2019 AMI Innovation Study

Utility Perspectives on AMI End Use Disaggregation

Research sponsored by:

Prepared By:

James Milford
Director of Technology
Lumidyne Consulting, LLC
james.milford@lumidyneconsulting.com
lumidyneconsulting.com

Cory Welch
Founder & President
Lumidyne Consulting, LLC
cory.welch@lumidyneconsulting.com
lumidyneconsulting.com

Dan Violette
Director, Energy
Lumina Decision Systems, Inc.
dan.violette@lumina.com
lumina.com

September 2019

© 2019 Lumidyne Consulting, LLC.

Table of Contents

© 2019 Lumidyne Consulting, LLC.

List of Tables

© 2019 Lumidyne Consulting LLC.

1 Study Overview

Improved analytics and increasing acceptance of advanced metering infrastructure (AMI) data to support core utility functions is enabling new use cases and expanding AMI's role in existing applications. This report focuses on how end use disaggregation of AMI readings can facilitate activities related to residential demand side management (DSM) programs and rate design and impact analysis.

AMI end-use disaggregation (hereafter referred to as "disaggregation") is the practice of using software analytics to itemize consumers' energy data by individual appliance or end use. Using machine learning algorithms, appliance usage is extracted from AMI-metered data and converted into useful insights. The disaggregation analysis updates dynamically according to usage patterns to reflect changes in occupancy and upgrades to appliances. The resulting disaggregation insights provide information about when and how energy is consumed within a residential premise. To date, disaggregation has focused primarily on residential customers, but it can also be relevant to small and medium business customers.

To better understand the potential use cases and implementation challenges for AMI disaggregation, Lumidyne Consulting conducted 19 interviews of experts from 11 electric utilities leading the AMI transformation. The interviews prioritized US and Canadian utilities that had: 1) large numbers of installed residential AMI meters; 2) significant percentages of AMI saturation among residential customers, and; 3) greater lengths of time at higher residential AMI saturation levels. The interviewees were employees of nine investor-owned utilities and two municipal utilities from geographical regions such as the Pacific Northwest, Midwest, Desert Southwest, Great Lakes, South Atlantic, California and Florida. By area of expertise, the interviewees consisted of ten DSM experts, ten ratemaking experts, and one load research expert.

Three surveys were developed to address questions specific to DSM, ratemaking, and load research respondents. The surveys included qualitative and quantitative questions to assess utility perspectives on various use cases, value propositions and barriers for employing disaggregation data.

The goal of this report is to summarize key findings from our discussions with utility experts. The report is organized into a section highlighting major themes from the research, followed by more detailed use cases and barriers specific to DSM, ratemaking, and several other utility activities. Direct quotes from the study participants are italicized throughout the report.

1.1 Cross-Cutting Themes

Several cross-cutting themes emerged from the research, regardless of whether interviews focused on DSM, ratemaking, or load research. These cross-cutting themes highlight the most common opportunities and challenges for AMI disaggregation. Common themes of all the opportunities identified for AMI disaggregation are three fundamental use cases: providing customers with personalized and actionable information, customer targeting, and load impact assessment.

1.1.1 Facilitating Customer Engagement and Load Management

Customers want better information about when and from what appliances energy is being consumed in the home. AMI disaggregation has the potential to provide detailed consumption data by time of day and by highest energy-consuming loads. This information can be used by customers to better understand utility bills, explore impacts of selecting a different rate structure, identify behaviors they can implement to reduce or shift loads, and make more informed technology purchasing decisions.

Ideally, any dashboard or web application providing customers with energy data relying on AMI disaggregation would include personalized and actionable tips or recommendations that benefit both the customer and the utility.

© 2019 Lumidyne Consulting LLC.

These tips can include behaviors that will reduce customer bills on current rate structures, suggestions on rate structures that might offer more value, or information about relevant energy efficiency (EE) and demand response (DR) programs. Furthermore, providing customers with estimates of customer-specific economic implications is a strong motivator for customers to take action.

> *"This resonates with our rate education initiatives and TOU pilots. We've talked about having shadow billing and driving customers to rates that are most advantageous for them. We have some customer portals in development that are heading that direction, but we're not there yet."*

1.1.2 Customer Targeting

AMI disaggregation helps utilities better understand their customers' loads and behavior, which provides opportunities to target specific customers for outreach, engagement, and customer service. Disaggregation data can provide insights into the types of equipment in a residence, timing and magnitude of loads, and some estimates of equipment and building envelope efficiencies.

This information can help DSM programs identify highest potential savers or improve the program or measure cost effectiveness by maximizing savings per dollar spent on incentives and administrative costs.

> *"The focus is to find loads that are substantial and have the ability to shift consumption through programs. We want to find loads where EE has the biggest bang for the buck."*

For DSM programs struggling to meet cost effectiveness thresholds, customer targeting can improve the economics and consequently enable more DSM measure offerings. Knowing which customers have controllable loads can also help demand response programs recruit participants. Additionally, identifying customers with the highest potential to reduce or shift load and consequently save on utility bills can lead to greater customer satisfaction and future willingness to engage in utility programs.

> *"I definitely think effective targeting, being able to isolate the right customers, reducing marketing and outreach costs, and increasing savings are all things that will impact cost effectiveness. That's where you really need program managers' engagement and understanding to really move the needle."*

Having more information about the composition of loads within a residence can help target customers for enrollment in specific rate structures. Respondents suggested that customers with electric vehicles (EVs), solar photovoltaics (PV), battery storage, electric space or water heating, or medical devices, for example, might be best served on rates specific to those loads. Similarly, customers whose loads can be shifted to different times of the day are good candidates for enrollment in time-varying rates. When focus groups are surveyed to better understand customers' response to rates, utilities can target individuals with specific behaviors or equipment operating characteristics identified with disaggregation data. AMI disaggregation can also be used to assess the impacts of targeted educational outreach and to provide greater visibility into which utility messages resonate with customers and how they convert that information into action.

