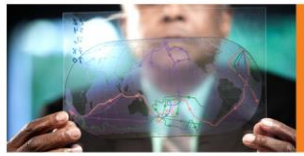
CADMUS



Residential Behavioral Savings Pilot Evaluation

Vermont Public Service Department

2014 – 2016

July 26, 2016

Agenda

1. Pilot Overview
2. Research Objectives
3. Methods
4. Key Findings
5. Conclusions and Recommendations

Residential Behavior Savings Overview

RCBS Pilot objectives:

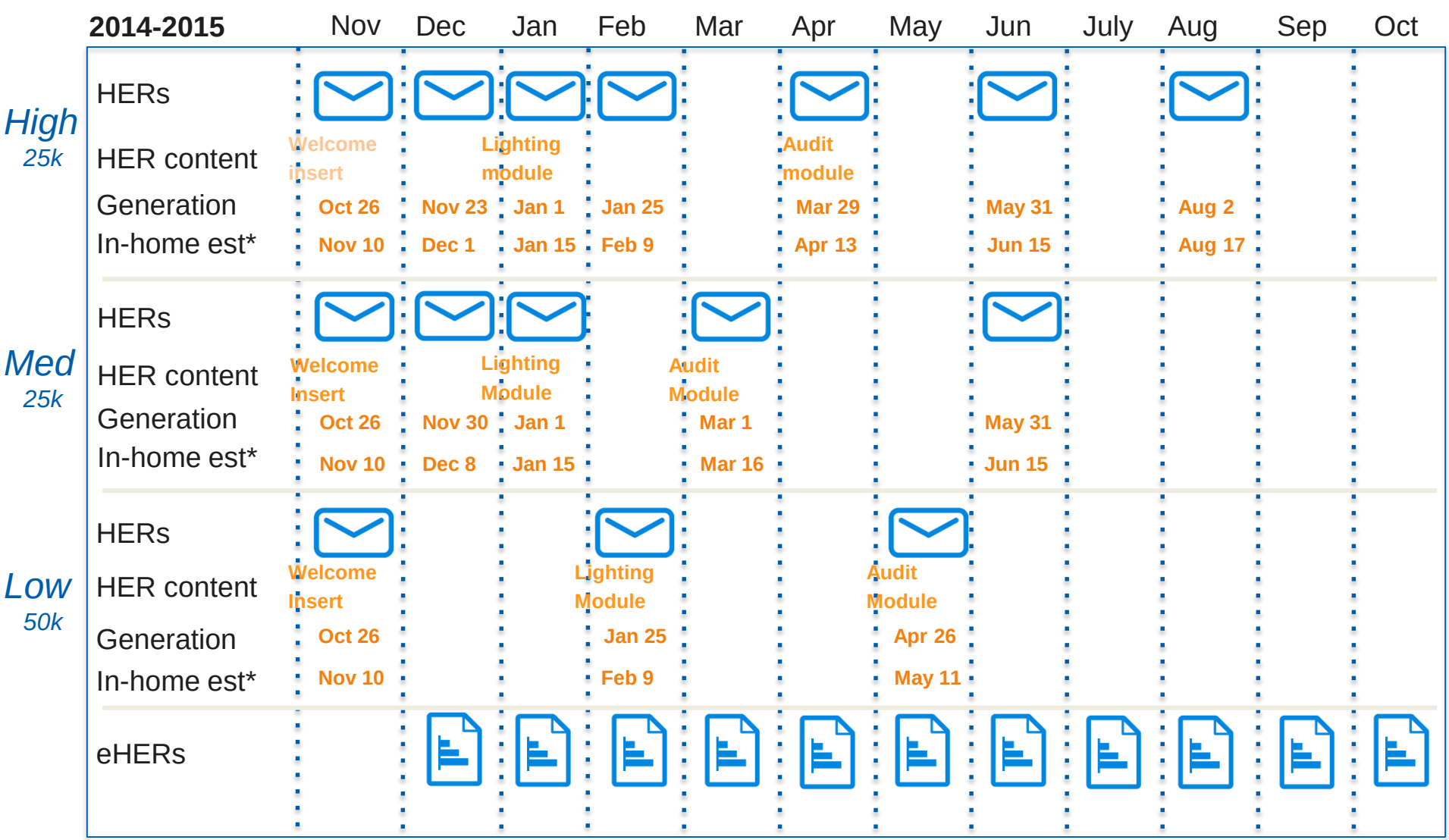
- Achieve verifiable, cost-effective savings for Vermont
- Increase customer awareness of energy efficiency
- Encourage customers to adopt energy-saving behaviors and measures
- Promote Efficiency Vermont's (EVT) energy efficiency programs and drive customers towards participation

HER = Home Energy Report

Pilot Design

Group and Use Band	HERs Delivery Frequency	Number of Customers
Treatment Group		
High Users	7 printed HERs; 6 electronic HERs; web portal access	26,232
Medium Users	5 printed HERs; 6 electronic HERs; web portal access	26,291
Low Users	3 printed HERs; 6 electronic HERs; web portal access	52,456
Total Treatment Group		**104,979**
Control Group		
High Users	N/A	5,262
Medium Users	N/A	5,203
Low Users	N/A	10,532
Total Control Group		**20,997**

Original HER Distribution Plan



Revised HER Delivery Cadence

Report frequency was designed to vary by Energy Use Groups. All groups experienced a five month pause in report delivery in 2015.

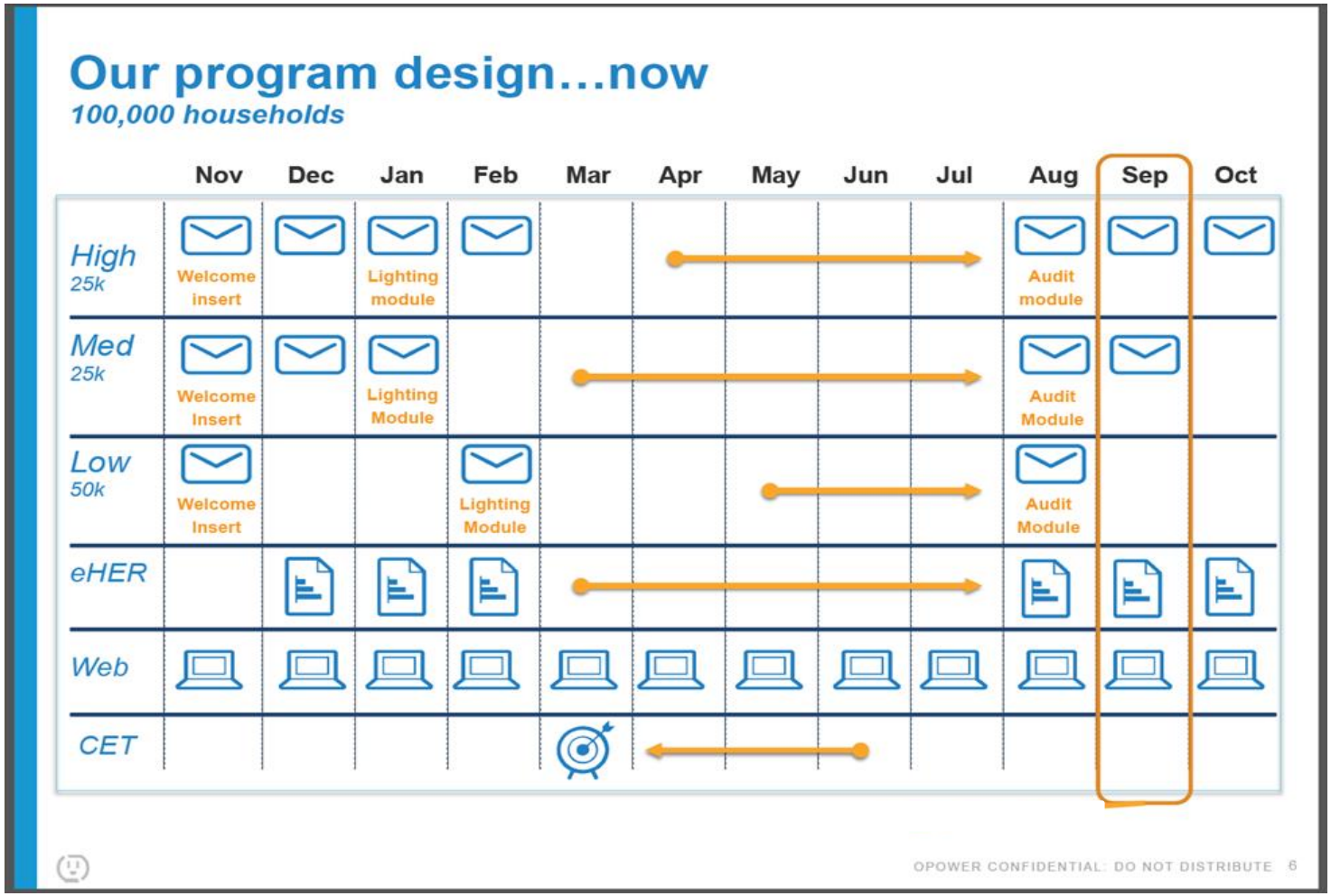
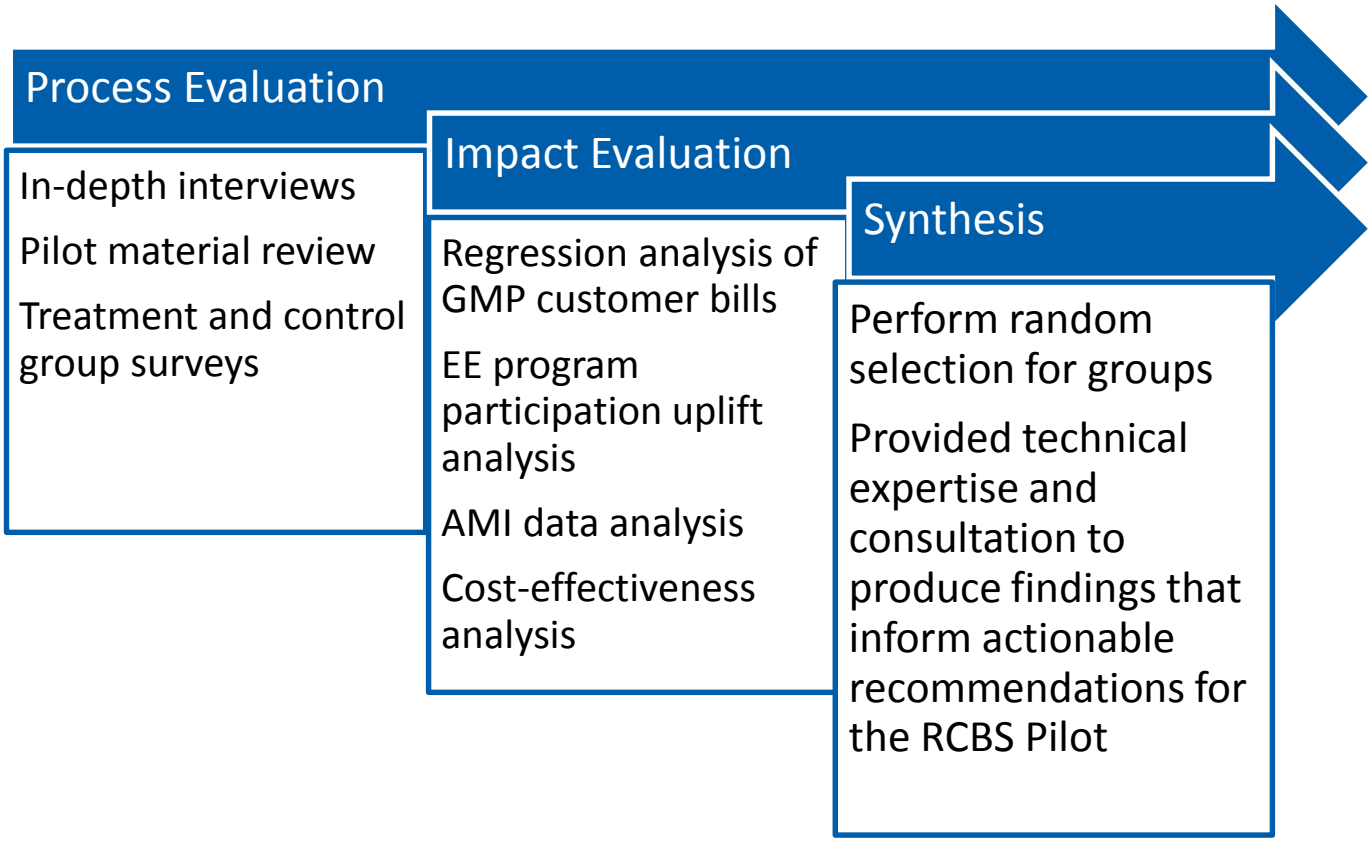


