Searching for Savings: Using Geospatial Analysis to Target Programs

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ABSTRACT

Geographic analysis tools, such as geographic information systems or GIS, have traditionally been used by utilities for managing physical assets and often reside on the desktops of utility transmission and distribution engineers. Yet geospatial analysis methods offer a range of opportunities for energy efficiency and demand response (EEDR) program designers, implementers, and evaluators to help in the sometimes elusive search for savings and demand reduction, and to help improve customer satisfaction. This paper describes an analysis of customer data for one utility, and the limitations encountered from examining the data in aggregated form, i.e., at the service territory. It then provides an example application of geospatial analysis for rate offerings related to smart meters to illustrate the expanded insights that can be achieved by adding a geographic dimension to customer research. This example study shows how adding the geographic dimension to an assessment can help utilities determine how and where their customers are likely to engage, whether such potential engagement is likely to produce enough benefit for the investment given physical system characteristics in those locations, or where an expanded pilot program or staged roll out should take place. These data and resulting information provide the utility a much richer and more detailed amount of information for strategic decision making.

Introduction

Utilities use many tools to analyze the potential for energy efficiency in their service territory typically segmenting customers by rate class or sector, such as residential, commercial, and industrial. Program evaluations similarly quantify the planned and actual savings and demand response (DR) resource by customer class at the service territory or system level. But few utilities conduct analyses on a geographically disaggregated basis. That's a missed opportunity because it's much easier to find something if you use a map.

As EEDR programs mature and mass marketing runs its course, utilities find that the cream has been skimmed off the top of savings opportunities. Even new programs would benefit from improved knowledge of target markets, where they are, and what can be expected in the way of savings. For DR programs, which will likely proliferate with the advent of more smart-meter and AMI-smart grid conversions, getting a good handle on customer response is critical and knowing *where* it takes place is even more important than with energy savings programs since operational infrastructure benefits are part of the picture. Indeed, the economics of smart grid business plans rely heavily on not only how much, but where, customers respond to a range of new service offerings aimed at system improvements.

Purpose and Scope of the Study

DNV GL (formerly KEMA) conducted a geospatial analysis of residential customers as part of a smart grid business case study for Louisville Gas & Electric (LG&E) and Kentucky Utilities (KU). Customer engagement in potential rate offerings related to smart meters was a key component of the utility's consideration of whether such an investment would be cost effective. The rate offerings included critical peak pricing, time of use, inclining block and peak time rebate. The operational team looked at such operational benefits as reduced meter reading costs, more efficient disconnection/reconnection and improved outage response management. While half of the study team investigated the potential operational benefits of smart meter conversion, the authors led an assessment of the kinds of customer response to four rate offerings that the utility wished to test. A previous pilot program had been conducted by the utility in 2009 in one small area of the service territory to assess the functionality of the smart meter systems, and obtain a preliminary read on the level of customer interest in, and reaction to participation in a set of services that combined the rate offerings plus communications hardware options. Following the pilot, the utility needed to understand how such an investment and set of services might be received system-wide.

To address this challenge, the study team posed three questions:

- Size – How large is the market for smart meters and related services?
- Likelihood of Engagement – What portion of the market is likely to participate?
- Location – What are the areas where those most likely to engage are located?

Table 1. Three phases of the analysis

Phase	What was done	What was the result
Phase 1: Data Collection and Review	Collection and initial review of utility and secondary data on customer characteristics, EEDR program participation, and awareness and attitudes toward smart meters and services.	This step provided an **initial profile** of the overall residential sector, its size, and characteristics related to smart meter acceptance and energy usage.
Phase 2: Statistical Analysis	Statistical analysis of Phase 1 customer data using regression modeling.	This step produced refined **measures of the propensity** to participate and the likelihood of delivering DR impacts.
Phase 3: Geospatial Analysis	Geospatial analysis and mapping of the results to target high potential response areas of the service territory given the results of the statistical analysis.	This final step recast the results of Phase 2 by zip code to identify the **areas within the service territory with residents who are the likeliest to participate.**

The next three sections describe these three phases of research and their findings.

