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ENERGY

Prepaid Metering Program Study in the Tennessee Valley

Measuring the Change in Energy Consumption

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What is Prepaid Metering (PPM)?

- PPM or “Pay as you go” programs are more than just paying for power in advance. Prepayment is a different way of doing business in order to:
  - Better meet the needs of some customers who want to closely manage electricity usage and payments
  - Mitigate some of the typical problems of utilities, like account receivables, delayed payments and revenue forecasting
- More than 95 U.S. utilities now have prepaid metering programs with most of them offered by cooperatives
- According to the current research, the global installed base of prepaid metering customers is expected to grow from 31.7 million in 2014 to 85.2 million in 2024

PPM can help utilities meet the needs of customers who want to control their usage and their payments. The benefits to utilities are decreasing account receivables and less late customer payments.

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Customer Benefits of Prepaid Metering

Prepayment offers customers the ability to:

- Avoid large deposits for service
  - Primary reason people initially elect PPM
- Empowers customers to:
  - Purchase power when needed but on their own schedule (especially appreciated in low-income market)
  - Manage their power needs like they do the fuel tanks in their vehicles
  - Better understanding of how their power is used
    - Customer learn which appliances are using the most electricity at any given time
    - Primary reason given why people remain on PPM

SOURCE: 2015 Cooperative Research Network – Coop Connection

Initially, customers are attracted to PPM to avoid large initial deposits for service. They remain on the programs because they learn, understand and can control their own electricity usage

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Objective of the Study

Statistically measure the change in energy consumption associated with participation in prepaid programs

- By calculating the actual and percentage change in consumption for customers using prepaid option (participants) as compared to customers using traditional post-payment plan (non-participants)
- Build on lessons learned through 2013-2014 Demonstration Project and continue the research
- TVA serves 66 LPCs that are offering, planning or considering PPM programs
  - The LPCs are in Tennessee, Mississippi, Alabama, and Kentucky
  - 33 Local Power Companies (LPCs) were solicited for participation in the study
  - 6 Volunteered to participate in a working group team
  - 3 additional LPCs requested to provide (all their programs were less than 1 year old)

The objective of the study was to understand and measure the statistical change in energy consumption associated with the participation in prepaid programs. A working group of 6 local power companies volunteered to participate in the study.

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Participants

Six volunteers participated on the PPM working group team

(Due to the client confidentiality agreements, the participants have adopted new names)

- Minnie Sparks Electric — 1,300 PPM / 14,665 Billing Customers

- Donald Duck Distributors — 1,665 PPM / 38,064 Billing Customers

- Mighty Mickey Power Company — 3,577 PPM / 28,743 Billing Customers

- Winnie Watt Electric Cooperative — 896 PPM / 42,085 Billing Customers

- Grand Goofy Electric Cooperative — 716 PPM / 24,845 Billing Customers

- Plug-in Pluto Power Association — 908 PPM / 29,444 Billing Customers

Six volunteers participated on the PPM working team.
The names of the LPCs are kept confidential.

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Overview of the Evaluation Process

Evaluation of the Impacts from Prepay Involves Several Data Collection and Analysis Steps:

Data Collection & Preparation:

- Prepay Customer Billing Data
- Control Group Sample of Non-Prepay Customers
- Clean the Billing Data, and Select Valid Samples for the Analysis Plan

Perform Statistical Analysis of the Data:

- Regression Analysis Comparing Energy Use of Prepay Customers to Control Group
- Control for Other Factors that Influence Usage (e.g. Weather, Seasonal Variations
- Sensitivity Testing of Model Results

Interpretation and Reporting of Results:

- Detailed examination of statistical results
- Calculation of Prepay program impacts for
  - Typical Prepay Customer
  - Over All Prepay Participants
- Write-up & Presentation of Results

The evaluation process involves data collection and preparation, statistical analysis and the interpretation of results.

