Pacific Gas and Electric Company

EPIC Final Report

Program	***Electric Program Investment Charge (EPIC)***
Project	***EPIC 2.21 – Home Area Network (HAN) for Commercial Customers***
Department	*Data Governance & Products*
Project Sponsor	Eileen Parker
Project Business Lead	John Lin
Contact Info	EPIC_Info@pge.com
Date	February 20th, 2018
Version Type	*Final*

TABLE OF CONTENTS

List of Tables

List of Figures

Table of Acronyms

API	Application Programming Interface
AMI	Advanced Metering Infrastructure
B2B	Business-to-Business
BEMS/BMS	Building Energy Management System
CC&B	Customer Care & Billing
CEC	California Energy Commission
CPUC	California Public Utilities Commission
D.	Decision
DA	Direct Access
degF	degrees Fahrenheit
DER	Distributed Energy Resources
DR	Demand Response
DSM	Demand-Side Management
EE	Energy Efficiency
EMS	Energy Management System
EPIC	Electric Program Investment Charge
EI	Enterprise Integration
FAN	Field Area Network
GHG	greenhouse gas
IEEE	Institute of Electrical and Electronic Engineers
I/F	Interface
IOU	investor-owned utility
IPv6	Internet Protocol Version 6
ISM	Industrial, Science and Medical
IT	Information Technology
HAN	Home Area Network
HCM	HAN Communication Manager
HVAC	Heating, Ventilation and Air Conditioning
kW	kilowatt
kWh	kilowatt-hour
kVAR	kilovolt-ampere-reactive
LAN	Local Area Network
LC&I	Large Commercial & Industrial customer
PAN	Personal Area Network
PG&E	Pacific Gas & Electric Company
PLS	Permanent Load Shift
PV	photovoltaic
RESI	Residential customer
RJ-45	Standard physical 8-pin connector for Ethernet
SaaS	Software-as-a-Service
SCE	Southern California Edison Company
SDG&E	San Diego Gas & Electric Company
SM	SmartMeter™
SSN	Silver Spring Network

SUT	System Under Test
TD&D	Technology Demonstration and Deployment
UIQ	Utility IQ
u/t	usage to temperature
WAN	Wide Area Network
WiFi	Wireless Fidelity - popular 2.4GHz/5GHz wireless Ethernet
ZigBee	2.4GHz PAN industry standard based on IEEE802.15.4 radio
ZSEP1.0	ZigBee Smart Energy Profile

1 Executive Summary

This report summarizes the project objectives, technical results, and lessons learned for Electric Program Investment Charge (EPIC) Project 2.21 Home Area Network (HAN) for Commercial Customers.

On March 12, 2009 the California Public Utilities Commission (CPUC or Commission) approved Pacific Gas and Electric Company's (PG&E) SmartMeter™ Program Upgrade. The Upgrade provided for two-way communication technology for the Advanced Metering Infrastructure (AMI) and included HAN device connection capability to deliver technology enabling customers access to their real-time electricity usage. The technology chosen was ZigBee Smart Energy Profile v1.0 (ZSEP1.0). PG&E SmartMeter™ residential meters were deployed with short range radios capable of forming a ZSEP1.0 network to connect devices at the customer premises.

This technology has the capability to support grid reliability efforts through Demand Response (DR). Using this technology, Large Commercial and Industrial (LC&I) customers can gain insight into their peak demand usage and develop and optimize DR strategies to participate in utility curtailment programs and events.

This EPIC project investigated the viability of migrating the technology designed for residential customers to large commercial customers. LC&I represent 51% of energy delivered by the PG&E distribution system, so the opportunity to enhance demand-side management is significant. Real-time data management at large commercial customer sites may also offer those customers improved DR and Distributed Energy Resource (DER) controls. This project was conducted to test the technology capability and to evaluate the opportunities for improvement to encourage wider commercial customer adoption.

This project set three objectives:

1. Verify that the existing technology applied to large customer SmartMeter™ models was viable.
2. Identify large commercial customer needs for real-time data.
3. Specify opportunities, barriers, and impacts of full-scale deployment.

Project tasks to achieve the objectives were organized into "stages" and implemented as a software under test (SUT) model. Stages II and II were dependent upon the previous step. All Stages were completed in the course of this work:

Stage I conducted laboratory controlled tests on the PG&E large commercial SmartMeter™ models linked with a commercially available HAN device (technology from the residential meter project). The communication links verified the technology was viable.

Stage II solicited 46 large commercial customers to participate in the project. The technology was deployed to a final group of 13 sites where a ZSEP1.0 SmartMeter™ was already installed or could be installed, and where the customer's information technology policies did not preclude connection of the HAN to their network.

Stage III conducted analysis of data collected during deployment, installation and operation of the technology at customer sites, interval meter data, external factors (i.e., demand events, ambient temperatures), and customer survey results.

Seven key findings came out of this project:

1. Commercial customer SmartMeter™ (those with ZSEP1.0) provided accurate real-time readings through HAN devices.
2. Effective installation of this technology required site-specific modifications.
3. Some LC&I customers had significant barriers to adopting this technology (i.e., Direct Access (DA) contracts, information technology policies, signal connectivity, meter set logistics).
4. Lack of customer experience and analysis tools limited full use of the real-time data.
5. Integration of real-time data into an Energy Management System (EMS) required customer Information Technology (IT) investment.
6. The HAN device for large commercial operations poses integration barriers that includes calibration of HAN software with site specific meter values and physical installation limitations.
7. Customer applications for real-time AMI data can be realized with longer timescales than the 15 second intervals the meters deliver.

Overall, access to real time data was identified as valuable to customer demand side energy management. However the technology limitations necessitate vendor-driven development before the technology can be adopted at large scale.

Sites reported access to real-time energy enabled them to:

- Remotely monitor site energy usage
- Detect incidents and unusual activity
- Optimize demand response event recovery
- Determine efficacy of a demand response strategy
- Adjust Energy Efficiency (EE) activity and installations

The project produced three key recommendations:

1. Recommend commercial vendors develop improved ZSEP1.0 compliant devices that make it easily installable by large commercial customers on their networks and EMS, ideally as a turnkey solution.
2. Enable any commercial customer where a ZSEP1.0 compliant driver to EMS is available to collect real-time meter data over the Wide Area Network (WAN) (e.g., use every opportunity to avoid using a commercial customer's Local Area Network (LAN) to access AMI data). The connection through the WAN removes a level of complexity for the customer.

3. Bundle marketing of the commercial turnkey product with use models, educational materials and analytic tools to increase adoption and support applications to drive customer energy efficiency and cost savings.

This project demonstrated the viability and usefulness of access to real-time energy use data to commercial customers. It also demonstrated the HAN device used for the residential solution for commercial applications posed several integration challenges due to the complexities on the customer side of the meter. The ideal solution will be future availability of a viable commercial device between the SmartMeter™ and the commercial customer system.

2 Introduction

This report documents the Electric Program Investment Charge (EPIC) Project 2.21 Home Area Network (HAN) for Commercial Customers achievements. It highlights key learnings with industry-wide value, and identifies future opportunities for PG&E to leverage this project.

The California Public Utilities Commission (CPUC) published two decisions that established the basis for this work product. The CPUC initially issued Decision (D.)11-12-035, *Decision Establishing Interim Research, Development and Demonstrations and Renewables Program Funding Level*[1], which established the EPIC program on December 15, 2011. Subsequently, on May 24, 2012, the CPUC issued D.12-05-037, *Phase 2 Decision Establishing Purposes and Governance for Electric Program Investment Charge and Establishing Funding Collections for 2013-2020,*[2] which authorized funding in the areas of applied research and development, technology demonstration and deployment (TD&D), and market facilitation. In this later decision, CPUC defined TD&D as "the installation and operation of pre-commercial technologies or strategies at a scale sufficiently large and in conditions sufficiently reflective of anticipated actual operating environments to enable appraisal of the operational and performance characteristics and the financial risks associated with a given technology."[3]

The decision also required the EPIC Program Administrators[4] to submit Triennial Investment Plans to cover three-year funding cycles for 2012-2014, 2015-2017, and 2018-2020. On November 1, 2012, in Application 12-11-003, PG&E filed its first triennial Electric Program Investment Charge (EPIC) Application at the CPUC, requesting $49,328,000 including funding for 26 Technology Demonstration and Deployment Projects. On November 14, 2013, in D.13-11-025, the CPUC approved PG&E's EPIC plan, including $49,328,000 for this program category. Pursuant to PG&E's approved EPIC triennial plan, PG&E initiated, planned and implemented the following project: 2.21-Enabling ZigBee for Commercial Customers. Through the annual reporting process, PG&E kept CPUC staff and stakeholders informed on project progress. This is PG&E's final report on this project.

[1] http://docs.cpuc.ca.gov/PublishedDocs/WORD_PDF/FINAL_DECISION/156050.PDF.
[2] http://docs.cpuc.ca.gov/PublishedDocs/WORD_PDF/FINAL_DECISION/167664.PDF.
[3] Decision 12-05-037 pg. 37.
[4] PG&E, San Diego Gas & Electric Company (SDG&E), Southern California Edison Company (SCE), and the California Energy Commission (CEC).

3 Project Summary

This project investigates the potential to leverage the HAN device and ZigBee Smart Energy Profile (ZSEP1.0) infrastructure developed for residential SmartMeter™ models for large commercial sites. The following subsections summarize the industry gap addressed by this project, as well as the project's objectives, the scope of work, major tasks, milestones, and corresponding deliverables.

3.1 Issue Addressed

Since its inception, SmartMeters™ have built expectations among regulators and utilities around leveraging energy consumption and pricing real-time data for net grid benefits. PG&E enabled residential and small commercial customers' real-time access to their SmartMeter™ data as ordered under CPUC Decision D.11-07-056.5 The Decision specifically directed implementation using a HAN device which, in the case of SmartMeter™ installations, were required to adhere to the ZigBee Smart Energy Profile (SEP) 1.0 or 1.1 specifications.[6] The HAN device provided those customers a communications link to their meter so they could monitor real-time energy usage and costs, accumulated costs "to date", and to receive DR alerts (i.e., Peak Day Pricing[7] events). This instant access to real-time data empowered customers to make timely demand decisions, thus making energy costs more transparent and controllable.

While the vast majority of PG&E customers are residential accounts, more than 50%[8] of energy delivered by the distribution system is to a small set (13% of total customers[9]) of LC&I. Energy management is an active function for these customers and our sales representatives have communicated our customers desire to obtain real-time data. Additionally, it was known these customers in many instances have installed monitoring and metering solutions to gain insight into factors affecting their operational efficiencies and costs. LC&I customers, however have different meter installations than residential customers, which made it necessary to demonstrate compatibility of these meters with HAN as well as assess potential barriers to adoption. PG&E developed this project to focus on making real-time data more readily available to the LC&I customer segment in recognition of their interest in better energy consumption usage and cost information.

The project identified important factors to support creation of a path to wider customer adoption of direct, real-time access to PG&E's SmartMeter™ data. These factors include:

- Logistical concerns at customer sites
- Meter swap requirements
- Identification of suitable installation sites
- Overall energy savings as compared to historical data

---

[5] http://docs.cpuc.ca.gov/Published/final_decision/140369.htm#P1315_289017 ORDER 11.

[6] ZigBee is an open global standard for wireless technology designed to use low-power digital radio signals for personal area networks. ZigBee operates on the IEEE 802.15.4 specification and is used to create networks that require a low data transfer rate, energy efficiency and secure networking. (https://www.techopedia.com/definition/4390/zigbee).