Phase 1: Data Collection and Review

Methodology

The initial phase of the research is typical of market assessments for energy efficiency programs and involved examination of utility data and secondary data. Primary utility sources included results from a pilot program of smart meters in a portion of LG&E's territory that tested four rate offerings in combination with types and communication devices, an appliance saturation survey, and a customer survey of awareness and interest in smart meter services. The study team identified and summarized characteristics in the LG&E and KU residential population that are most indicative of smart meter engagement:

Results

Homeownership. The average LG&E and KU customer owns and lives in a single family home and uses more electricity than the national average household. Homeownership is at 68%, virtually the same as the national average.

Usage and bills.The average annual electric bill for LG&E and KU customers is 16% lower than the average bills nationally due to lower rates ($1,130 per year versus $1,340), even though their consumption is 23% higher (13,939 kWh per year versus 11,320 kWh).

Interest in bill reductions. Expectations of direct monetary gains were the most cited benefit by customers of smart meter related programs in both LG&E and KU and industry studies. However, the amount of savings that LG&E and KU customers expected was higher than the actual results from the pilot programs. Fifty-one percent of respondents in the residential smart meter survey said they would want to see at least $25 in savings per month to be interested in implementing smart meter technology. With an average monthly bill of $94.16, that would represent a 26% savings, whereas the actual dollar savings experienced in the pilot program was significantly lower due to lower levels of customer engagement.

Controllable appliances. Some differences are notable from examining the data by the two service territories for LG&E and KU separately. Controllable Appliances - Between the two companies, LG&E customers have both a greater saturation of central AC systems (62 percent versus 24 percent for KU) and at least one of the three primary controllable appliances tapped in the Direct Load Control Program (66 percent), whereas KU customers are more likely to have two of the three controllable appliances than LG&E customers (45 percent versus 26 percent).[1]

In addition to appliance holdings, the question of responsiveness to various time-differentiated rate offerings depends partly on when these appliances are in use, and whether customers have an opportunity to shift or reduce load. Figure 1 presents a graph of usage patterns by appliance type and time of day on weekdays.[2]

[1] LG&E and KU Residential Appliance Saturation Survey data provided by the utility.
[2] Source: Figure from Bellomy, Residential Smart Meter Survey; 2012 Presentation on Results

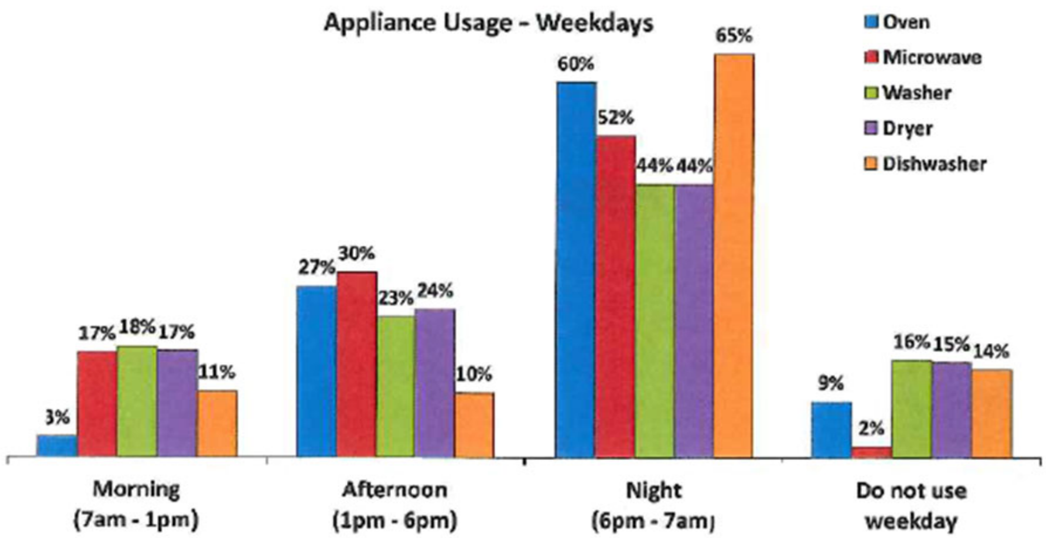

Figure 1. Appliance usage by type and time of day.

