

# AMI-Based Load Research— KIUC Demonstration

*Confirming the Value of AMI*

FINAL REPORT | MAY 31, 2014



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## **The National Rural Electric Cooperative Association**

NRECA is the national service organization for more than 900 not-for-profit rural electric cooperatives and public power districts providing retail electric service to more than 42 million consumers in 47 states and whose retail sales account for approximately 12 percent of total electricity sales in the United States.

NRECA's members include consumer-owned local distribution systems — the vast majority — and 66 generation and transmission (G&T) cooperatives that supply wholesale power to their distribution cooperative owner-members. Distribution and G&T cooperatives share an obligation to serve their members by providing safe, reliable and affordable electric service.

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NRECA's Cooperative Research Network™ (CRN) manages an extensive network of organizations and partners in order to conduct collaborative research for electric cooperatives. CRN is a catalyst for innovative and practical technology solutions for emerging industry issues by leading and facilitating collaborative research with co-ops, industry, universities, labs, and federal agencies.

CRN fosters and communicates technical advances and business improvements to help electric cooperatives control costs, increase productivity, and enhance service to their consumer-members. CRN products, services and technology surveillance address strategic issues in the areas:

- Cyber Security
- Consumer Energy Solutions
- Generation & Environment
- Grid Analytics
- Next Generation Networks
- Renewables
- Resiliency
- Smart Grid

CRN research is directed by member advisors drawn from the more than 900 private, not-for-profit, consumer-owned cooperatives who are members of NRECA.

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## FOREWORD

The National Rural Electric Cooperative Association (NRECA) has organized the NRECA-U.S. Department of Energy (DOE) Smart Grid Demonstration Project (DE-OE0000222) to install and study a broad range of advanced Smart Grid technologies in a demonstration that involved 23 electric cooperatives in 12 states. For purposes of evaluation, the technologies deployed have been classified into three major sub-classes, each consisting of four technology types.

Enabling Technologies:	Advanced Metering Infrastructure Meter Data Management Systems Telecommunications Supervisory Control and Data Acquisition
Demand Response:	In-Home Displays & Web Portals Demand Response Over AMI Prepaid Metering Interactive Thermal Storage
Distribution Automation:	Renewables Integration Smart Feeder Switching Advanced Volt/VAR Control Conservation Voltage Reduction

To demonstrate the value of implementing the Smart Grid, NRECA has prepared a series of single-topic studies to evaluate the merits of project activities. The study designs have been developed jointly by NRECA and DOE. This document is the final report on one of those topics.

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## AMI-Based Load Research – KIUC Demonstration

### 1. INTRODUCTION

The Kauai Island Utility Cooperative (KIUC) has begun a first-ever formal Load Research Study for the cooperative’s electric system, using the newly installed Advanced Metering Infrastructure (AMI) system developed in association with the National Rural Electric Cooperative Association (NRECA) under the Smart Grid Demonstration Project. The Load Research Study is being undertaken for engineering and regulatory purposes, and will form the basis for certain rate studies expected to be filed with the Hawaii Public Utilities Commission in the near future. The value of an AMI system in providing robust statistical information on electric loads with a high degree of confidence is being demonstrated through this formal load research program, now underway. This report describes the development of the AMI system, the background for load research activities, the sense of accomplishment from the use of the system, and the expectations for accomplishing a robust evaluation of system load characteristics.

### 2. THE AMI-BASED LOAD RESEARCH PROGRAM

#### 2.1 Research Objectives

The advent of AMI has been expected to provide a vastly improved foundation for electric utility system load research. The NRECA Smart Grid Demonstration Project included installation of advanced metering at the vast majority of the traditionally metered locations throughout the KIUC service territory. This installation was especially timely from the standpoint of providing an advantageous platform for demonstrating the value of AMI in completing a load research study.<sup>1</sup>

Until such time as the AMI system was installed, for rates and tariff development, KIUC had relied on sample data from comparable utilities or limited information from uniquely placed monitoring equipment. The Hawaii Public Utilities Commission (HPUC), particularly at the urging of the Hawaii Division of Consumer Advocacy<sup>2</sup> (Consumer Advocate) during the last KIUC rate case, has recommended that KIUC undertake a utility system-specific load research study. That study was intended to provide detailed information on electric usage characteristics among and within KIUC’s consumer classes of service—Residential, Small and Large Commercial, and Industrial. Estimates at the time indicated that such a load research study, using traditional sampling and individually installed meters, would require hundreds of thousands of dollars to complete. In addition, updating research results would require similar levels of effort.

The AMI system installed at KIUC was identified as an efficient and effective means, among the many other potential uses of AMI information, of accomplishing a load research program in a cost-effective manner. Using AMI-installed equipment for data gathering and analysis provides for ready availability of requisite sample information, data accumulation, and analysis using already installed equipment, and load research statistics that can be updated easily. The

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<sup>1</sup> Over the study period, approximately 10% of KIUC’s residential customers had opted not to accept installation of a smart meter. The level of “opt-out,” however, was not considered significant in relation to the sample size, nor in limiting the usefulness of smart meters for conducting load research. Additionally, certain large power customers retained traditional meters as a result of totalizing metering applications.

<sup>2</sup> The Division of Consumer Advocacy is a division within the State Department of Commerce and Consumer Affairs.

information provided can be of such detail as to fully satisfy regulatory requirements and plan for and monitor the impacts of alternative rate structures on consumer behavior response.

## **2.2 Project Characteristics**

The AMI installation was undertaken at KIUC for a variety of reasons. These included providing the following: (1) remote monitoring for reduced meter reading expenses; (2) engineering data for feeder load analysis; (3) consumer energy use characteristics associated with on-site solar hot water heating and photovoltaic (PV) installations; (4) limiting cycle billing adjustments from staggered meter reads; (5) remote cutoff and reconnection; (6) monitoring of load control impacts; and (7) routinely detailed demand and energy use statistics of individual load centers and aggregate loads. The AMI installation project included a radio transmission system for communications between the utility and the metering equipment, and installation of data collection software that would adequately provide for initiation of signals out from the cooperative and data transmission back from the individual metering points.

Once the installation was nearly complete, KIUC began the specific load research study using the AMI system. A contract was prepared for Leidos Engineering (Leidos was then a part of SAIC) to help set up the study, provide expertise in sample design and selection, and perform the necessary data analysis. NRECA was involved early in the contracting process, supporting the use of the AMI system in that fashion and coordinating with Leidos on the information gathered and application of the results.

## **2.3 Development and Implementation**

Leidos designed the KIUC load research program, which included consideration of sharing information on the undertaking with NRECA by supplying periodic information during the year-long research. Leidos' efforts have included collecting preliminary load data from KIUC from which to evaluate the level of detail required within existing consumer classes to form statistically relevant programmatic data collection.

The load research program directed by Leidos was initiated in early summer 2013 with the anticipation of data collection through a complete one-year cycle. As the study progressed, it was determined that load research results would be developed across rate classes for calendar year 2013. As of late May 2014, the data collection was complete, and work was underway to finalize the analysis and prepare a final report.

## **2.4 Evaluation Criteria – Effectiveness**

KIUC has demonstrated the effectiveness of using AMI for the load research program, in that the vast reach of a broad-based installation across a significant portion of the entire consumer base provides for essentially unlimited data sources. The primary limitation to use of the aggregate data is the sheer volume of information available, such that slightly different sampling techniques are required compared to traditional methods. The advantages are clear, in that all meters are available and random tests can be performed to validate the sample selection by identifying variances and deviations. A comparison to the difficulties experienced through load research using traditional sampling and metering approaches shows, in stark relief, the advantages of AMI. Information on unique sites that reflects implementation of distributed generation sources and load management programs from readily accessible AMI data provides additional benefits in rate setting for special incentive programs, as well as traditional cost-of-service studies.

## 2.5 Regulatory Acceptance and Justification

KIUC is now able to provide evidence of the load characteristics of a variety of consumers throughout the system, fully responding to the regulatory request for utility-specific load research. No longer will proxy data be required, nor will significantly disruptive and expensive research programs be required for rate structure updates or revisions to cost-of-service allocations. Questions as to the efficacy of incentive programs can be accomplished routinely by aggregating data from those locations at which programs were applied and via continuous monitoring of consumer response.

As the load research program at KIUC was initiated in 2013 and is continuing, the final results will not be available until mid-2014. As a result, the regulatory acceptance of the load research findings may be addressed in more detail following Consumer Advocate and HPUC staff review of the load research program and results at KIUC.

## 3. THEORETICAL BASIS OF LOAD RESEARCH

### 3.1 Value and Applications of Load Research

“Load Research” has been defined as “(a)n activity embracing the measurement and study of the characteristics of electric loads to provide a thorough and reliable knowledge of trends, and general behavior of the load characteristics of the customers serviced by the electrical industry. Simply put, Load Research allows utilities to study the ways their customers use electricity, either in total or by individual end uses.”<sup>3</sup> The information obtained through load research provides the knowledge of electric use patterns and characteristics that the electric utility requires to effectively meet the service requirements that provide consumer and utility value.

A number of functional areas of the electric utility operation depend on this knowledge and load research results to perform effectively. These include the following:

- ◆ Generation – Net system output analysis, production cost and system model development, capacity planning, and load duration curves;
- ◆ Electric Choice – Load profiling, forecasting, settlement accounting, program and project evaluation;
- ◆ Distribution – Substation load analysis, transformer sizing, circuit load studies, load management, and loss studies;
- ◆ Marketing – Individual customer analysis, customer class analysis, on-peak demand, load studies, demographic studies, and major account demand analysis;
- ◆ Rates and Pricing – 8,760 class demand studies, billing determinants, allocation schedules, sample design and management, class and system peak analysis, and major account demand analysis; and
- ◆ Other – Demand-side management, weather normalization, and product development.

The Load Research Committee of the Association of Electric Illuminating Companies (AEIC) identifies the value proposition of AMI in the categories and activities shown in **Table 1**.<sup>4</sup>

<sup>3</sup> AEIC. “*Why Electric Utilities Need Load Research*,” a Load Research Primer for Electric Utility Leaders.

<sup>4</sup> AEIC. *Load Research Value Calculation*. January 9, 2007.

