Pepco Maryland In-Home Display Pilot Analysis

PREPARED FOR



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This report was prepared for Pepco by The Brattle Group. All results and any errors are the responsibility of The Brattle Group analytical team.

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Executive Summary

The Potomac Electric Power Company (Pepco) began deploying its in-home display (IHD) pilot program in the Fall of 2014 in its Pepco Maryland service territory. Approximately 300 Pepco residential customers received an IHD device. The IHDs display real time hourly energy usage, estimated monthly billing information based on instantaneous usage amounts, and information on how to conserve energy.

This study compares consumption of the treatment group, which received IHDs, with a control group, which did not receive IHDs, before and after the IHDs were deployed. More specifically, a regression analysis using a difference-in-differences methodology was conducted to compare the usage levels of the treatment and control group customers and determine whether the implementation of IHDs had any impact on customer usage. The analysis accounts for exogenous factors such as weather, calendar impacts, and other utility conservation programs which would have also affected customer usage. The study also surveyed treatment customers at the beginning and end of the pilot to gauge their degree of interaction with the IHD devices. Additionally, surveys and market research around customer preferences were undertaken by Opinion Dynamics and are summarized in this report.

Pepco's initial treatment group was comprised of approximately 300 customers. However, approximately 50 were unable to connect with the IHD device. Another group of customers who were able to connect their devices experienced many intermittent connectivity issues. The analysis excluded customers who were outliers and also customers who had net energy metering status. After excluding customers who did not have a true IHD experience and after excluding customers with insufficient data for the analysis, the treatment group contained 182 treatment customers (see Section III for details).

This study finds that the IHD program enabled residential customer participants to reduce their annual energy consumption by 2.8%.¹ This result is statistically significant at the 10% level.

¹ Other Ceiva IHD studies have shown greater savings amounts.

I. Introduction and Background

Pepco began deploying its in-home display (IHD) pilot program in the Fall of 2014 in its Pepco Maryland service territory. Pepco worked with The Brattle Group to randomly select eligible residential customers living in single-family homes in the Pepco Maryland service territory to receive IHD devices. Approximately 16,000 customers were sent a letter asking them to participate in the study. Study participants were required to agree that they would be located in their existing premise for one year, and agree to complete surveys during the study period. In return, 300 customers received an IHD device manufactured by Ceiva.² The IHD devices are in the form of a digital picture frame, which cycles through information on real time energy usage, monthly billing data, and information describing the conservation of energy. IHD study participants also had the opportunity to upload pictures to the device.

Alongside the customers who received IHD devices, approximately 350 control group customers were selected. These customers did not receive any IHD devices and were unaware that they were selected. The control group was randomly drawn from the same sample as the treatment group.

Pepco's IHD program is supported by the activation of its Advanced Metering Infrastructure (AMI) System. While IHDs are not necessarily a new concept, the utility industry has limited experience with IHDs that are able to accurately display near-real time information for an entire premise and able to connect to the internet and receive real time updates.³

IHD devices have no physical impact on energy usage. That is, they do not decrease voltage or have any other effects that would be passive for customers. Similar to Pepco's Energy Management Tools (EMTs), IHDs drive energy savings if customers actively change their consumption behavior in response to the information displayed on the IHD screen.

² Approximately 80% of customers received and activated their IHD devices in November and December 2014. The remaining customers activated their devices over the next few months.

³ For a review of first generation IHD pilots, see Ahmad Faruqui, Sanem Sergici, and Ahmed Sharif (2010), "The Impact of Information Feedback on Energy Consumption—A Survey of the Experimental Evidence," *Energy* 35: 1598–1608. In their survey, the authors found that consumers who actively use an IHD can reduce their electricity usage by about 7 percent.

II. Data

A. DATA OVERVIEW AND CRITERIA

The study required a comprehensive data compilation effort. For all customers, the following data series were compiled:

- Daily consumption data;
- Connection information (includes IHD activation date, login data, and connectivity gaps);
- Weather data (dewpoint and temperature);
- Net energy metering (NEM) status;
- Opower program participation status and enrollment date; and,
- Demand-side management (DSM) program participation.

The master dataset in our final models is based on daily data for September 2013 through April 2016.

Approximately 50 customers were not able to connect their IHD device. Of the 251 customers who were able to connect, some customers did not have the full IHD experience, having many gaps in internet connectivity and gaps in energy usage connectivity.⁴ During a "gap in internet connectivity," a customer cannot receive information from Pepco on historical consumption, while they can continue to receive information on real-time usage. During "gaps in energy usage connectivity," a customer is unable to receive real time energy consumption information from their premise's AMI meter, which is one of the key strengths of this IHD program, but they can receive information on historical consumption.