Other socio-demographic indicators. A customer survey indicates that the households most interested in smart meters tend to have higher levels of education, higher income, and are more technologically driven than the average household. The residential smart meter survey found that customers who agree with the statement "Technology makes my life easier" had a higher likelihood of participating in a smart meter program. This survey also suggested that among the respondent pool, once the program was explained to them, younger respondents tended to be more interested in smart meter programs than older respondents.

Customer attitudes and perceptions. Of those that responded to the residential smart meter survey:

- Twenty-seven percent reported being aware of smart meters. This varied both by age and income with younger and lower-income households being less likely to be aware of smart meters.
- When those who were aware of smart meters were asked about the advantages and disadvantages of smart meters, many people could not provide a response. Forty-six percent said they did not know of any advantages and 59% said they did not know of any disadvantages.
- Advantages listed by at least 5% of the respondents included the ability to track electricity usage, conserve energy, save money, and rate plans based on electricity usage. About 8% said there were no benefits of smart meters.
- Disadvantages included loss of control, inaccurate/possibility of malfunction, uncomfortable temperature, and lack of privacy. About 5% said there were no disadvantages of smart meters.

Participation in energy efficiency and demand response programs. LG&E and KU already offers several energy efficiency DR programs, some voluntary or opt-in, and some provided to all customers with the caveat that they may opt-out if they wish (e.g., the Smart Energy Profile program). This information provides evidence of the propensity of LG&E and KU customers to take advantage of services related to energy use and costs similar to what might be offered as part of a smart meter strategy. Participation in opt-in energy efficiency programs ranges from 1% to 2% across 7 programs, with 5% participation in the incentive programs. Direct load control participation is at 23%. The only opt-out program available is the Smart Energy Profile (behavior change program), which has been successful in retaining 99% of the original enrollees, or 42% of the residential customer sector.

This descriptive portion of the research provided initial insights into the potential for customer participation in smart meter related rate programs. The company was interested in whether to offer opt-in or opt-out services.

Phase 2: Statistical Analysis

Methodology

DNV GL undertook a data mining analysis to uncover insights regarding customer engagement with LG&E and KU utility programs and offerings, by stitching together components from internal LG&E and KU billing and customer data, public-domain American Community Survey (ACS) data (U.S. Census Bureau), residential appliance saturation survey (RASS) data, and residential smart meter data.

The objective of this analysis was to examine the variation in observed outcomes such as enrollment in opt-out programs, opt-in programs, and likelihood of participation in rate plans by potential explanatory variables such as customer usage, demographics, attitudes, technology adoption, and other factors.

In order to conduct such an analysis, we require and use disaggregated data. In lieu of individual level data, five-digit zip code level information provided by the utility was combined with data from other sources such as ACS for an enriched understanding of the customer.

While propensity to stay enrolled in an opt-out program and participation in an opt-in program such as a direct load control program were examined using regression models that included utility customer data and data from ACS, this paper elaborates on the analysis undertaken to study the propensity to participate in a pricing plan/rate program and the subsequent mapping of the results of this analysis.

The analysis follows an arc that progressively adds to the utility's understanding of their customers and attempts to answer the following questions in order:

- What is the level of interest for this offering?
- How large/small are the segments with levels of interest ranging from the trenchant/disinterested to the highly interested?
- Who are these customers and what do/can we know about them in terms of their usage, attitudes, and demographics (customer segment profiles)?
- Where are they and how do we reach them?