[7] Peak Day Pricing (PDP) is a PG&E DR pricing plan rolled out to complement current time-of-use pricing or replace flat rates that do not vary with time. PDP provides lower energy prices during the summer in exchange for higher rates during certain hours on 9 to 15 peak event days per year.

[8] PG&E 2017 Annual Report, p. 15.

[9] PG&E Corporation, website: http://www.pgecorp.com/corp_responsibility/reports/2016/bu01_pge_overview.jsp.

- Qualitative feedback from customers about the overall experience and technology
- Operational savings
- Customer equipment analysis
- Recognizing substitution opportunities from existing submetering systems (i.e. current clamps)

3.2 Project Objectives

The project's objectives are as follows:

1. **Verify the Technology**

   Through lab testing, verify whether HAN devices report LC&I electric meter electrical usage values accurately as they do for residential electric meters, so that real-time usage information is made available to the commercial customers.

2. **Specify opportunities, barriers and impacts of full-scale deployment**

   Identify the operational impacts of enabling this technology for commercial customers systems and organizations (i.e., information technology, customer support, change management).

3. **Identify and assess LC&I customer needs for real-time data**

   Provide insight into how customers leverage real-time data, how HAN integrates into an existing energy management system (EMS), and evaluate how real-time usage information can integrate into customer's existing EMS system to provide additional functionality.

3.3 Scope of Work and Project Tasks

The EPIC 2.21 project approached the subject as a System Under Test (SUT) to prove the capability of a HAN to link with SmartMeter™ models for commercial installations. The SUT in this case consisted of a commercial SmartMeter™, a commercial HAN device, and local area network (e.g. customer premise set-up) on the customer side of the meter (Figure 1). The SUT was defined so that the SmartMeter™ would communicate with the HAN device using its ZigBee Smart Energy Profile v1.0 standard. The HAN device is linked with the customer's local area network.

Figure 1 Scope of System under Test (SUT)

Work tasks to complete the project were organized into three sequential stages:

- Stage I – Evaluate HAN devices and their general interoperation and functionality with commercial site SmartMeter™ models. The milestone was proof the SUT is operationally capable.
- Stage II – Deploy, install and operate the SUT. This milestone was to collect information on what constituted a successful installation, and to identify the salient issues surrounding successful integration into existing enterprise IT and energy management systems.
- Stage III – Collect information from sites on the installation and the real-time data service use through phone, email, and on-site interviews and surveys, and analyze both interval data and qualitative information from site observation and customer surveys. The milestone was the compendium of operating results, site observations, and customer surveys.

4 Project Activities, Results, and Findings

4.1 Technology Evaluation (Stage I)

HAN devices were evaluated with commercial SmartMeter™ models equipped with ZSEP1.0 under controlled laboratory conditions to verify that HAN device can link to each model successfully. The evaluation aimed to determine HAN device capabilities and differences in the large commercial customer scenario compared to the residential scenario.

4.1.1 Technical Development and Methods

This technology solution used a commercial HAN device as the integration tool between SmartMeter™ AMI data and the customer specific EMS.

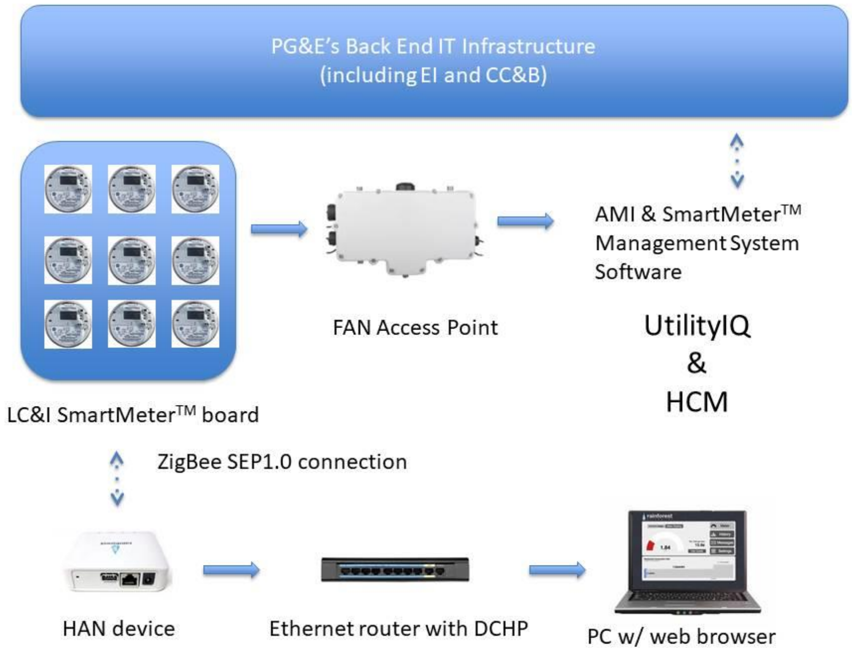
The purpose of the controlled laboratory test was to demonstrate that HAN devices can provide real-time usage information from large commercial customer meters. The test setup consisted of system elements listed in Table 1 System Under Test (SUT) Elements below.

Table 1 System Under Test (SUT) Elements

Test System Element	Purpose
EI: Enterprise Integration	Middleware layer that transfers data and command files between back end systems
CC&B	Database containing individual accounts and meter configuration information. It is connected to HCM via Enterprise Integration
UIQ	Commercial application to manage the meters, connections, and data flows
HCM: HAN Communication Manager	Commercial application to manage demand side ZigBee SEP1.0 device connections
Access point	Commercial hardware router to aggregate the Internet Protocol Version 6 (IPv6) traffic of the meshed AMI network, then channel the traffic to the utility head end system
Meter board	A set of laboratory meters with load attachment capability, to facilitate verification and testing of individual meters through a test AMI and IT infrastructure
HAN device	A ZigBee Smart Energy Profile 1.0 (ZSEP1.0) device that is capable of connecting to individual SmartMeters™ using the ZSEP1.0 communication protocol, and is able to read electrical usage information directly from the meter in real-time
Ethernet router	IP networking device that the HAN device can connect to in order to receive an IP address, and transmit data through an IP network
PC with a web browser	A PC running a standard web browser, to access the web application running on the HAN device, so that data received from the SmartMeter™ can be read.

The test setup, shown in Figure 2 simulated the communications flow from the SmartMeter™ to the customer's IT (a PC in this test model) through the HAN device and also through the commercial access point to PG&E's IT infrastructure. A commercial utility head-end application "UIQ" managed the meters on the test AMI network and performed the data collection. The test instance of UIQ was connected to a complete test instance of PG&E's back-end IT systems, including the Customer Care and Billing (CC&B) database. The commercial HAN Communication Manager (HCM) test instance was used to provision the devices onto the meters on the meterboard. CC&B records related to meter setup configuration were referenced for individual meter testing.

Figure 2 Stage I Test System



Eleven SmartMeter™ models (sourced from two different manufacturers) typically used at LC&I sites were selected for the tests. The testing involved setup and measurement of each individual HAN-to-meter devices through the test instance of the HCM. Once the HAN device was provisioned, an electrical load was presented to the SmartMeter™ and the SmartMeter™ measured value was recorded.

The CC&B record of the meter was also referenced to draw the "multiplier" value of a meter installation. This meant that the LC&I meters were installed with the necessary adjustment factors appropriate for the dynamic range of the metrology to accurately measure the kilowatt (kW) load.

Note that "multiplier" values are applied to meter readings to give the "true" value of the power being measured. For actual customer sites, the multipliers are site installation specific and will need to be searched within the customer records to provide for accurate meter reading values.

4.1.2 Test Results and Observations

The SmartMeter™ models in Table 2 represent the set of field deployed SmartMeters™ that PG&E currently employs for large commercial customers. In the project, one commercial HAN device was used. Stage I results were based on test steps shown in Appendix D: Laboratory Test (Stage I) to compile the basic connectivity and interoperability results of the set of SmartMeters™ to the HAN Device. The tests verified that when the multiplier was applied to the HAN reading, the actual load amount matched the value observed on the meter and HAN devices to within a percent (Table 2 Meter Models and HAN Device). In addition, HAN device connections were tested with kilovolt-ampere-reactive (kVAR) meters and the accuracy was measured using kVAR meter software and verified that the values are accurate and can be transmitted through ZSEP1.0.

Table 2 Meter Models and HAN Device

SmartMeter™	SmartMeter™ Model	HAN Device Reading Test Result (error)
1	A	PASS (~0.15%)
2	B	PASS (~0.94%)
3	C	PASS (~0.28%)
4	D	PASS (~0.165%)
5	E	PASS (~0.126%)
6	F	PASS (~0.87%)
7	G	PASS (~0.12%)
8	H	PASS (~0.2%)
9	I	PASS (~0.299%)
10	J	PASS (~0.135%)
11	K	PASS (~0.31%)
HAN Device	HAN Device Model	
1	X	Pass

*"PASS" means kW measured values at meter and at HAN are <1%.

Stage I results verified that large commercial sites with installed SmartMeters™ can utilize the ZSEP1.0 HAN device functionality to read real-time data directly from the meters with accuracy. An important takeaway is that site-specific equipment "multiplier values" are required to be applied to the HAN technology in order to get the correct kW measurement values. These multiplier values are recorded in the customer database; however this information generally is only accessible through a search of the specific service point record in the database. Without these multiplier values determined during installation and setup of the electrical circuit at the site, the real-time data read would be incorrect and markedly off its true value.

4.2 Deployment & Operation (Stage II)

Completion of Stage I tests provided the basis for field deployment and operation at customer sites in Stage II. The purpose of Stage II was to deploy the HAN Device, collect information on what constituted a successful installation, and to identify the salient issues surrounding successful integration into existing enterprise IT and energy management systems. One of the key questions in providing real-time data to customers was to determine how this data gets used. Many commercial customers when asked expressed strong interest to obtain "real-time" data, but do not yet express specific applications and how this information can be used. Work tasks in Stage II were selected to obtain answers to these questions.

The methodology used in Stage II used both qualitative and quantitative approaches. Customer surveys, interviews, and email communications were used to develop a qualitative understanding of the value of such deployments to the customers. In parallel, meter interval data was collected to serve as a quantitative baseline of usage during this period. Note that the real-time data sent through the HAN device is not received by PG&E and therefore, it was up to the site to determine its use and storage.

4.2.1 Commercial Site Selection

Commercial customer sites were recruited to participate through solicitation by PG&E's customer account managers who focused on key business accounts. Participants were selected based on their initial interest and qualifications to participate and receive the HAN device. The selection process provided insights into the reasons for and against participation, and shed light on some of the adoption barriers for real-time service.

PG&E solicited a total of 46 customer locations for participation. Of these 46 locations which were based on PG&E internal recommendations (see summary Table 3), 33 could not move forward with a HAN installation for two primary reasons:

1. The existing meters were not ZSEP1.0 compliant and the sites were under contractual constraints with Direct Access[10] energy providers to pursue a meter exchange to a HAN capable device.
2. Facilities had site authorization issues due to logistically not being able to internally manage a meter exchange. This included IT security approval barriers to introduce a non-enterprise class HAN device onto an internal corporate IT Network.