To ensure that only customers who received a full IHD treatment are included in the analysis, customers with more than 12 unique internet connectivity gaps or 12 unique energy connectivity gaps were excluded from the analysis. Similarly, customers who experienced internet or energy connectivity gaps during 20% or more of the treatment period days were excluded from the analysis. The threshold for dropping customers is thus relatively high so that many customers who had significant connectivity issues were still included in the analysis. A

⁴ Ceiva IHD representatives have noted that they are able to remedy many connectivity issues if they are contacted by the customer.

stricter threshold for dropping customers could potentially result in higher estimated reduction impacts.

Because the objective of the analysis was to isolate the impact of IHDs on electricity consumption, customers with NEM status were excluded from the dataset, as the energy consumption profile for these customers is different from that of an average residential customer. Furthermore, days where an event day was called for Pepco's dynamic pricing program, the Peak Energy Savings Credit (PESC) Program, were excluded from the analysis, as those days would result in atypical consumption profiles. Customers whose electricity usage indicated that they are outliers were likewise excluded from the analysis. For this analysis, outliers are defined on the customer level, based on energy consumption, as customers with more than 10% of days in the top or bottom 1% of all observations. Table 1 presents the number of initial treatment customers excluded from the analysis and the reason for these exclusions.

Step:	Customers
Initial Treatment Customers	251
Drops	
Unavailable data	-15
More than 12 Internet gaps	-10
More than 12 energy gaps	0
More than 20% treatment days Internet gaps	-19
More than 20% treatment days energy gaps	-7
NEM	-10
Outlier	-8
Treatment Customers for Analysis	182

Table 1: Initial Treatment Customers Excluded from Analysis⁵

The resulting final dataset includes 512 total customers, of which 182 are treatment customers and 330 are control customers. The final dataset has a total of approximately 488,000 observations.

⁵ Table 1 includes all criteria for excluding treatment customers from analysis, even if a single criterion does not result in any exclusion.

B. CONTROL GROUP VALIDATION

The eligible customer population for IHD pilot participation is residential customers residing in single-family homes. For Pepco's IHD pilot program, control group customers were randomly selected from the group of customers who were eligible for the pilot. The customers in the treatment and control groups have been randomly assigned to their respective groups, as discussed above. The process of randomly selecting customers from the same sample supports the validity of the control group. It is important to compare the treatment and control groups to ensure that they have similar usage profiles, and that differences in the groups will not bias the analysis. To do this, the daily consumption, which is the primary dependent variable, was compared between the groups. This comparison is illustrated in Figure 1 and indicates that the treatment and control groups are very similar in their usage patterns.



Figure 1: Treatment and Control Group Comparison

III. Methodology

A difference-in-differences analysis was conducted through the use of a panel data regression approach to estimate the impact of IHDs. The difference-in-differences analysis compares the usage of the treatment and control group customers before and after the IHD treatment. Other factors that could potentially confound the IHD impact were accounted for, such as weather conditions, DSM program participation, Opower participation, and calendar dummies. The difference-in-differences approach isolates the true impact of the treatment by netting the differences in the treatment and control group load profiles before and after the treatment period. Table 2 presents a simplified demonstration of the difference-in-differences approach.

	Treatment Group	Control Group	DID
Pre-Treatment	Usage= 3 kWh	Usage= 2.5 kWh	
Post-Treatment	Usage= 1.5 kWh	Usage= 2 kWh	
Difference	1.5 – 3 = -1.5 (A)	2 – 2.5 = -0.5 (B)	A-B=-1 kWh

Table 2: Demonstration of Difference-in-Differences Methodology

The most important factor to account for in this regression was the impact of weather conditions on electricity usage. This analysis used a daily temperature humidity index (THI) that combined dewpoint and temperature into one variable.

It is important that a customer's reduction in usage from another utility conservation program is not attributed to the IHD treatment, as that would make IHD impact estimates significantly overstated. Therefore, the regression analysis includes control variables for DSM and Opower programs. A dummy variable for Pepco's AMI-enabled Energy Management Tools (EMT) program was not included, as the program was fully implemented before the beginning of our study period and is thus included in the baseline consumption prior to the IHD treatment, for both treatment and control groups. Furthermore, a dummy variable for Pepco's AMI-enabled Conservation Voltage Reduction (CVR) program was not included as treatment and control customers are expected to be equally affected.