Participation in a Pricing Plan

The wide-ranging residential smart meter survey of a sample of LGE and KU customers asks respondents about their attitudes towards energy efficiency, their motivations to conserve energy and save money, and the perceived benefits and disadvantages of the smart meter. The survey data includes merged monthly and annual actual bill information regarding electricity and natural gas usage at the respondent level and demographics such as income, age, household size, education level, appliances in the home, and usage habits. The survey also asks respondents to indicate on a 1-5 scale, where 5 means highly likely to participate and 1 means highly unlikely to participate, their likelihood to participate in pricing plans, such as time of use (TOU), critical peak pricing (CPP), peak time rebates (PTR), and inclined block base (IBB).

We first analyze propensity to participate in any rate offerings of a smart meter program using the response data base from the Residential Smart Meter Survey conducted by Bellomy Research, Inc. in 2012. As the best acceptable proxy measure available in any of our data sources for propensity to adopt time-differentiated rate plans, we construct a compound indicator of likelihood to adopt rate plans based on responses to all four questions on participation in pricing rate plans as follows. If the respondent is highly likely (4 or 5) to participate in all four pricing plans, then they are assigned a score of 4, and if they indicate high likelihood to participate in three of the four plans they are assigned a score of 3, and so on. Respondents who do not indicate likelihood to participate in any of the four plans are assigned a score of 0. Table 1 presents a summary of utility customer likelihood of participating in a smart meter rate offering based on the compound score constructed as above, and then by specific rate type.

Table 2. Percent of customers responding to smart meter rate options

	Likelihood to participate in [4,3,2,1,0] rate offerings Constructed based on responses to 4 rate types					Rate Types - % 4 or 5 on a 1-5 scale				Sample size
	Highly Likely	Somewhat likely			Highly Unlikely	Time of Use	Critical Peak Pricing	Peak Time Rebate	Inclining Block	
	4	3	2	1	None	TOU	CPP	PTR	IB	
LG&E	24%	24%	19%	17%	16%	60%	55%	71%	38%	216
KU	21%	20%	20%	20%	20%	52%	44%	70%	38%	280
Total	22%	22%	19%	18%	18%	55%	49%	70%	38%	496

Source: Residential Smart Meter Survey, Bellomy Research, Inc., 2012

It must be noted that customer intent as reported in a survey does not directly translate into action. Studies show that among those who indicate interest in a rate offering, 5%-10% will typically actively engage. This yields five segments of respondents of near equal size ranging from 18%-22% with vastly different propensity to participate (Figure 2).