Table 1. Value of AMI

Category	Activity
System Analysis and Rates – Electric	<ul style="list-style-type: none"> <li>◆ Main rate case</li> <li>◆ Real-time pricing (design and implementation)</li> </ul>
System Analysis and Rates – Gas	<ul style="list-style-type: none"> <li>◆ Main rate case</li> </ul>
Electric Choice/Deregulation	<ul style="list-style-type: none"> <li>◆ Load profiles</li> <li>◆ Energy procurement for basic service</li> <li>◆ Hourly energy market price calculations</li> </ul>
Load Management	<ul style="list-style-type: none"> <li>◆ Transformer study</li> <li>◆ Load response programs</li> </ul>
Data Warehousing/Data Access	<ul style="list-style-type: none"> <li>◆ Meter data management</li> <li>◆ Interval data distribution (for fee)</li> </ul>
Forecasting	<ul style="list-style-type: none"> <li>◆ Air conditioning</li> <li>◆ Residential and Commercial</li> </ul>
New Technology	<ul style="list-style-type: none"> <li>◆ New meter testing and support</li> </ul>
Intellectual Capital	<ul style="list-style-type: none"> <li>◆ Subject matter expertise</li> <li>◆ Consulting</li> </ul>
Settlement	<ul style="list-style-type: none"> <li>◆ Shadow settlements</li> <li>◆ Estimate peak contributions for ISO-installed capacity markets</li> <li>◆ Estimate hourly loads for ISO energy markets</li> </ul>
Market Research Support	<ul style="list-style-type: none"> <li>◆ End-use analysis</li> <li>◆ Conditional demand analysis</li> <li>◆ Rate evaluation</li> <li>◆ Sales analysis (unbilled revenue)</li> <li>◆ Ad hoc data request</li> </ul>
Customer Service Support	<ul style="list-style-type: none"> <li>◆ Billing determinants</li> <li>◆ Reporting and analysis of customers' interval data</li> <li>◆ Revenue protection investigations</li> </ul>
Asset Management/Optimization/Acquisition	<ul style="list-style-type: none"> <li>◆ Generation</li> <li>◆ Transmission</li> <li>◆ Distribution</li> </ul>

Through its various categories, activities, and applications of the knowledge obtained, load research contributes value to the utility, both strategically and financially. This value can be identified by the contribution of load research information to the financial parameters associated with system operations and revenue collection. The value is the portion of a measurable event that either increases revenue or produces real savings. This being the case, the continuity of the load research information is important, and gaps in knowledge, or failure to recognize changes in usage characteristics, can lead to failures in recognizing impending or actual losses of the savings or revenues.

### 3.2 Load Research Approach

A wide range of source data is available on the fundamentals of load research using “Smart Grid” technologies. This is now well known throughout the industry, and includes extensive work by the Electric Power Research Institute (EPRI) and others, such as AEIC’s National Load Research Committee. For example, AEIC has provided a primer on why load research is important for electric utilities, and EPRI conducted a workshop in October 2010 for its members

to identify how “...broad application of Smart Grid or AMI could both increase the need for and reduce the cost of acquiring high-quality load research data.”<sup>5</sup> The concern at that time was that much of the load shapes that the industry had developed in years past and remained in use were perhaps no longer accurate representations of system characteristics. The cost of collecting data at the end-use level was considered quite expensive, due to special metering requirements.

The abstract of the EPRI workshop proceedings described a situation in which utilities and operating organizations sought better load shape information, and the deployment of smart meters presented both opportunities and challenges—the opportunity being the ability to capture system-wide load shape information without the need for the special metering. However, the widespread coverage of smart metering and the immense amount of data available required “rigorous” data collection and sampling procedures to obtain the requisite and relevant information at the “required levels of precision.” Also, while smart meters provided premises-level data, additional research was needed to clarify whether the metering could be used to identify the impact on load shapes of new technologies, response to dynamic pricing, information feedback, and demand response programs.

### **3.3 Historical Methods of Load Research**

Electric utilities have been conducting load research almost since the inception of the electric system through monitoring or recording of metered delivery by using strip chart recordings of voltage and current for motor loads and other devices. The so-called “modern era” of load research began with the introduction of demand recorders that used magnetic tape cartridges to record data pulses from a special meter that replaced the normal billing meter. The cartridges were collected and downloaded to mini-computers that translated the pulse data into time-series interval measurements of power. Similar systems were used for demand recording of Large Commercial and Industrial loads. Later evolution of the systems provided for devices that delivered load data via telephonic systems, hand-held recorders (the “automated meter reading” or AMR), radio, and power line carrier signals over the distribution network. These later systems provided greater capability than demand and energy recorders, and subsequent systems have expanded upon those capabilities, ultimately to provide “two-way” communications for delivery and receipt of information.

## **4. ENABLING TECHNOLOGY OF AMI-BASED LOAD RESEARCH**

### **4.1 The KIUC AMI System**

KIUC initially started looking at an AMI system in 2008 and, with the assistance of Power Systems Engineering, developed a business case for the implementation of an AMI. Once the business case was presented and accepted, KIUC enlisted the assistance of Katama Technologies to develop a Request for Proposal (RFP) to determine the requirements and selection criteria for an AMI system. In 2009, KIUC selected the Landis+Gyr (L&G) Gridstream® system, based on a radio frequency (RF) mesh network, and was ready to proceed with implementation when federal stimulus funding became available. An RFP meeting the requirements for stimulus funding was prepared in 2011 with the assistance of the NRECA National Consulting Group and was supplied to vendors.

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<sup>5</sup> *End-Use Load Research in a Smart Grid World*. EPRI Abstract. September 23, 2010.

## 4.2 AMI Selection Criteria of KIUC

KIUC and its consultants conducted a very rigorous proposal evaluation of the vendor offerings. **Table 2** reflects the range of considerations used in evaluating the offerings; this resulted in the selection of an L&G system.

**Table 2. KIUC Vendor Evaluation – Technical Specifications**

Section	Technical Specification Requirement	Weight
6	General System Requirements	40
7	AMI Server Hardware and Software	40
8	Load Control Hardware and Software Requirements	10
9	WAN/Backhaul Communications	5
10	Fixed Network LAN Communications	20
11	Residential Electric Meters	20
12	Commercial and Industrial (C/I) Electric Meters	20
13	Load Management Hardware	10
14	Electric Grid Management Applications	15
15	System Administration and Security	20
16	Documentation	5
17	Quality Assurance, Testing, and System Acceptance	10
18	Vendor Support and Training	15
19	Implementation Roles and Requirements	5

The initial system implementation plan included seven collectors, 106 standard routers, and 29,630 electric meters; equipment installations were chosen strategically per design, so that the system implementation would not disrupt KIUC’s normal operating procedures. The functionality included capability for in-home displays, home area networks, dynamic pricing, and selective load control.

## 4.3 Installation and Operation Issues and Actions

Overall, KIUC has been very pleased with the decision to go with L&G for its AMI metering system (**Figure 1**). While it did encounter “bumps in the road” throughout the installation process, L&G and its deployment contractor were very prompt and competent in addressing the issues. The equipment is working as expected, and KIUC is excited to be the leader in the state of Hawaii in smart meter deployment. KIUC also is working on the rollout of a web portal to provide members with detailed usage from their smart meters.

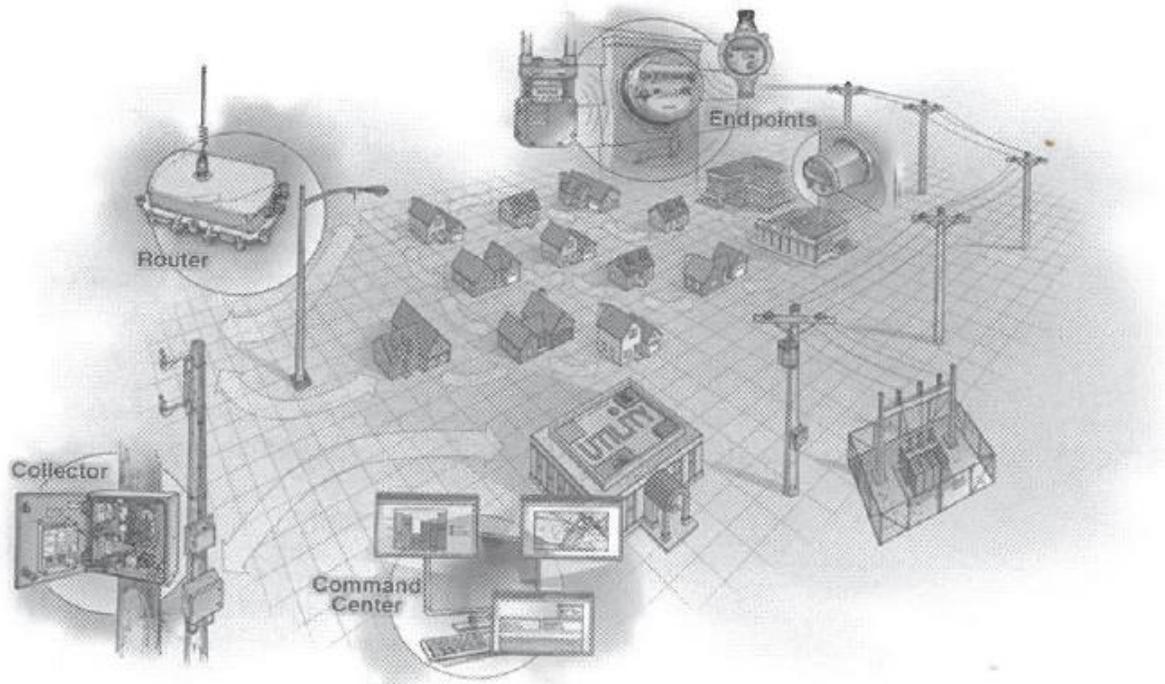


Figure 1. Landis+Gyr RF Mesh Network

## 5. AMI-BASED LOAD RESEARCH PROGRAM NOW UNDERWAY AT KIUC

The sequence of events for development of the load research study by Leidos is straightforward:

Sample Design and Selection → Meter Data Acquisition → Data Analysis → Reporting

Implementation of the AMI and the prevalence of the pre-existing interval metering simplified the process of sample selection, but only somewhat, in that a representative sample was still necessary for class load estimates. The ability to increase sample sizes cost effectively, both to achieve greater precision and allow for sub-sampling, was a key benefit of the AMI metering. For example, given the large variability of loads in the Large Commercial and Large Power classes, and their size relative to the other classes, the team decided simply to sample all customers in these classes (i.e., achieving what is commonly referred to as a “census” for these classes).

The load research is proceeding in steps, which include the following:

- ◆ Selecting sample consumers that are sufficiently representative to ensure precision of class load estimates;
- ◆ Capturing hourly or sub-hourly sample loads;
- ◆ Validation of the data collected;
- ◆ Reporting the class loads and load detail; and
- ◆ Supporting downstream analysis with the load information.

A sample design was prepared with the goal of maximizing precision with the sample size constraints that made use of data from a specified time period of metered data. Stratified

sampling segmented the consumers into homogenous groups to improve precision, using one of the more common stratification variables—billed energy. The strata boundaries then were determined by statistical methods and samples allocated across the strata, followed by simple random sampling within the strata to capture sufficiently large sub-samples. The sample selection was determined using load data from January 2012. AMI-based load data from March 2013 then were received and processed.

The validation step is fundamentally a review of the recorded data for erroneous and/or missing values, which may be replaced with estimates in some instances. If certain samples are suspicious or unexplained, they may be replaced by samples of higher confidence.

Class load estimation is derived from the weighted mean across the strata of the hourly loads, followed by determination of class peak loads and identification of class loads during the system peak hour. Sample billing data obtained through July 2013 proved useful for “expansion” to full class representation, and system peak information was made available to Leidos for determination of system peak timing and benchmarking to ensure the representativeness of the load estimates.

The load research plan initially contemplated a November 1, 2012 to October 31, 2013 test-year period. However, the test-year period subsequently was moved to the 2013 calendar year. The data gathered in the study will be used to produce estimated class loads, including coincident and non-coincident class peak loads and load profiles. In addition, a series of benchmarking analyses are being performed to ascertain the reasonableness of the resulting class loads as compared to known system-level load data and class billing determinants.