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Key Definitions

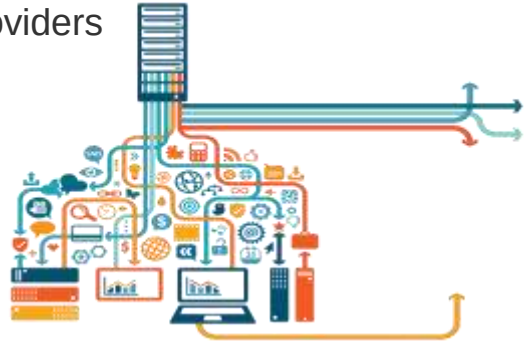
- **Seasonalized usage** is calculated by taking the average usage per day, during a defined period, multiplied by the number of days in the period. The average usage per day, multiplied by 365 days, yields the annualized usage.
- **Annualized savings** assumes that a customer participates in the program for a full year after initially entering. However, the program data shows that customers, once entered into the program, may leave and re-enter the program multiple times. This results in less than a full year of participation after their initial entry into the program.
- The relationship of the amount of time that a customer is in the program as compared to a defined period (e.g. year or a season) is called the **In-Program Ratio**.
- The **Achieved Annual Reduction** is the annualized savings multiplied by the in-program ratio. The product is the expected savings by a participant and power system over the defined period.
- For this analysis, **Winter** is defined as October through April (212 days) and **Summer** is defined as May through September (153 days).

Key Terms Defined: Seasonalized Usage, Annualized Savings, In-Program Ratio, Achieved Annual Reduction and the Winter and Summer Periods

Data Collection and Preparation

Data Delivery

- Formal data requirements document were distributed during participation solicitation
- Volunteers agreed to meet the data requirements
- Inputs for the statistical analysis required the monthly billing data, PPM program data, and temperature data
- Analysis covered calendar years 2010 through 2014
- Service providers, in conjunction with the information technology experts at the LPCs, supplied most of the data for the research
- Five out of the six LPCs have the same billing and service provider
- Data challenges
  - Data collection was the greatest challenge
  - Correct format was not a priority to the billing or service providers



Formal data requirements were established and volunteers agreed to meet the requirements. The data collection was the greatest challenge.

Summary of Participating Local Power Companies

	Population N	Sample n	Annual Average Use kWh	Annual Median Use kWh	Summer Use kWh	Winter Use kWh
Minnie Sparks	2,198	350	17,010	15,304	6,685	10,259
Donald Duck	2,764	184	15,909	15,579	6,913	9,152
Mighty Mickey	6,278	201	20,336	18,887	8,133	12,167
Winnie Watt	1,424	183	20,546	19,966	7,088	13,511
Grand Goofy	810	145	19,893	20,605	7,351	14,445
Plug-in Pluto	1,508	76	17,523	17,999	6,144	12,227
Weighted Results	**14,982**	**1,139**	**18,744**	**17,857**	**7,354**	**11,588**

- Mighty Mickey Power Company had the highest number of participants. Grand Goofy Electric Cooperative had the fewest.
- Winnie Watt Electric Cooperative participants had the highest annual usage and Donald Duck Distributors had the lowest.
- In all cases, Winter usage exceeded Summer

In the participating LPCs, statistics show winter usage exceeded summer usage.

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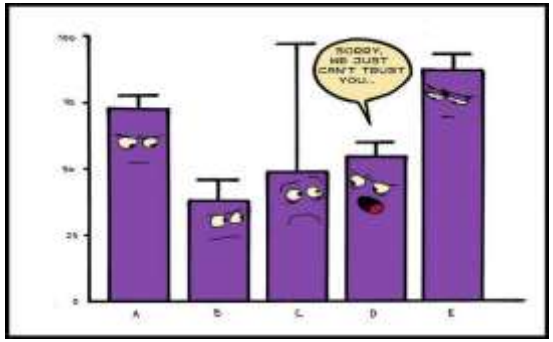
Sampling Methodology

Identify the PPM Participant Group and include all with sufficient data

- Customers who were participating in PPM at the time of data transfer (participants)
- Significant difficulties encountered in identifying qualified participants (e.g. rate codes, new billing systems that change with time)
- Incorporating all participants with sufficient data in the sample size was the most prudent approach

Identify the Comparison Group

- Customers who did not participate in PPM programs but have usage characteristics that closely matched the PPM participants (non-participants)
- Develop the strict criteria to represent the participants



The participants are customers who were in PPM programs at the time of data transfer and who had sufficient data were included in the sample.