> *"If people aren't using the educational tools that we're giving them, we want to know. We're doing surveys to understand this better… Broadly, people are starting to understand the difference in energy and demand, that they can't use all their appliances at once, and that certain loads are power hogs. We want to understand if customers understand these concepts and how they are responding to that knowledge."*

© 2019 Lumidyne Consulting LLC.

1.1.3 Understanding Emerging Technologies

Utilities want in-depth knowledge of how emerging technologies operate to understand their role in load impacts, cost of service, bill impacts, and DSM programs. Knowing these technologies' consumption and savings profiles, peak coincidence, load factors and other disaggregation insights provides much of the data required to assess the grid impacts, benefits and costs of these technologies.

Rate designers want to quantify how emerging technologies will impact cost of service and whether rates are appropriately designed to recover those costs. As PV, EVs, battery storage, and indoor plant cultivation, among others, penetrate the market, rate designers want to ensure rates are equitable and reflect the impacts that these technologies have on cost of service.

> *"We tried to show why rates do or don't address these technologies properly. I don't think that utilities, who say there's a cost shift due to solar but who don't have data to support it, are credible. When you can demonstrate it with data, there's a better story there."*

Using rate designs to encourage beneficial technologies that act as grid resources is just as important as addressing cross subsidies from general ratepayers to customers who have equipment that increases the cost of service. AMI disaggregation provides valuable information to inform whether new rate structures are required or whether existing rates robustly address the suite of new technologies coming to market.

By developing better performance data for emerging technologies, DSM programs can make more informed decisions about whether and how to include these technologies in their portfolios. Additionally, more detailed data minimizes the risk in supporting new technologies.

> *"We now have R&D budget to identify new measures, test them out, figure out savings potential, and get them into our portfolio. We use AMI data to help us figure out savings for measures that we pilot. We've used it for smart thermostats, ductless mini-split heat pumps, and motors in the commercial sector. Identifying that new class of energy-saving technologies is important for us."*

In a similar spirit, AMI disaggregation enables more rigorous analysis of how fuel switching to electricity for end uses like space and water heating will impact loads, cost of service, and utility bills. This is especially important for jurisdictions preparing for a world with more electrification.

1.1.4 Data-Driven Support for Utility Initiatives

Having more detailed data helps utilities support their case for maintaining or changing disputed assumptions, programs or processes. AMI disaggregation provides DSM programs with more evidence to define deemed savings or parameters feeding into ex-ante calculated savings. Likewise, disaggregation can permit more rigorous evaluation of realized or ex-post savings.

> *"Knowing the hours of operation is becoming important for HVAC EM&V. There's lots of disagreement with the state evaluator on the appropriate value. AMI is equivalent to DNA testing, and we'll know exactly what's going on."*

For ratemaking, disaggregation insights help paint a picture of why rates are or are not appropriately addressing cost of service and equitably recovering those costs from specific customer segments. Contentious subjects like equitable rates and bill stability for low income customers, or the magnitude of cross subsidies going to PV customers, can benefit significantly from detailed analysis relying on disaggregation data. Data-driven analyses can enable greater utility confidence in the decision-making process, less pushback from regulators and stakeholders, and improved effectiveness at meeting desired goals.

© 2019 Lumidyne Consulting LLC.

1.1.5 Developing the Analytical Infrastructure

Many utilities are still uncertain about the best path forward for addressing data collection, data storage, and data analysis systems and staffing resources. Many respondents indicated that their utility does not yet have the infrastructure or the staffing in place to do the types of analyses relying on AMI disaggregation that they find beneficial.

> *"We're running into IT and resource constraints. The opportunities are front and center in our minds, but not fully incorporated yet. We're not using it the way we'd like to."*

Questions remain about: the optimal granularity of interval data to collect; how to securely transmit and store the data; the computational power required to analyze the data; how to integrate these insights into existing data management systems; and the type of personnel to hire. Whether the utility is better served by allowing vendors to perform these functions or by developing these capabilities in-house is a key question for many utilities.

> *"Just having the data, it's a real struggle. There's a sudden need for multiple data scientists to help make use of the data."*

1.1.6 Insights Must be Reliable

The insights and analysis from AMI end use disaggregation must be robust, reliable and validated. Utilities, regulators and other stakeholders will want assurance that AMI disaggregation algorithms produce data having accuracy within acceptable uncertainty tolerances. If the algorithms have limitations or are less reliable under specific conditions, utilities will want full transparency to avoid misusing the information.

> *"It has to be proven, and it needs a certain confidence interval with it. You can't bring non-robust data to the table, or critics will eat you up."*

It is likely that protocols to validate the disaggregation data will be required and re-assessed over time as consumption patterns change. Since consumption patterns and equipment preferences can vary widely across and within service territories and customer segments, validation of disaggregation data will need to consider locational and segment-specific differences.

> *"Credibility of evaluation work is important. We need to make sure it's accurate. How can we verify the accuracy of the disaggregation results? If it's a black box, we'd get criticized in our evaluation work for relying on data or disaggregation techniques that we couldn't vouch for. We would need to perform some kind of parallel monitoring study, and hopefully it mirrors the AMI results."*

In sum, the case must be made that AMI disaggregation can perform as well as or better than conventional methods applied in ratemaking and DSM activities, and the benefits must outweigh the financial cost.

1.2 DSM Themes

The research uncovered several themes specific to DSM activities. These themes are discussed in the following sections.

1.2.1 Reliance on 3rd-Party Implementers

A theme that emerged from most DSM experts is that utilities need to work with third-party implementers to determine how to share access to these insights and fully capitalize on the value of AMI disaggregation analysis.

> *"With laws about data privacy, we're currently very careful about releasing data. We conduct third-party reviews and draft security contracts. At least for the short run, we cannot provide raw data, so we do the analytics in-house. We do the customer targeting, and then we pass those*

customers' information along to the implementer. This data would expressly be used for the program, so it's easier to distribute than total population data."