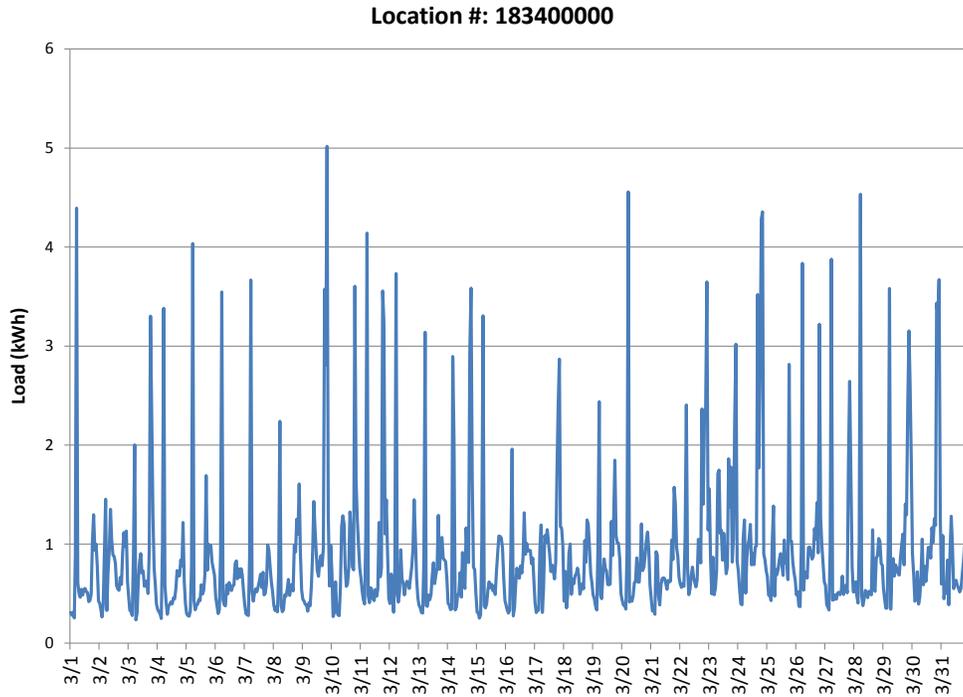
A complete year of load research data has been collected, and Leidos will be revising the data sets and calculations developed over the course of the year and making necessary adjustments based on subsequent decisions with respect to stratification, sampling, or other issues.

### **5.1 Initial Findings of the Load Research Study, as Reported in November 2013**

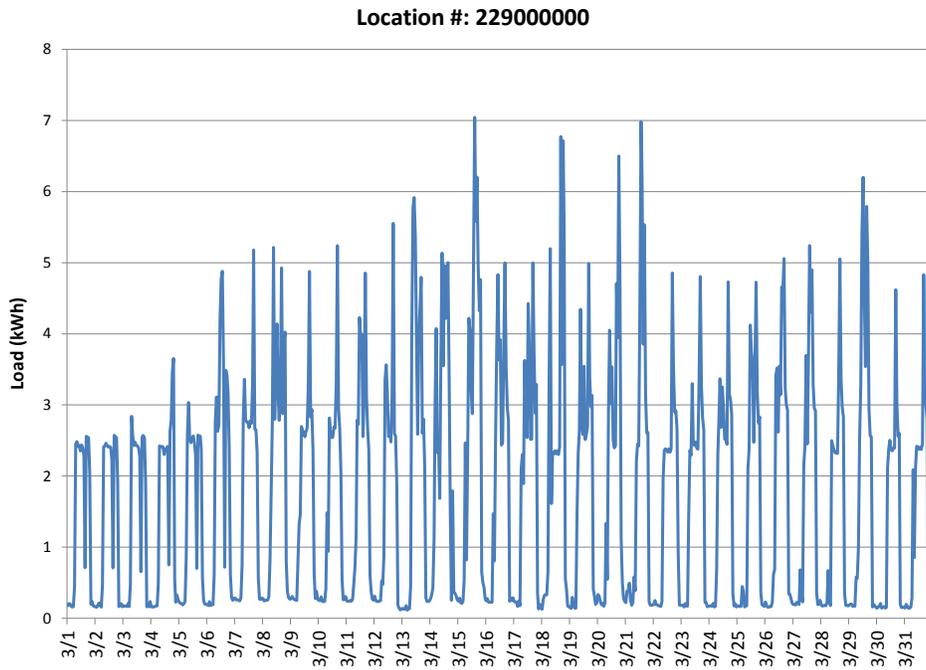
The initial findings, based on the March 2013 load data, reflected some typical load behaviors, including volatile intra-day loads, a high variance across the months, and numerous meters with zero usage in early March. Some examples of residential meter profiles are shown in **Figures 2-4.**<sup>6</sup>

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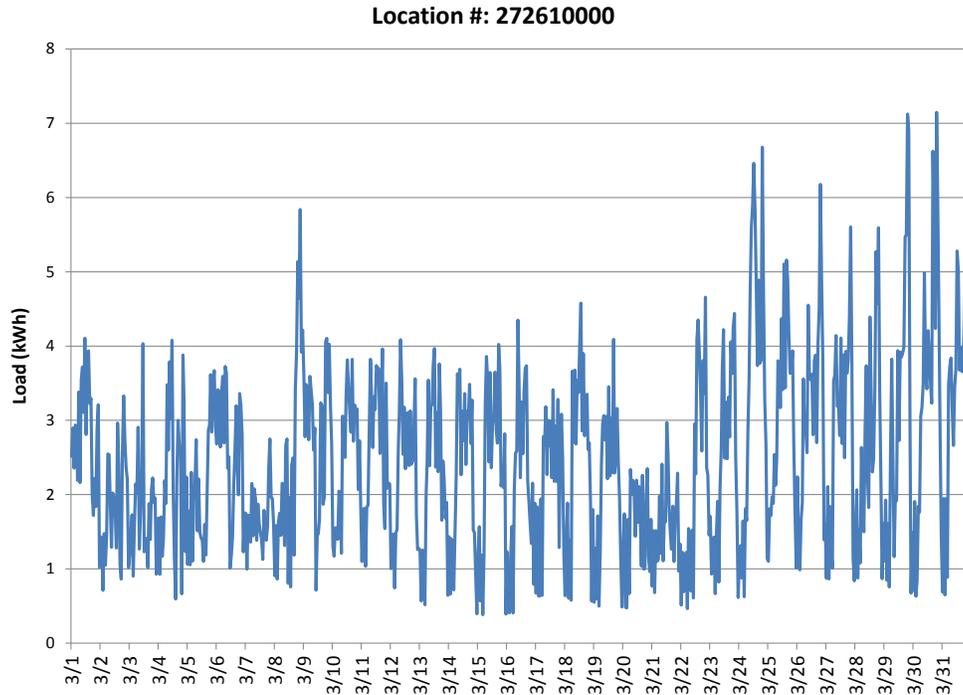
<sup>6</sup> In the examples, the Y-axis is marked as kWh; however, as the data are given on an hourly basis, the data are kWh/hr, or simply kilowatts.



**Figure 2. Residential Meter Profile – Example 1**

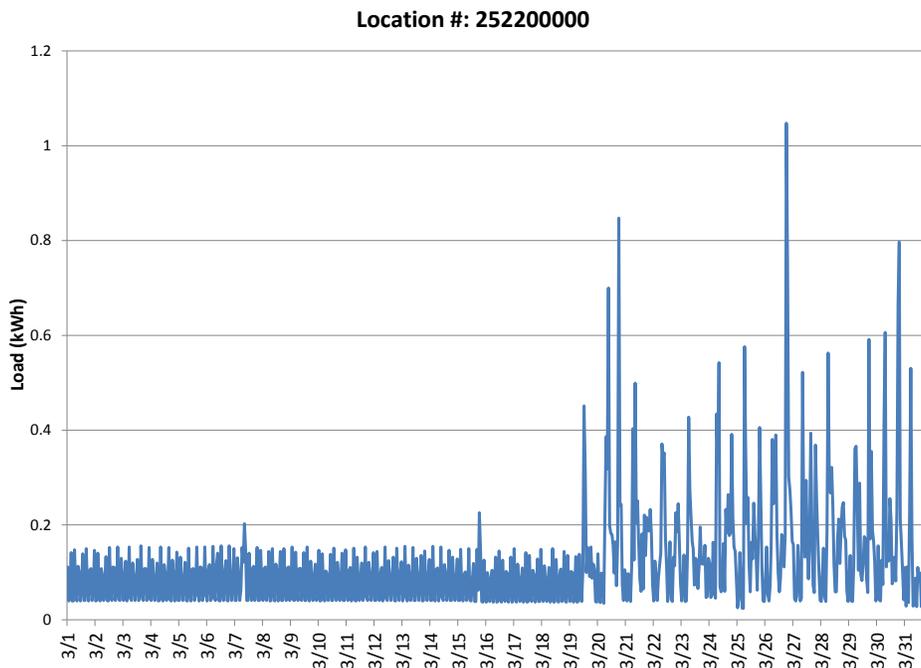


**Figure 3. Residential Meter Profile – Example 2**



**Figure 4. Residential Meter Profile – Example 3**

In a few cases, unusual residential load patterns were observed, such as periodic low loads, periodic spikes, and periodic zero loads. However, these were largely observed to be functions of typical vacation home occupancy patterns, responses to weather conditions, and other explainable events and conditions (**Figures 5–7**).



**Figure 5. Residential Meter Profile – Example 4 (Periodic Low Loads)**

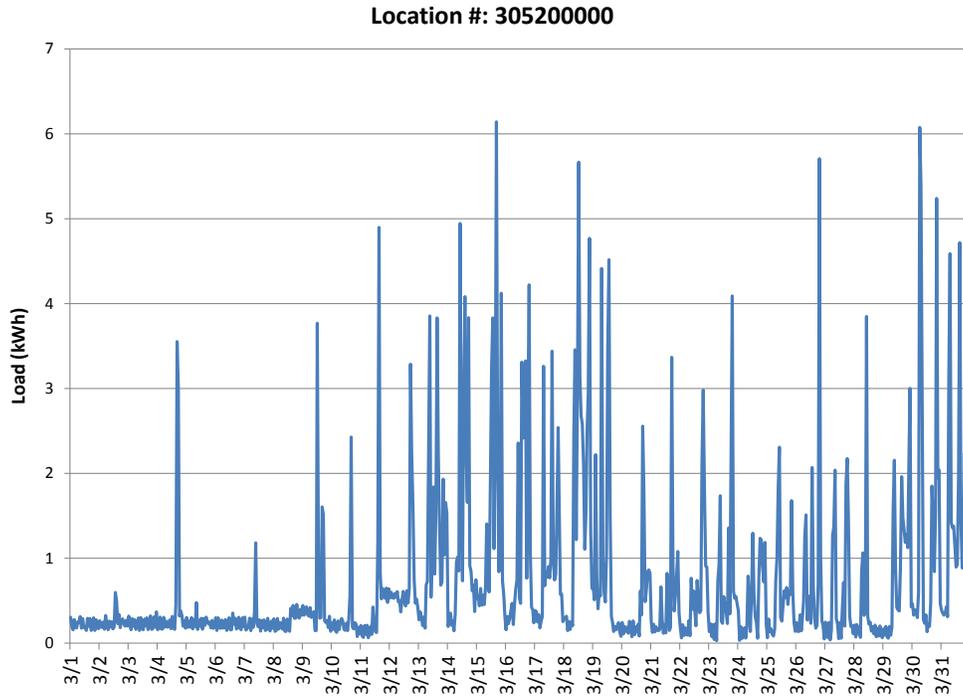


Figure 6. Residential Meter Profile – Example 5 (Periodic Low Loads)