Table 3 Site Solicitations

Total Sites Solicited	Total Sites In-eligible	Meters – Not HAN Capable	Site Authorization Issues	Candidate Sites
46	33	24	9	13

Table 4 lists the remaining 13 candidates that were eligible to participate in the demonstration. The selected participating sites received a drop shipment of the HAN device, introduction letter, participation agreement, and PG&E support contact information. All customers were found capable of managing the HAN device configuration out-of-box based on manufacturer directions with additional information about site multiplier values. The production HCM was used to pre-provision the customer devices, and when a HAN device was powered up and within wireless range of the SmartMeter™ ZSEP1.0, the device was verified to automatically join the ZSEP1.0 network. This was observed through the HCM software at PG&E. Once the HAN devices joined, and LAN cable connection was established and reported by the customer, the on-site setup was deemed complete.

[10] Energy providers that sell energy directly to customers, bypassing the regulated utility.

Table 4 Participating Sites

Site Key	Category	Location	Install Date	Existing EMS	Approximate Size
GOV – 1	Government Building	Stockton	6/14/2016	Not applicable	74,000 sq. ft.
SCH – 1	School	Fresno	9/6/2017	PG&E InterAct	115,000 sq. ft.
SM- 1	Supermarket 1	Berkeley	1/8/2017	Proprietary	44,000 sq. ft.
SM – 2	Supermarket 2	Los Altos	9/21/2016	Proprietary	45,000 sq. ft.
CM – 1	Commercial Building 1	Menlo Park	7/28/2016	HVAC EMS	46,255 sq. ft.
CM – 2	Commercial Building 2	Menlo Park	7/28/2016	HVAC EMS	62,920 sq. ft.
CM – 3	Commercial Building 3	Menlo Park	7/28/2016	HVAC EMS	46,255 sq. ft.
T-1	Tech Campus 1	Silicon Valley	1/23/2017	SaaS EMS	30,000 sq. ft.
T-2	Tech Campus 2	Silicon Valley	2/4/2017	SaaS EMS	22,000 sq. ft.
T-3	Tech Campus 3	Silicon Valley	1/26/2017	SaaS EMS	Outdoor lighting facility
T-4	Tech Campus 4	Silicon Valley	1/31/2017	SaaS EMS	39,200 sq. ft.
T-5	Tech Campus 5	Silicon Valley	1/9/2017	SaaS EMS	40,000 sq. ft.
T-6	Tech Campus 6	Silicon Valley	1/19/2017	SaaS EMS	30,000 sq. ft.

NB: SaaS EMS refers to energy management system utilizing vendor software-as-a-service platform

The participants were sent questionnaires after completion of this initial setup. The questions aimed to understand installation difficulties, as well as particular site characteristics that may be important to understand each site's energy usage characteristics. Based on the results, participants were then asked follow-up questions either by email, phone, or on-site during and at the conclusion of the project.

A concerted effort was made to not influence customer decisions on how to utilize the data. It was important to obtain uninfluenced feedback from each customer to determine if, when, and how they decided to apply the data to their operations and the perceived value it would have. Interconnection to existing EMS was an important aspect of this SUT. Table 4 column 5 identifies customers in this SUT with the EMS the facility employed. The surveys and subsequent interviews were used to identify any issues surrounding integration efforts.

4.2.2 Site Challenges

While Stage I was a straightforward technology verification of the SUT, Stage II identified a number of site suitability challenges that limited the number of participating customer in the demonstration as shown in Table 3. Those challenges were significant to the outcome of this project and were part of the qualitative results as they were indicative of the challenges to implement this technological solution on a mass scale.

For participating sites, a common challenge was to obtain operational approval to deploy the HAN devices. Many large commercial customers had IT security policies so approval and authorization to install a HAN device was necessary, and this added time to any deployment. Furthermore, there were concerns raised due to the introduction of a new device onto a company's IT network, and it resulted in clarification and support by PG&E to mitigate system security concerns. Of the 13 sites that were eligible to participate, all granted authorization for this project.

Participants also cited that calibrating the HAN software to actual value (by applying the multiplier obtained from PG&E) added a degree of difficulty in that a known demand value had to be applied to confirm values after the multiplier was applied to meter reads. It was difficult to confirm that after-multiplier values accurately reflected the energy consumed because past data needed to be referenced to confirm the results seen from the data reading software's connected to the ZSEP1.0 devices.

4.2.3 Results and Observations

The SUT deployment and operation at participating sites exposed customer issues affecting their ability to fully utilize real-time data. These issues are classified into three categories: Installation, EMS Integration, and Operation.

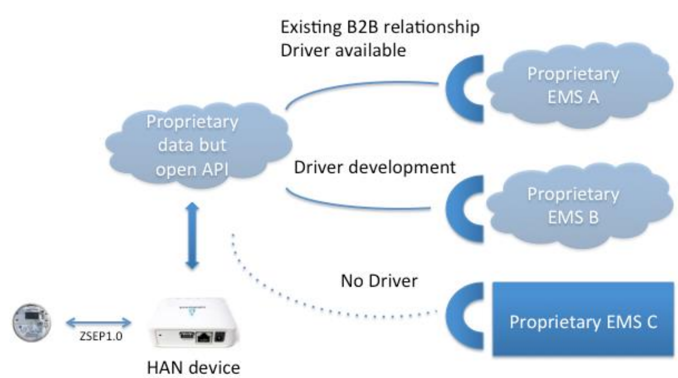
1. **Installation**

   Two sites faced problems related to LAN connectivity. At one location the SmartMeter™ did not have a RJ-45 Ethernet receptacle near a power source and sufficiently close to the SmartMeter™ for the HAN device to operate. In this case the HAN device was relocated to an acceptable location. At the alternate site, the location near the meter had no wired Ethernet; however campus WiFi was available. So by installing a low cost WiFi bridge the HAN device at this site was able to tap into the LAN and resolve this connectivity issue

2. **EMS Integration**

   Twelve of the thirteen participating sites that had successful SUT installations also had an operating EMS. These sites presented individual challenges due to the nature of the fragmented energy management system market and its connectivity situation. In order to integrate ZigBee real-time data to an energy management system, software connectivity drivers were required based on B2B[11] relationships. If none exist, a software driver needed to be created in order to make the HAN device data compatible with the EMS. Figure 3 shows the different combinations of support an EMS exhibits for the HAN device data.

Figure 3 Interconnection Variety



Existing B2B Driver Availability

[11] Refers to business conducted between companies.

When the HAN device vendor had established a Business-to-Business (B2B) relationship with an EMS solution vendor, drivers[12] were made available. Six tech campus sites were able to take advantage of this feature and integrate their HAN devices with their EMS with little difficulty.

Driver Development Required

Two participating sites (both supermarkets), had proprietary EMS and data connection drivers from the EMS to the HAN device were not available. These participants provided software engineering resources as part of the SUT to implement the EMS-HAN integration.

At three locations an Heating, Ventilation and Air Conditioning (HVAC) EMS existed, however these participants did not have funding nor resources to develop drivers to integrate the data into their EMS. This resulted in relying on the default minimum visual dashboard on their EMS to view real-time data.

No Driver

One site used PG&E's InterAct system, which is an online energy-usage, analysis, reporting, and curtailment-notification service. It was not possible to integrate real-time data stream into the InterAct system and the purchase of a new EMS was not considered.

Each customer was required to determine the level of effort to interconnect a HAN-based real-time data into their existing EMS. A decision level and path model is presented in Figure 4. The green level is normally within the realm of a facility energy manager to decide and enact. When the yellow levels are reached, an EMS solution specialist is required to make a decision on the paths along with determining the resources required. If the decision extends to the orange level then it becomes the realm of a software engineer, and quite far from the experience of a local facility energy manager. Hence it is reasonable to assume that any EMS and HAN driver combination that necessitates decisions beyond local facility manager knowledge and capability will be challenging to implement. Table 5 summarizes the participating site integration results.

[12] Drivers refer to pieces of software used to communicate with the hardware such as the HAN device.

Figure 4 Interconnection Decision Levels

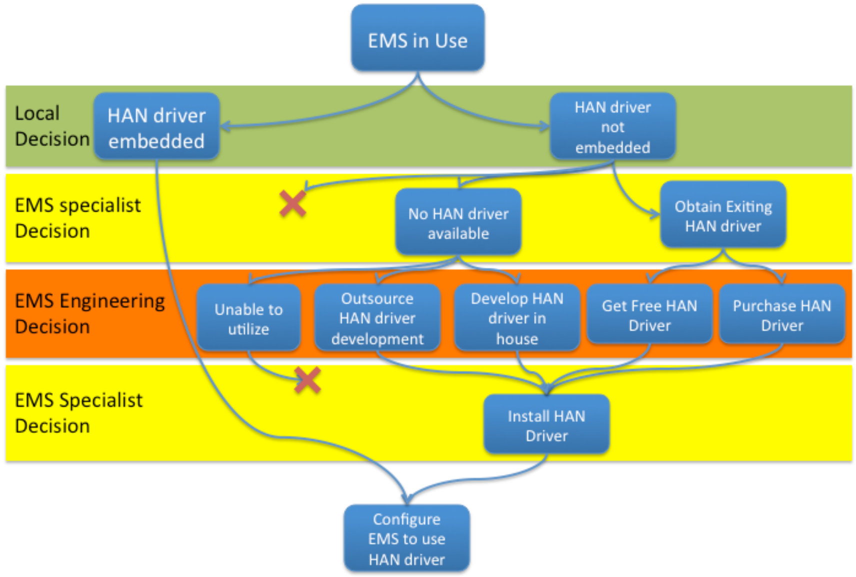


Table 5 Summary of Real-time Data Integration

Integration Item	# Sites	# Sites RT Data Integration	Comments
Existing B2B Driver	6	6	Sites had existing B2B relationship drivers available.
Driver Development Required	5	2	Three sites did not have the budget to develop drivers for EMS integration. Two sites had the financial resources to develop drivers
No Driver (Integration not Possible)	1	0	At this site, it was not possible to integrate SmartMeter™ data into their accustomed InterAct System. Only the SUT commercial gateway device could be utilized
No EMS	1	0	Site did not have an energy management system. Only the SUT commercial gateway device could be utilized.
Total	13	8	Five sites could not integrate real-time data

3. Operation

The primary value of real-time data to the customer is immediately knowing how load is actively managed on site. Given that value is associated to access of the data, it follows that ease of access to the real-time data impacts its usefulness. When a site is unable to interconnect the real-time AMI data to its existing EMS, it immediately became challenging to maintain customer interest in the data stream using manual means.

Based on interviews, it was clear that sites utilizing the default data visualization service found the HAN based-functionality as having limited usefulness. This appears to have caused a precipitous drop-off in use of the data for those sites.

4.3 Analysis (Stage III)

Stage III compiled information accumulated through SUT deployment, installation, and operation (applications of real-time data). This information was then combined with interval meter data and external variables (i.e., Events, temperature), and results from customer surveys. Analysis was performed to identify the overall contribution of site-specific real-time data.

4.3.1 Technical Development and Methods

Fact-based qualitative analysis and quantitative data were employed to determine notable impacts of introducing real-time data capabilities. For the qualitative analysis, information gathering was conducted throughout the span of the project using surveys, emails, and customer site visits. Information was obtained from the participants on significant operational details of their energy management activities and in their use of real-time data. For the quantitative analysis, meter interval data was retrieved to gain insight to any measurable impact of the installation of the HAN device real-time data capability. Results of the analysis are described in terms of both *qualitative* and *quantitative* results, correlated where relevant.