Image provided by Opower

Evaluation Research Questions

- What were the RCBS Pilot's impacts on household electricity consumption in 2014 and 2015?
- What impacts did the RCBS Pilot have on customer energy use behaviors? How much savings were attributable to behavior change, as opposed to measure adoption?
- How did RCBS Pilot savings and behavior change vary across high, medium, and low energy use groups?
- What impact did the RCBS Pilot have on participation in EVT's energy efficiency programs?
- What was the RCBS Pilot's benefit to cost ratio (cost-effectiveness)?
- How might the HERs or RCBS Pilot design be improved?

Evaluation Activities



Evaluation Methods

Conducted Interviews

Stakeholders	Number of Interviews	Number of Interviewees
PSD program staff	1	4
EVT program staff	2	4
OPower program staff	1	3
Total	**4**	**11**

Conducted Surveys (1,206 respondents)

Reviewed Materials

- Planning workshop presentation
- EVT HER program design presentation
- HER detailed distribution timeline
- OPower program design, eligibility, selection, and review memos
- HER welcome letter
- Printed and electronic HERs for high, medium, and low energy users
- Vermont single-family existing homes report
- Vermont single-family retrofit market research report
- Vermont single-family retrofit market process evaluation report

Impact Methods

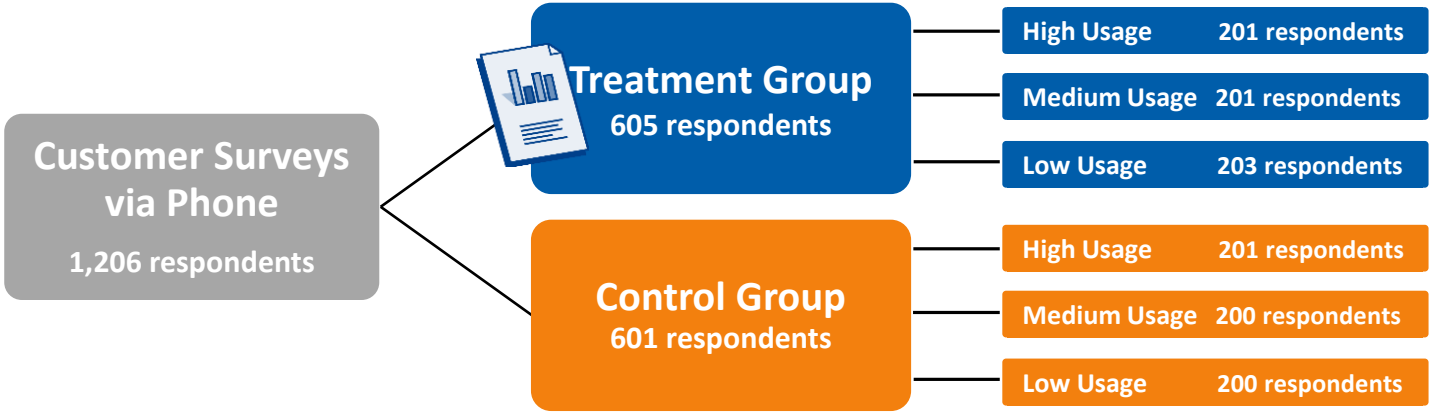
- Perform random assignment of customers to treatment and control groups for RCT
- Data collection
- Billing analysis
- Savings estimation
- AMI data analysis
- Energy efficiency program uplift analysis
- Cost-effectiveness analysis

KEY FINDINGS

Survey Method

Customer surveys fielded in December 2015 at 12-month mark of pilot

Survey Sample



Analysis

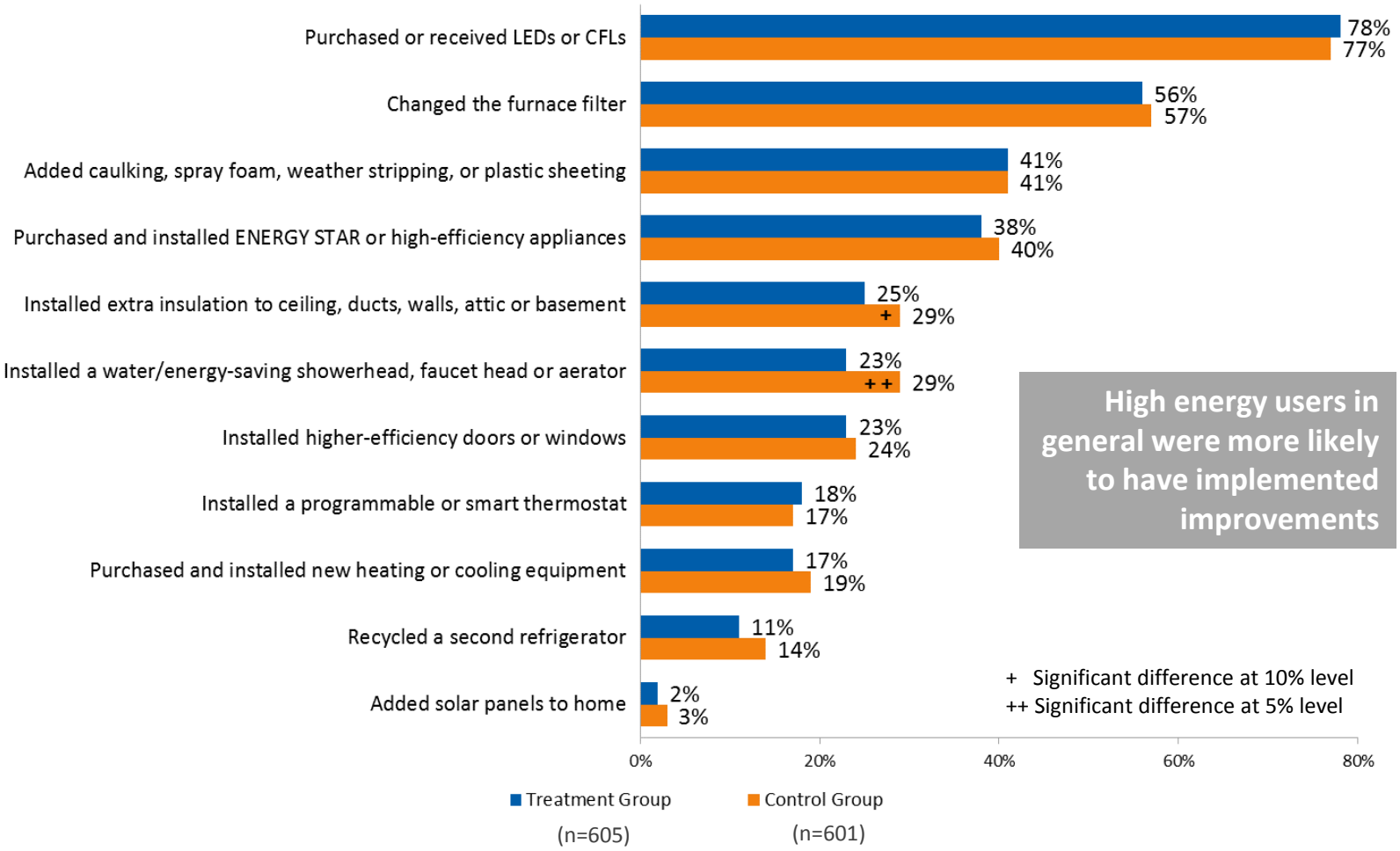
t-test to compare proportions and means between treatment and control groups and energy usage groups

5% significance level ($p \leq 0.05$)

10% significance level ($p \leq 0.10$)

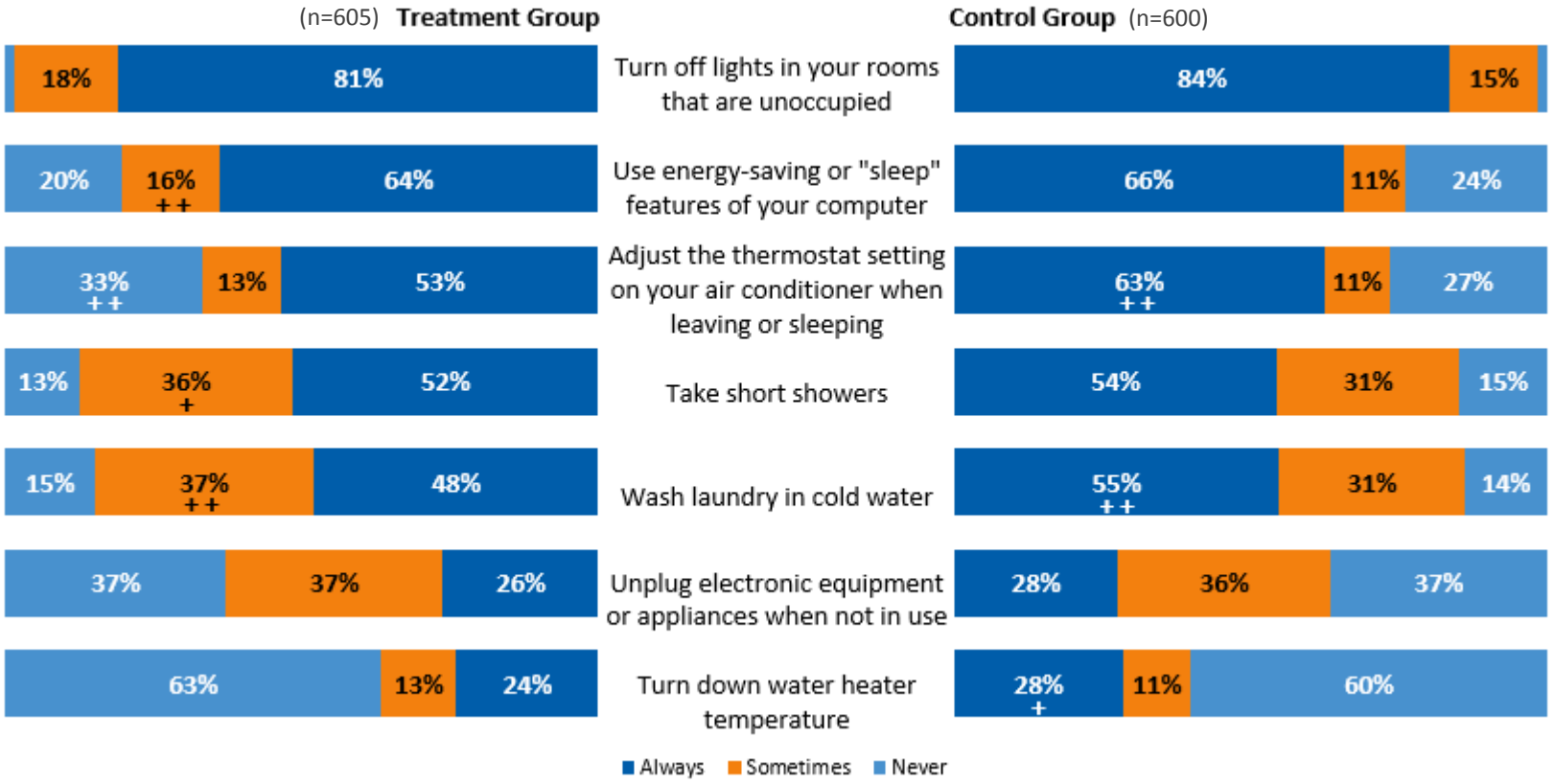
Reported Energy-Saving Improvements

Treatment respondents did not implement improvements at a higher rate than control respondents; control respondents show higher implementation rates