Development of the Participant Group

- Using the billing data of the participants, duplicate records were eliminated, and unique multiple records were consolidated on a revenue-month basis
- Analysis excluded revenue-month records if the record had uncommon durations (less than 15 days or greater than 45 days) or zero consumption
- Participants can enter and leave the PPM program at any time
  - The individual customer bills fall into a “pre-program period” or a “program period”
  - The “pre-program period” are the bills in the months before the customer’s earliest participation date in the PPM program
  - The “program period” are the bills after the customer’s initial entry into the PPM program
- To get a robust data set, the monthly bills of the participants had to meet a minimum threshold of billing days in each critical analysis period

Minimum Threshold	Period Minimum Days
Annual	150
Summer	75
Winter	75

The participant group had to meet a minimum threshold of billing days.

Development of the Comparison Group

- The comparison group pool consisted of customers who did not participate in the PPM program (non-participants)
  - The customers in the comparison group pool had to meet the same criteria and restrictions as the participants
- For each customer in the comparison group pool, DNV GL calculated the annualized, and seasonalized (summer and winter) usage were calculated for each participation date.
- Members of the control group pool were matched to each participant based on rate codes and participant date. The squared difference between the comparison group pool members participants seasonal and annual usage were calculated.
- Five comparison group pool customers with the lowest mean square error (MSE) were designated as the matched comparison group members for that specific participant.

Annual, Seasonal Pre-Program Usage	Participants	Comparison Group	% Percentage Difference
Annual	17,010	17,071	-0.4%
Summer	6,685	6,757	-1.1%
Winter	10,259	10,263	0.0%

The Comparison group was matched by usage periods to the participant group.

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Analysis Methodology

- Data set for the analysis consisted of temperature data merged with the billing data
- For each participant and comparison, the degree days were calculated for each billing cycle, for a range of set points or group based on their matching participant
- A regression model, which used temperature to predict monthly consumption, was applied in an initial analysis
- Any observation with an absolute value of a standardized residual greater than three was designated as an outlier and eliminated from the analysis
- Identified the significant independent variables and optimal degree day set points for each customer in the analysis
- The optimal form of the model was determined using a stepwise regression approach with the selection criteria of maximizing the adjusted coefficient of determination (R^2)

Model Parameter		
R-Squared	71%	83%
HDD Reference	58	58
CDD Reference	67	68
Percent of Models Including:		
HDD	84%	91%
CDD	89%	96%
Participation Indicator	91%	82%

A regression model used temperature to predict monthly consumption. The optimal model was selected by a stepwise approach that maximized the R2.

Typical Model Results

- Average annual usage of the participants was consistent with the population annual usage
- On an annual usage basis, the comparison group (17,071 pre-program kWh) was well matched to the participant group (17,010 pre-program kWh)
- Energy reduction attributed to the PPM program for Minnie Sparks Electric was estimated to be 1,054 kWh/year/participant
- This is a 6.2% decrease in energy consumption
- The savings are statistically significant

Group	Pre-program kWh	kWh Reduction	Percent Reduction	Confidence Interval (kWh)	Relative Confidence Interval (%)
Participants	17,010	(1,398)	8.2%	±210	±15.0%
Comparison	17,071	(345)	2.0%	±52	±15.0%
Net	**17,010**	**(1,054)**	**6.2%**	**±158**	**±15.0%**

The savings for Minnie Sparks Electric was 6.2% which was statistically significant.

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Results by Season and Size

- The Minnie Sparks Electric Power Prepaid Metering (PPM) program savings analysis was based on a sample of 350 PPM participants.
- The customers were stratified into two strata “small” and “large” based on the annual usage (i.e., the small is less than the median pre-program annual usage).
- The average annual savings and achieved annual savings in total, by season (summer and winter), and by customer size (small and large)
- For Minnie Sparks Electric, the achieved energy savings are slightly higher in the winter than summer period. The achieved energy savings for the small customers were slightly higher than for the large customers.