Third-party contractors are often in a key role to utilize disaggregation data since many utilities are relying on third parties to manage and implement programs, and since EM&V is typically performed by third parties. Whether third parties assess where the greatest savings potential resides, focus on which customers should be recruited, or estimate the savings realized from program efforts, disaggregation insights can improve the efficacy of these efforts.

1.2.2 Utilities Are Interested in DSM Use Cases

Utilities expressed interest in DSM use cases for AMI disaggregation. When asked to provide a rating (on a 0-5 scale) of each utility's interest in several DSM use cases, more respondents indicated their utility had high interest than any other interest level, as shown in Table 1. The ratings also showed that DSM staff are most interested in the "customer targeting" use case.

Table 1. Rated Interest in AMI Disaggregation Use Cases for DSM

Major Use Cases for DSM	Average Rated Interest (0-5 Scale)	Count of Responses by Interest Level[1]		
		Low (<2.5)	Med (2.5-3.5)	High (>3.5)
Customer Targeting	4.3	1	1	6
EM&V	3.4	2	3	4
Estimating Technical Savings Potential	3.3	2	3	4

The DSM respondents indicated that estimating technical savings potential provides the greatest monetary benefits (without consideration of cost) of the three DSM use cases. The average estimate of benefits from estimating technical savings potential was 5.3 times larger than the estimate for EM&V, as shown in Table 2.

Table 2. Estimates of Relative Average Monetary Benefits for DSM Use Cases

Major Use Cases for DSM	Rank #	Relative Average Benefits ($/$)
Estimating Technical Savings Potential	1	5.3
Customer Targeting	2	1.4
EM&V	3	1

Note: This report does not include actual values of estimated monetary benefits because the magnitude of each estimate varies with the number of customers, the size of the DSM program, and the annual revenue of the utility interviewed. Rather, the report emphasizes the relative magnitude among use cases.

1.2.3 Barriers in DSM

In addition to the cross-cutting challenges described in Sections 1.1.5 and 1.1.6, the interviews revealed barriers specific to the use of AMI disaggregation in DSM activities.

- Reliance on deemed savings
- Limitations and restrictions on customer targeting
- Concerns about data privacy

[1] Though nine DSM interviews were conducted, the total responses for a given use case may not add to nine because responses where interviewees said they were "uncertain" have not been included in the table.

- Institutional lock-in to traditional EM&V methods

1.3 Ratemaking Themes

The surveys discovered several themes specific to ratemaking activities. These themes are discussed in the following sections.

1.3.1 Rate Design is Moving Toward Greater Sophistication

A common response among ratemaking experts was that there is increasing pressure to offer a wider variety of rates and to design more sophisticated rate structures. Drivers for this trend included customer service, encouraging beneficial customer behavior change, minimizing ratepayer cross subsidies, and better aligning rates with fixed and variable costs of service. As utilities move in this direction, AMI disaggregation data can support these advancements.

> *"I think we're going to be challenged in the next 2-5 years to greatly expand our rate offerings. We'll have to go into areas where we have no comfort whatsoever... If we have analytics based on AMI data, it could go a long way to shaping the path forward."*

Importantly, customers can also benefit from disaggregation insights as more rate options become available and as more personalized usage information is required to effectively manage load on increasingly sophisticated rate structures.

1.3.2 Rate Design and Impact Analysis Use Cases Have Value

Most ratemaking experts saw high value in five of the six rate design and impact analysis use cases investigated in the survey, as shown in Table 3. When asked to provide a rating (on a 0-5 scale) on the value of each rate design use case, the responses indicated that providing customers with recommendations on how to respond to rates was most valuable. Quantifying PV production was a close second in perceived value to utility respondents.

Table 3. Rated Value of AMI Disaggregation Use Cases for Rate Design & Impact Analysis

Use Cases for Rate Design & Impact Analysis	Average Rated Value (0-5 Scale)	Count of Responses by Value Level		
		Low (<2.5)	Med (2.5-3.5)	High (>3.5)
Providing Customers with Recommendations on how to Respond to Rates	4.0	2	0	7
Quantifying PV production	3.9	1	1	7
Assessing the Equity of Rate Designs	3.4	2	0	6
Determining the Degree to which End Uses Respond to Rates	3.3	3	3	3
Quantifying EV consumption	3.3	3	1	5
Segmenting Customers by End Use Loads (among other characteristics)	3.1	3	0	6

© 2019 Lumidyne Consulting LLC.

The experts' ratings indicated that, in aggregate, the rate design use cases provide nearly the same monetary benefits (without consideration of cost) as the DSM use cases. The average estimate of benefits from DSM use cases was 10% larger than the estimate for rate design use cases, as shown in Table 2.

Table 4. Estimates of Relative Average Monetary Benefits for Disaggregation Use Cases

Use Cases for Disaggregation	Rank #	Relative Average Benefits ($/$)
DSM Use Cases	1	1.1
Rate Design & Impact Analysis Use Cases	2	1

Note: This report does not include actual values of estimated monetary benefits because the magnitude of each estimate varies with the number of customers, the size of the DSM program, and the annual revenue of the utility interviewed. Rather, the report emphasizes the relative magnitude among use cases.

1.3.3 Barriers in Rate Design and Impact Analysis

In addition to the cross-cutting challenges described in Sections 1.1.5 and 1.1.6, the interviews revealed barriers specific to the use of AMI disaggregation in rate design and impact analysis.

- Institutional aversion to analysis complexity
- Lag time in profiting from structural changes
- Political/regulatory acceptance for billing
- Minimal direct effect on utility financial standing

1.4 Report Structure

Sections 2 and 3 of this report provide greater detail regarding utility perspectives on DSM- and ratemaking-specific use cases, including quantitative value or interest ratings provided by the utilities. Section 4 addresses several other use cases outside of the normal purview of DSM and ratemaking that were also identified during the interviews. Section 5 summarizes key takeaways and provides final remarks.

2 Applications for DSM Programs

This section focuses on AMI disaggregation use cases for DSM activities, though in some instances the use cases and/or disaggregation insights are also useful for ratemaking and other functional areas. The DSM-specific survey explored three use cases for disaggregation, although several other use cases emerged from the discussions.