- **Qualitative Results**
  The participating site survey and interview results were used in conjunction with data to gain a qualitative measure of significant and valuable real-time data use cases. The information gathered was anecdotal. The SUT was limited in its participating population size, and generalized conclusions were implied, not proven. Nevertheless, the analysis pointed to important value propositions based on representative use cases.

- **Quantitative Results**
  The participating sites each had key start dates, where interval meter data was collected and observations were organized as PRE and POST HAN device installation start dates. Regression analysis of usage-to-temperature (u/t) ratio, together with 30-day moving averages was also used to help analyze the data for key site characteristics.

4.3.2 Results and Observations

Each participating site contact person was interviewed for notable impacts, and through this process it became clear that those sites which successfully integrated the real-time data with their respective EMS were the sites that registered the most impact. The qualitative analysis was able to draw some noteworthy conclusions about various barriers and impediments to adoption of this technology. Furthermore, the quantitative analysis preformed using a regression analysis yielded additional real-time data impact findings.

4.3.2.1 Qualitative Results from Customer Survey

The project performed phone, email, and site interviews with participating sites. The following summarizes the important results of a qualitative evaluation of the responses, together with important details of the other 33 sites that could not participate from the initial pool of candidates.

1. **Barriers to Deployment - Unsuccessful Installations**

   Of the 46 sites from the initial list of participants, 33 were unable to participate. This was attributable most commonly to an adoption barrier best described as “the technology not being appropriate for the site". It was identified that adoption at a site was hindered by two primary categories described below, each having a couple of specific sub-categories.

- Exchange to SmartMeter™, "meter swap"

  Direct Access customers
  Commercial sites under Direct Access power purchase contracts were prevented from installing a ZigBee SmartMeter™ due to site contract terms and conditions with a Direct Access energy provider.

  AMI Signal Issues
  Some of the sites presented SmartMeter™ installation difficulty due to the location of the meter panel. This proves to be true for hotels and large office buildings in urban areas. The meters were often in the basement outside of reach of the AMI network signal. This presented issues for PG&E to install additional signal relay equipment and thus not within the timeframe of the project. These meter exchanges were logistically complex and outside of the scope of the core activity of the project.

- Corporate IT Network

  Availability of LAN connection
  The typical commercial SmartMeter™ was located outside and around locations overseen by facility management organizations. Many of these locations were traditionally equipped for HVAC, water, and steam meters, but not as locations with IT infrastructure. In a number of these potential sites, LAN connection was not available. Compounding the problem was the fact that the HAN device specified in this SUT required a RJ-45 Ethernet connection, as it lacked wireless LAN access capability (WiFi). The organization activity and cost investment required to install a LAN was not a viable option for many of these sites, and therefore those sites were dropped from the potential participant list.

  Security Assessment/Network Configurability
  Larger organizations had corporate IT administration with set security policies. The proposed HAN device for this project is a "residential" class device with very limited network configurability. For one, it is not capable of arbitrary PORT settings, nor able to set static IP addresses. This meant that basic security-oriented configuration settings were unable to be set by the corporate IT administration and resulted in outright rejection based on security policy.

2. Barriers to Utilization - Successful Installations

Once the final 13 participating sites were confirmed, and information collected on the installation and operations through participant interviews, it became clear that the sites separated into two sub-groups: (1) sites that were able to utilize the technology, and (2) sites that were not able to effectively use the technology. The sites with barriers to utilization had common characteristics. These being lack of methods to utilize the data and the necessary context to readily leverage real-time data.

- *Knowledge and Facilitating Tools*
  Site personnel did not possess the access to resources to leverage new data if the project was not a complete turnkey solution accompanied with training. This project did *not* give any prescriptive advice on training. This was done with specific purpose to reveal the site response to new technology. For certain sites, it became apparent fairly quickly that sufficient information was not available to the facility managers to enable them to utilize the real-time data. While motivated to oblige and cooperate to bring in the new technology of this project, facility personnel involvement did not extend beyond the initial installation tasks once the installations were done. Thus real-time data technology did not translate to tools to act on; knowhow and tools to apply the data were needed.

- *Incentives to Act*
  Once the HAN device was delivering data, some sites treated it as a novelty. While interesting, the new information did not change the behavior for these sites. Existing systems and tools were completely sufficient for the well-defined tasks site personnel were held responsible for, so there was little incentive to expand site personnels' scope of work with the newly available data. The introduction of real-time data technology did not in itself provide an incentive for action.

3. **Successful Utilization of Real-Time Data**

For those sites that were able to successfully use ZSEP1.0 AMI real-time data at their sites, several common observations can be made:

- *Integration Capability*
  While the lack of a turnkey solution acted as barrier for utilization at five of the sites, the remainder of the sites (total 8), were able to bring the real-time data source into their existing EMS tool for effective utilization. The eight sites that successfully leveraged real-time data all had active integration of the real-time data into existing EMS. The key factor for these eight sites across three customers was their ability to integrate data. This integration ability was from commercial EMS solutions that could connect to the specific HAN device data and also had software engineering support.

- *Budget and Human Resources*
  It is important to note two customers spanning seven sites had well defined resources to actively integrate and leverage real-time data. This is in contrast to the other sites, where participation in the project was opportunistic. The sites that leveraged the data were willing, able, and awaiting access for such capability. These sites immediately funded initiatives that the data could be fed into, and this more than anything resulted in full utilization of this new data stream. Most notable was abundance of personnel with skills, and well-defined budget to address issues and tasks as part of regular work responsibility for those involved.

- *Cost Factor*
  These same two customers spanning seven sites can be considered to be first movers with both human and financial resources. The cost of the ZSEP1.0 based solution was described as being clearly an attractive feature, where systems that cost $2,500 to $10,000 per location per installation can be replaced with a HAN-device solution costing a few hundred

dollars. It can be assumed that should mass adoption solutions ever become available to large commercial and industrial customers, cost sensitivity will be an important factor to technology adoption.

4.3.2.2 Qualitative Results from Specific Use Cases

For participating sites with active utilization of real-time data, the project performed follow-up interviews and discussions to understand the specific use cases of the data. The following categorized three use cases with the most impactful scenarios: Remote Site Monitoring, DR Event Response Optimization, and photovoltaic (PV) Inverter Failure Monitoring.

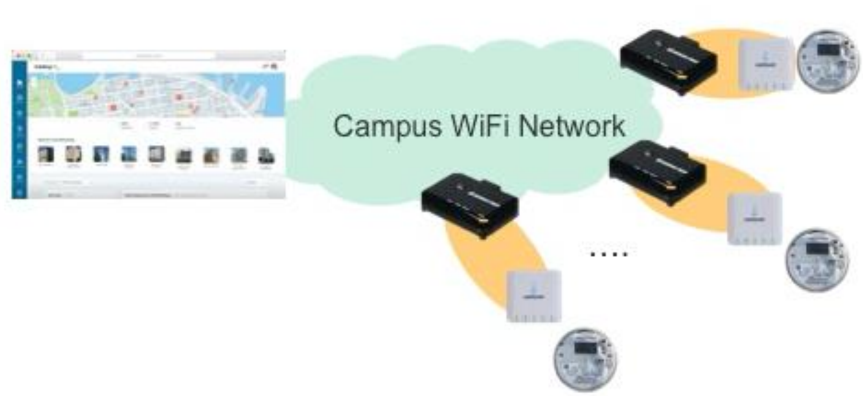
1. **Remote Monitoring**

   The six participants with site key "T-" (Table 4) were tech campus buildings managed under one facility management organization. The facility management utilized an internet based building energy management system (BEMS) from a commercial developer. The SUT HAN device was plug-in ready to the BEMS, and so this tech campus was able to channel the individual outputs of the HAN devices directly to the BEMS platform for comprehensive remote monitoring of all six project sites (Figure 5).

   The main use was centralized remote monitoring, enabling immediate action based on real-time usage data. The facility manager expressly stated that the SmartMeter™ enabled real-time data solution was a viable substitute for more expensive sub-metering systems.

   Observations:
   1) Direct avoided cost of a more expensive submetering system at more than $2500 per location.
   2) Monitoring of effectiveness of energy management and DR strategy and associated feedback.
   3) Low connectivity cost was enabled by utilizing WiFi bridge to extend a campus-wide WiFi network.

Figure 5 Remote Site Monitoring



2. Demand Response Event Optimization

One site participated in DR events on May 2nd, 2017 from 4-5pm and on May 3rd, 2017 from 3-7pm while having real-time data access from SmartMeterTM for this project (Figure 6).

May 2nd DR Event: The data from the HAN device showed that the building responded well to the DR event on May 2nd. However, due to hot weather the load recovered back after the event and created a "rebound" peak load around 6pm, implying that the HVAC system overcompensated for loss of cooling capacity during the DR event. Based on this timely feedback from the real-time data feed, the HVAC strategy was immediately changed for this building to smooth out recovery after the DR events (e.g. ramp up the A/C much more slowly) to avoid the "rebound" effect.

May 3 rd DR Event: The prior day (May 2nd) the building initially dropped load, but by 4pm the thermal load increased and all the A/C were activated again to achieve set-point before the end of the event at 7p.m. The profile for May 3 rd (second profile of Figure 6) shows that the additional HVAC control tuning kept the load down for the whole duration of the event through a pre-cooling strategy.

Note: 20 kW demand was avoided, along with associated demand charges in the second DR event through elimination of the "rebound" effect. Also it is important to note that the DR event for May 3rd, the hotter of the two days, showed a 24.2 KWh reduction compared to May 2. This modification was enabled through immediate feedback for next day HVAC DR operational strategy modification.

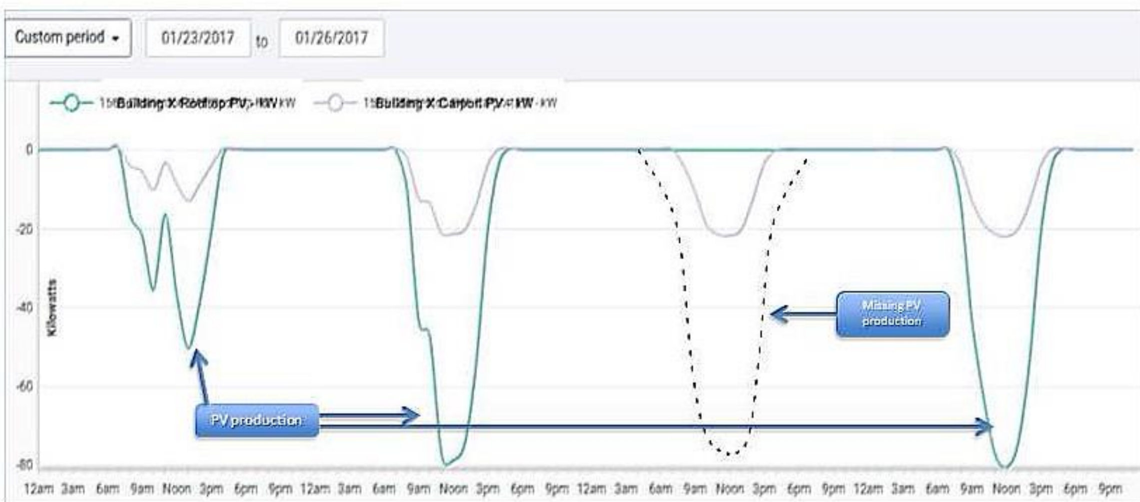
Figure 6 DR Day Demand Profile

Profile 1: May 2nd 2017; Profile 2: May 3 rd 2017

3. Incidence Monitoring: Photovoltaic Array Inverter Failure

One technology campus site was equipped with two photovoltaic solar generation systems and was being monitored using real-time data through their BEMs. The graph in Figure 7 identified that the solar panels were providing no output starting at 8am on January 25th, 2017 showing that the central inverter had failed. A technician crew was dispatched based on quick detection of the incidence through real-time HAN data to repair the system, which may have taken longer to detect without HAN, directly impacting demand and energy costs. The immediate response enabled limiting production loss to 387 KWh on January 25th, 2017, equating to about $58 of lost production for every day the maintenance issue would have gone undetected.

