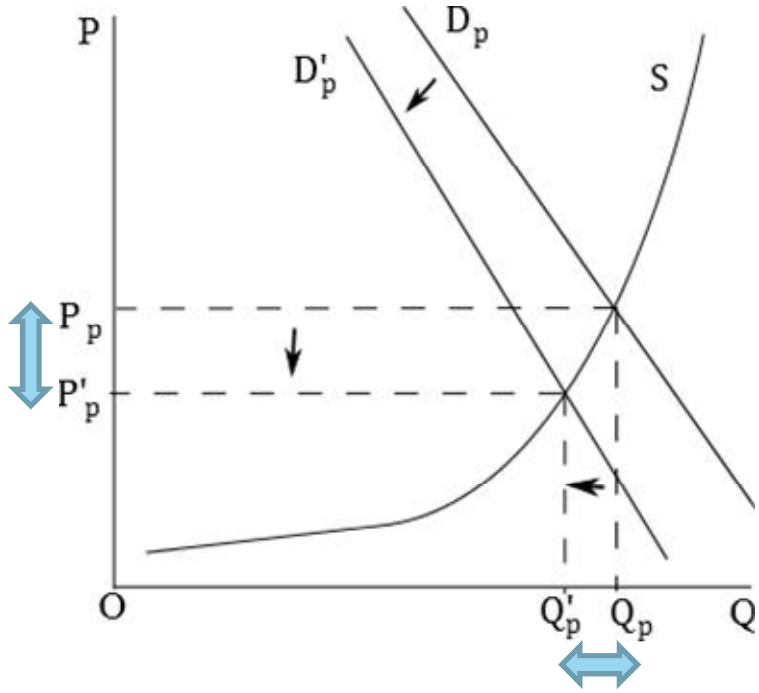
Additional Slide I:
Why DR programs?

four groups – participant, market-wide, reliability, and market performance (Albadi and El-Saadany, 2008)