The regression analysis used a Fixed Effects (FE) estimation technique to ensure that the estimated coefficients from the resulting model were unbiased. FE estimation assumes that the unobservable factor in the error term is related to one or more of the model independent variables. The technique therefore removes the unobserved effect from the error term prior to

model estimation. The resulting estimation accounts for individual time-invariant characteristics of each customer.

The final regression equation used for this analysis is as follows:

$$ln(kWh_{it}) = \beta_0 + \beta_1 * TreatPeriod_i + \beta_2 * IHD_{it} + \beta_3 * THI_t + \sum_{m=1}^{12} (\beta_{4m} * Monthm_t + \beta_{5m} * Monthm_t * THI_t) + \beta_6 * MonthTrend_t + \beta_7 * DSM_{it} + \beta_8 * Opower_{it} + v_i + \varepsilon_{it}$$

Where:

kWh _{it}	Average daily consumption for household <i>i</i> in day <i>t</i> .
TreatPeriod _i	Flag indicating the start of the treatment period
IHD _{it}	Flag indicating the customer has had IHD activated
THI _t	Impact of Temperature Humidity Index on usage
$Monthm_t$	Month specific impact common to all households
$Monthm_t * THI_t$	Month specific impact of the Temperature Humidity Index
$MonthTrend_t$	Linear monthly time trend
DSM _{it}	Indicator that a customer is participating in DSM/EE program
0power _{it}	Indicator that a customer is participating in Opower program
v _i	Customer fixed effect
ε_{it} Indepe	endently and identically distributed error term, clustered by customer

IV. Study Results

A. ECONOMETRIC ANALYSIS RESULTS

The results of the econometric analysis indicate that IHDs have led to a 2.8% decrease in electric energy consumption across all hours. This result is statistically significant at the 10% level (see Appendix A for the estimation results). This estimated impact is robust and unbiased.

This study has confirmed that Pepco's IHD pilot program has resulted in reduced consumption for residential customers. This program is supported through Pepco's AMI System, which allows customers to see their real time energy consumption on the IHD devices. Furthermore, AMI allows this econometric analysis to use daily consumption data that is more granular than monthly billing data.

B. SURVEY RESULTS

Opinion Dynamics fielded two surveys to participants in the Pepco IHD pilot. In total, 195 respondents completed the first survey, and 198 completed the second survey, resulting in response rates of 77% and 80% respectively. The first survey, fielded on a rolling basis after the display had been paired and registered, assessed the recruitment, enrollment and implementation processes to identify any opportunities for improvement. The second survey, fielded nine months after the first survey, focused on customer familiarity with demand response events and perceived value of the display. Survey respondents tend to be well-educated and of fairly high socio-economic status. The goal of these surveys was to assess customer acceptance, use, and response to the IHD display, and strategies to increase its effectiveness. Some of the highlights from the surveys are as follows (details can be found in Appendix B):

- **Respondents report high satisfaction with the pilot.** However, respondents report a decrease in satisfaction with the display over time.
- Respondents report increases in energy savings knowledge, participation in Pepco's DSM programs, and the Peak Energy Savings Credit Program compared to when they first received the display. Nearly all respondents indicated that the energy display frame helped them think about their energy use slightly more or much more often. Results suggest that program participation may have increased participants' feelings of self-efficacy with regard to making changes to their energy-related habits. Furthermore, nearly all respondents had heard of Peak Savings Days. Of these, a little under half recalled receiving a notification during a Peak Savings Day, while nearly three quarters

indicated that they had taken actions to reduce their energy use during a Peak Savings Day.

- Respondents found information provided by the display to be useful, but usefulness of the information and engagement with the display decreased over time. While the majority of respondents found the information shown on the display to be useful, the perceived utility of the information decreased over time. More specifically, the perceived usefulness of information regarding hourly, daily, and weekly energy and estimated bills decreased overtime, whereas it increased for the energy saving tips provided by the display. Additionally, engagement with the display decreased over time. In the first survey, 67% of respondents reported looking at their displays multiple times per day; by the second survey, this number had dropped to 27%.
- Respondents report taking energy-saving actions during pilot. Over a quarter of respondents with a working display and applicable equipment, replaced equipment after receiving the display. Nearly all respondents with a working display and one or more applicable energy-saving actions, took at least one energy-saving action since receiving the display through the program. Of the respondents who took action, more than half (56%) claimed they were influenced by information from the display. The data suggest that there may be some relationship between income level and propensity to take substantial energy-saving actions. Specifically, high energy actors more often tended to be low or middle income rather than high income. However, given limited sample sizes of lower income customers, future research is required to confirm this pattern of results.