Annual and achieved savings are shown in the individual tables by season and size.

Summary Table and Additional Findings

- How the LPC implements their program and their unique operational characteristics, the maturity of their program, or other factors affect results
- Individual LPC relative annualized savings range from 6.1% to 12.8%.
- Individual LPC relative achieved annual reduction ranges from 5.0% to 11.7%
- Grand Goofy is significant at 11.7% achieved annual reduction.
  - Newest program with least amount of participants (810)
  - Proportion of high credit risk, cost sensitive, customers was greater than other LPCs
  - The relative savings are expected to decrease as the program matures
- Relative confidence intervals for the individual LPC estimates of savings range from ±9% to ±24%

	PC	Annualized Savings		Achieved Annual Reduction			Confidence Intervals	
	Annualized Pre Use	kWh	% Percent	In-Program Ratio	kWh	% Percent	kWh	% Percent
Minnie Sparks	17,010	1,054	6.2%	91.1%	960	5.6%	158	±15.0%
Donald Duck	15,909	1,216	7.6%	88.0%	1,071	6.7%	176	±14.5%
Mighty Mickey	20,336	1,440	7.1%	70.5%	1,014	5.0%	295	±20.5%
Winnie Watt	20,546	1,732	8.4%	81.9%	1,419	6.9%	247	±14.2%
Grand Goofy	19,893	2,553	12.8%	91.2%	2,329	11.7%	237	±9.3%
Plug-in Pluto	17,523	1,397	8.0%	85.7%	1,197	6.8%	339	±24.2%

The achieved energy savings for the LPCs ranged from 5.0% to 11.7%.

The savings were slightly higher in the winter than summer period for all LPCs.

Conclusions

Conclusions

- This analysis shows that participation in a PPM program reduces the participants' energy consumption.
- PPM is generic term, and the energy reduction impacts for specific programs are influenced by implementation parameters, and program maturity.
- The analysis provided robust results for forecasting the impacts of other PPM programs. A method to calculate on overall, aggregate result can be used for expected savings.
- The in-program percentage has a significant impact on the expected savings. Accordingly, when planning, use the in-program percentage.

Participation in PPM programs reduces energy consumption. The use of an in-program ratio has a significant impact on the expected savings.

Questions ?

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Individual Results by Season and Size

Minnie Sparks Electric	Annualized Pre-Use (kWh)	Annual Savings (kWh)	Annual Savings (Percent)	Achieved Savings (kWh)	Achieved Savings (Percent)
Summer	6,685	387	5.8%	349	5.2%
Winter	10,259	628	6.1%	575	5.6%
Small	10,926	751	6.9%	677	6.2%
Large	22,252	1,316	5.9%	1,212	5.4%
Overall Weighted Results	**17,010**	**1,054**	**6.2%**	**960**	**5.6%**

Donald Duck Distributors	Annualized Pre-Use (kWh)	Annual Savings (kWh)	Annual Savings (Percent)	Achieved Savings (kWh)	Achieved Savings (Percent)
Summer	6,913	427	6.2%	374	5.4%
Winter	9,152	627	6.9%	553	6.0%
Small	10,355	606	5.9%	535	5.2%
Large	21,113	1,790	8.5%	1,572	7.4%
Overall Weighted Results	**15,909**	**1,216**	**7.6%**	**1,071**	**6.7%**

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Individual Results by Season and Size

Mighty Mickey Power	Annualized Pre-Use (kWh)	Annual Savings (kWh)	Annual Savings (Percent)	Achieved Savings (kWh)	Achieved Savings (Percent)
Summer	8,133	509	6.3%	361	4.4%
Winter	12,167	949	7.8%	665	5.5%
Small	13,262	809	6.1%	547	4.1%
Large	25,844	1,931	7.5%	1,414	5.5%
Overall Weighted Results	**20,336**	**1,440**	**7.1%**	**1,014**	**5.0%**