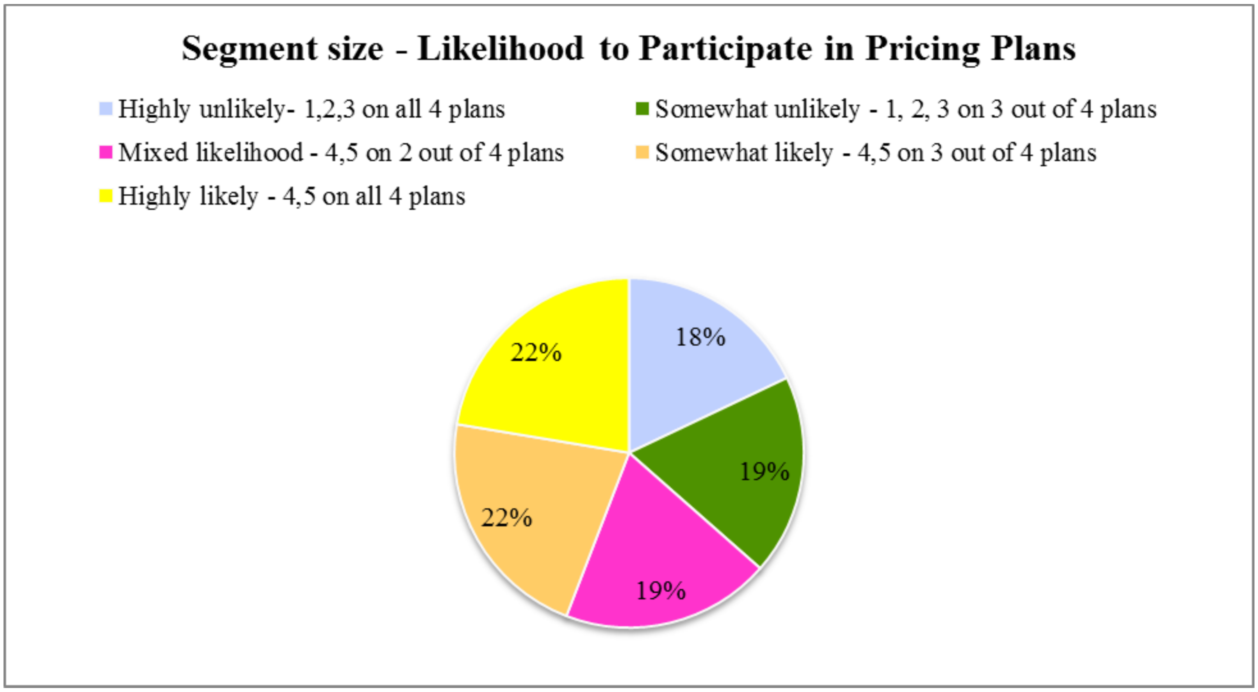

Figure 2. Likelihood to participate in pricing plans.

Customer Segment Profiles

These segments are also profiled by factors including utility, energy consumption, attitudes towards energy efficiency, income, age, perceived benefits and disadvantages, and household size. They provide a textural feel/more fleshed out picture of the typical customer in each likelihood group.

"Highly Likely" customer profile. Survey results indicate that 22% percent of customers are highly likely to participate in all of the four pricing plans (TOU, CPP, PTR, and IB) under a smart meter program. The characteristics of the household that is most likely to respond favorably to a smart meter rate offering are relatively lower average electricity usage, higher prevalence of programmable thermostats, higher concurrence on considering themselves "green," higher agreement on having a low carbon footprint and moving towards a low-carbon future. There is no (0%) prevalence in this segment of those who agree that smart meters have no benefits.

"Highly Unlikely" customer profile. Approximately 18% percent of households surveyed are not likely to participate at all in any Smart Meter program. On the surface, this household looks similar to the highly likely customers on aspects such as education (almost 60% of both groups possess a college degree), cell phone ownership, smart phone ownership, and internet access, but they have divergent attitudes on energy and technology. This household has relatively higher gas usage, is willing to pay for comfort, and thinks reducing usage is unimportant in higher numbers than other segments. They consider checking devices a nuisance although they currently have similar levels of phone and internet prevalence as other segments. Almost one in four (23%) agree that smart meters have no benefits or are not interested in smart meters.

“Somewhat likely” customer profile. The majority (60%) of respondents to the survey indicated positive intentions toward one to three of the four rate offerings described as being part of a smart meter program. While these households vary considerably in terms of socio-demographics and attitudes, a composite profile can be described as follows: They lie in the middle between the “highly likely” and the “highly unlikely” with respect to their attitudes toward conserving energy, saving money, and reducing their carbon footprint. They have the highest electricity and gas usage relative to the other two segments described above, the highest prevalence of those with income over $50,000 (66% for this segment versus 49% and 46% for the above two, respectively), and relatively the lowest smart meter awareness.

The statistical analysis described above provides a second level of insight into the populations most likely to participate in a smart meter rate offering. However, more can be learned to help inform the utility as to possible strategies for considering next steps, such as where to conduct additional pilot tests, where demand response might be most likely to be produced from those participating, and how customer engagement might be co-located with system features in most need of the benefits from demand response. The geographic analysis was produced to provide this additional level of insight.