Frequency of Energy-Saving Behaviors

Treatment respondents do not take energy-saving actions more frequently than control respondents; control respondents significantly take actions more often

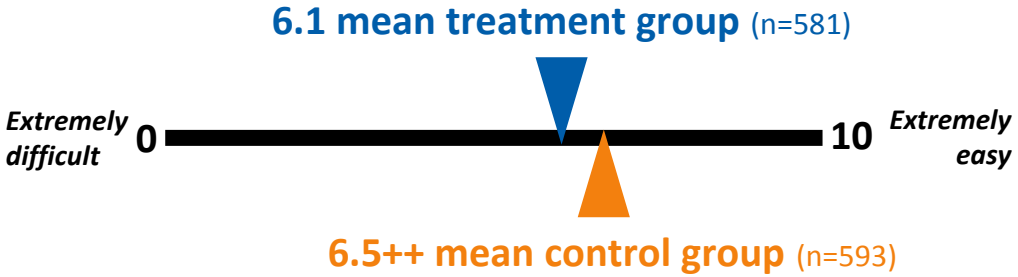


\+ Significant difference at 10% level ++ Significant difference at 5% level

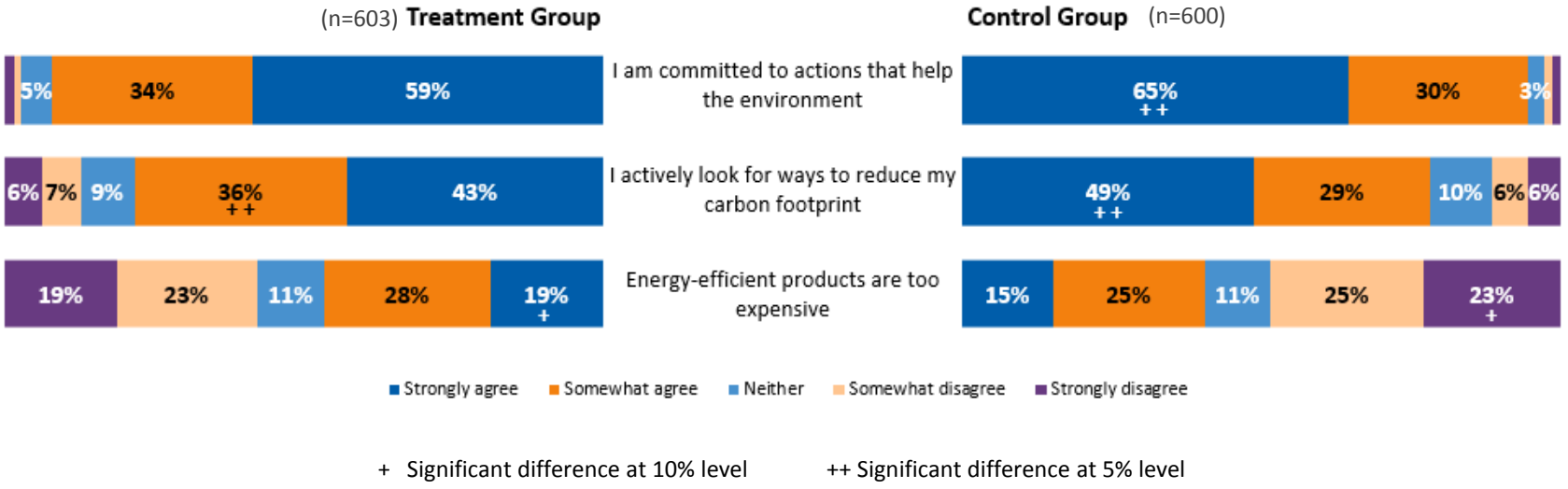
Energy Efficiency Attitudes & Barriers

Control respondents find saving energy in the home significantly easier than treatment respondents; control also shows a significant bent towards green

Ease of Saving Energy in Your Home



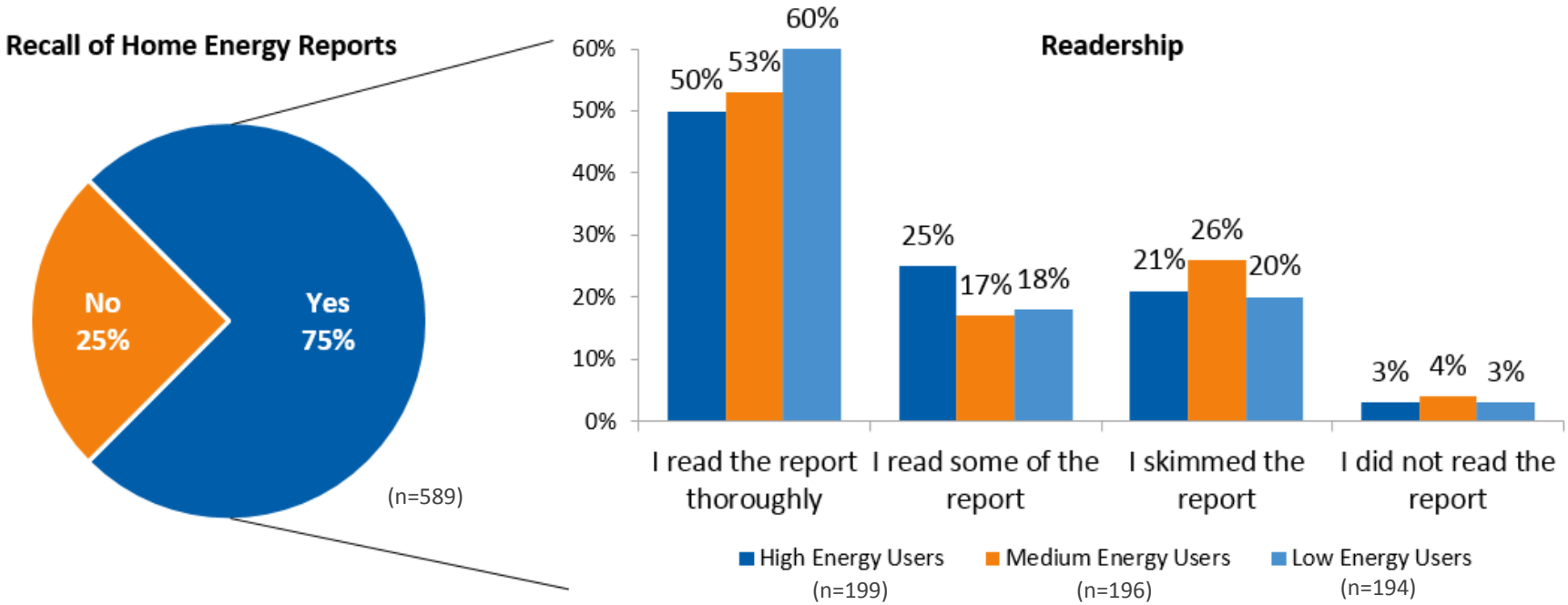
Agreement Levels to Barrier Statements



\+ Significant difference at 10% level ++ Significant difference at 5% level

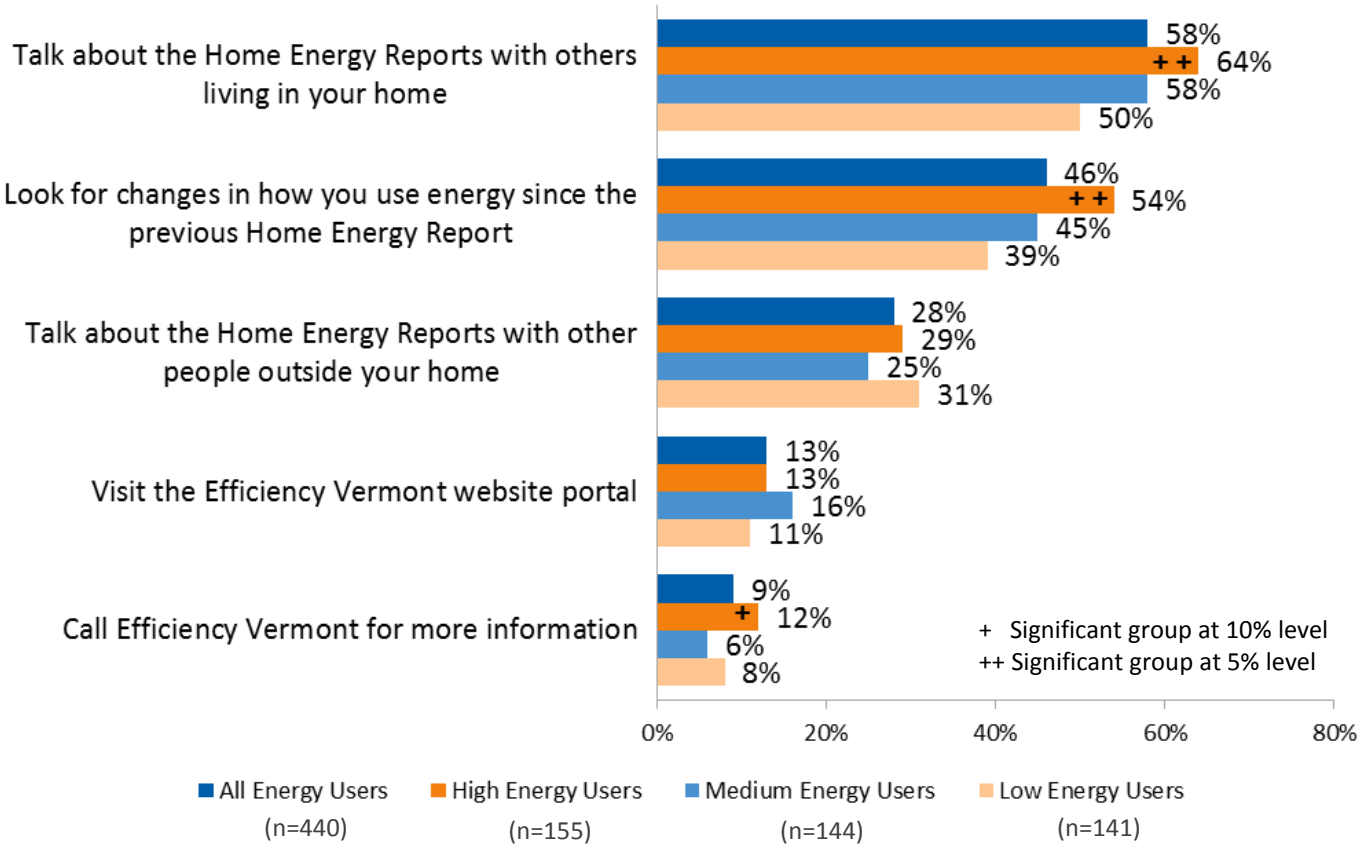
Awareness & Readership of HERs

75% of respondents recalled the HERs; 74% of these respondents read the HERs to some extent with low energy users showing the strongest readership level