The three DSM use cases addressed by the survey included 1) customer targeting, 2) evaluation, measurement and verification (EM&V), and 3) estimating technical savings potential. The survey asked utility participants to rate their interest in these high-level use cases (on a 0 to 5 scale, with 5 indicating highest interest), and the results are shown in Table 5.

Table 5. Rated Interest in AMI Disaggregation Use Cases for DSM

Use Cases for DSM	Average Rated Interest (0-5 Scale)	Count of Responses by Interest Level[2]		
		Low (<2.5)	Med (2.5-3.5)	High (>3.5)
Customer Targeting	4.3	1	1	6
EM&V	3.4	2	3	4
Estimating Technical Savings Potential	3.3	2	3	4

Respondents indicated highest interest in customer targeting, with EM&V and estimating technical savings potential rated lower. One reason customer targeting ranked highest in interest is that the interviewees believed the benefits of improved customer targeting can be realized more quickly. Another driver for higher interest in customer targeting is that there is less of an imperative to have well validated disaggregation data and rigorous review by regulators and stakeholders, which affects how quickly benefits can be realized.

In follow-up questions, the interviewer asked DSM experts to estimate the annual monetary benefits (without consideration of costs) of the three described DSM use cases. Surprisingly, the average ranking of the use cases in terms of annual monetary benefits was not correlated with the ranking of interest in the use cases (shown in Table 5). Averaged across respondents, estimating technical savings potential was believed to provide 5.3 times more monetary benefit than EM&V, as shown in Table 6.

Table 6. Estimates of Relative Average Monetary Benefits for DSM Use Cases

Use Cases for DSM	Rank #	Relative Average Benefits ($/$)
Estimating Technical Savings Potential	1	5.3
Customer Targeting	2	1.4
EM&V	3	1

Note: This report does not include actual values of estimated monetary benefits because the magnitude of each estimate varies with the number of customers, the size of the DSM program, and the annual revenue of the utility interviewed. Rather, the report emphasizes the relative magnitude among use cases.

Reducing the cost of surveys and monitoring studies was the main driver behind the higher value given to the estimating technical savings potential use case. For the EM&V use case, it was noted that the lower monetary benefits were simply a function of the limited budgets allocated to EM&V activities (e.g., less than 5% of the total DSM budget) and were not reflective of the usefulness of the disaggregation insights.

Having identified each DSM respondent's ratings for the three DSM use cases, the survey then asked the experts to elaborate on their two highest-rated use cases. The key takeaways from those more detailed use case discussions are provided in the following sections.

2.1 Customer Targeting

Most utilities and third-party contractors are already targeting customers for participation in DSM programs, but the level of sophistication varies considerably. AMI disaggregation can enhance these efforts by providing

[2] Though nine DSM interviews were conducted, the total responses for a given use case may not add to nine because responses where interviewees said they were "uncertain" have not been included in the table.

customer-level information about equipment types and efficiencies, along with numerous indicators for consumption levels and behaviors. The general goal of customer targeting is to improve energy savings, demand savings, cost-effectiveness, and benefits to the customer.

Respondents were asked to rate the value of specific disaggregation insights related to customer targeting (on a 0 to 5 scale, with 5 indicating highest value), the results of which are shown in Table 7.

Table 7. Rated Value of AMI Disaggregation Insights Relevant to Customer Targeting

Insights for Customer Targeting	Average Rated Value (0-5 Scale)	Count of Responses by Value Level		
		Low (<2.5)	Med (2.5-3.5)	High (>3.5)
Equipment Detection	4.1	0	2	5
Equipment Consumption Coincident with Peak	3.9	1	1	5
Presence of Low-Efficiency Equipment	3.7	0	3	4
Likelihood that Participant Will Benefit	3.4	2	1	4
Above-Average End Use Consumption	3.4	0	5	1

Interestingly, all insights except above-average end use consumption were ranked as having high value by most DSM experts. Knowing above-average end use consumption was deemed less valuable because there are many reasons other than non-optimal consumption behavior or low equipment efficiencies that can cause higher end use consumption. Equipment detection was said to be useful for identifying customers with equipment specifically targeted by existing EE and DR programs, or customers lacking in beneficial technologies like smart thermostats. Several respondents also mentioned that equipment detection can be especially important for identifying EV owners, which informs opportunities for educational outreach or enrollment in load-shifting programs or EV-specific rates. Most respondents agreed that there is high value in knowing equipment consumption coincident with peak demand. In addition to providing value to DR participant recruitment, this information can aid EE programs that are increasingly prioritizing the secondary benefits of peak demand reduction.

Several other comments warrant inclusion in this section on customer targeting. The first was a statement about the importance of merging equipment detection and consumption indicators from AMI disaggregation with customer bill indicators and demographic, psychographic, building characteristics, and programmatic (e.g., prior program participation) data where available. The combination of these data is expected to improve the effectiveness of customer targeting.

Another respondent referenced a study that showed in a retrospective analysis how customer targeting based on specific consumption indicators could have increased savings appreciably across participants for several programs examined.[3] In addition to enabling higher savings per participant, this insight also suggests that customer targeting has potential to improve program cost effectiveness.

Lastly, interest was expressed in the ability to look specifically at low-income customers or low-income areas and customize the DSM measure offerings to maximize benefit to those customers. For example, if disaggregation data indicated that poor building envelopes were major contributors to energy consumption, outreach to those low-income customers could be tailored to engage them in programs focused on building envelope.

[3] Adam Scheer, Borgeson S., Rosendo K., 2017, "Customer Targeting for Residential Energy Efficiency Programs: Enhancing Electricity Savings at the Meter," PG&E, MIT, Convergence Data Analytics, October 27, https://www.pge.com/pge_global/common/pdfs/for-our-business-partners/energy-efficiency-solicitations/Customer-Targeting-Final-Whitepaper.pdf

2.2 EM&V

EM&V activities are used to assess the performance of DSM programs by estimating the *realized* energy and demand savings compared with the *expected* savings. Because AMI disaggregation can discern consumption changes for specific loads in response to a DSM intervention without requiring additional on-site monitoring equipment, it can be a useful tool for EM&V.