Figure 7 Detection of Solar Inverter Fault



The above three use cases 1) Remote Site monitoring, 2) DR Event Optimization, and 3) Incidence Monitoring show us "real-time" actionable data can mean latency measured in minutes to be sufficiently useful and appropriate for these applications, and it appears that lower resolution of interval data (seconds) would not provide added value in these scenarios.

4.3.3 Quantitative Analysis

General Methodology

Beyond the qualitative observations and results, PG&E's back-end system records interval data for each site through the SmartMeter™ (typically usage, at kWh, every fifteen minutes). This metered data was combined with local temperature data from the customer to normalize and correlate pre and post operation of the HAN. This was done to evaluate possible impacts of the use-cases achieved through real-time AMI data introduction.

The time of day, date, and weather conditions were used to separate site data into comparable groupings and five temperature ranges: Very Cold, Cold, Average, Warm, Hot. Furthermore, PRE/POST project installation analysis showed that seven sites recognized the same or lower normalized usage this season as shown in Table 6. This data, combined with qualitative results, showed two sites that were able to actively utilize real-time data to verify and quantify the benefits of the energy efficiency strategy implemented.

Table 6 Project Site Average Energy Use Results for weather when POST compared with PRE

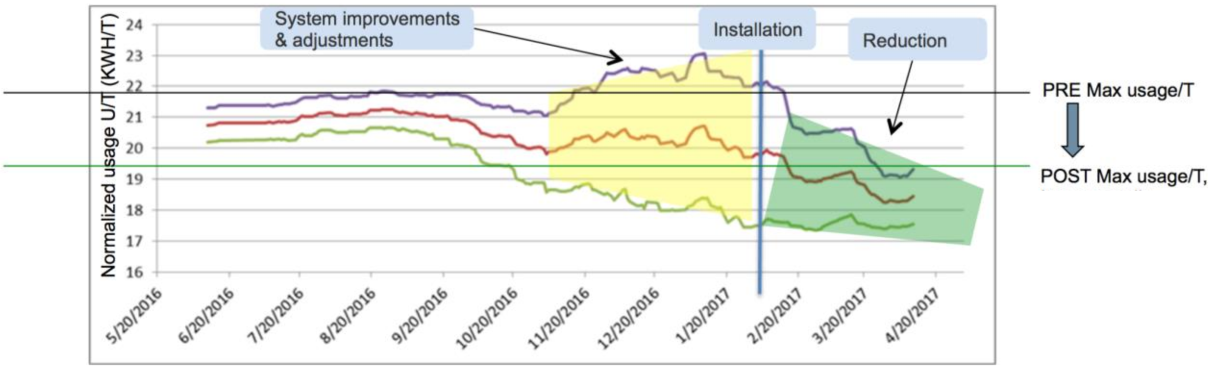
Key	Hot	Warm	Average	Cold	Very Cold	Overall
CM – 1	LOWER	LOWER	LOWER	LOWER	LOWER	LOWER
GOV – 1	LOWER	LOWER	LOWER	LOWER	LOWER	LOWER
CM – 2	LOWER	LOWER	LOWER	LOWER	LOWER	LOWER
T – 6 NEMS	UNKNOWN	LOWER	UNKNOWN	UNKNOWN	UNKNOWN	UNKNOWN
T – 1 NEMS	UNKNOWN	UNKNOWN	UNKNOWN	UNKNOWN	UNKNOWN	UNKNOWN
T – 3 NEMS	LOWER	LOWER	LOWER	LOWER	LOWER	LOWER
SM – 1	HIGHER	HIGHER	HIGHER	HIGHER	LOWER	HIGHER
T – 4	HIGHER	HIGHER	HIGHER	HIGHER	HIGHER	HGIER
T – 5 NEMS	LOWER	LOWER	LOWER	LOWER	LOWER	LOWER
CM – 3	UNKNOWN	LOWER	UNKNOWN	HIGHER	HIGHER	HIGHER
T – 2	LOWER	LOWER	LOWER	LOWER	LOWER	LOWER
SM – 2	LOWER	HIGHER	HIGHER	LOWER	LOWER	LOWER
SCH – 1	INCONCLUSIVE	INCONCLUSIVE	INCONCLUSIVE	INCONCLUSIVE	INCONCLUSIVE	INCONCLUSIVE

Moving Average of Usage to Temperature Ratio

Sites that leveraged real-time data were analyzed in detail to follow the change between pre and post HAN integration into the customer's BMS. Based on the two sites (T-2 and SM-2) that were able to leverage real-time data, the results showed that: (1) intervention drives temperature usage dependency away from a strict proportional relationship, and (2) the benefit was highly dependent on the actual intervention involved.

Figure 8 shows a systematic reduction in energy consumption had occurred after installation for Site T-2. The peak consumption prior to this date was roughly 23 kW/degrees Fahrenheit (degF) and reduced linearly to 19 kW/degF afterwards. This coincidental data may point to a cause-effect relationship. It is believed that the decline in u/t ratio was a result of incremental improvements made by the facility over time to lower building energy consumption, but this was not supported by the qualitative customer surveys. However, as factual evidence to support this data, customer interviews revealed that Site T-2 implemented an LED lighting system at this time. Additionally, the facility management team commented that the data availability helped validate energy efficiency strategies and LED based savings immediately.

Figure 8 Pre-Post Energy Usage Comparison through Real-time Data



Range of Values, rolling window of 30 days compared against kW/Temp site for T-2

Figure 8 Key

- Blue: maximum value of a 30-day running window, centered on day of interest
- Red: average over 30-day running window, centered on day of interest
- Green: minimum value of a 30-day running window, centered on day of interest

Qualitative and Quantitative Summary

In summary, three high value use cases were observed at participating sites that were able to utilize real-time data: multi-site monitoring, incidence monitoring, and event optimization. Additionally the system may be important for measurement and verification activities. The former three use cases were derived from direct observation and the latter was demonstrated through quantitative data analysis.

5.0 Value proposition

The purpose of EPIC funding is to support investments in technology demonstration and deployment projects that benefit investor owned utility customers. This project has demonstrated a commercial scale deployment of SmartMeter™ real-time data to commercial customer meets both primary and secondary EPIC principles, subject to certain conditions made clear in this report.

5.1 Primary Principle

The primary and mandatory EPIC Program guiding principle for this project is affordability. The project objectives addressed the beneficial use of real-time AMI data to customer Demand-Side Management (DSM). The technology presented in this project offers an affordable option to maximize DSM once installation requirements are met.

Payback periods will necessarily vary by site. As discussed in this report, some sites required modification or adaption to implement real-time data feeds, while other sites required a greater investment in time and resources to integrate the data into their EMS. The greatest benefits are likely to accrue where multiple locations are under a single EMS. In these cases this technology solution avoids submetering (4.3.2 Results and Observations) costs estimated to exceed $2,500 per instance. The energy savings from implementing this technology would be calculated on a site specific basis.

5.2 Secondary Principles

Flowing directly from adherence to the Primary Principles, three of EPIC's set of complementary Secondary Principles are achieved:

1. Societal benefit: this project demonstrated that LC&I customers can increase their efficient use of energy. The commercial development and deployment of this technology is expected to improve demand side management opportunities for commercial and industrial ratepayers.

2. Greenhouse Gas (GHG) emission reduction: This project has shown real-time data directly enabled intervention actions related to quick PV system failure detection and recovery, and modification to DR strategy during DR event period (site T-2). These two interventions can lead to reduction in GHG gas emissions through lower energy usage and increase up-time of renewable energy resources.

3. Efficient use of ratepayer monies: This project leveraged the infrastructure built for residential SmartMeter™, and applied the same technology to LC&I customers. Development of a commercial turn-key technology solution in conjunction with commercial SmartMeter™ installations would be the preferred method to provide this capability.

6 Accomplishments and Recommendations

This project was an initial investigation into the applications and integration of real-time data delivered directly from SmartMeters™ to LC&I customer sites. Beyond specific laboratory verification results, customer perspectives and realistic technology adoption factors have been revealed. The following summarizes the key accomplishments and recommendations.

6.1 Key Findings

The key findings from this project demonstrated the potential value this technology has to commercial customers, and pointed out key barriers to deployment that will need to be overcome as part of any commercial product development process:

<u>Key Finding 1: HAN devices provide accurate readings of commercial meters.</u>
HAN devices were determined to provide accurate real-time readings of commercial site SmartMeter™ models with ZSEP1.0 functionality once site specific multiple values were applied. Without these multiplier values the real-time data readings were not their true values.

<u>Key Finding 2: Effective installation of this technology required site-specific modifications.</u>
There were significant Installation and integration issues in the deployment and implementation of the HAN technology at participating customer sites. Installation difficulties centered around LAN networking issues as well as with the availability of software drivers to allow data to be integrated into the facilities existing energy management systems.

<u>Key Finding 3: Some commercial customers had significant barriers to adopting this technology.</u>
These barriers include:

1. Direct Access contractual obligations: a meter in a DA contract could not be swapped out for a SmartMeter™.

2. Meter swap logistics: Work scheduling and downtime required for meter swap during business hours presented a problem for sites with need for constant availability of power.
3. Signal Connectivity: Meter location, in some instances, made it difficult to connect to the AMI network of the SmartMeter™ if it were to be substituted.
4. IT security policies and network configuration setup requirements to connect ZSEP1.0 and the HAN device presented problems for inclusion into customer LAN networks.

Key Finding 4: Lack of customer experience and analysis tools limited full use of real-time data.
Currently the market can be characterized as "early" in that real-time AMI data ZSEP1.0 devices for the commercial customer segment do not exist. It is not likely analysis tools will be available until commercially viable data delivery solutions are available. As a result, users required additional training to leverage the data. But even with additional training there is a lack of incentive in some cases to devote the time to use the data without supporting analytical tools.

Key Finding 5: Integration of real-time data into an EMS requires IT investment.
Integration of data into existing EMS required configuration changes and software work that often were beyond the skillset of the facility manager.