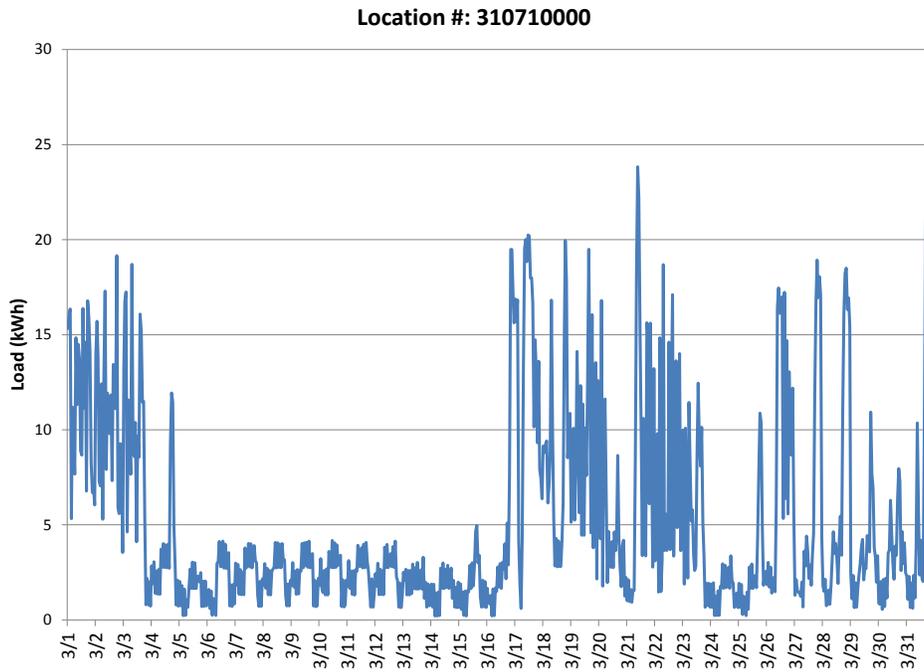


Figure 7. Residential Meter Profile – Example 6 (Periodic Low Loads)

Similar patterns emerged from the Small Commercial data set, with typical profiles and occasional periodic low loads (**Figures 8 and 9**).

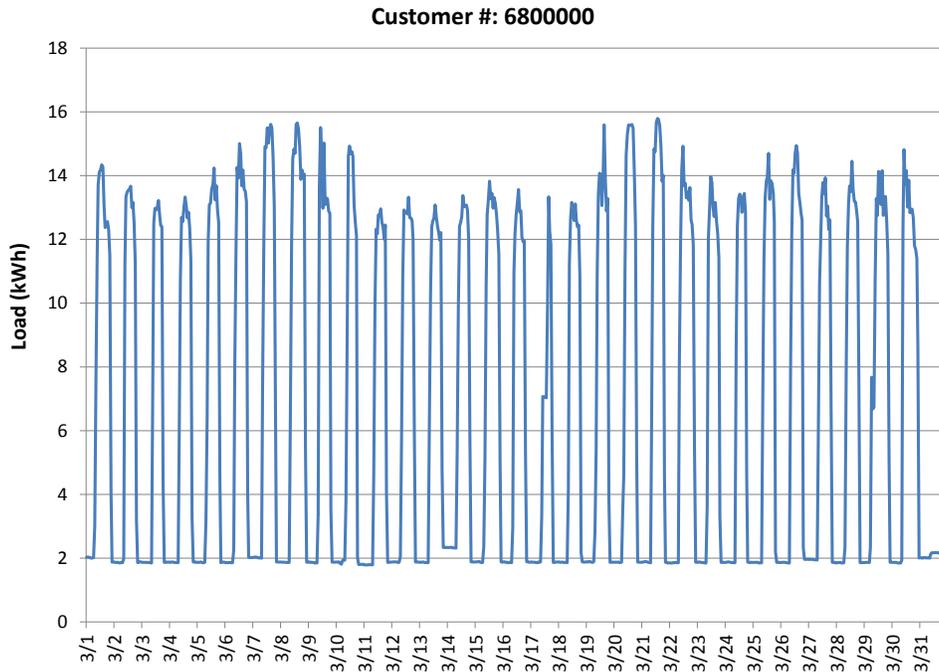


Figure 8. Small Commercial Meter Profile – Example 1

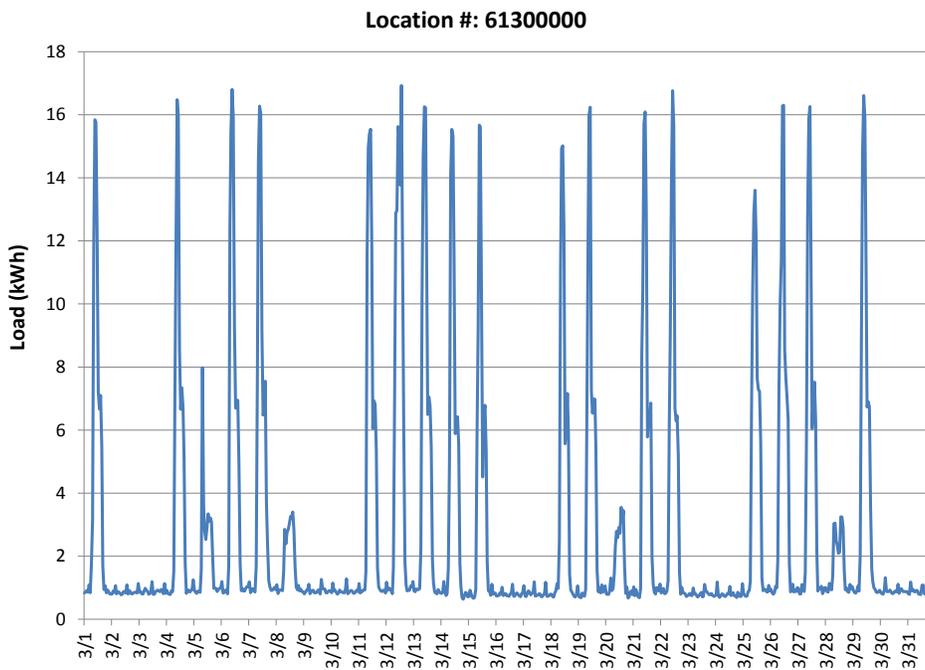
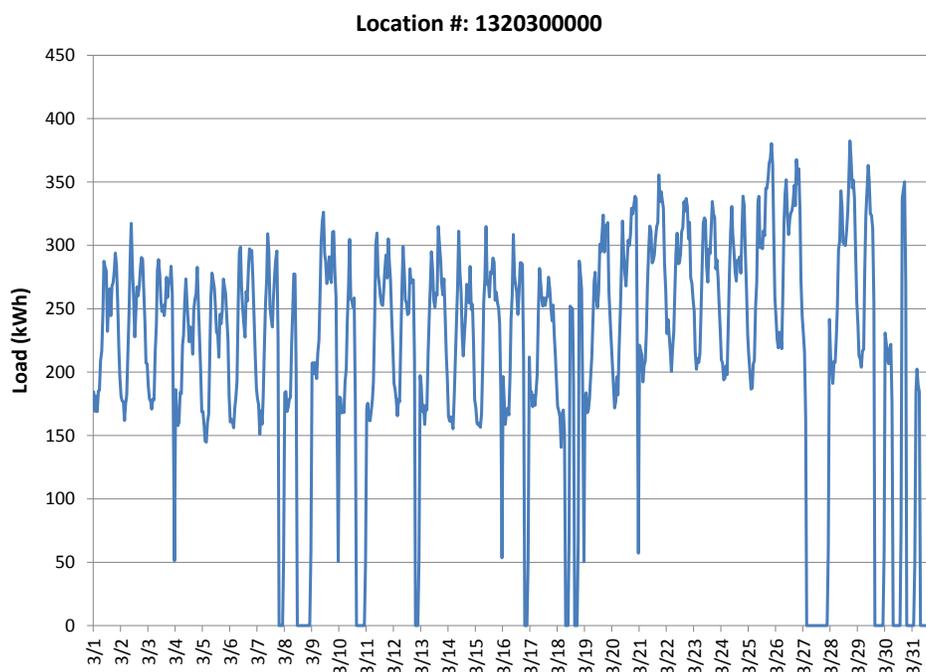


Figure 9. Small Commercial Meter Profile – Example 2

With Large Power, for which all metered consumers were expected to be included in the data set, an example of a periodic zero load reading was identified, calling for further investigation (**Figure 10**).



**Figure 10. Large Power Meter Profile Example**

## 5.2 Conclusions Drawn from the Initial Sampling and Selection

The conclusions drawn from the initial AMI-based data set are that the data appear remarkably clean and generally error free. Most locations follow sensible patterns, with typical weather variability and day-type patterns (especially the non-residential classes). Some locations reflect unusual operations, such as periodically unoccupied rental or condominium housing, intermittently higher-demand appliances or other end uses, and commercial facilities with odd hours.

The availability of data from the AMI system across nearly all consumers provides the opportunity to sample and identify anomalies—patterns that may not be recognized easily by traditional sampling and recording systems. Deriving sample data from an AMI system has allowed for larger samples than otherwise could be achieved cost-effectively and the ability to more easily identify and exclude samples containing invalid data without sacrificing precision.

Aside from a few minor clean-up issues, the estimated class loads are expected to be representative and reasonable. From the information available to date, the system load profiles for March 2013 are shown in **Figures 11–15** (excluding, in the case of the System Load Profile, certain non-metered loads and losses).