Respondents were asked to rate the value of specific disaggregation applications related to EM&V (on a 0 to 5 scale, with 5 indicating highest value), the results of which are provided in Table 8.

Table 8. Rated Value of AMI Disaggregation Applications Relevant to EM&V

Applications for EM&V	Average Rated Value (0-5 Scale)	Count of Responses by Value Level		
		Low (<2.5)	Med (2.5-3.5)	High (>3.5)
Estimating Equipment Hours of Operation	4.4	0	0	5
Visibility into Timing of Savings	4.4	0	0	5
Enhancing Pre/Post Billing Analysis	4.2	0	1	4
Reducing Time between Installation and Evaluation	3.6	0	3	2
Incorporating Larger EM&V Sample Sizes	3.4	0	5	1
Evaluating Savings Persistence	3.2	1	3	1
Verifying Equipment Installation	3.0	1	3	1

All DSM respondents rated highly the estimation of equipment hours of operation via AMI disaggregation. This rating reflects the importance of quality estimates of hours of operation due to their significant impact on savings estimates and their high variability from one customer to another. Compared with estimating hours of operation using on-site monitoring equipment, AMI disaggregation can offer a less costly and less labor-intensive alternative, whereby a greater number of installations can be sampled to provide more accurate usage assumptions. Moreover, gaining these insights using AMI disaggregation is much less intrusive to customers, which removes a barrier to participation in some programs.

A similarly high rating was given to improving visibility into the timing of savings. Respondents suggested this is important for accurately estimating avoided costs for cost-effectiveness analyses. This benefit is increasingly important in jurisdictions where avoided energy costs are heavily influenced by a small number of high-cost hours. Greater visibility into savings profiles can help utilities quantify DSM impacts on system-wide or localized peak demand and can also help to avoid amplifying low-load conditions or negative wholesale prices in areas with high variable renewable generation.

The ability to use AMI disaggregation to discern savings from individual measures installed in the same residence was a key factor driving the favorable rating for enhancing pre/post billing analysis. Compared with traditional billing analysis, AMI disaggregation can facilitate attribution of savings from multiple co-located measures to their appropriate programs. That said, one interviewee highlighted that estimating savings is more challenging than simply quantifying pre- and post-intervention consumption, even when the accuracy of the consumption estimates is high.

Though there was uncertainty about how many processes can be streamlined, several respondents expressed interest in using AMI disaggregation to automate certain EM&V tasks and generate regular feedback on program

© 2019 Lumidyne Consulting LLC.

performance. More frequent updates on performance throughout a program cycle can allow program managers to continuously assess and modify their strategies and re-allocate resources to maximize program effectiveness.

Most interviewees were comfortable with current methods relying on the expected useful life of a measure to determine savings persistence. However, it was suggested that AMI disaggregation could be helpful in estimating savings persistence of behavioral measures.

2.3 Estimating Technical Savings Potential

Estimating technical savings potential requires information about the prevalence of and consumption from different types and efficiencies of equipment stocks among many customer segments to calculate region-wide energy and demand savings potential of DSM measures. For residential customer segments, traditionally these analyses have relied on customer appliance saturation surveys to estimate the prevalence of equipment types and efficiencies. This saturation data is often paired with building energy simulation models, samples of measured end use consumption from on-site monitoring, total household energy consumption data, and weather information to estimate average consumption patterns and annual energy intensities (e.g., kWh/year per premise) for various appliances and equipment. Many of these insights can be revealed using AMI disaggregation, with the added advantage of automation, more frequent updates, and greater granularity and population representation.

Respondents were asked to rate the value of specific AMI disaggregation insights related to estimating technical savings potential (on a 0 to 5 scale, with 5 indicating highest value), the results of which are shown in Table 9.

Table 9. Rated Value of AMI Disaggregation Insights Relevant to Estimating Technical Savings Potential

Insights for Estimating Savings Potential	Average Rated Value (0-5 Scale)	Count of Responses by Value Level		
		Low (<2.5)	Med (2.5-3.5)	High (>3.5)
Monthly/Annual End Use Consumption	4.3	0	1	5
Equipment Saturation	4.0	0	1	5
End Use Load Shapes	3.8	1	1	4
Equipment Efficiency	3.6	2	0	4
Size of Equipment	3.2	2	1	3
Number of Equip. Units per Premise	3.1	2	2	2

Respondents found the most value in having better estimates of monthly or annual end use consumption. Given that traditional approaches to estimating end use or equipment consumption require triangulation using many different data sources of varying quality, AMI disaggregation has the potential to generate more accurate estimates using larger and more granular customer samples. Another benefit of having disaggregation data is the ability to quantify distributions around customer equipment consumption. One expert thought it would be useful to include these distributions in the stock turnover models often used in savings potential estimates.

Though many experts believe customer surveys are useful and informative, they see AMI disaggregation as a pathway to collecting larger sample sizes and improving the accuracy of equipment saturations, particularly if complemented with efficiency estimates. This information is useful for customer targeting and for better understanding how appliance and building codes and standards are changing the efficacy of DSM programs. Additionally, more frequent information about equipment saturation trends can improve forecasting of technology adoption.

Comments describing the advantages of generating end use load shapes from disaggregation data were similar to those in Section 2.2: avoiding costly and intrusive monitoring, improving estimation of avoided costs, and estimating peak-coincident demand. For jurisdictions covering many climate zones and having many customer

© 2019 Lumidyne Consulting LLC.

usage patterns, AMI disaggregation can make it easier and less costly to generate load shapes from larger samples across many segmentation criteria.

One concern about estimating the number of equipment units is that it could require high frequency AMI data (e.g., 15-minute intervals or less). Respondents suggested that this is an area where customer surveys might be better suited for estimating regional technical savings potential.