Additional Slide II:
Regression Results – Peak Load Analysis

RCT Results

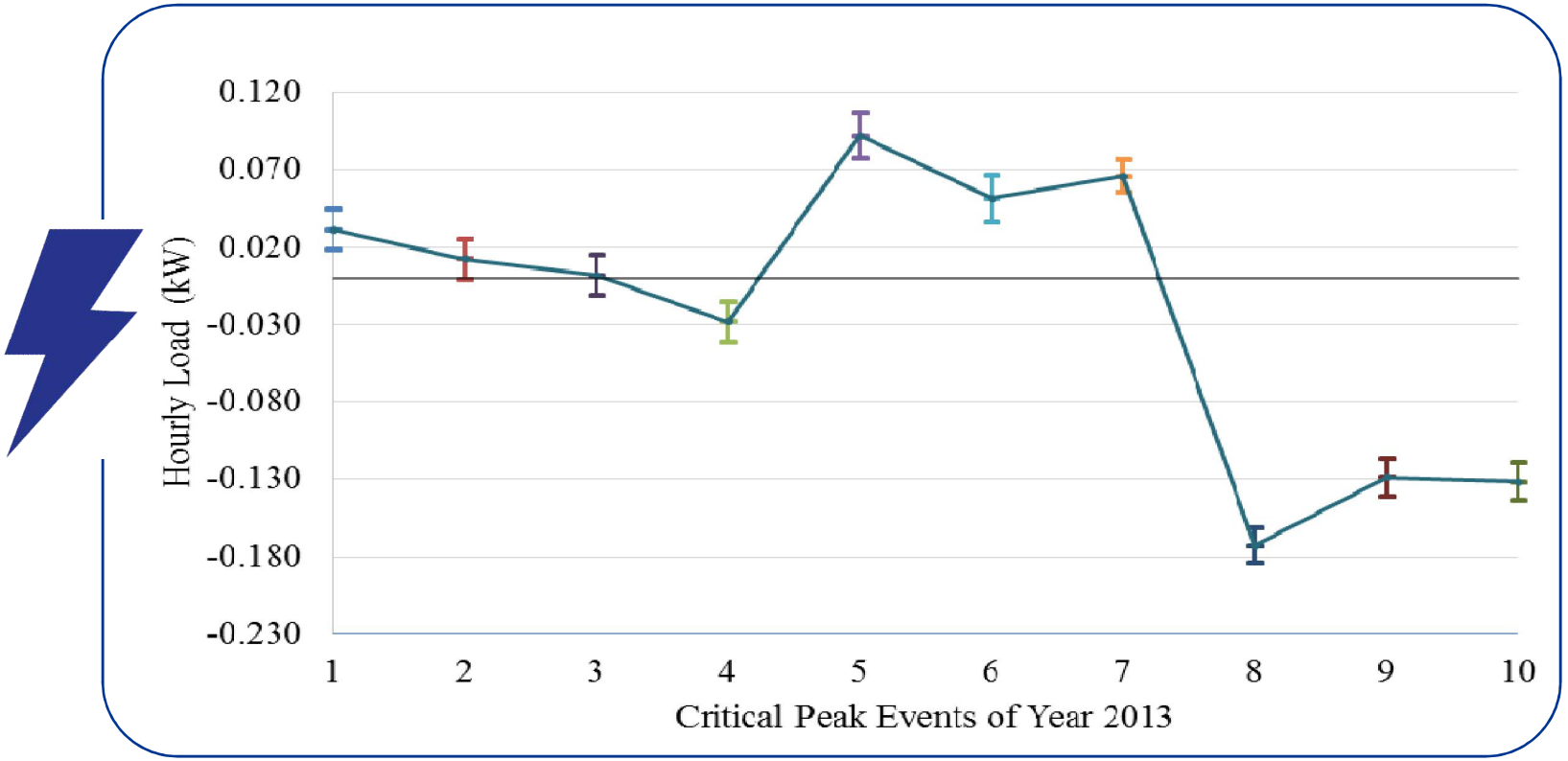
Treatment Groups	*Only Group*	*Interaction of Group*Events*		
		DB	*DE*	*DA*
		0.069***	-0.034	0.147***
		(0.016)	(0.023)	(0.019)
CPR	0.025	-0.006	-0.045	-0.032
	(0.022)	(0.021)	(0.031)	(0.026)
CPR with IHD	-0.013	0.006	-0.068*	-0.028
	(0.025)	(0.027)	(0.036)	(0.030)
CPP	-0.013	0.033	-0.051	0.002
	(0.023)	(0.022)	(0.031)	(0.026)
CPP with IHD	-0.017	0.024	-0.103***	0.010
	(0.026)	(0.027)	(0.036)	(0.031)
Control with notification	0.011	-0.025	-0.053*	-0.032
	(0.008)	(0.023)	(0.032)	(0.027)
Number of observations		*26,378,106*		

*note: *** p<0.01, ** p<0.05, * p<0.1*

RED, LATE Results

Independent Variables	*RCT Analysis*	*RED Analysis*	*LATE Analysis*
Before Event Hours * CPP	0.033	0.038	0.0406
	(0.022)	-(0.026)	(0.028)
Before Event Hours * CPP - IHD	0.024	0.027	0.0285
	(0.027)	-(0.030)	(0.032)
During Event Hours * CPP	-0.051	-0.058	-0.0632
	(0.031)	-(0.036)	(0.039)
During Event Hours * CPP - IHD	-0.103***	-0.116***	-0.1247
	(0.036)	-(0.040)	(0.043)
After Event Hours * CPP	0.002	0.002	0.0021
	(0.026)	-(0.030)	(0.032)
After Event Hours * CPP - IHD	0.010	0.011	0.0118
	(0.031)	-(0.035)	(0.038)

Additional Slide III:
Persistence Analysis during critical peak events of 2013



Additional Slide IV:
Comparing Peak load changes with Temperature