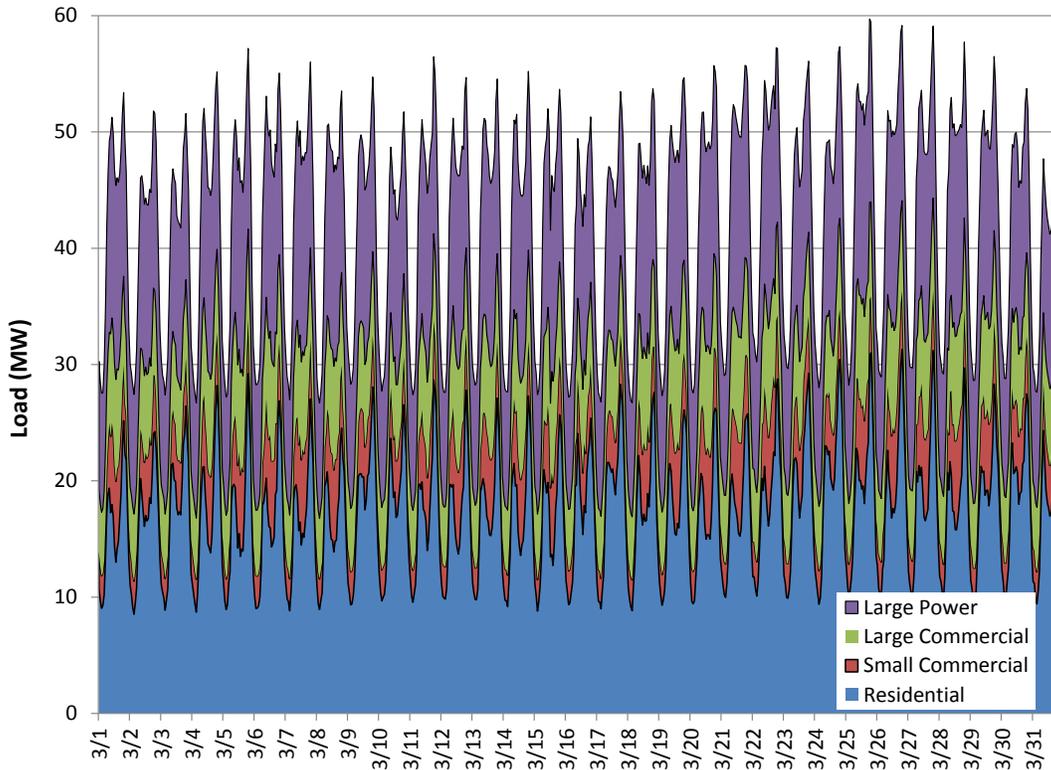


Figure 11. Partial System Load Profile – March 2013

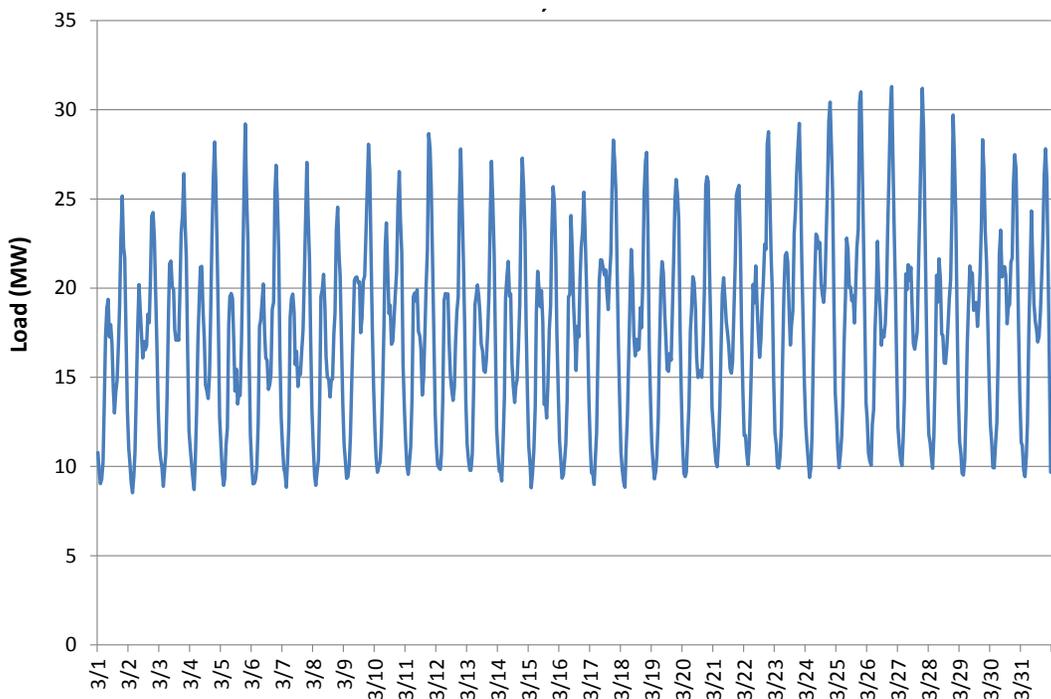


Figure 12. Residential Load Profile – March 2013

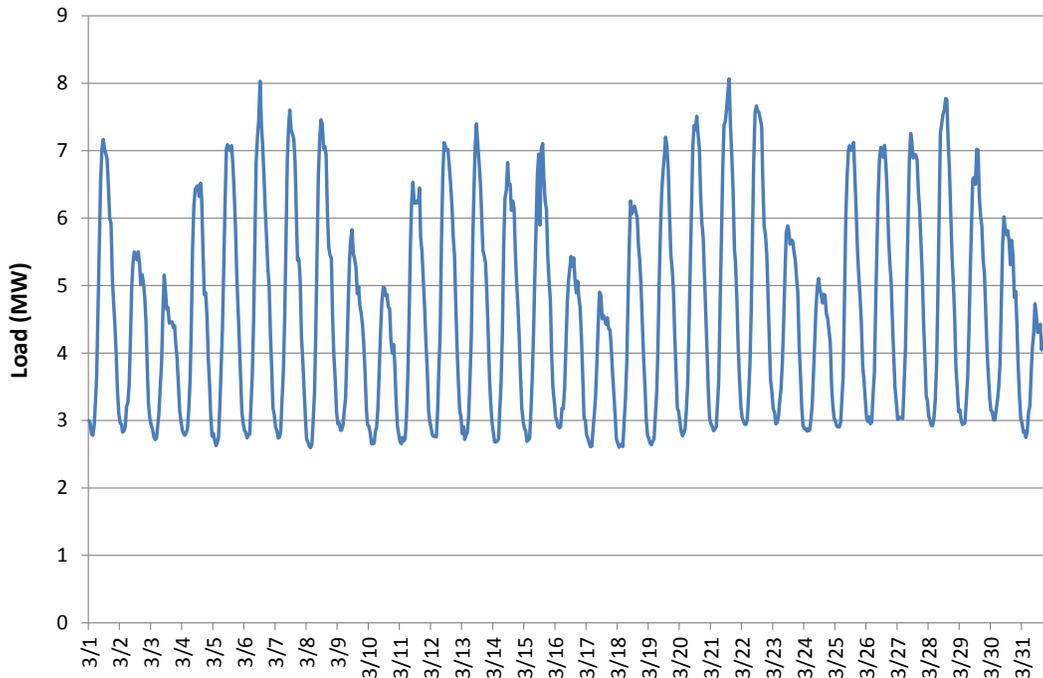


Figure 13. Small Commercial Load Profile – March 2013

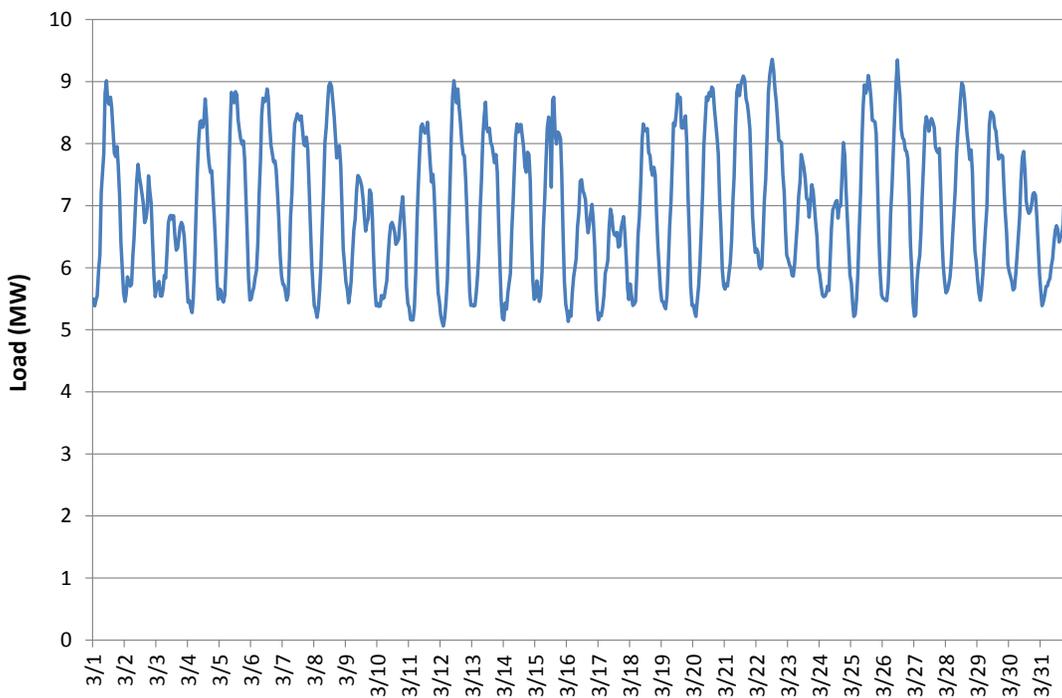
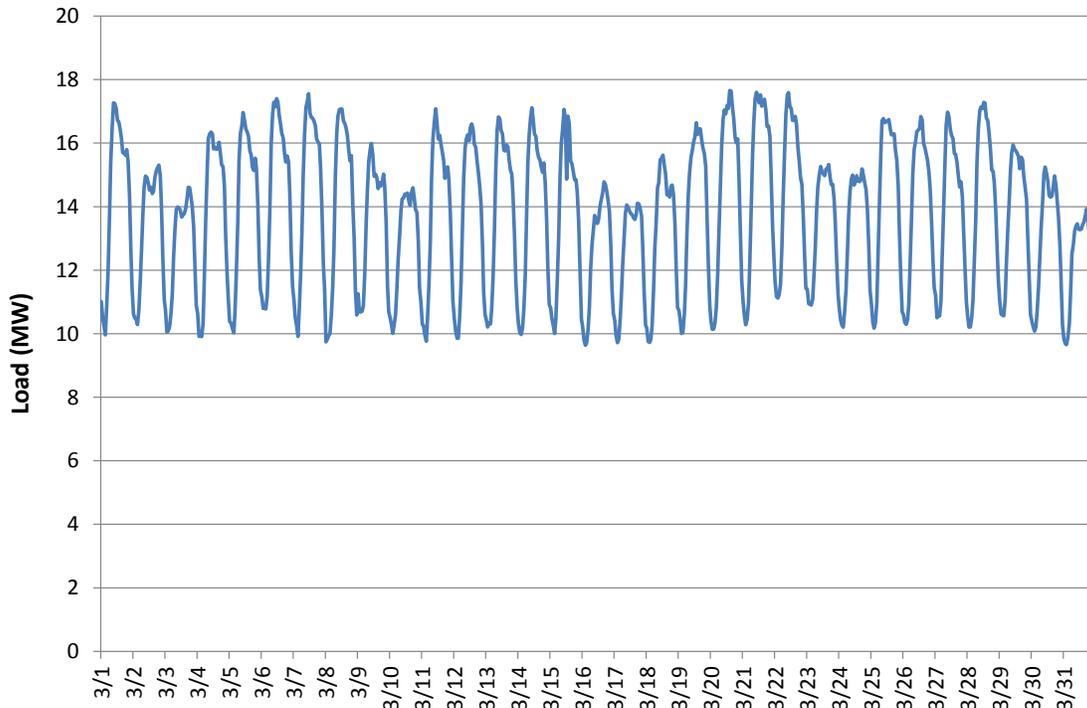
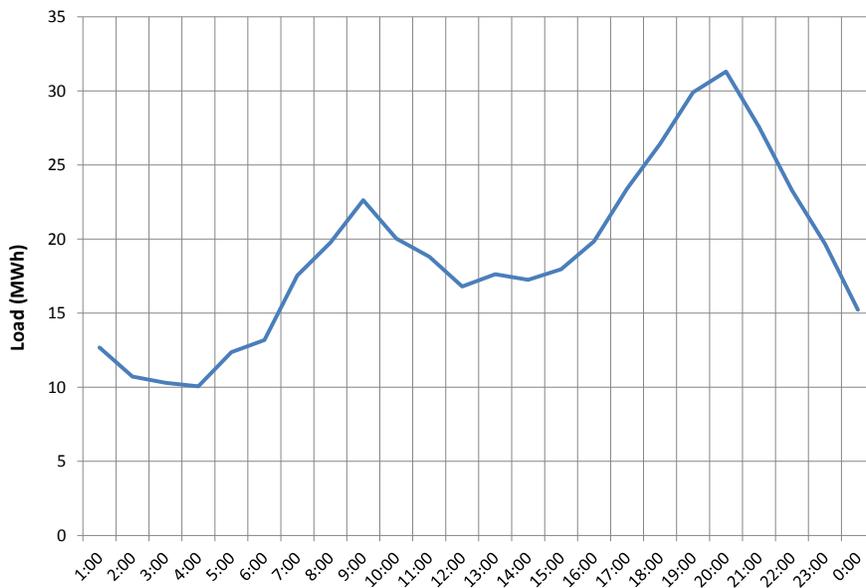


Figure 14. Large Commercial Load Profile – March 2013



**Figure 15. Large Power Load Profile – March 2013**

Figures 16–19 depict the estimated load profiles of the Residential, Small Commercial, Large Commercial, and Large Power classes on the system peak day, illustrating the differences in contribution to the system peak relative to the class loads in question, which is of significant interest in cost-of-service calculations.