2.4 Additional DSM Use Cases

Two additional DSM use cases for disaggregation data emerged during utility discussions, including:

Market Transformation

Disaggregation insights can augment longitudinal studies quantifying market transformation. Having more equipment saturation and detailed consumption data across non-participating customers provides insights into the market effects of DSM programs.

Inoperable Devices

AMI disaggregation can be used to detect inoperable devices installed for DR and EE programs. For example, one utility was particularly interested in identifying whether smart thermostats with one-way communication are still responding to control signals. This idea is applicable to load control switches commonly used in DR programs, or any device with one-way communication.

2.5 Barriers to Achieving AMI Disaggregation's Full Value to DSM

In addition to the cross-cutting challenges described in Sections 1.1.5 and 1.1.6, the interviews revealed additional barriers specific to the use of AMI disaggregation in DSM activities.

The most frequently cited barrier involved deemed savings. For measures that rely on deemed savings, there is minimal incentive to target the highest potential savers or pursue detailed EM&V because programs and implementers can only claim the deemed savings amount. However, AMI disaggregation can improve the accuracy of the deemed savings for efficiency measures.

For customer targeting, respondents noted that there is little benefit to upstream retail programs. Moreover, some jurisdictions have restrictions on customer targeting due to concerns about fairness and a desire to make programs available to all relevant customers. However, most surveyed utilities had flexibility to target specific customers in their marketing and outreach activities.

Reliance on third-party contractors for program management, implementation and EM&V requires that AMI disaggregation data be shared outside of the utility. One expert noted this presents some data privacy concerns and requires special legal considerations in how contracts are designed and upheld. Given that third parties have been working with AMI data for many years, many of these challenges are already being addressed.

Lastly, regulatory and institutional lock-in to traditional methods might hinder use of disaggregation insights for EM&V. Several respondents postulated that there likely will be short-term pushback against moving to new EM&V methods because of how much effort has gone into developing traditional EM&V processes like technical reference manuals, which many stakeholders have grown accustomed to using.

3 Applications for Rate Design and Impact Analysis

This section focuses on AMI disaggregation use cases for rate design and impact analysis activities, though in some instances the use cases and disaggregation insights are also useful for DSM and other functional areas.

© 2019 Lumidyne Consulting LLC.

The rates-specific survey focused on six use cases for disaggregation, though additional use cases emerged from the discussions.

The survey asked utility participants to rate the value of six use cases for AMI disaggregation data (on a scale from 0 to 5, with 5 indicating highest value), the results of which are shown in Table 10.

Table 10. Rated Value of AMI Disaggregation Use Cases for Rate Design & Impact Analysis

Use Cases for Rate Design & Impact Analysis	Average Rated Value (0-5 Scale)	Count of Responses by Value Level		
		Low (<2.5)	Med (2.5-3.5)	High (>3.5)
Providing Customers with Recommendations on how to Respond to Rates	4.0	2	0	7
Quantifying PV production	3.9	1	1	7
Assessing the Equity of Rate Designs	3.4	2	0	6
Determining the Degree to which End Uses Respond to Rates	3.3	3	3	3
Quantifying EV consumption	3.3	3	1	5
Segmenting Customers by End Use Loads (among other characteristics)	3.1	3	0	6

Five of the six ratemaking use cases were deemed by most ratemaking experts to be of high value. The highest rated use case of helping customers respond to rates was driven by goals to achieve behavior change and to minimize barriers to enrollment in new rates. Respondents were interested in quantifying PV production to gain a better understanding of its impact on cost of service and to forecast load impacts. The ratemaking experts who assigned a low value rating to quantifying EV consumption did so because EVs have not gained much traction yet in their jurisdictions, but they acknowledged that quantifying EV consumption will be valuable in the future. Interestingly, the low average rating for segmenting customers by end use is a bit misleading because the distribution of responses was bimodal. Most respondents saw value in this use case, and those who did not suggested that there was little institutional pressure to investigate segmentation that considered end uses.

Like the DSM survey, ratemaking participants estimated the combined annual monetary benefits (without consideration of costs) of the six proposed disaggregation use cases. When compared with each of the three DSM use cases (customer targeting, EM&V, and estimating technical savings potential), the combined monetary benefit of ratemaking use cases was higher than any of the individual DSM use cases. However, the estimated monetary benefits from the three DSM use cases in aggregate were 10% higher than those of the ratemaking use cases, as shown in Table 11.

Table 11. Estimates of Relative Average Monetary Benefits for Disaggregation Use Cases

Use Cases for Disaggregation	Rank #	Relative Average Benefits ($/$)
DSM Use Cases	1	1.1
Rate Design & Impact Analysis Use Cases	2	1

Note: This report does not include actual values of estimated monetary benefits because the magnitude of each estimate varies with the number of customers, the size of the DSM program, and the annual revenue of the utility interviewed. Rather, the report emphasizes the relative magnitude among use cases.

Having identified each ratemaking respondent's ratings for the six rate design and impact analysis use cases, the survey then asked experts to elaborate on factors influencing that rating. Key takeaways from those more detailed use case discussions are provided in the following sections.

© 2019 Lumidyne Consulting LLC.

3.1 Informing Customers about How to Respond to Rates

To provide customers with actionable and personalized recommendations to respond to rates, detailed information about how customers are using energy is required. As rates rely more on time-varying pricing and demand charges, AMI disaggregation can be a powerful tool for helping customers gain insight into how energy is consumed. While describing a pilot study on a demand-based rate, one rate expert noted that the utility's customer service line had received calls from concerned pilot participants trying to understand what caused a spike in their demand. Though dashboards showing whole-home interval data are an improvement to billing summaries, load disaggregation insights can help enable customer behavior change and minimize customer service calls.

Sophisticated rates—such as time-of-use, real-time, demand-based, or critical peak pricing—could gain more buy-in from customers if those customers have access to disaggregation insights supplemented with relevant recommendations. Several rate experts noted that if recommendations are tailored to a specific customer's loads and consumption patterns, while still considering important factors like customer comfort, it would significantly improve customer service. Additionally, recommendations based on disaggregation insights can encourage customers to participate in relevant DSM programs to lower their monthly bills.