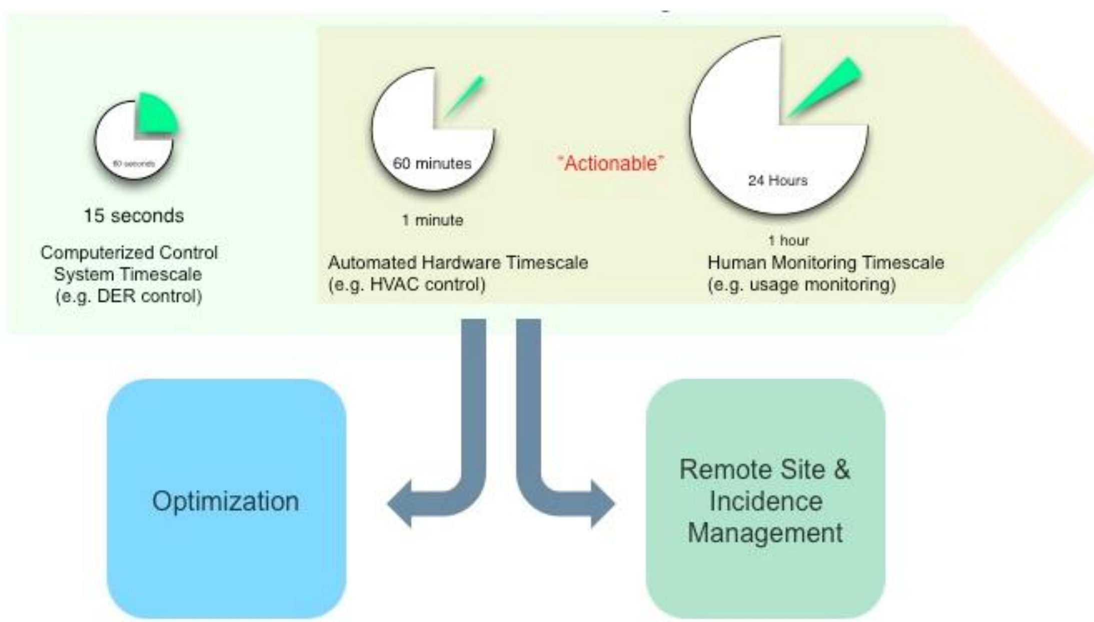
Key Finding 6: The HAN device for large commercial operations poses integration barriers
While the HAN device was linked to the SmartMeter™, its limitations appeared on the customer site, resulting in:

1. Too few locations where it could be installed in some circumstances
2. Physical installation problems
3. Customer system integration barriers
4. Customers unwilling to overcome the operational complexity

Key Finding 7: The real value of real-time AMI data can be realized with longer timescales. Currently, the SmartMeter™ is capable of delivering meter demand every 15 seconds to a ZSEP1.0 device. This project has shown that three observed use cases did not require a low resolution of interval data. In fact minute the data showed that 1 minute intervals were sufficient for the use cases exhibited in this report. According to customer interviews, the need for 15 second real-time data is necessary only when DER control system integration is required or retro-commissioning activities are pursued. The actionable data enables two categories of benefits, as shown below in

Figure **9**.

Figure 9 Use case Timescales for ZSEP1.0 AMI Data



Overall, the technology was identified as valuable to customer demand side energy management. However the technology limitations will require further vendor development before the technology can be adopted at large scale. Sites reported access to real-time energy enabled them to:

- Remotely monitor site energy usage
- Detect incidents and unusual activity
- Optimize demand response event recovery
- Determine efficacy of a demand response strategy
- Adjust energy efficiency activity and installations

6.2 Key Recommendations

Key recommendations all relate to commercial development of a ZSEP1.0 compliant product that large commercial customers can easily and simply install on their networks and EMS.

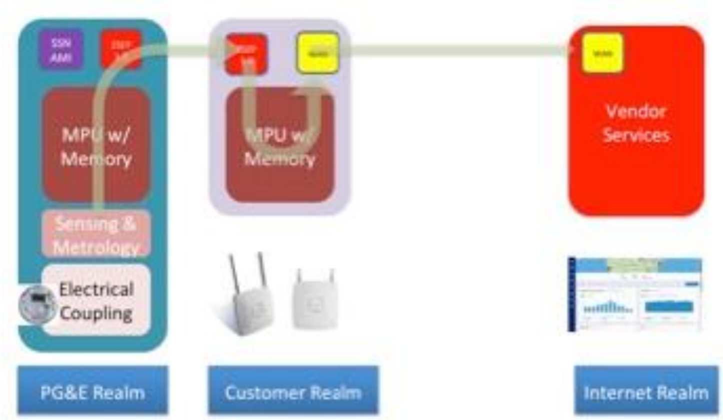
Recommendation 1: Develop a commercial turnkey product conforming to the ZSEP1.0 standard.

As the limited number of capable site implementers in this project suggests, a more "turnkey" technological approach for commercial customers to access real-time data is needed (rather than a drop shipment of the current HAN device with supporting documentation) in order for more sites to be able to install and utilize the real-time usage data. It was clear site energy managers require simple, straightforward access to the data.

Recommendation 2: Enable the turnkey product to use a WAN connection where a ZSEP1.0 compliant driver to EMS is available.

Commercial customers that have an embedded ZSEP1.0 driver EMS would benefit from having a commercial turnkey product to connect to the WAN. This will reduce the real-time data access complexity by eliminating the LAN element within the consumer realm, and instead provide a direct ZigBee-to-WAN capability on the ZSEP1.0 device as shown in Figure 10. The results of this project suggest that reduction of complexity is of paramount importance to achieve greater adoption.

Figure 10 Simplified technology for ZSEP1.0 AMI Data



Recommendation 3: Bundle marketing of the commercial turnkey product with use models and education.

Turnkey technology installation and integration will still be challenging when one introduces new capability such as real-time data delivery to site managers. The technology will require bundling with characterization of specific real-time data usage and analysis models to aid users to assess impact it may have on their energy management results. Product marketing and delivery to commercial customers should be bundled with support in the form of:

1. Model cost-benefit analysis to demonstrate the value and payback potential from real-time energy use monitoring.
2. Information as to how customer networks will not be compromised by the product.
3. An analytical tool to manage the volume of data (for customers without an EMS).

7 Technology Transfer Plan

7.1 IOU's technology transfer plans

A primary benefit of the EPIC program is the technology and knowledge sharing that occurs across all investor-owned utilities (IOU), the CEC and the industry. In order to facilitate this knowledge sharing, PG&E will share the results of this project in industry workshops and through public reports published on the PG&E website. Specifically, below are information sharing forums where some of the results and lessons learned from this EPIC project were presented:

Information Sharing Forums Held

- *Emerging Technologies Coordinating Council, TRIO Symposium and Roundtable: Technology Innovation and Utility Engagement*
  PG&E Pacific Energy Center, 851 Howard Street, San Francisco, CA | June 9, 2017
- *Webinar on the results of EPIC 2.21, held September 14, 2017 with SCE and SDG&E*

7.2 Adaptability to other Utilities and Industry

The real-time data available via the ZSEP1.0 network from the SmartMeter™ is a common technical scenario for all IOU in California and many utilities in the U.S. The results of this project are therefore applicable to all those utilities with ZSEP1.0 enabled SmartMeter™ models. Furthermore, the solution vendors serving the specific functionality of ZSEP1.0 connectability all are national and international companies that serve multiple markets. As such the issues presented in this project exist equally in other markets, and therefore the present results are understood to be applicable to other utilities nationally and internationally.

This project suggests that access to a turnkey solution for real-time AMI data is important to customers. PG&E encourages industry to develop turn-key solutions in an effort to support higher adoption rates of real-time data to enable customer energy efficiency. Such solutions will address the barriers and key findings communicated in this report.

8 Data Access

Upon request, PG&E will provide access to data collected that is consistent with the CPUC's data access requirements for EPIC data and results.

9 Metrics

The following metrics were identified for this project and included in PG&E's EPIC Annual Report as potential metrics to measure project benefits at full scale. Given the proof of concept nature of this EPIC project, these metrics are forward looking.

Table 7 Proposed Metrics and Potential Areas of Measurement

D.13-11-025, Attachment 4. List of Proposed Metrics and Potential Areas of Measurement (as applicable to a specific project or investment area)	Reference
1. Potential energy and cost savings	
e. Peak load reduction (MW) from summer and winter programs	4.3.2.2
f. Avoided customer energy use (kWh saved)	4.3.2.2
h. Customer bill savings (dollars saved)	4.3.2.2
3. Economic benefits	
b. Maintain / Reduce capital costs	4.3.2.2
4. Environmental benefits	
a. GHG emissions reductions (MMTCO2e)	4.3.2.2
7. Identification of barriers or issues resolved that prevented widespread deployment of technology or strategy	
b. Increased use of cost-effective digital information and control technology to improve reliability, security, and efficiency of the electric grid (PU Code § 8360)	4.3.2.1, 6.2

10 Conclusion

ZigBee SEP1.0 HAN devices work *in the same way in LC&I ZigBee enabled meters as for RESI ZigBee enabled meters.* Laboratory tests verified actual load amount (with multiplier applied) matched ZigBee device's value within an observed 1% difference.

Overall, the technology was identified as valuable to customer demand side energy management and beneficial to grid reliability efforts through demand response. The use cases in this technology demonstration showed that LC&I customers can gain insight into their peak demand usage to develop and optimize DR strategies to participate in utility curtailment programs and events. Additionally, ZigBee enabled meters enabled customers to increase up-time of solar power generation through inverter fault detection. Despite these positive attributes of real-time data, the technology limitations necessitate vendor-driven development before the technology can be adopted at large scale. There are also barriers related to adoption and customer education required to see real-time ZigBee SEP1.0 HAN devices effectively adopted at a larger scale. These barriers include:

Adoption

- Customers with Direct Access contracts do not have ZigBee enabled SM and could not participate because the DA entity manages access to the meter reconfiguration.
- Facilities had authorization and logistic complexities. Either meters could not be replaced with ZigBee-based meters, or customer IT security approval hindered introduction of HAN devices into an internal corporate IT network.

Integration

- Process Takes Time: Calibrating HAN software to meter value (multiplier) requires customers to obtain site specific values from PG&E and confirm that these values accurately reflected the energy consumed (13/13 sites).
- Physical Installation Limitations: Physical barriers had to be overcome to install HAN device, e.g., RJ-45 Ethernet receptacle with a power source close to meter. A low cost Wi-Fi bridge rectifies this issue if Wi-Fi is available.
- Technical Know-How: Customers did not have the technical understanding of the requirements to integrate real-time data (i.e., drivers, EMS) or have the financial resources (i.e., engineering support to develop drivers, installation of an EMS) to interconnect ZigBee SEP1.0 HAN-based real-time data system. This resulted in poor utilization for sites that could not make this connection.

Utilization

- Customer interest in real-time data access was low without EMS connection.
- Customers who were unable to integrate ZigBee data into their EMS (e.g., due to lack of drivers) resulted in using the HAN default data visualization services. These minimum visualization services of the HAN based-functionality had limited usefulness.

Recommendations that would see the technology move towards commercial readiness are:

- Develop a commercial turnkey product conforming to the ZSEP1.0 standard.
- Enable the turnkey product to a use a WAN connection where a ZSEP1.0 compliant driver to EMS is available.
- Bundle marketing of the commercial turnkey product with use models and education.

As a result of this Project, PG&E will promote the findings within the vendor solution companies and other utilities, to help define a more readily adoptable large commercial and industrial real-time data solution utilizing the SmartMeter™.

Appendix A: Data Analysis & Technology Overview

The following section summarizes the quantitative analysis performed on the interval-based AMI[13] data for comparison to potential observables due to installation of HAN devices, along with description of the relevant technologies involved.

A1.1 Quantitative Analysis

Refer to Table 4 for the list of participants.

Data was analyzed together with available weather data. Analysis of average usage range over 9:00-17:00 for each temperature range relevant for each site where compared for PRE/POST, using boundary conditions for characterizing the behavior of each site, where UB: upper bounds, LB: lower bounds of usage, and indicate POST. The results indicate the in general, a majority of the sites showed energy usage reduction, as shown in Table 6.