**Figure 16. System Peak Day Load Profile – Residential (March 2013)**

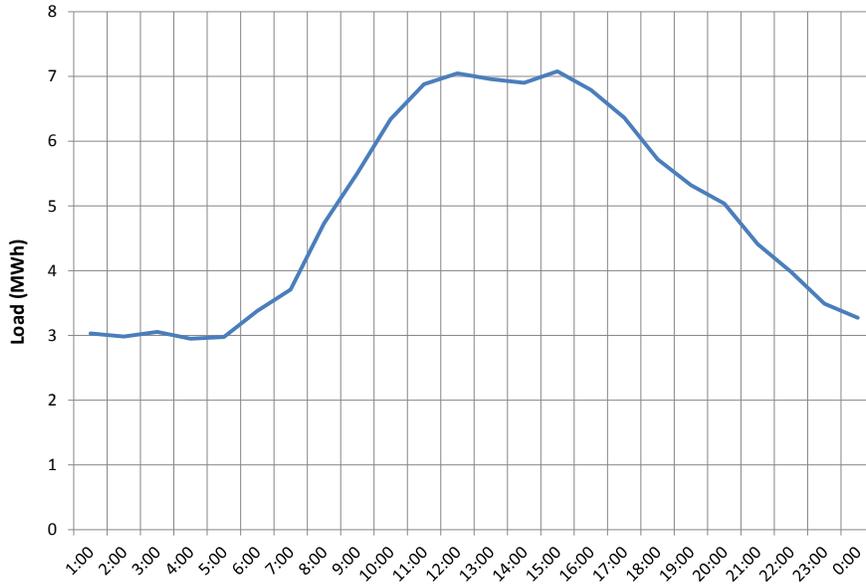


Figure 17. Peak Day Load Profile – Small Commercial (March 2013)

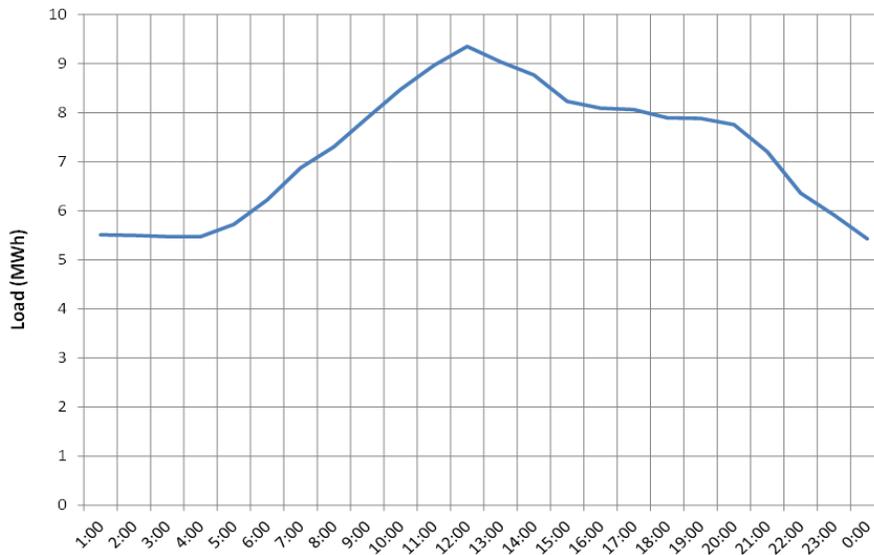
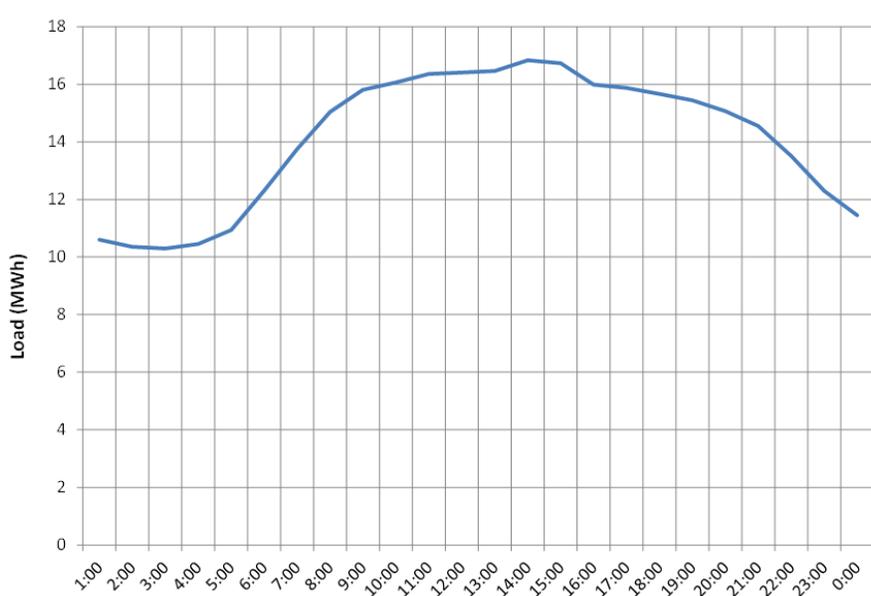


Figure 18. Peak Day Load Profile – Large Commercial (March 2013)



**Figure 19. Peak Day Load Profile – Large Power (March 2013)**

The initial AMI-based load research results also identified the opportunity to examine additional categories of load behaviors, such as net metered consumers providing a portion of their own generation requirements. By virtue of the AMI, information has become available to monitor those loads effectively.

For example, some average net load and generation profiles of net metering consumers on the KIUC system were available in March 2013 (**Figures 20–23**). The data represent net delivered and net received energy, rather than the full load requirements and total generation of the net metering customers.