3.2 Quantifying PV Production and EV Consumption

In many jurisdictions, utilities don't have insight into energy production profiles from behind-the-meter PV systems. Respondents described how engineering models or metered samples are often used to estimate the production from a typical PV system, but lack of premise-level production data makes it difficult to discern the real-world variability in PV production and gross customer consumption (i.e., prior to subtracting PV generation). AMI disaggregation can improve visibility into site-specific PV production and gross consumption profiles.

Disaggregation insights can play a similar role in estimating EV consumption patterns, with several added benefits. Unlike PV systems, the location of in-home EV chargers can be unknown to utilities. AMI disaggregation can help detect EV charging and enable outreach either for educational purposes or to enroll these customers in utility programs. Some EV-specific rates require separate EV meters and others require the whole premise to be put on the rate. One rate expert suggested it might be politically feasible to separately bill EV consumption determined by AMI disaggregation on special EV rates, while billing the premise's remaining consumption on another rate.

3.3 Understanding the Degree to Which End Uses Respond to Rates

There is increasing interest in using price signals to encourage customer behavior that reduces the cost of service. As one rate expert highlighted, some rates are designed to function like demand response programs to reduce loads when there is stress on the system. However, there is still much to be learned about how rates can most effectively accomplish these goals. AMI disaggregation can play a role in this discovery phase by helping utilities understand the degree to which specific loads respond to rates.

Respondents talked about how focus groups and customer surveys are trying to figure out the behavioral aspects of *why* customers do or don't respond to rates, and AMI disaggregation provides more quantitative analysis about *how and to what degree* they respond. Identifying which loads are being reduced or shifted is useful in customer targeting and messaging. For example, utility outreach might be able to say, "Customers with similar appliances and usage as you saved X dollars on this rate by doing Y." Disaggregation insights also provide an opportunity to verify whether educational outreach is inducing customers to respond as intended. When combined with equipment saturation insights or equipment usage patterns, load impacts can be extrapolated to customers having similar characteristics within a region or customer segment, which is valuable when estimating impacts of many customers transitioning to mandatory or opt-out rates.

© 2019 Lumidyne Consulting LLC.

3.4 Assessing Equity of Rate Designs

A key objective of rate design is to ensure that rates equitably recover utility costs and minimize cross subsidies among ratepayers. This objective requires rate designers to characterize consumption patterns of various customer classes and appropriately allocate the utility's cost of service to those customers based on cost causation. Then rates are designed to recover those allocated costs. Since there is variability in customer usage patterns within a given customer class, some customers will inevitably subsidize costs caused by other customers. With disaggregation data, however, rate designers can better understand which equipment types or behaviors are most responsible for cross subsidies or cause the greatest inefficiencies in cost recovery. Then they can design rates to remedy those issues. Two suggestions from survey participants included 1) using this information to either design rates that more robustly address all observed end-use patterns (e.g., three-part rates with customer and time-varying energy and demand charges), or 2) relying on end use-specific customer charges (e.g. fixed charges or minimum bills).

This idea is especially relevant to emerging technologies like PV, EVs, and battery storage. Gaining more insight into how these technologies will impact the cost of service and assessing whether rates efficiently recover those costs is becoming more important.[4] In many jurisdictions, PV adoption has reached levels where diverse stakeholders are asking for quantitative assessments of whether rates are equitably addressing these systems. Disaggregation data can facilitate those assessments. Additionally, one respondent noted that utilities are beginning to look at these same rate design issues to address widespread electrification of end uses like space and water heating. Ultimately, utilities will want to ensure that rates encourage technologies and behaviors that benefit the grid and ensure equitable cost recovery from those that do not.

Lastly, several rate experts mentioned that they look carefully at rate impacts on low-income customers. If low-income customers are moved onto time-varying rates, rate designers want to know how those customers will be affected. A useful application of disaggregation is better assessing how much flexibility low-income customers have to manage their loads and avoid consuming energy during high-priced time periods.

3.5 Customer Segmentation

The granularity of utility definitions of customer classes and sub-segments within customer classes varies, but a common goal is to identify groups of customers with similar characteristics regarding cost of service. As mentioned in the previous section, ensuring equity in rate design for customers within and across customer classes is a key objective of rate designers. If there are political or regulatory factors making it difficult to design more sophisticated rate structures to address inequities, another option is to segment customers into classes that better align with cost causation. Some of the utilities interviewed currently have rates specific to end-use loads like electric space and water heating. Experts mentioned that these rates tend to attract scrutiny from stakeholders, and that having AMI disaggregation data to quantify load impacts of these end uses across larger customer samples could strengthen the case for proposed charges.

[4]For an example of determining cost of service and bill impacts of emerging technologies under various rate structures, refer to the following citation:
Missouri Public Service Commission. *In the Matter of Union Electric Company d/b/a Ameren Missouri's Tariffs to Increase Its Revenues for Electric Service*. 3 July 2019. Case No. ER-2019-0335 (Direct Testimony of Steven M. Wills). https://www.efis.psc.mo.gov/mpsc/Docket.asp?caseno=ER-2019-0335

3.6 Additional Rate Design Use Cases

Two additional rate design use cases for disaggregation data emerged during the discussions, including:

Eliminating Secondary Meters

Some respondents saw an opportunity to eliminate separate metering of some end uses (e.g., electric space and water heating, EVs, and PV) and to rely on consumption estimates from AMI disaggregation. This could reduce metering costs associated with installation, maintenance, and data management.

Detecting Fraud

For rates specific to end uses that are not separately metered, some utilities rely on coarse billing indicators to detect whether qualifying loads are present. Respondents think detection and verification of qualifying loads can be improved using disaggregation insights. For rates that employ secondary metering of specific loads, utilities have found that some customers add non-qualifying loads to those metered circuits to take advantage of more favorable rates. Again, disaggregation data helps identify those non-qualifying loads and reduce customer fraud.