Winnie Watt Electric	Annualized Pre-Use (kWh)	Annual Savings (kWh)	Annual Savings (Percent)	Achieved Savings (kWh)	Achieved Savings (Percent)
Summer	7,088	379	5.3%	308	4.3%
Winter	13,511	1,377	10.2%	1,142	8.4%
Small	14,757	344	2.3%	295	2.0%
Large	26,528	3,167	11.9%	2,471	9.3%
Overall Weighted Results	**20,546**	**1,732**	**8.4%**	**1,419**	**6.9%**

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Individual Results by Season and Size

Grand Goofy Electric	Annualized Pre-Use (kWh)	Annual Savings (kWh)	Annual Savings (Percent)	Achieved Savings (kWh)	Achieved Savings (Percent)
Summer	7,351	823	11.2%	746	10.1%
Winter	14,445	2,015	14.0%	1,847	12.8%
Small	14,521	1,987	13.7%	1,800	12.4%
Large	24,637	3,053	12.4%	2,803	11.4%
Overall Weighted Results	**19,893**	**2,553**	**12.8%**	**2,329**	**11.7%**

Plug-in Pluto Power	Annualized Pre-Use (kWh)	Annual Savings (kWh)	Annual Savings (Percent)	Achieved Savings (kWh)	Achieved Savings (Percent)
Summer	6,144	316	5.1%	268	4.4%
Winter	12,227	1,082	8.8%	993	7.6%
Small	13,229	394	3.0%	334	2.5%
Large	21,388	2,302	10.8%	1,993	9.3%
Overall Weighted Results	**17,523**	**1,397**	**8.0%**	**1,197**	**6.8%**

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Confidence Intervals derived from n Estimates

The Challenge:

- We have a sample of n participants.
- For each Participant a linear regression equation estimate was developed to describe their usage. In this equation, certain terms defined the estimate of savings of a program.
- The point estimate of savings ("s") for each individual participant can be calculated , using coefficients of the equations. Accordingly, each individual estimate has an attendant standard error, defined by the regression equation.
- The average program estimated saving is the average of the point estimates of participants.

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Confidence Intervals derived from n Estimates

We need to report the uncertainty of average savings estimates… How do you calculate the uncertainty associated with the average savings:

Approach 1: The uncertainty of the average savings estimate can be estimated by the combined variance of the n estimates of savings. (i.e., sqrt(Σ SE^2)

Approach 2: An uncertainty estimate could be calculated using a Monte Carlo simulation, to determine a distribution of average program savings. During the simulations, each individual participant savings would be equal to their savings plus a random normal deviation based on their standard error.

Approach 3: Redefine the model as a one pooled model (i.e., separate variables for each participant), and use the standard error of the estimate from this model?

Approach 4: The uncertainty of the mean of the point estimates is the standard error of the mean of s;

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Confidence Intervals derived from n Estimates

Solution

Approach 4: Report the uncertainty of the mean of s, as if there were no error in the individual estimates of s. The idea is that the observed variability of the estimates s_i includes both the variability of the true savings (assuming there is such a thing) and the variability of the estimates relative to their true values. If you add the estimation error on top of the observed variance across the sample, you're double counting the estimation error. Stu Hunter used to refer to this as the estimation error being "entrained" in the simple calculated variance of the estimated mean.

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Confidence Intervals derived from n Estimates

Solution

- Monte Carlo provides a much smaller band because the only source of variation being injecting is the error in individual savings estimates, not the variation in what individuals you have in your sample. So you have the model error but not the sampling error. You'd need to bootstrap the sample itself to capture that source of variation. If you had a big enough original sample and a big enough bootstrap simulation set, the bootstrap would give you more or less the same thing as the ordinary SE(mean) calculated from the sample, without adding on the model SE.
- The pooled model approach has a lot of highly correlated observations. When you treat them all as independent you get a spuriously small SE because of the big n. These have to have SE calculated

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