Phase 3: Geographic Analysis

Methodology

This portion of the analysis built upon the descriptive and statistical insights through examining the data along their geographic dimension. Given the relatively small sample sizes of the survey data, which resulted in some zip codes with very few data points, a point by point geocoding of accounts was not feasible or appropriate.[3] Instead, the study team grouped the data at the finest level of geography both feasible and appropriate to the data examined to protect the confidentiality of customer information and the integrity and limitations of the survey results (i.e., the sample was not designed to produce statistically valid results by geographic area). For most census and utility data, zip code level presentations are made. Due to its sample design, the Residential Smart Meter Survey required different treatment. That survey captures responses from 496 customers residing across 122 distinct zip codes. The survey data used in this analysis has sparse data in some areas at the five-digit zip code level, with as low as a single observation from a zip code. In order to overcome this sparse data problem, we create larger geographical groupings based on the first three digits of the zip code called Sectional Center Facility or SCF, which is simply a definition we borrow from the U.S. Postal Service as a device in order to conduct an analysis on the geographic distribution of our propensity to participate in pricing plans segments.

Results

The first step taken in the geographic analysis was to map selected characteristics in the population that relate to potential rate offerings. As an example, one of these characteristics is the use of electricity as the dominant heating type. The figure below (Figure 3) presents these results as based on U.S. Census data at the zip code level.

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[3] In other words, in some zip codes the number of respondents to the survey is too sparse for accurate representation to be appropriate for plotting. Only those zip codes with adequate sample are included in the geographic analysis.

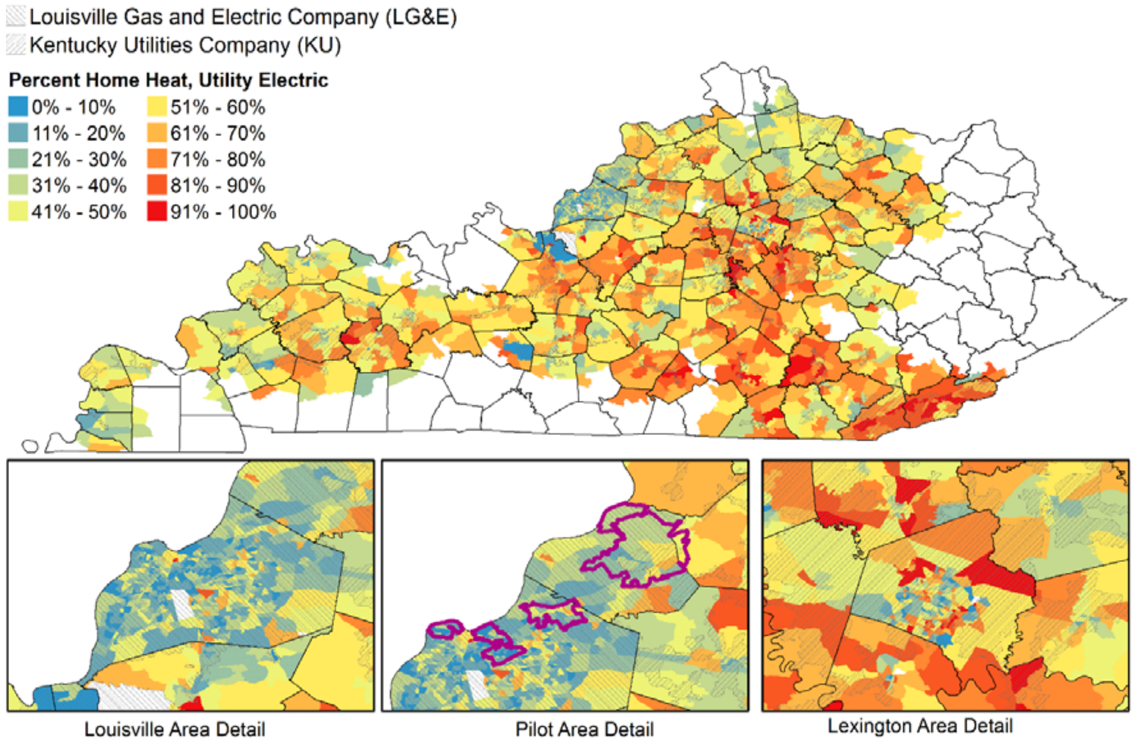

Figure 3. Distribution of electric heating.