A1.2 Regression Analysis

The sites were then examined for dependency of usage to temperature, based on a simple proportionality model. The R-squared value for each point was used to evaluate the fit of the behavior to a linear model assumption. The ranges of R-squared values were divided into three ranges (0 to 0.39 light red, 0.4-0.69 pink, 0.7-1.0 light green). Upon comparison of Pre to POST period, more sites became temperature independent within the POST period. Of the sites whose 15 minute interval data were examined, sites SM-2 and T2 showed most changes. Their R-squared values are given below in Table.

Table 8 Distance from linear fit / measurement of temperature dependence

Before (PRE) and After (POST) installation of Real-Time data device

Site (BEFORE)	R squared Value (0 ~ 1)	Site (AFTER)	R squared Value (0 ~ 1)
T – 2	0.76	T – 2	0.09
SM – 2	0.96	SM – 2	0.73

A1.3 Temperature-Independent Moving Average Analysis

Figure 8, represents a compilation of the usage-to-temperature for one project site (weekends & holidays removed). A number of the sites had shown proportional dependency of usage to temperature over the span of the project timeline, and thus the electrical usage was largely dependent on the HVAC system. In order to discern systematic changes in energy management distinct from HVAC operation, a monthly (30-day) moving average analysis was performed for four (out of thirteen) sites with clear u/t ratio relationship based on PRE measured values. Furthermore for these sites, the standard deviation calculation of the PRE / POST installation date was performed and compared with daily measured u/t ratios to identify system improvements. One site (T-2) exhibited clear measured difference in u/t ratio as seen by significant change in the ratio based on standard deviation spread (i.e., the measured impact is discernable and real). The other three sites did not yield discernable change in PRE/POST u/t ratio as judged from moving average standard deviations. The change in the

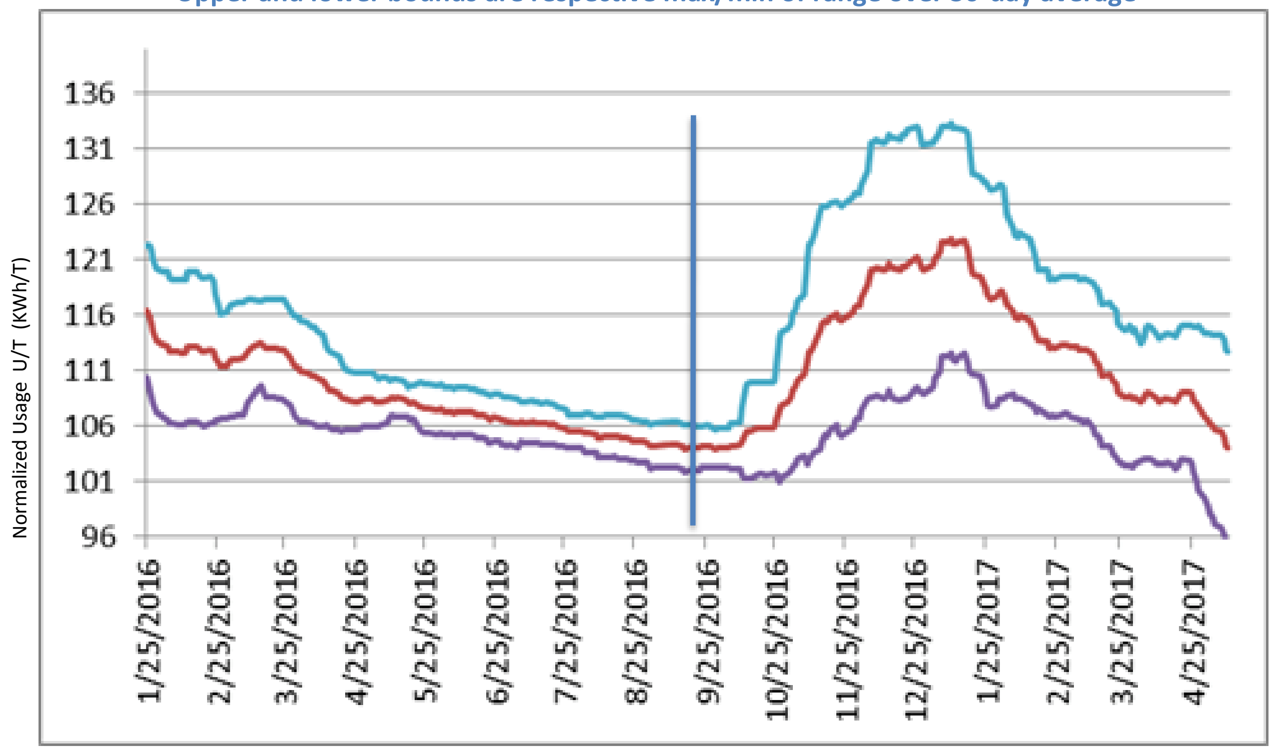
[13] AMI = Advanced Metering Infrastructure.

u/t ratio indicates that a systematic factor other than existing HVAC operation is effective to reduce energy consumption.

As factual evidence to support the data, customer interview has revealed that Site T-2 implemented an LED lighting system about the same time as the real-time data enablement; hence the reduction in u/t ratio is clear, though the relative impact and interaction of LED lighting vs. real-time data based intervention cannot be separated; suffice to say, *the facility management has commented that the data availability helped validate energy efficiency strategies and LED based savings immediately*.

In comparison, the u/t ratio for site SM – 2 is shown as moving average over 30 days in Figure 11. The installation date is 9/21/2017. There is a marked increase in variability of the u/t ratio in the POST period. For this site, installation of real-time data capability was part of an activation of a real-time control system based on even finer time interval than 15 seconds. The impact of the active control can be seen by the increase in variability of the usage per temperature. There is increase in usage for temperature range between 54.47-62.01 degrees Fahrenheit for this location. As the system got optimized, a general downward trend of the u/t ratio became dominant.

Figure 11 Usage vs. Temperature u/t ratio SM-2
Upper and lower bounds are respective max/min of range over 30-day average



Graph of 30 day moving average for site SM-2
Vertical line is placement of HAN device at 2016/9/21
uncertainty given by upper and lower graphs

A1.4 Specific Incidence Analysis

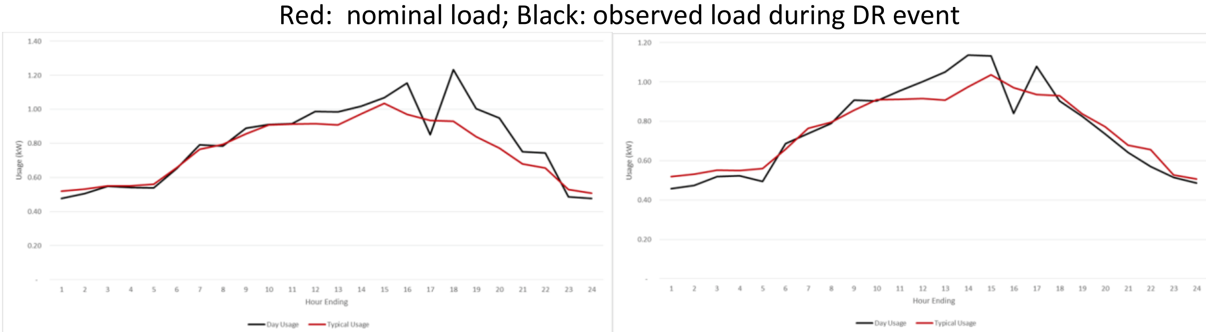
Beyond the general observables from the interval data over the period of the Project, notable use case events have been recorded for specific site and incidents, and this affords opportunity to examine the quantitative impact of the events. In section 4.3.2.2, two Tech campus sites exhibited incidents that are examined here.

Site T-2 Demand Response Event

The DR events of May 2nd, 2017 and May 3rd, 2017 were captured both with the real-time data HAN device and AMI interval data. Based on the interval data, the following impact graphs Figure 12 were obtained for the two days. The HVAC rebound is eliminated on the second day. The quantitative impact benefit is given as 24.2 KWh reduction from May 2nd to May 3rd.

Figure 12 May 2 and May 3 DR event

Red: nominal load; Black: observed load during DR event

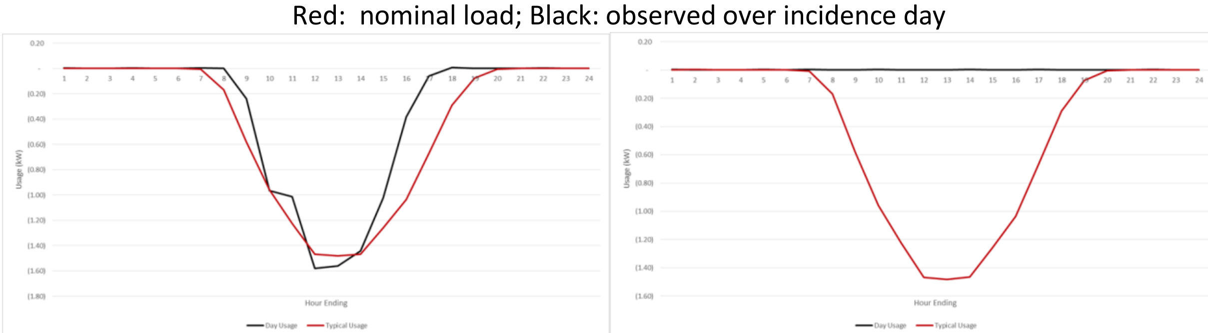


Site T-1 PV Inverter Failure Event

The PV inverter failed on January 24th, 2017, and based on the event and remedy, the system was back up on January 25th, 2017. The interval data Figure 13 captures the lost PV production volume over the 24 hour period. The lost capacity translates to 387 kWh at the cost of $58.

Figure 13 PV Inverter Failure

Red: nominal load; Black: observed over incidence day



A1.5 Conclusions of Data analysis

The interval data from the Project yielded just a few sites with unambiguous data when observing the u/t ratio and average usage over time. Based on a selection of those Project sites, data showed clear effects. However, the installation of real-time capability coincided with overlapping initiatives on those sites and thus the pure impact of availability of real-time data could not be known under the conditions of the Project as it lacked a control group. However, the initiatives did involve real-time data capabilities and thus we can say that there is obvious impact; as to whether there is net benefit or not, the scope and breadth of data obtained for the quantitative data analysis was not suited to address those questions.

Figure 8 and Figure 11 show different effects of real-time capability. Unfortunately a general and consistent quantitative net benefit impact cannot be associated at this point due to lack of sites, examined time, and operational differences. Nevertheless, the impacts may be described in two parts: (1) change in R-squared of linear regression modeling away from a direct proportionality of usage to temperature, and (2) systematic change in the consumption of energy, where in the case of T-2, it is lower, and for SM-2, the usage grows over a period. Both impacts are beyond one standard deviation from the measured data and therefore suggests a systematic real effect; post installation intervention methods used differ between the two sites and thus for T-2 results arrive at the desired outcome, whereas for SM-2, the optimization is a continuing effort to this day.

Lastly, specific incident results show that real-time data has efficacy in terms of initiating immediate corrective action. The impact cannot be generalized; however the monetary benefit is clear and characteristic of individual fault or problem occurrences and the opportunity and optimization costs involved. For the two observed incidences, the monetary benefits are clear to the LC&I customer and as calculated in A1.4.