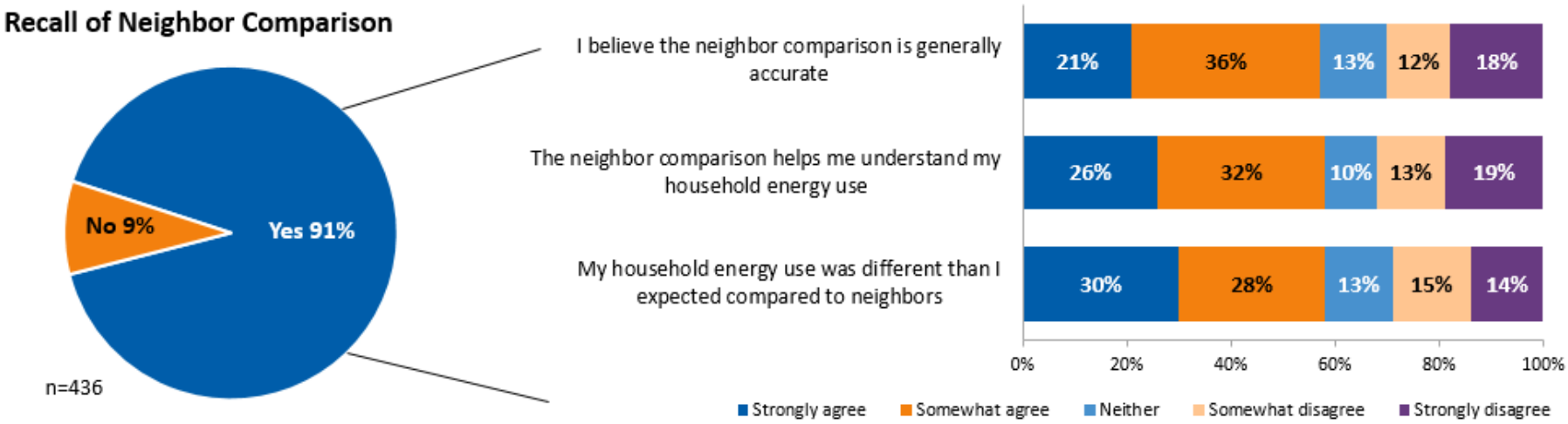
Engagement with HERs

The HERs get households to talk about energy usage, but the HERs do not get households to seek information from EVT; high energy users showed significantly higher engagement with the HERs



Neighbor Comparison

Recall of neighbor comparison component was very strong; 57% of respondents believed the neighbor comparison to be accurate; a significantly higher proportion of low energy users believed the neighbor comparison to be accurate



Agreement Level with *I believe the neighbor comparison is generally accurate*

52% agree	57% agree	65% agree++
High Energy Users	Med Energy Users	Low Energy Users
(n=128)	(n=115)	(n=100)

++ Significant difference at 5% level

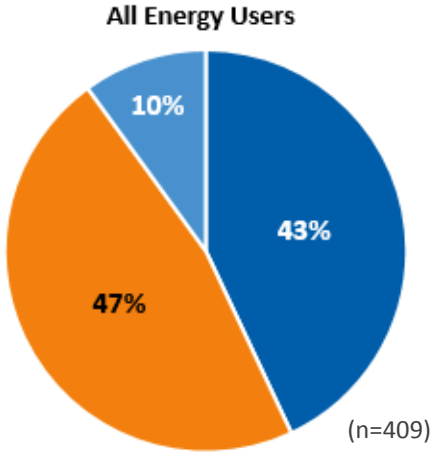
Satisfaction with HERs

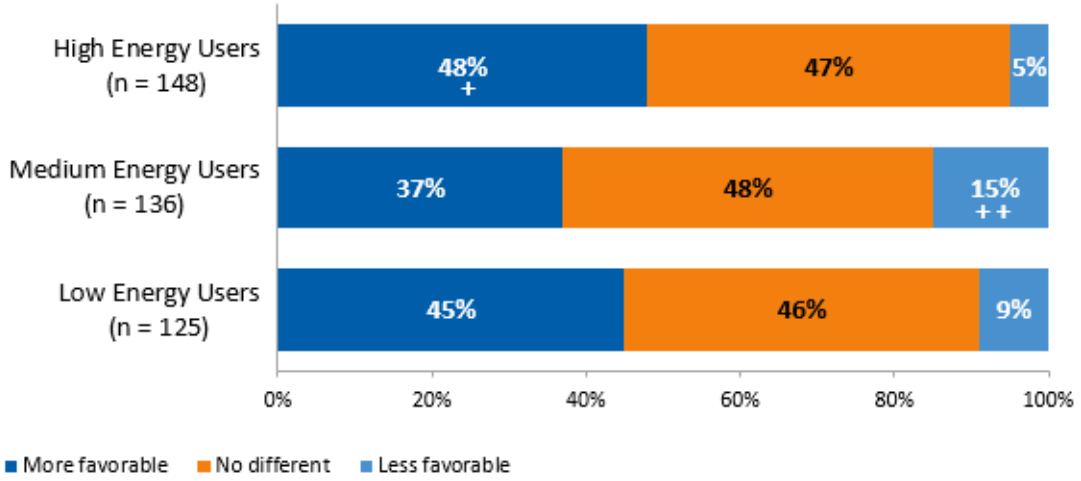
Overall, respondents were moderately satisfied with the HERs; low energy users show significantly higher satisfaction; 43% of respondents reported feeling more favorable of EVT after receiving the HERs, especially the high energy users

Overall Satisfaction

5.9 mean	5.6 mean	5.6 mean	6.5 mean++
All Energy Users	High Energy Users	Med Energy Users	Low Energy Users
(n=434)	(n=150)	(n=144)	(n=140)

Perception of EVT After Receiving HERs





\+ Significant difference at 10% level ++ Significant difference at 5% level

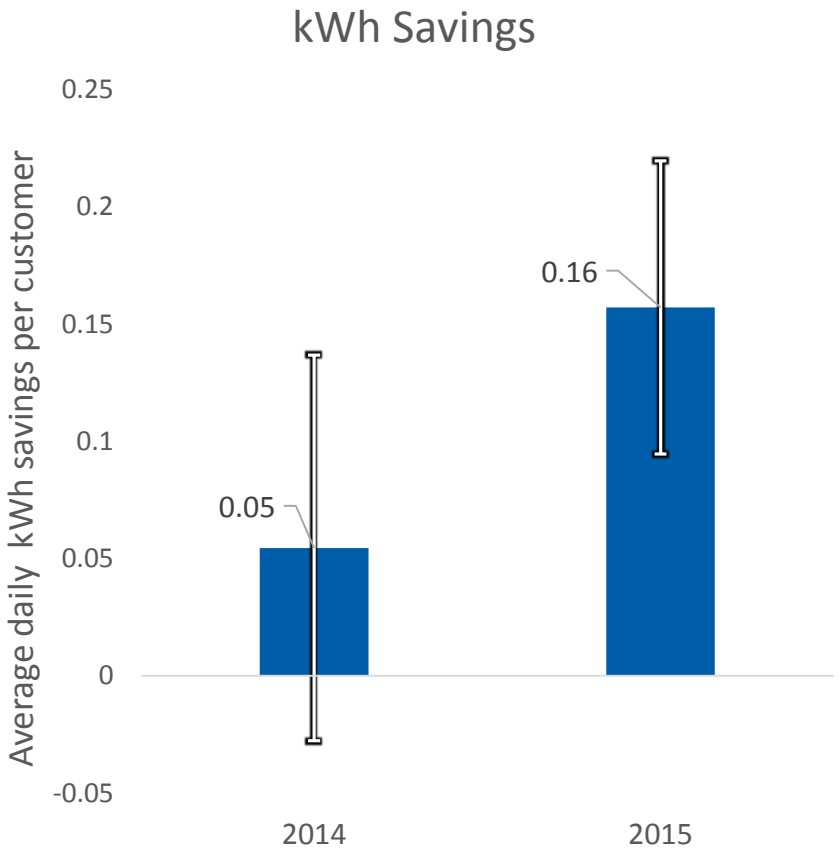
Impact Evaluation

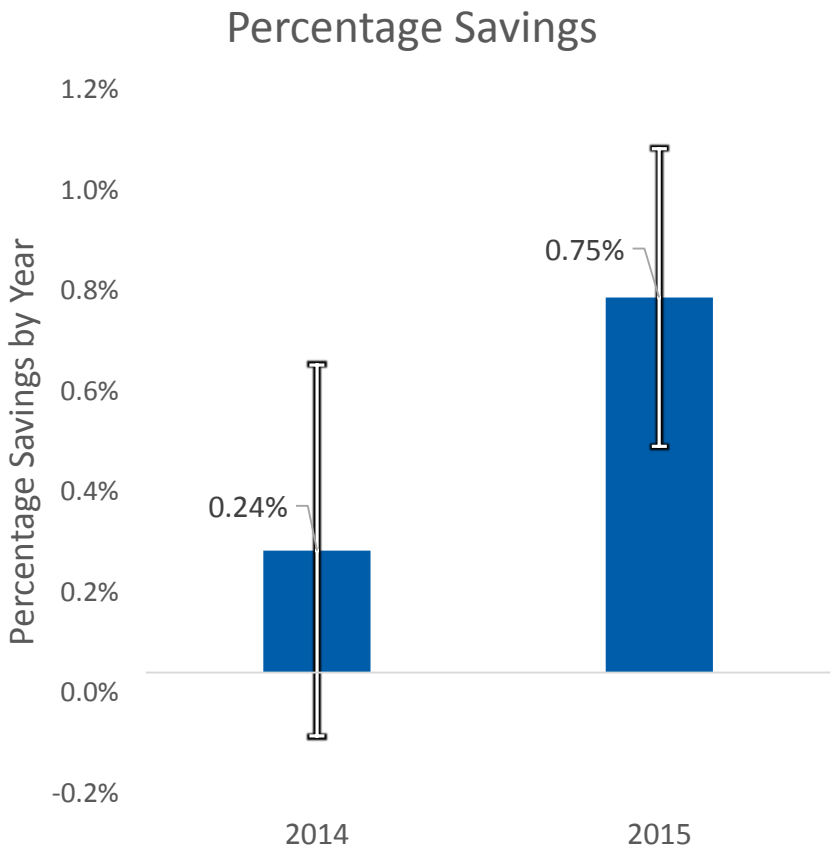
ENERGY SAVINGS

Billing Data Analysis

- Objective to estimate electricity savings
- Collected pre- and post-treatment monthly electricity bills for randomized treatment and control group customers
- Panel regression analysis of customer monthly consumption
  - Difference-in-differences model of average daily consumption with customer fixed effects
- Different model specifications to test robustness of savings estimates