The percent of homes heating with electricity was derived from the 2007- 2011 ACS. The number of occupied housing units with electricity as a primary fuel was divided by the total number of housing units for each of the ACS block groups. To generate the above map, the utility service territories were used to select only the ACS block groups that are serviced in part or whole by one of the utility clients.

Examination of this one variable displayed in geographically disaggregated form on the map already provides a few interesting insights that would not be readily gleaned from a table or chart:

- The pilot study area appeared to contain low percentages of homes that used electricity as a heating fuel. This may have impacted consumer expectations and satisfaction of how much electricity smart meters would save them given their lower overall electric burden.
- KU's southeast service area has a higher proportion of home using electricity as a heating fuel, this bears closer examination.
- Census block groups with large proportions of homes using electricity as a heating fuel could provide higher levels of customer engagement through targeted marketing campaigns to those areas.

Next the study team combined several variables into a ranking of likelihood to adopt a smart meter time-varying pricing plan. Figure 4 is a visual representation of the geographic distribution of propensity to participate in time-varying rate plans with smart meters, overlaid on the LG&E and KU territory.

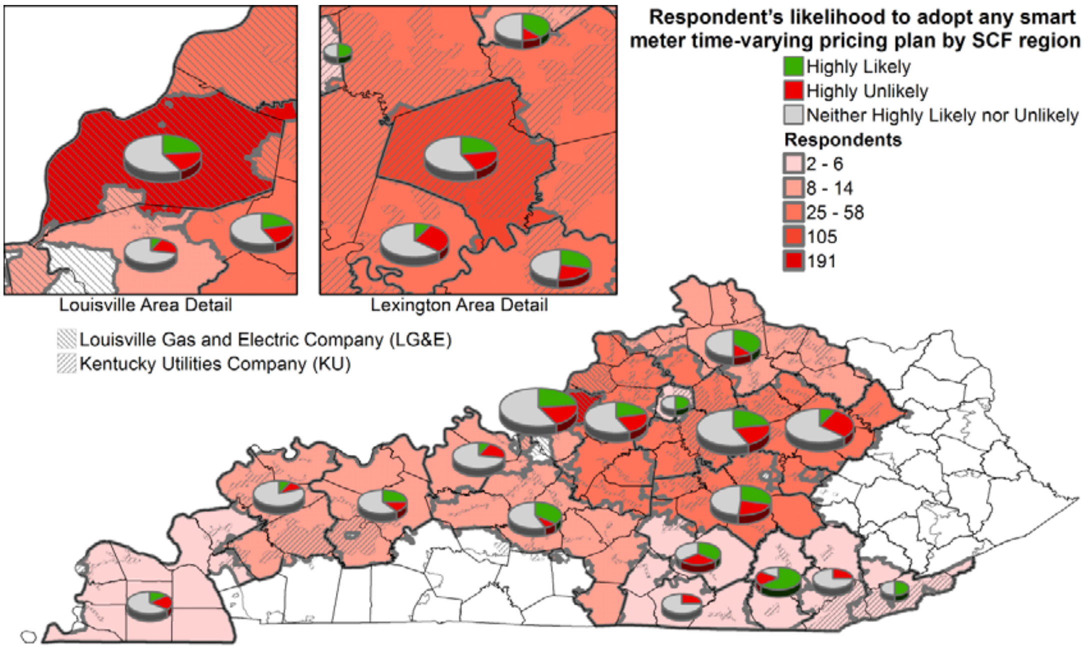

Figure 4. Geographic distribution of propensity to participate in pricing plan segments.

While we still have low sample size for some SCFs, even after collapsing records to the SCF level, we note from the figure above that there might be some pockets of concentrated interest in these pricing plans (e.g., the southeast corner on the map above).