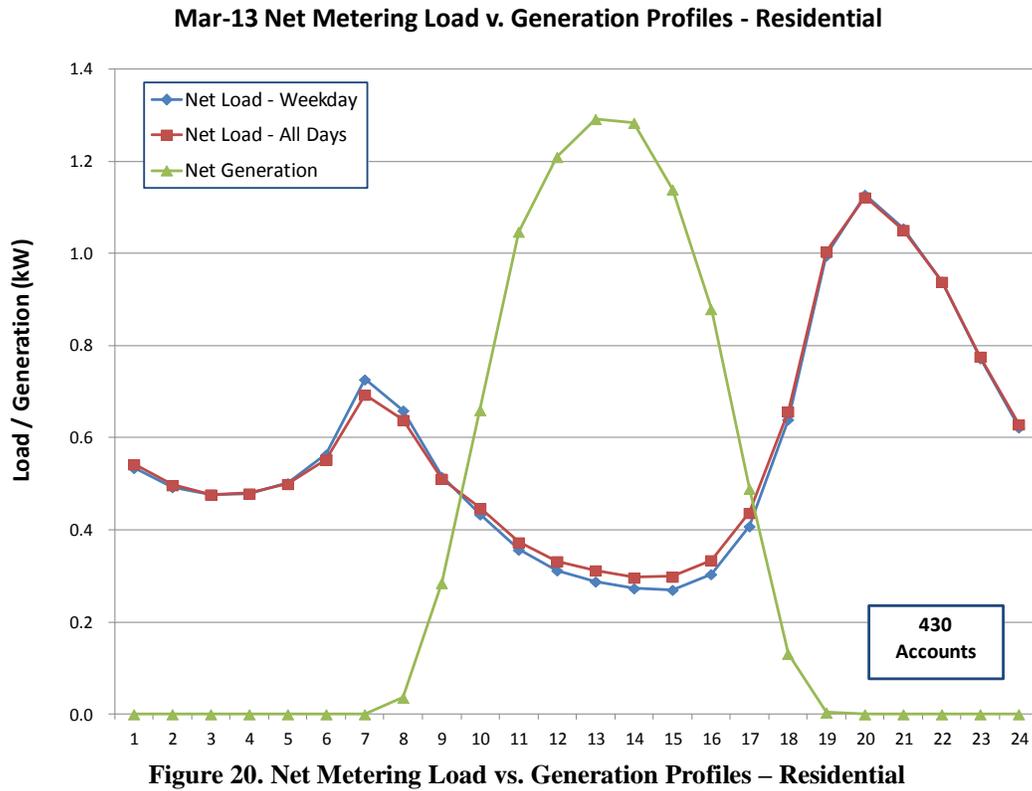


Figure 20. Net Metering Load vs. Generation Profiles – Residential

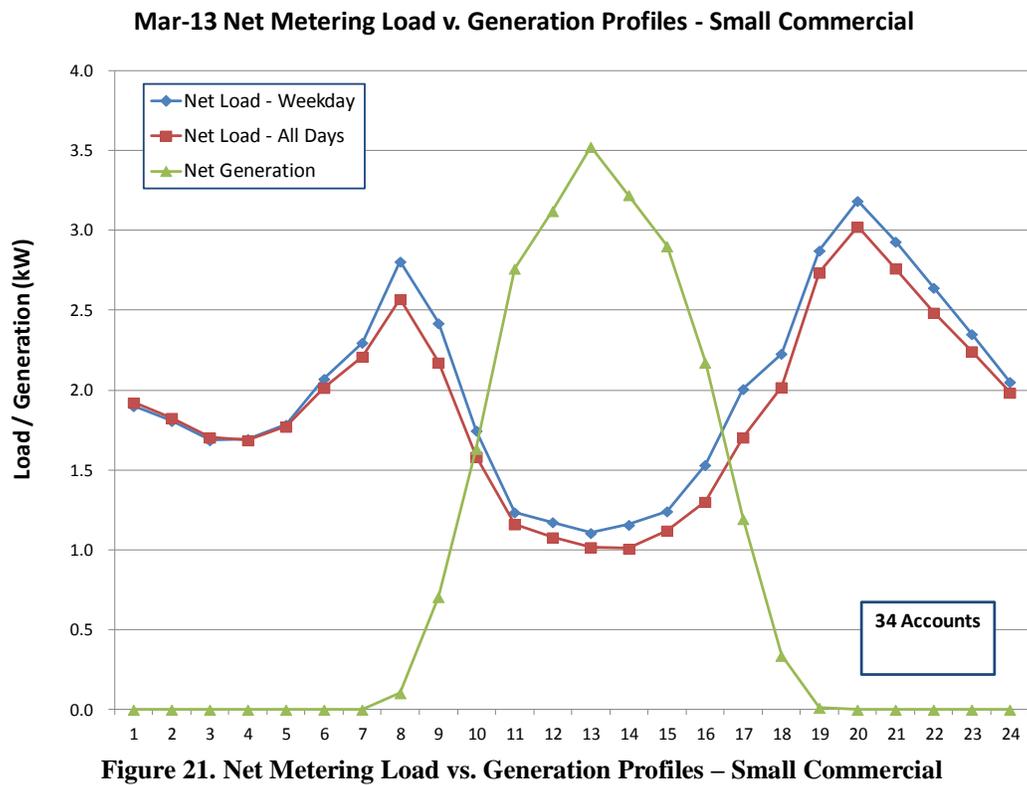


Figure 21. Net Metering Load vs. Generation Profiles – Small Commercial

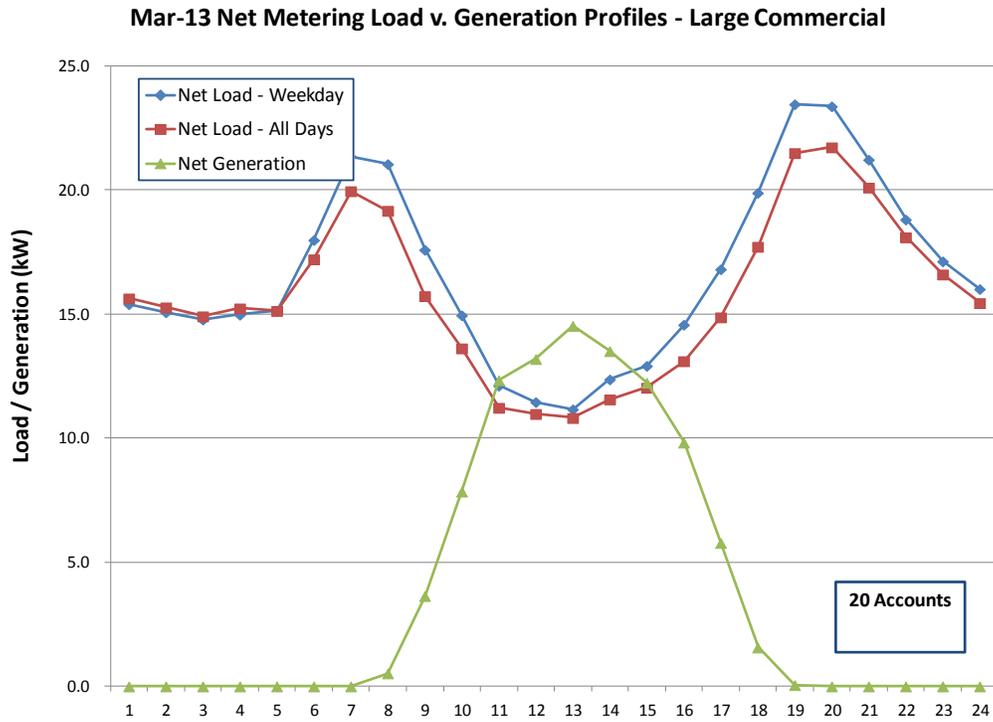


Figure 22. Net Metering Load vs. Generation Profiles – Large Commercial

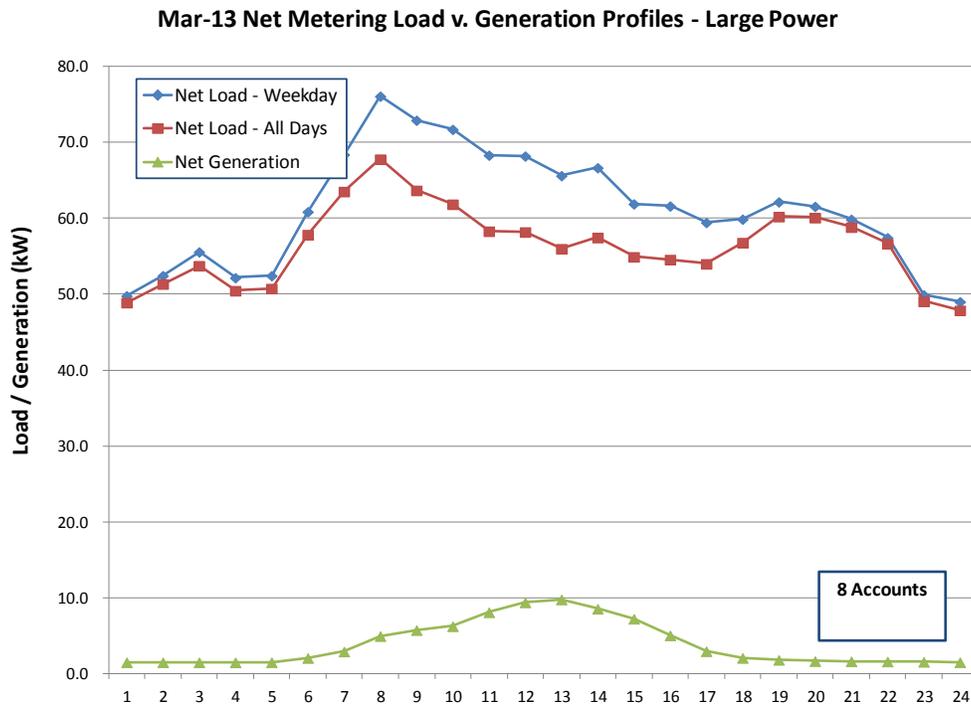


Figure 23. Net Metering Load vs. Generation Profiles – Large Power<sup>7</sup>

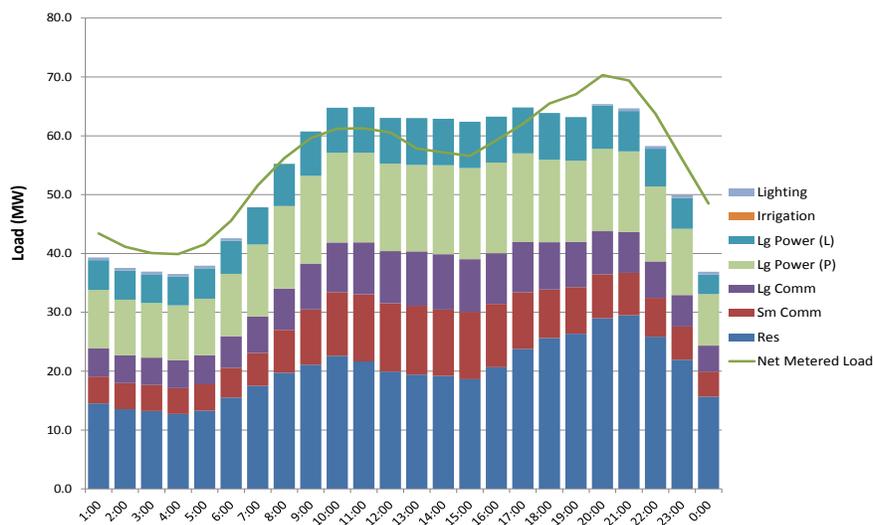
<sup>7</sup> With a limited sample size, however, generalized results may not be fully representative of the rate class.

### 5.3 Intermediate Results of the Load Research Study – May 2014

By late April 2014, data had been collected and load research results developed across the rate classes for the 12-month test year of calendar 2013. This included rate class loads and load profiles, as well as the data for the net energy metered loads, and those contributors of energy to the system from power in excess of on-site generation requirements. Continued success in the data collection was achieved through the use of the AMI system, which provided the level of detail appropriate for the load research study.

By that time, however, information became available that warranted further investigation. The items to investigate are related to the capability of the AMI system to provide a significant means for understanding the KIUC load situation. The availability of the AMI system information is relevant for evaluating differing information available to the cooperative.

One such issue is the measurement of the impact of on-site generation on the customer’s load and the utility’s system, a condition becoming more prevalent across the industry. The intermediate load research study results determined that the test-year peak load for the KIUC system occurred in July 2013.<sup>8</sup> The class contribution to the peak day load and the net metered load for generation by the system utility generation is shown in **Figure 24**. The item of particular interest to the demonstration study is the relationship and impact of the net metered loads and on-site facilities providing generation to the system.



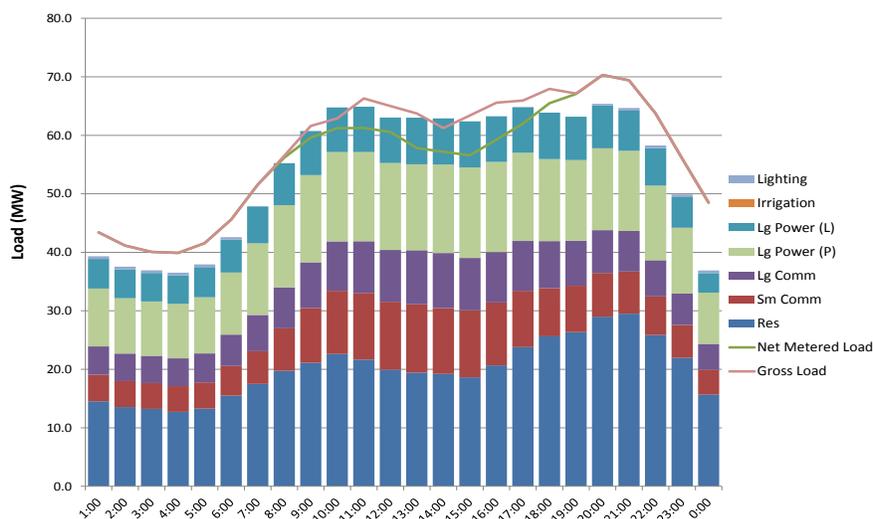
**Figure 24. Sum of Class Loads vs. Metered System Peak Load – Peak Day July 2013**

The net metered load in **Figure 24** is the load level reported by the KIUC SCADA system and is the sum of the feeder loads at the substation delivery points. In the absence of net metering and on-site distributed generation feeding into the grid, that load level typically would be above the sum of the individual class loads by a more or less constant percentage, representing distribution

<sup>8</sup> The actual system peak occurred, however, in December 2013, based on a later examination by KIUC of system losses. Confirmation of this will be incorporated in the final documentation of the study.

losses on the system and the level of power supply required to be supplied by the KIUC generation facilities. Thus, the load level reported by SCADA is the system load, net of the on-site generation.

The differential between the sum of the metered loads and the substation feeder load profile is the “backfeed,” or level of exported on-site distributed generation, contributing to meet the total load of the system and distribution losses. A hypothetical adjustment to the substation feeder loads to account for the backfeed is included in **Figure 25**. The gross load of Figure 25 is a hypothetical estimate of the amount of energy exported by the on-site generation facilities that has been added to the metered feeder loads to obtain a representation of the level of gross generation requirement.