Energy Savings

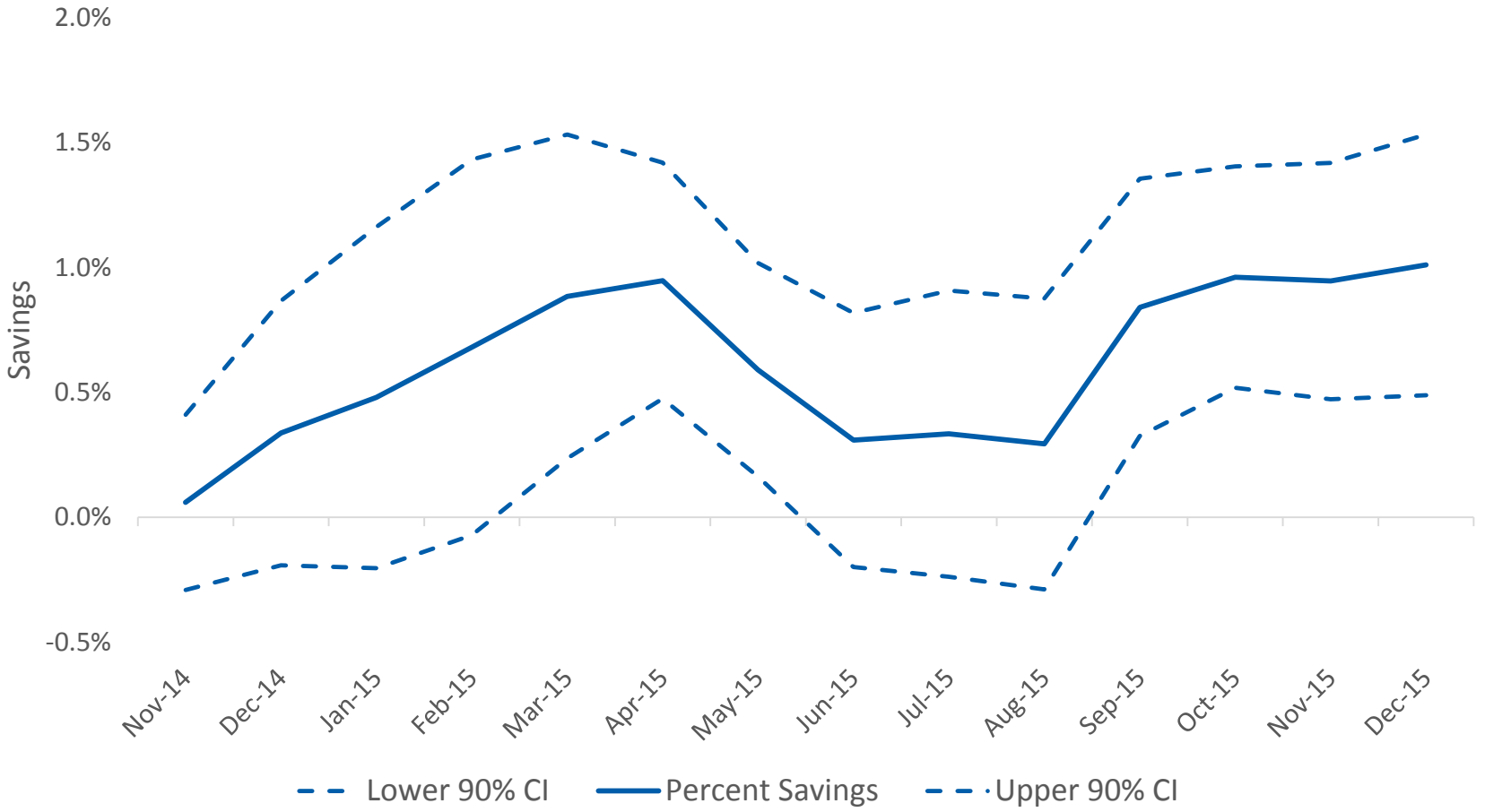




Notes: Savings estimated with regression of customer average daily electricity consumption. Models estimated by OLS and standard errors in parentheses clustered on customers.

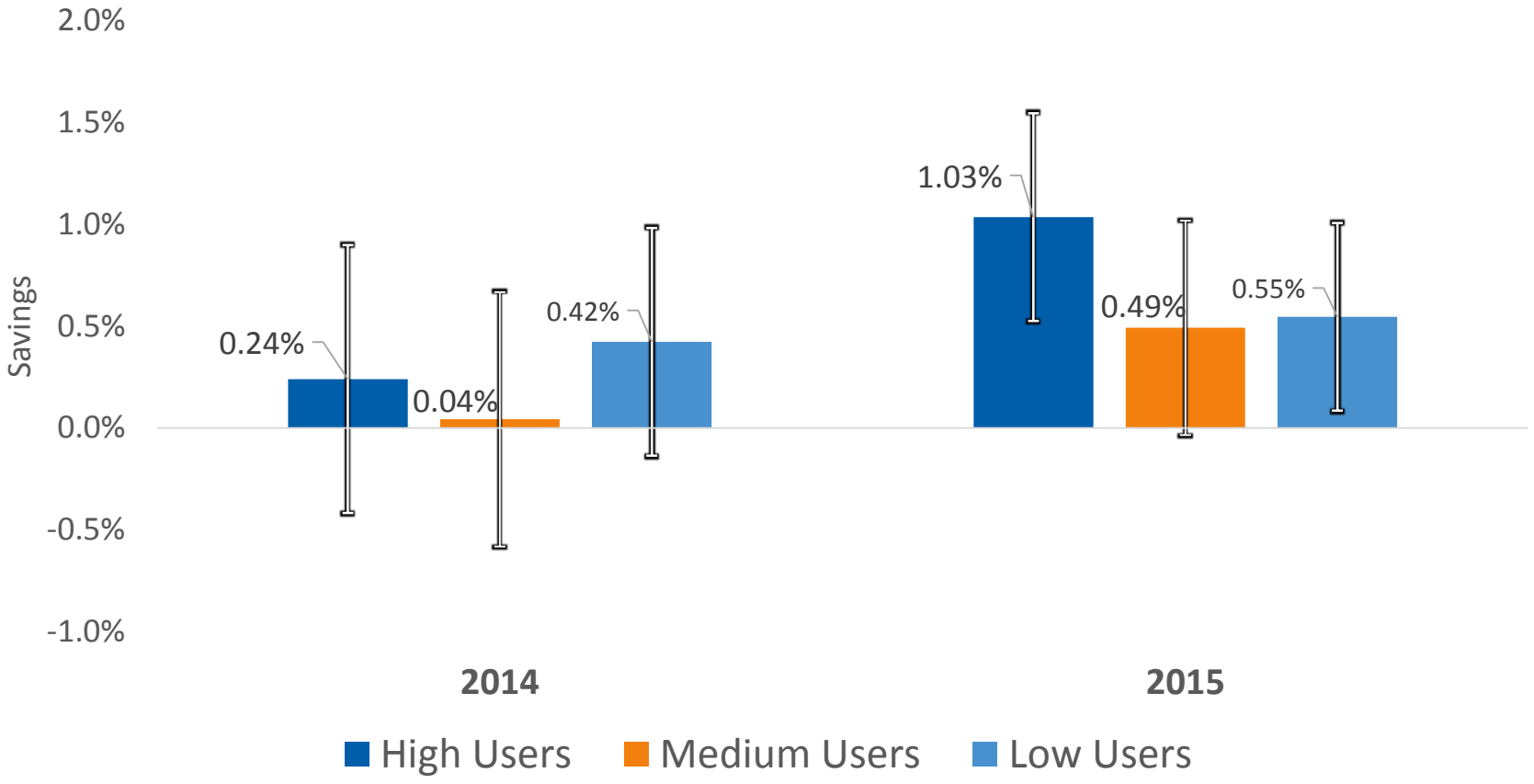
Note: Percentage savings estimated as ratio of average daily savings per customer from Model 1 to average daily consumption of control group customers.

Monthly Program Electricity Savings



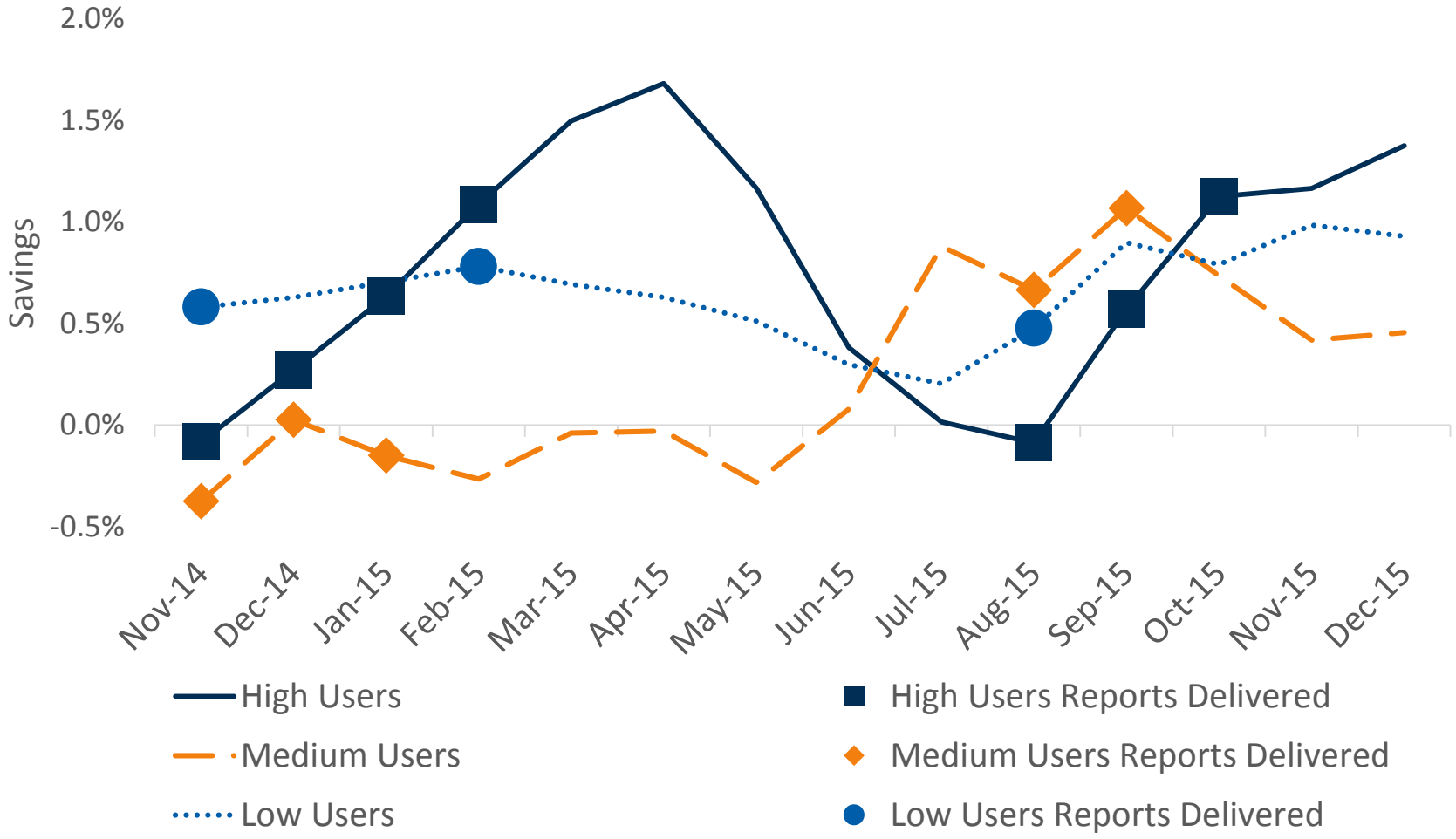
Notes: Savings estimates based on D-in-D regression analysis of customer monthly energy use on month-year fixed effects, HDD and CDD weather variables, customer fixed effects, and month-year fixed effects interacted with treatment indicator variable. Confidence intervals estimated using standard errors clustered on customers.