Appendix A: Estimation Results

		Continued	
IHD Impact	-0.0284*	THI	-0.0161***
	(0.0146)		(0.000683)
Treatment Period	0.0262**	February x THI	-0.00146***
	(0.0121)		(0.000414)
DSM Flag	-0.0166	March x THI	-0.00512***
	(0.0175)		(0.000441)
Opower Flag	0.00951	April x THI	0.00338***
	(0.0140)		(0.000604)
Month Trend	-0.00374***	May x THI	0.0535***
	(0.000686)		(0.00113)
February	0.0253	June x THI	0.0741***
	(0.0173)		(0.00126)
March	0.148***	July x THI	0.0815***
	(0.0201)		(0.00151)
April	-0.386***	August x THI	0.0766***
	(0.0319)		(0.00161)
May	-3.518***	September x THI	0.0725***
	(0.0705)		(0.00117)
June	-4.929***	October x THI	0.0123***
	(0.0860)		(0.000761)
July	-5.481***	November x THI	-0.00346***
	(0.110)		(0.000524)
August	-5.142***	December x THI	-0.00242***
	(0.115)		(0.000501)
September	-4.852***	Constant	4.152***
	(0.0788)		(0.0404)
October	-0.893***		
	(0.0425)	Observations	488,113
November	0.0575**	R-squared	0.240
	(0.0255)	Number of Customers	512
December	0.0772***	Robust standard errors	in parentheses
	(0.0227)	*** p<0.01, ** p<0.05,	* p<0.1

Appendix B: Survey Results













 No online surveys were sent to parti Survey 1: Fielded on a rolling basis b participants after pairing and register weekly basis. Respondents received Survey 2: Fielded to all participants c (depending on when the device was 	cipants. between December 2 ing the IHD. Email re a \$10 incentive. collectively approxima paired and registere	2nd 2014 and June eminders were ser ately nine months d), between Octol	e 3rd 2015 nt on a later ber 20 and
 December 18, 2015. Email reminders Some questions were asked in both S Results comparisons include only an 	s were sent on a wee Surveys in order to the stomers who apswer	ekly basis. rack changes ove red the question in	r time.
surveys.		Survey 2	
Population of Participants	Survey 1	Survey 2	
Population of Participants Eligible ^a Participants in Sample	Survey 1 253 222	Survey 2 253 248	
Population of Participants Eligible ^a Participants in Sample Total Respondents	Survey 1 253 222 195	Survey 2 253 248 198	
Population of Participants Eligible ^a Participants in Sample Total Respondents Overall Response Rate ^b	Survey 1 253 222 195 88%	Survey 2 253 248 198 80%	

































More Control Of Energy Use There was at 3 percentage point increase from Survey 2 (21%) compared to Survey 1 (19%) of respondents who strongly agree that they have more control of their energy use. Respondents who agree that the device gave them more control remained the same at 36% for both surveys. I have more control of my energy use. 40% 36% 36% 35% 30% 30% 26% 25% 19% ^{21%} 20% Survey 1 12% 10% 15% Survey 2 7% 10% 4% 5% 0% 1-Strongly 5-Strongly 4 3 2 Disagree Agree Opinion **Dynamics** Pepco IHD Pilot Survey Results 24















Reaction to Photo Sharing Monthly Fee Amounts A majority of respondents expect the monthly fee to be less than five dollars, including half (47%) who expect there to be no fee. Correspondingly, most participants said they would not purchase the device if there was even a nominal monthly fee. How likely would you be to purchase this device if the price involved a monthly fee? What would you expect the monthly fee to be for photo sharing service? 47% 50% 41% Not at All 40% 67% Likely 30% Not Very Likely 25% 20% Somewhat 9% 10% 6% Likely 1% 1% 1% 0% Dort Know 596's10 576-520 egt ingles Very Likely 2% en en 62 Opinion **Dynamics** Pepco IHD Pilot Survey Results 32





Findings (II)

- The majority of participants indicated being knowledgeable about saving energy around their homes, and slightly over half of the participants indicated being knowledgeable about Pepco's energy efficiency programs and/or the PESC program.
- Using the device helped increase customer awareness of Peak Savings Days.
- Over half of respondents who reported taking energy savings actions claimed that the device had some influence on their decision.
 - Participants took a range of actions, from small steps to making major purchases.
- Despite developing energy savings action scores, we did not find any correlates between taking action and specific household characteristics or demographics.

Opinion Dynamics

Pepco IHD Pilot Survey Results

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Appendix C: Sample IHD Images

































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