**Figure 25. Sum of Class Loads vs. Metered System Load w/Adjustment – Peak Day July 2013**

The level of exported on-site generation by an individual customer differentiates one customer from another within any of the customer classes and is an important consideration in rate design efforts. This information is particularly important for consideration of time-of-use rates or other pricing incentives to help optimize the power supply of the cooperative. **Figures 26** and **27** provide a comparison of load profiles within two rate classes (Residential and Small Commercial) differentiated by facilities that self-generate and/or export energy, identified as “NEM/Q” customers.<sup>9</sup> Additionally, observation of the start and end loads suggests that larger energy users may have greater generating capability than the typical customer.

<sup>9</sup> “NEM/Q” refers to participants in the KIUC Net Energy Metering programs, or those that export power from on-site generation to the KIUC system under the Schedule Q tariff.

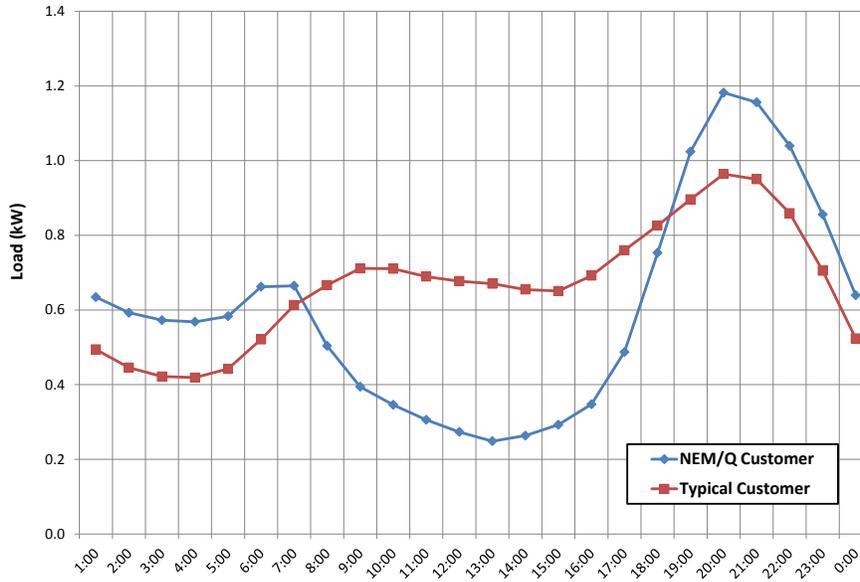


Figure 26. Residential Load Profile – Typical vs. NEM/Q – Peak Day July 2013

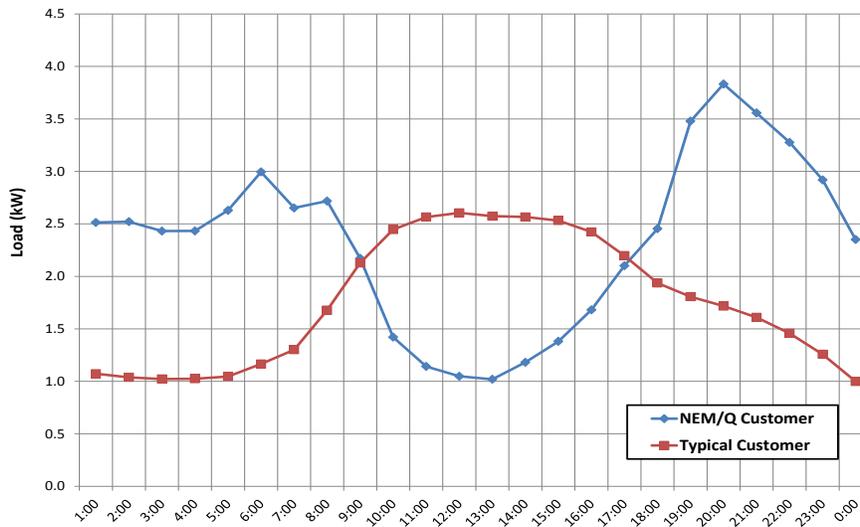


Figure 27. Small Commercial Load Profile – Typical vs. NEM/Q – Peak Day July 2013

The amount of energy contributed to the KIUC system by the NEM/Q customers varies over time as a result of external conditions and the amount of the internal load of the self-generating facility. For example, the average backfeed profile for residential customers is shown in **Figure 28**, indicating the differences by month in the amount of net generation provided to the system by on-site generation facilities. Adjustments to the generation profiles to develop “normal” on-site generation expectations may be required to ensure proper representation of loads for planning and evaluation purposes.

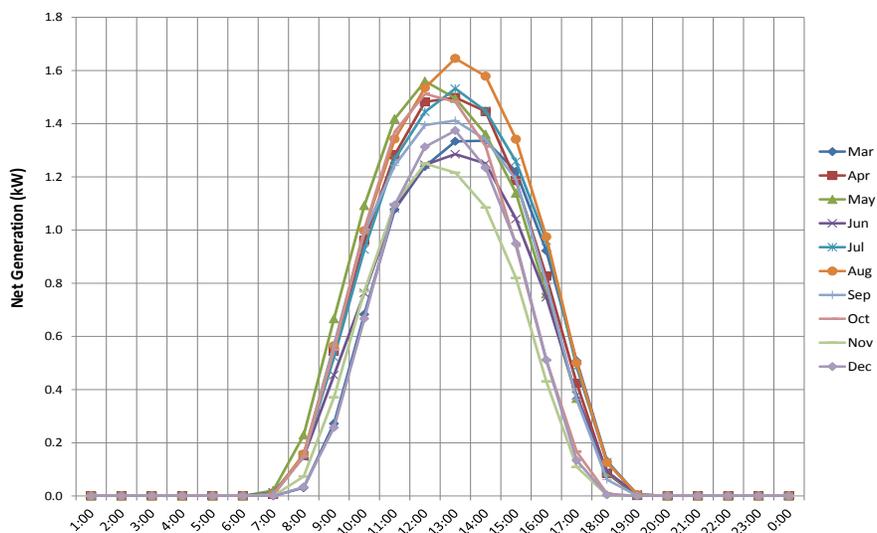


Figure 28. Average Residential NEM/Q Export, Calendar 2013

Another issue identified in the data collected over the test-year period was the impact of shifts in the status of the customers selected for the sampling of load data. The sample identified in the initial phases of the study was maintained throughout the data collection. However, changes within and between the classes were evident when reviewing the samples across the month. In addition to adding NEM/Q customers and the non-AMI metered accounts, a contributing factor was the gradual roll-out of AMI metering across the classes, leading to lower numbers in the earlier months of the year (e.g., January through March). The most significant shift can be seen in the Residential and Small Commercial NEM/Q participants, as shown in **Table 3**.

Table 3. KIUC Load Research Samples, by Month, Calendar 2013

Month	Residential (Sched D)	Small Comm (Sched G)	Large Comm (Sched J)	Large Power (Sched L)	Large Power (Sched P)	Res NEM/Q	Small Comm NEM/Q
Jan	343	274	197	8	97	N/A	N/A
Feb	375	289	215	8	98	N/A	N/A
Mar	399	304	226	8	99	430	34
Apr	434	324	251	8	99	478	37
May	437	334	271	8	99	483	38
Jun	317	293	216	7	74	230	13
Jul	440	342	269	8	95	486	42
Aug	446	347	286	8	96	495	41
Sep	447	354	294	9	97	500	42
Oct	448	361	296	8	96	503	41
Nov	446	360	297	9	95	504	41
Dec	445	358	298	9	96	504	43
Accounts	28,300	4,300	310	13	103	1,694	*

In 2013, for example, it was reported that there were approximately 800 new applications for NEM/Q interconnections among residential energy users. When using annual data, timing is an issue for establishing the sample; in addition, capturing the transfers between classes of customers or among specific customer characteristics is important to fully reflect the conditions of the system. The data from the AMI are available and accommodate the adjustment of the sample strata. Such adjustment is required to capture the following: (1) the growth in on-site generation; (2) the size of the systems installed; (3) the shift between customer classes; (4) the changes in customer class usage profiles due to that growth; and (5) the changed contribution to system energy through export.

Other issues related to the load research study not directly applicable to the demonstration include adjusting for certain large loads for which AMI meters may not have been installed due to unique operating or connection requirements, the correlation of system load and estimated loads, and other benchmarking refinements.

#### **5.4 Next Steps in KIUC AMI-Based Load Research**

Over the remainder of the load research study, Leidos and KIUC will be working together to address the issues identified relative to on-site generation characteristics and some remaining issues related to the data analysis, including the following:

- ◆ Resolving benchmarking issues
  - Differences identified between sampled and billed energy;
  - Differentials between hourly estimated and actual system load;
  - Late morning and early afternoon hours;
  - Late evening hours;
- ◆ Ensuring the correct capture of gross system load;
- ◆ Refinement of the solar generation profile; and
- ◆ Verifying the sample stratification (based on the 2013 system peak month rather than the January 2012 data, and re-stratifying if appropriate).

Once complete, the analysis and accompanying report will form the basis for rate design studies and supporting documentation that can be supplied to the HPUC and the Hawaii Consumer Advocate for a utility system-specific load research study by and for KIUC.

## **6. CONCLUSIONS FROM THE AMI-BASED LOAD RESEARCH DEMONSTRATION**

The KIUC AMI-Based Load Research Demonstration has shown that the AMI system has provided remarkably clean and generally error-free data, reflecting the integrity of its system and data collection protocols and communications network. In addition, data collection was much more efficient than it would have been had traditional manually read meters been employed for the study. The comprehensive set of profiles for the initial month suggested that the full-year data set would be reasonable and fully representative of load class contributions to serve as a basis for rate studies and other purposes. The intermediate results provide even more compelling evidence for the use of the AMI for load research, particularly regarding the identification of differences in recorded information, and in providing the ability to revise a sample or include alternative data sets. Such capability avoids the onerous process of meter changeouts as strata change, as would be the case when using traditional load research metering.

With the full test-year calendar period results having been obtained and currently being refined, in part by additional and alternative data from the AMI system, it is apparent that an AMI-based system provides a better design for obtaining the requisite data than traditional equipment. The research objective of demonstrating the use of the AMI system for load research has been met through the initial and intermediate work. The benefit of the AMI system in support of ratemaking and other studies will derive from the integrity and availability of the comprehensive data. The load research results to date and analysis of the data supply evidence that AMI provides an effective and efficient means to collect the necessary data, and that the research objective of demonstrating the value of AMI in completing a load research study has been met.

The AMI system has allowed KIUC to avoid incremental costs in acquiring the load data, and the system has shown overall integrity and provides data uniquely associated with the KIUC consumer base on which it may rely. The ability to create a sample from a relatively unlimited database of recorded metering information has been useful for the sampling design and will assist in developing adjustments to reflect changes throughout the test period. Further work on the data collected and resolution of anomalous results will help to clarify unique features of the KIUC load requirements, including such factors as net metering circumstances and other non-utility generation. Furthermore, the AMI provides the opportunity to selectively identify unusual and anomalous loads; investigation of causes and impacts will provide for improved operating efficiencies.

## **7. RECOMMENDATIONS FOR FURTHER STUDY**

Pending the final analysis and the results of regulatory acceptance of the research findings, several factors in the application of the AMI system for load research may be worthwhile candidates for further study. These include the following:

- ◆ The impact and effect of metering “opt-outs” and the impact on derived load characteristics for the system;
- ◆ Comparison with more traditional systems, such as PLC-based data collection, for data integrity and data continuity; and
- ◆ The value of periodic repetition of the sampling and the appropriate time frame for re-examination.