3.7 Barriers to Achieving AMI Disaggregation's Full Value to Rate Design & Impact Analysis

In addition to the cross-cutting challenges described in Sections 1.1.5 and 1.1.6, the interviews revealed additional barriers specific to the use of AMI disaggregation in ratemaking activities.

The most common barrier that respondents highlighted was institutional aversion to added complexity in rate design or classes. For some institutions, there is little appetite for creating multiple rates for different segments of traditional rate classes or for evaluating rate impacts and equity at an end-use level. This partly stems from a desire to minimize the effort and complexity of rate analysis, but it also appeared to be a result of the current lack of detailed data required to perform more advanced analyses.

Another barrier is time lag. For example, changes in segmentation and rate structure are generally phased in slowly to avoid bill instability and gain customer acceptance, so the benefits of more sophisticated rate design relying on AMI disaggregation must be viewed as a medium-term strategy.

For rates specific to certain loads, there is uncertainty about the political or practical feasibility of billing that relies on consumption estimates from AMI disaggregation. As such, separate metering might be the preferred alternative.

Lastly, much of the direct value stemming from better rate design goes to customers and not necessarily to the utilities. Even when improved rate design can save customers millions of dollars by correcting cost subsidies, there might not be a strong institutional incentive to make rate changes unless consumers are advocating for reform. That said, market research shows that improvements in customer satisfaction can create measurable financial benefits for utilities, so indirect effects of enhanced rate design can still be compelling to utilities.

4 Other Use Cases Identified

Several other interesting use cases emerged from the surveys that are not directly under the purview of DSM or rate design departments. These use cases are described below.

© 2019 Lumidyne Consulting LLC.

4.1 Load Forecasting

There is value in improving load forecasts with disaggregation insights since forecasts have many applications. Disaggregation can provide insight into the composition of end use loads, providing a foundation for forecasting. One respondent thought disaggregation could be useful for understanding how much energy efficiency is already included in the current load versus how much potential remains. When trended over time, equipment saturation insights can inform adoption forecasts for emerging technologies or common equipment with higher efficiencies. Additionally, AMI disaggregation can determine customers' load response to rates, permitting forecasters to extrapolate load impacts to customers predicted to enroll in different rates and include extrapolated impacts in the forecast.

4.2 Distribution Planning

Distribution planning activities can also benefit from AMI disaggregation. For example, knowing the location and the load impacts from PV and EVs can help with transformer and distribution system planning. As the need to perform hosting capacity analyses for distributed generation increases, disaggregation data can provide planners with information about which loads are prevalent on a circuit and whether those loads can be modified through utility programs to increase hosting capacity. One respondent speculated that these insights might be able to identify equipment known to have inductive loads for the purpose of estimating their impact on power factor. Another study participant succinctly noted that "if utilities understand their customers' loads and know where customers live, then they can optimize their grids."

4.3 Equipment Health Monitoring

Monitoring equipment health and alerting customers of issues is another potential application for disaggregation. Respondents suggested that this can enable revenue-generating services for the utility, whereby the utility is compensated for referring customers to vetted trade professionals. In parallel, the utility can leverage these customer touchpoints by informing customers about relevant utility programs.

5 Final Remarks

Changing market dynamics require that utilities gain a better understanding of their customers' loads and behavior. With greater insights into their customers, utilities can develop more effective DSM programs and price signals to balance increasingly variable sources of electricity supply and demand. The next evolution in DSM and ratemaking strategy will be to cultivate a system of flexible loads and optimized customer behavior with the benefits shared among utilities and customers. By surveying utility experts, this study identified opportunities for AMI disaggregation to play a role in that evolution. Information provided by survey respondents suggests that the most promising use cases for AMI disaggregation include the following applications:

- **Load impact assessment** – quantifying load impacts of technologies, behaviors and end-use loads to assess opportunities for DSM savings, impacts on cost of service, and contribution to customer bills.
- **Customer targeting** – identifying customers most likely to contribute to the goals of utility programs or rate initiatives and maximally benefit from engagement.
- **Providing customers with personalized and actionable information** – empowering customers with knowledge about their energy use and providing recommendations to take beneficial actions.

These use cases are relevant to both DSM and ratemaking activities, along with other core utility functions. When combined, these applications provide three key ingredients for creating a future system of flexible loads and optimized behavior that serve as grid resources.

© 2019 Lumidyne Consulting LLC.

Utilities and other stakeholders can approach AMI disaggregation with prudence, while the industry gains familiarity and acceptance of disaggregation methods and use cases. To build stakeholder confidence, AMI disaggregation can be explored through proofs of concept. Utilities and implementers can incrementally test the merits of disaggregation analytics by defining specific use cases where successful application of disaggregation insights generates a clear value proposition in the near term and has a high reward-to-risk ratio. Upon completing each proof of concept, analysts can assess results, address limitations, share lessons learned, and scale as appropriate. In short, taking small steps, demonstrating AMI disaggregation's delivered value, and gradually evaluating more use cases can best serve stakeholder interests and build industry confidence.

Inevitably, growth in industry experience will help establish best practices and prescribe validation tests. For example, groups in California have made steps toward identifying best practices and establishing protocols related to normalized metered energy consumption (NMEC) when using whole-premise AMI data in energy efficiency evaluation. Similar collaborations and protocols can be applied to AMI disaggregation methods across its many DSM and ratemaking use cases.[5,6]

To conclude, the utility experts interviewed during this research indicated that AMI disaggregation can support high-value use cases in DSM and rate design and impact analysis activities. Through case studies and pilot programs, the industry can further explore the opportunities and challenges of each of these use cases and determine how to most effectively take advantage of the broad range of AMI disaggregation insights.

[5] For an overview of the California Public Utility Commission's Normalized Metered Energy Consumption Working Group, see https://www.cpuc.ca.gov/General.aspx?id=6442461286.
[6] Southern California Edison has established a "Normalized Metered Energy Consumption Savings Procedure Manual," which can be accessed at:
https://www.etcc-ca.com/reports/normalized-metered-energy-consumption-savings-procedures-manual#

© 2019 Lumidyne Consulting LLC.