Savings by Energy Use Group



Notes: Error bars indicate 90% confidence intervals based on standard errors clustered on customers.

Program Savings by Month and Usage Group



RCBS Pilot Savings

Year	Opower Savings Forecast**		OPower Savings Estimate*		Cadmus Evaluation Savings Estimate		OPower Estimate Within Evaluation 90% Confidence Interval?
	MWh	Percent Savings	MWh	Percent Savings	MWh	Percent Savings	
2014	465	0.70%	460	0.31%	304	0.24%	Yes
2015	8,012	1.11%	6,284	0.84%	5,621	0.75%	Yes
Total	8,477	0.93%	6,744	0.74%	5,925	0.65%	Yes

*Source: EVT - Monthly Savings Results - Jan 2016.xlsx. Workbook provided to Cadmus from EVT and originally provided to EVT by Opower.

**Opower made forecasts in October 2014 and October 2015. Source: EVT – Monthly Savings Results – Oct 2015.xlsx and EVT – Monthly Savings Results – Jan 2016.xlsx . Workbooks provided to Cadmus from EVT and originally provided to EVT by Opower.

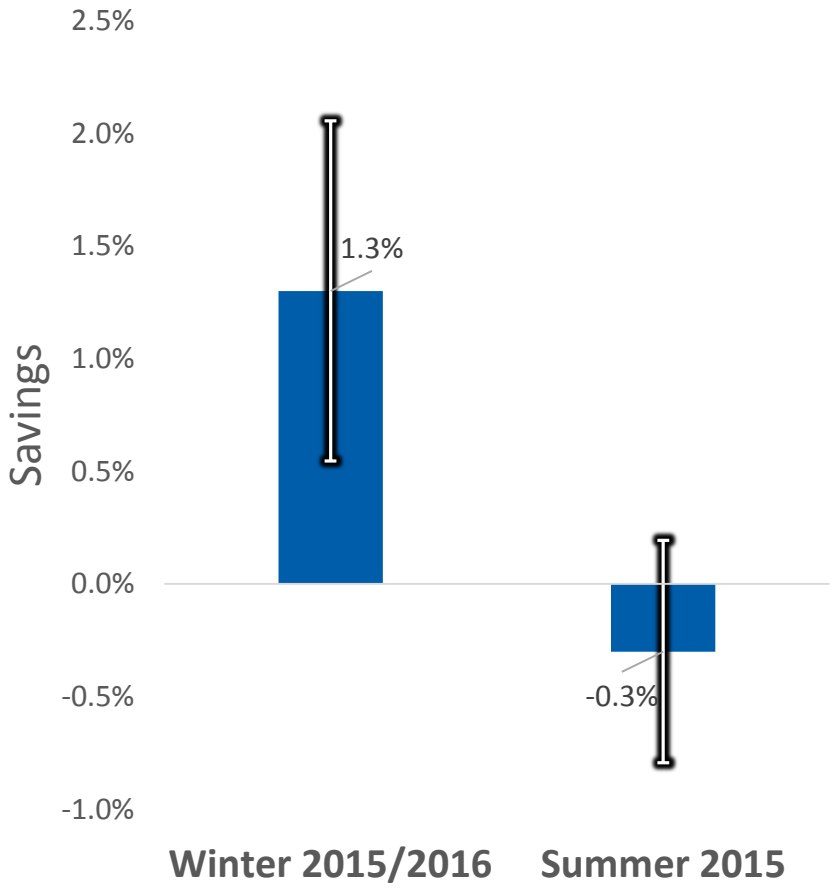
Impact Evaluation

PEAK EFFICIENCY SAVINGS

AMI Data Analysis

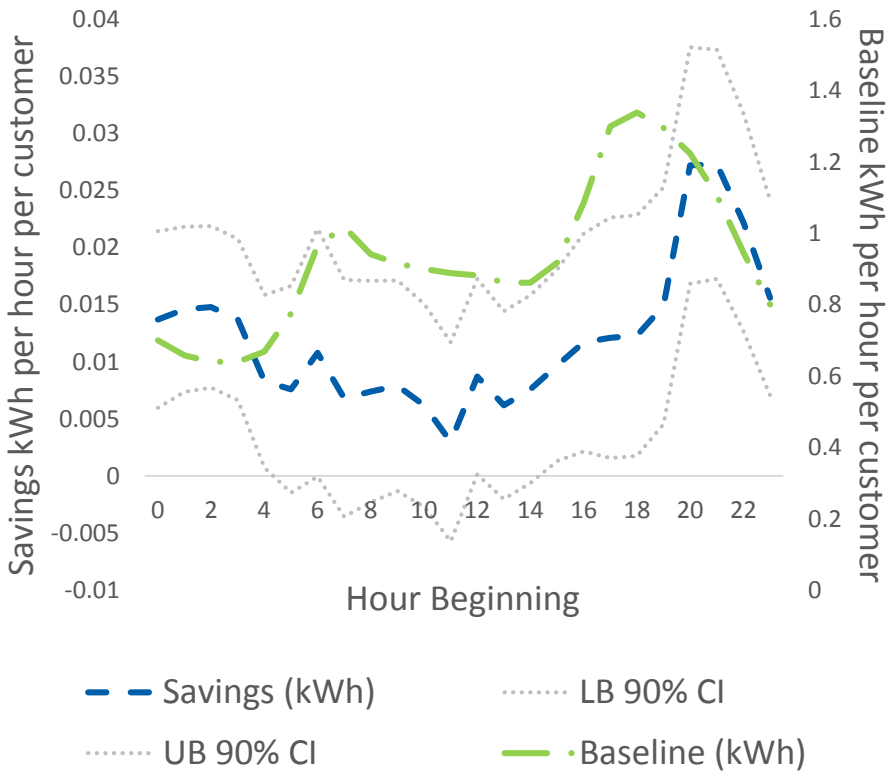
- Objective to estimate peak efficiency savings and to obtain insights about customer behaviors
- Collected pre- and post-treatment AMI 15-minute interval electricity use data for treatment and control groups customers
  - Over 3 billion records
  - Winter 2013/2014, Winter 2015/2016
  - Summer 2014, Summer 2015
- Panel regression analysis of customer hourly usage
- Analysis resulted in estimate of average kWh savings per hour per customer for each hour of the day

Peak Coincident Energy Savings



- Pilot saved 1.3% of consumption during ISO New England winter peak hours
  - Equaled 140% of savings during winter non-peak hours
  - 1.57 MW of peak savings
- Pilot did not save energy on peak during summer 2015
  - Suspension of report delivery

Winter 2015-2016 Savings by Weekday Hour



- Customers saved energy during all weekday hours
- Peak savings of 2% achieved between 8:00 p.m. and 10:00 p.m.
  - Lighting, plug loads
- Savings were about 1% during rest of day

Impact Evaluation

ENERGY EFFICIENCY PROGRAM UPLIFT

EE Program Uplift Analysis

- Objective to estimate pilot effect on EVT efficiency program participation and savings
  - Uplift savings must be subtracted from portfolio savings to avoid double-counting
- Data collection
  - EVT data on downstream residential rebate program participation and savings
  - Customer self-reports about efficient lighting purchases from customer surveys
- Compare rates of participation and savings per customer of treatment and control group customers

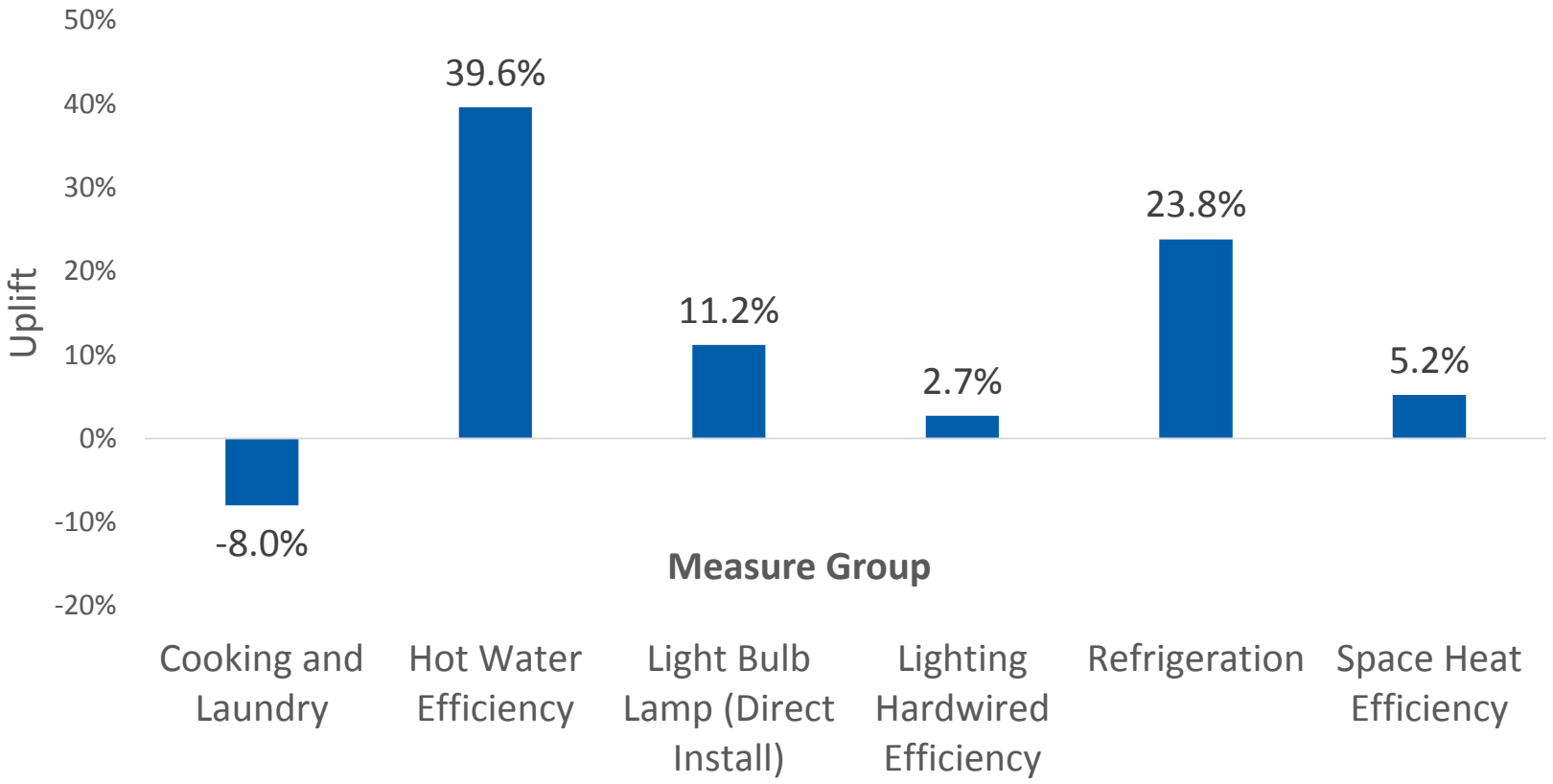
EVT Efficiency Program Uplift

Year	Baseline Participation Rate (per 1,000 Customers)	Participation Uplift (Treatment Effect on Participation Rate)	% Participation Uplift
2014	16.0	1.4	8.5%
2015	41.9	3.2	7.6%

Notes: Results based on analysis of EVT energy efficiency program tracking data and HER program participation data for November 2014-December 2015. Participation uplift estimated as the ratio of pilot treatment effect on EVT EE program participation rate to baseline EE program participation rate.