A second map below (Figure 5) shows the five top areas by their urban-versus-rural designation where customer participation—and therefore benefits to the utility—would be expected to be highest, according to the data.

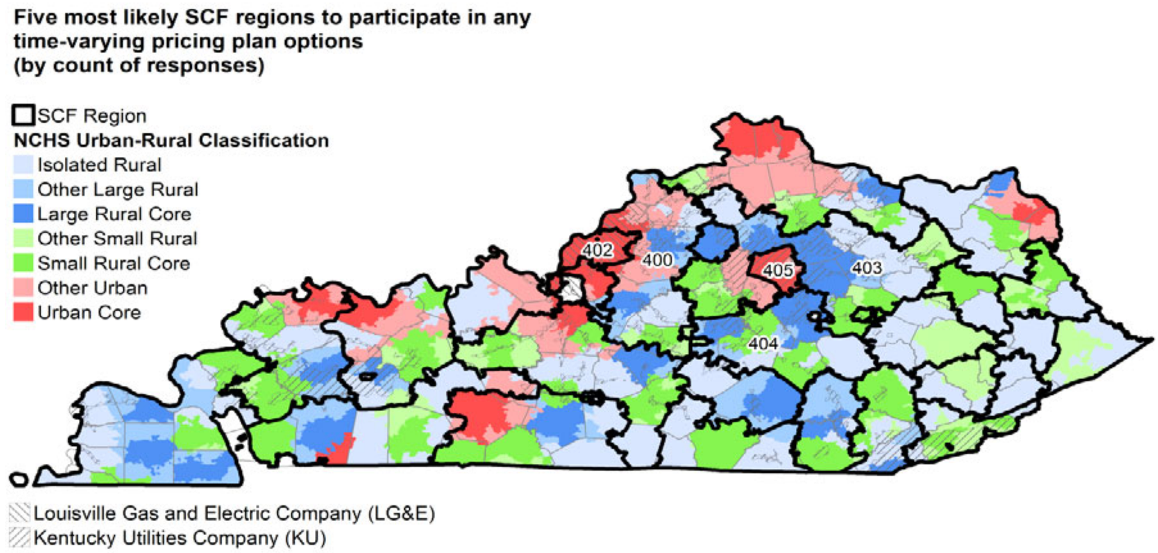

Figure 5. Top five areas of most likely customer engagement in time-varying rate programs.

DNV GL combined the results of this analysis of potential for customer engagement with those of the operational benefits analysis, and provided final recommendations to the utility regarding the business case for smart meter investment. The utility subsequently has filed the report with the regulatory commission in Kentucky as part of their smart grid docket. The full report is available at http://psc.ky.gov/order_vault/orders_2014/201400003_01302014 (1158-1264). While awaiting comment, the utility is considering how to apply the results of the analysis in their future smart grid plans.

Conclusions

This example study shows how adding the geographic dimension to an assessment can help companies determine how and where their customers are likely to engage, whether such potential engagement is likely to produce enough benefit for the investment given physical system characteristics in those locations, or where an expanded pilot program or staged roll out should take place. These data and resulting information provide the utility a much richer and more detailed amount of information for strategic decision making.

This paper has described an enhanced approach for examining customer data beyond tabulation, descriptive, and statistical analysis by adding the geographic dimension. Utilities are uniquely tied to the physical geography in which they sell their product. Location is important both in terms of where customers are located on a map, but also how their location relates to the utility's physical assets—generating units, feeders and substations, distribution lines and poles—and ultimately the meters attached to the facilities they serve. Smart grid transformations will increasingly allow utilities to better understand the relationship between customer demand response opportunities and the potential benefits to operations and physical assets that are co-located in the same area. This study provides a small window into what is possible through geospatial analysis.

References

LG&E 2009 Smart Rate Program Assessment, Executive Summary Report; Bellomy Research, Residential Smart Meter Survey (2012).

http://psc.ky.gov/order_vault/orders_2014/201400003_01302014 (1158-1264).