- In 2015, savings from efficiency program participation uplift was negligible (3 MWh)
- No statistically significant differences in self-reported efficient lighting purchases

Uplift by Measure Group



Impact Evaluation

COST-EFFECTIVENESS

Cost-Effectiveness Analysis

- Evaluated pilot cost-effectiveness using the Societal Cost Test (SCT)
  - Electricity benefits (energy and capacity)
  - Program administration costs
  - DRIPE
  - Electric externalities (emissions reductions)
  - Non-energy benefits (15% adder)
- Employed Vermont Statewide Cost-effectiveness Screening Tool to perform the analysis

Cost Effectiveness

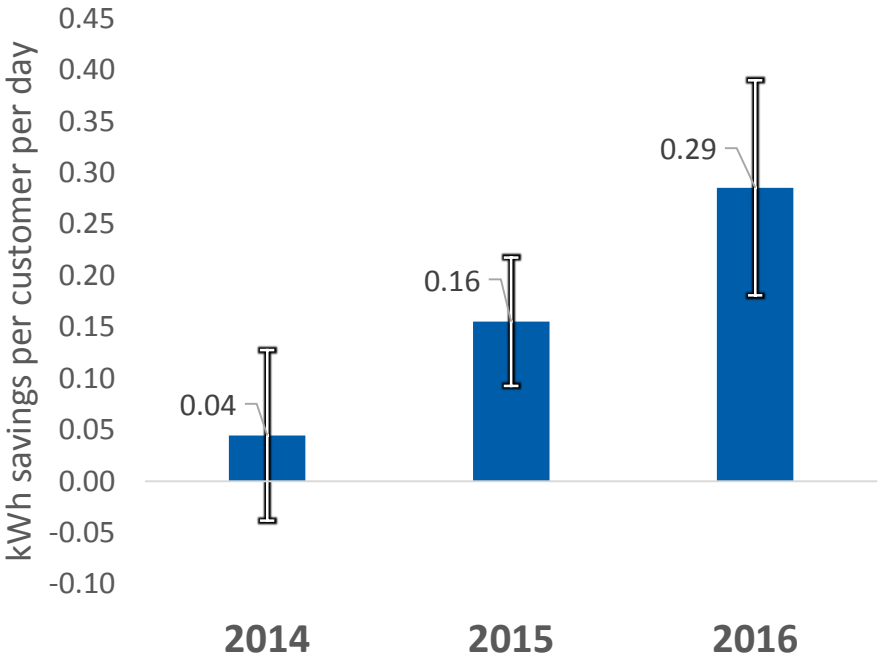
Parameter	2015	2014–2015
Benefits	$898,804	$940,598
Costs	$678,096	$1,060,528
Net Benefits	$220,708	($119,929)
Levelized $/kWh	$0.121	$0.179
Benefit/Cost Ratio	**1.33**	**0.89**

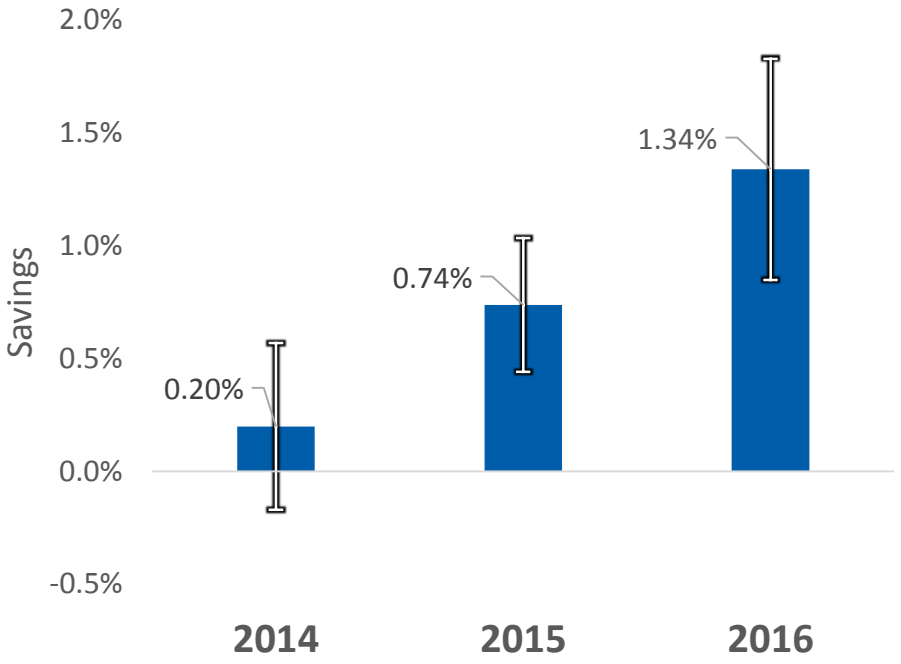
- Societal Cost Test
- Pilot proved cost effective in 2015
- Pilot was not cost-effective for 2014-2015
  - Program set up costs
  - Pause in report delivery
  - Pilot would have been cost-effective if savings had been 15% higher

Impact Evaluation

2016 SAVINGS UPDATE (JANUARY- MAY)

Energy Savings, 2014-2016





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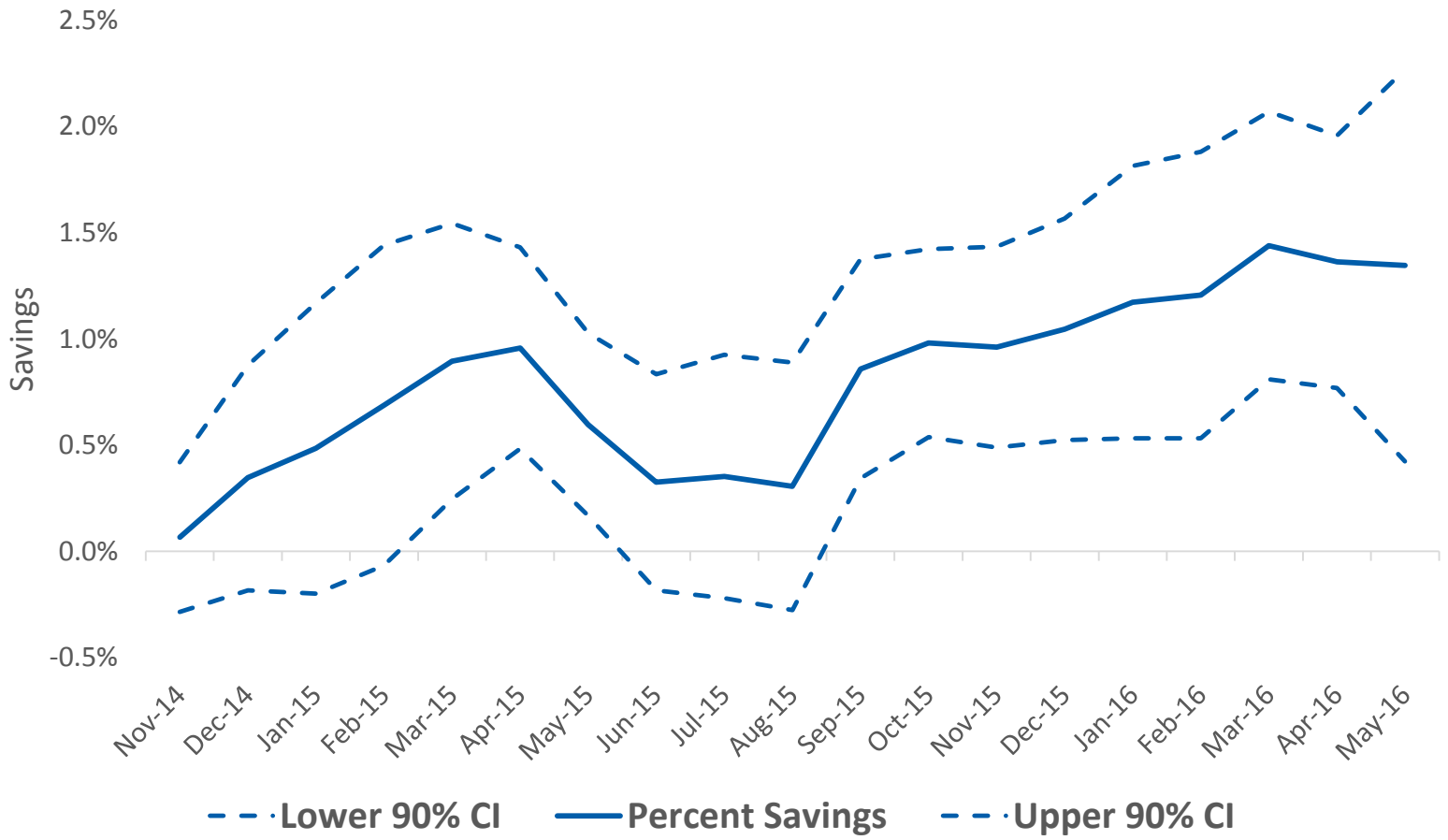
Note: Percentage savings estimated as estimates of average daily savings per customer from Model 1 to average daily consumption of control group customers.

Monthly Program Electricity Savings



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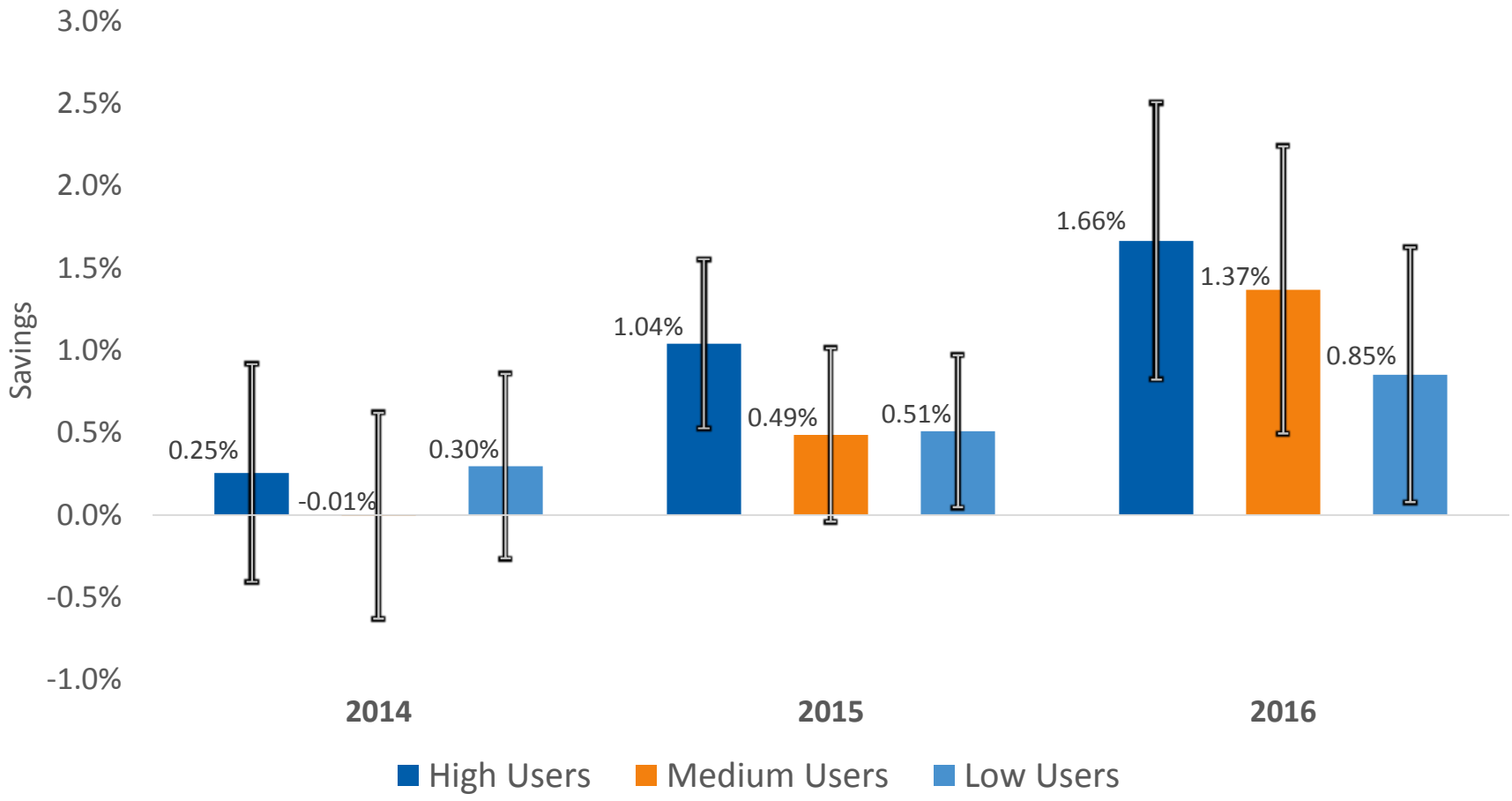
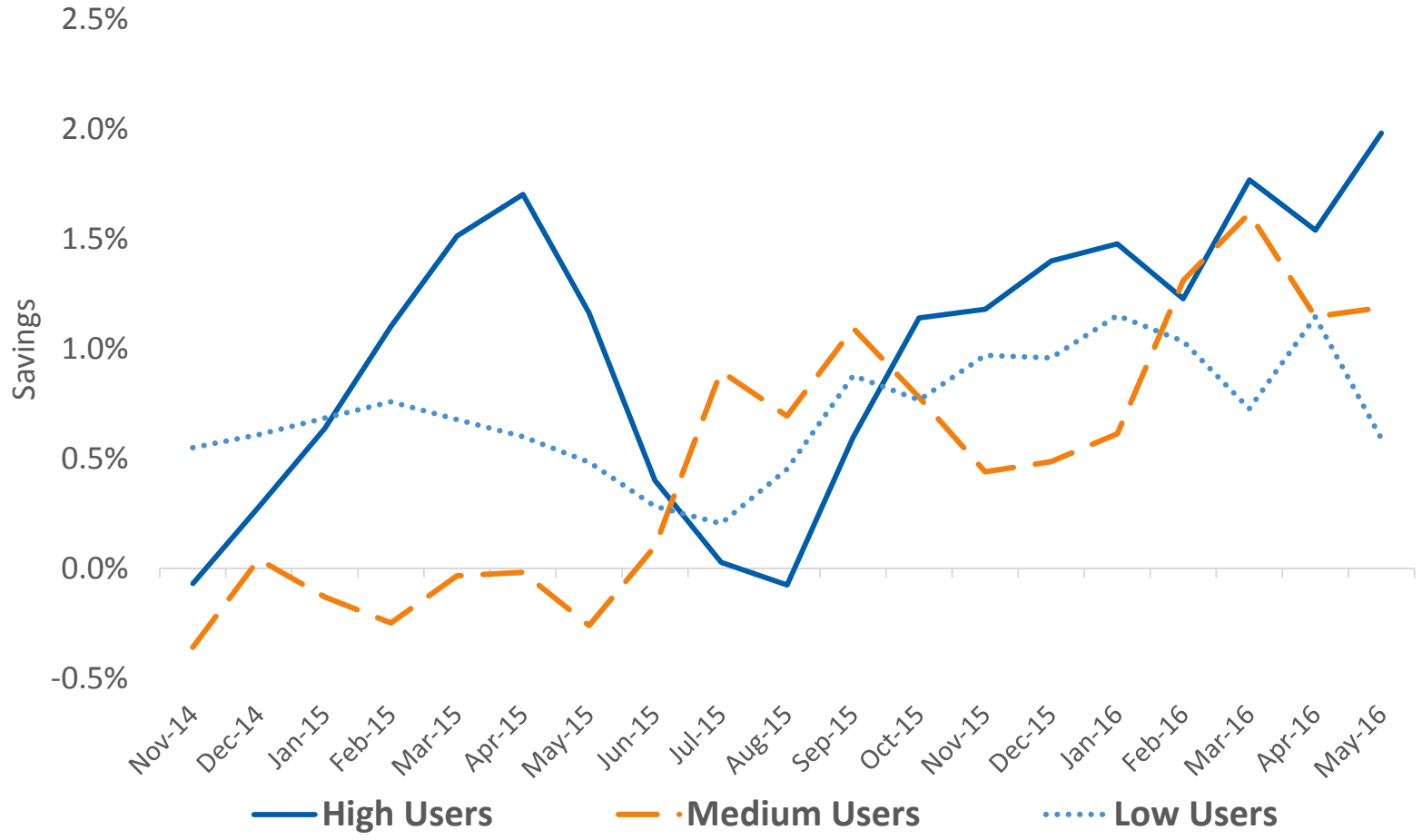


Notes: Error bars indicate 90% confidence intervals based on standard errors clustered on customers.

Monthly Program Savings by Usage Group



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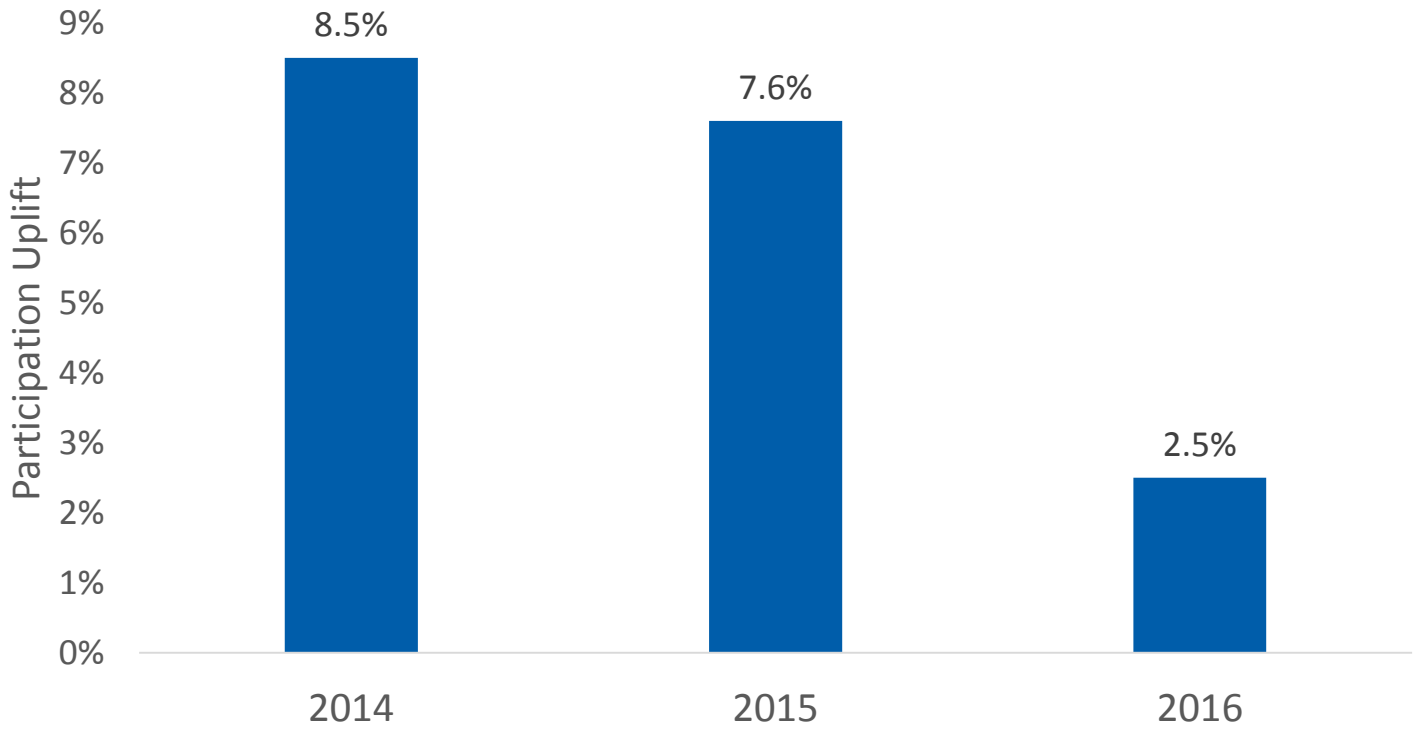
2014	465	0.70%	460	0.30%	248	0.20%	Yes
2015	8,012	1.11%	6,284	0.85%	5,549	0.74%	Yes
2016	3,872	1.22%	4,484	1.62%	4,002	1.34%	Yes
Total	12,350		11,289		9,799		Yes

*Source: EVT – Monthly Savings Results – Jan 2016.xlsx . Workbooks provided to Cadmus from EVT and originally provided to EVT by OPower.

**Source: EVT - Monthly Savings Results - May 2016.xlsx. Workbook provided to Cadmus from EVT and originally provided to EVT by OPower.

EE Program Participation Uplift



Note: Participation uplift estimated as the ratio of pilot treatment effect on EVT EE program participation rate to baseline EE program participation rate.

Cost Effectiveness, 2014-2016

Parameter	2014–2016
Benefits	$1,420,657
Costs	$1,514,061
Net Benefits	($93,404)
Levelized $/kWh	0.176
Benefit/Cost Ratio	**0.94**

- Societal Cost Test
- Pilot cost-effectiveness improved after accounting for higher savings for first five months of 2016

CONCLUSIONS

Energy Savings and Energy Use Group Effects

Conclusion	Recommendation
Pilot performance improved Savings = 0.2% in 2014; 0.8% in 2015; 1.3% in 2016	• EVT should continue to monitor monthly savings to determine whether performance continues to improving
High energy use group produced largest savings per customer	• Consider expanding the pilot to include more high-energy use customers • Consider expanding beyond Green Mountain Power customers

Implication of Suspended Delivery of HERS

Conclusion	Recommendation
Pause in report delivery reduced pilot savings and C-E but allowed EVT to address customer concerns	• Continue to send redesigned reports and evaluate design changes
Pilot saved 1.3% on peak during winter months	• Continue to measure peak savings • Promote measures that can save energy on peak

Behavior Outcomes and Uplift

Conclusion	Recommendation
Control group customers reported more energy saving actions, but treatment group purchased more LEDs	• Focus HER savings tips on lighting measures and behavior change actions
Participation lift of 15%, but savings from this lift is small	• Continue cross-program marketing through HERS

RCBS Pilot Design Implications and Improvements

Conclusion

Report changes resulted in improved perceptions of neighbor comparison's accuracy

EVT's Net Promoter Score (NPS) improved

Recommendation

- Re-evaluate RCBS Pilot in July 2016 and assess savings impacts

RCBS Pilot Cost Effectiveness

Conclusion

RCBS pilot was not cost-effective for 2014-2015

Pilot cost-effectiveness improved in 2016

Recommendation

- Re-evaluate cost-effectiveness at the end of 2016

QUESTIONS/DISCUSSION