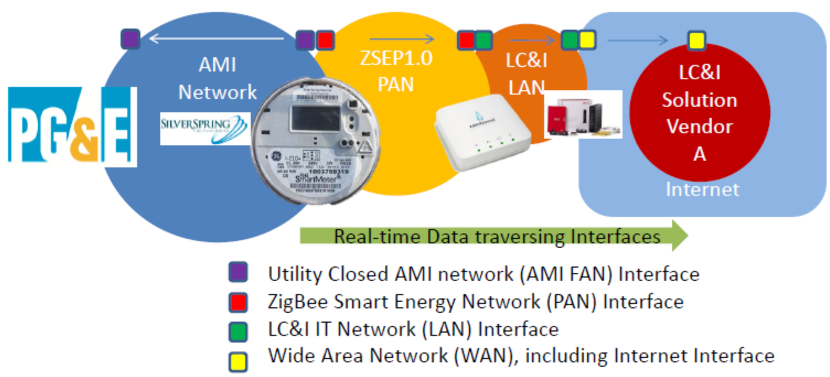
Appendix B: Technology Overview

In this Project we examine the real-time SmartMeter™ data delivery technology to assess some of the important features needed for data delivery to LC&I customer environments. The descriptions below gives an overview of the technology involved. The particular use case under evaluation is enablement of the real-time electrical usage data from SmartMeters™ to on-site systems and Internet-based systems for the benefit of our LC&I customers.

B1.1 Managing Complexity: Inter-Networking the Real-time Data to deliver Value

Many new energy solution providers also deliver their service over the Internet. Hence the more real-time data can be delivered to an Internet-based service, the more useful and valuable that data becomes. Time and again, customer interviews reveal the high expectations for availability of real-time energy data. In this Project, we examined the technological factors that need considering in order for the data to reach is maximum potential. The figure below depicts the different realms a data must traverse in order to reach the Internet.

Figure 14 Traversing Network Realms



Each network access is shown as an interface, as in the colored boxes of Figure 14. The SmartMeter™ creates its own network based on ZigBee Smart Energy Profile 1.0 Personal Area Network (ZSEP1.0 PAN), and in order to join that network, a ZSEP1.0 Network interface (red box) is needed in a LC&I customer device. This is a wireless module with an embedded microcontroller (typically a 16-bit RISC or 32-bit ARM CortexM0 or better) running a full communication software stack based on ZigBee Pro/2007 specification with the ZSEP1.0 application. Multiple semiconductor chip vendors provide solutions for embedded microcontrollers, and major wireless module makers manufacture a solution that is capable of connecting to ZSEP1.0 equipped SmartMeters™.

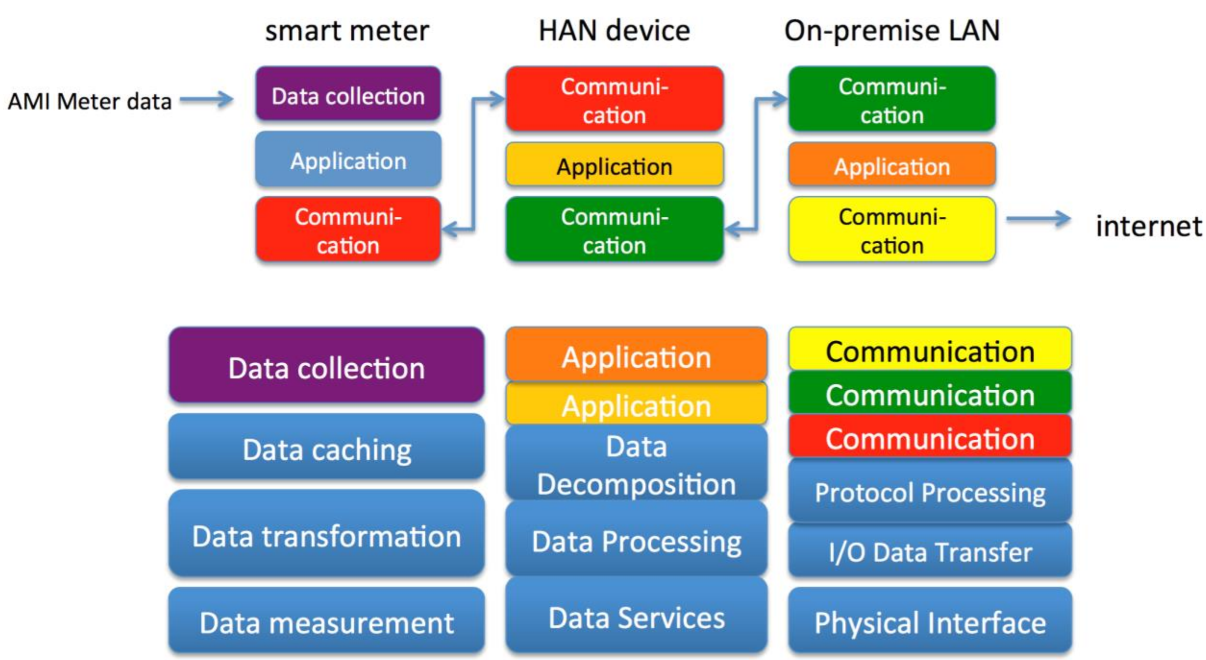
In order for the real-time usage data to be used by an Internet-based energy solution provider, the ZSEP1.0 data must be transported onto the Internet. This is accomplished by a number of device vendors using a ZSEP1.0 PAN-to-LAN gateway device (typically a "HAN device" – Home Area Network device). A LAN interface (green box) function on a gateway device, can take the data after converting into a vendor specific format, and provide that data onto the Internet via a wide area network interface (yellow) by handling the data through typically a cable or DSL modem, and sometimes a 3G/4G cellular data connection.

B1.2 Technology Stack

To help clarify the breadth of technology involved in delivering data to on premise and Internet-based services, it is instructive to explore the *technology stack* Figure 15 involved to take the data from the SmartMeter^{TM} onto an on-site system or an Internet-based system.

AMI meter data is collected on the left with the SmartMeter^{TM}, and through the ZSEP1.0 communication interface, data is transferred to the HAN device, represented by the middle stack. The data on the HAN device is then transferred to the on premise LAN system and on to the internet. Note that there are numerous technologies involved at each stage of the communication of the AMI data.

Figure 15 Technology Stack



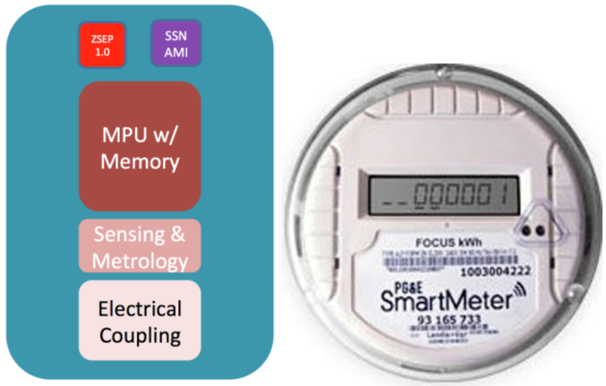
Data collection involves at minimum, data measurement and drawing data from the meter metrology. Data requires local caching within the SmartMeter^{TM}, and then it is queued to be transformed using ZSEP1.0 data model, to send to the HAN device. Applications for the SmartMeter^{TM}, HAN device, and LAN access point/router differ but in general have common functions: data decomposition of the data model in use, data processing to draw value from the transferred data, and data services such as communication API to further transfer data to other applications. Finally, the communications protocol differs at each stage. At the SmartMeter^{TM}, the AMI data is transferred to HAN device using the Institute of Electrical and Electronic Engineers (IEEE) 802.15.4 and ZigBee Pro NWK transport, while the HAN device relays the data in its own data model using XML over HTTP to a server on the WAN. Therefore each stage has its own protocol processing to handle the handshake messaging, transfer the datagram to the I/O buffer, and send off the binary data over wired and wireless physical layers.

The following sections touch on individual components of the technology stack.

SmartMeter^{TM}

A PG&E SmartMeter^{TM} is a solid state measurement and communication device. A simplified block diagram below illustrates the major systems of the meter, Figure 16.

Figure 16 Hardware configuration of a SmartMeter^{TM}

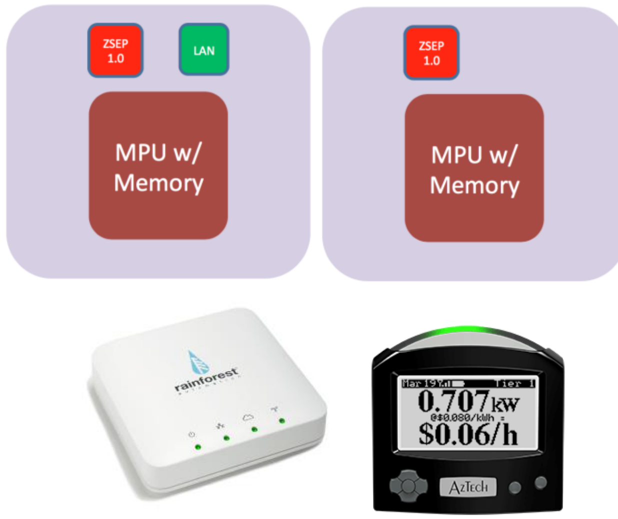


The PG&E's SmartMeter^{TM} contains two communications components, both enabling wireless communications. The "SSN AMI" function of Figure 16 is the main communication module to allow the SmartMeter^{TM} to be individual nodes that communicate with the Silver Spring Network (SSN) advanced metering infrastructure (AMI), a type of a Field Area Network (FAN); the nodes are wirelessly meshed to carry IPv6 packets to/from onto the aggregation points, and to the utility head end system. The meters can be read up to frequency of once every 15 minutes; meter metrology delivers usage data with granularity of every 60 minutes for residential, and 15 minutes for LC&I customers. The SSN wireless mesh operates in the 902-928 MHz Industrial, Science and Medical (ISM) band using its own radio and has communication range of over several kilometers. The other communication module, designated "ZSEP1.0" is a short range wireless module in the 2405-2485 MHz ISM band and has a range of about thirty meters. The SmartMeter^{TM} metrology can deliver a usage reading once every 15 seconds to the ZSEP1.0 module over the Personal Area Network (PAN) it forms. This Project concentrates on utilizing the capabilities of the ZSEP1.0 module for LC&I customers.

HAN Device

The SmartMeter^{TM} ZSEP1.0 modules communicate with what are commonly referred to as "HAN" devices. HAN stands for "Home Area Network" but in fact any device that conforms to ZSEP1.0 can communicate with the SmartMeter^{TM} ZSEP1.0 module, not just home/residentially oriented technologies. The simplified diagram below shows the basic configuration of a HAN device, Figure 17.

Figure 17 Hardware configuration of HAN devices



HAN devices are self-contained communicating computing devices; there are two main types: ones that connect onto the PAN of ZSEP1.0 and also on to an on premise Local Area Network (LAN), and another that only communicates exclusively within the ZSEP1.0 network. The former can also be described as “gateway” devices, in that it functions as an access point to transfer information from the ZSEP1.0 PAN onto the LAN network. Once the information is on the LAN (usually an IPv4 Ethernet based network that connects to the Internet), the data obtained is available for use in a variety of systems and services that exist on the Internet over wide area network (WAN). A typical HAN gateway device is used in this Project, while devices such as an In-Home Display can show the electrical consumption on a tabletop liquid-crystal display device.

B1.3 LC&I Customer On-premise LAN

Each customer site has existing corporate LAN network with its security policies and required set-up for network access. Typically these relate to suitability of HAN device LAN interface, thereby setting network mask values, static IP address, and port assignments.

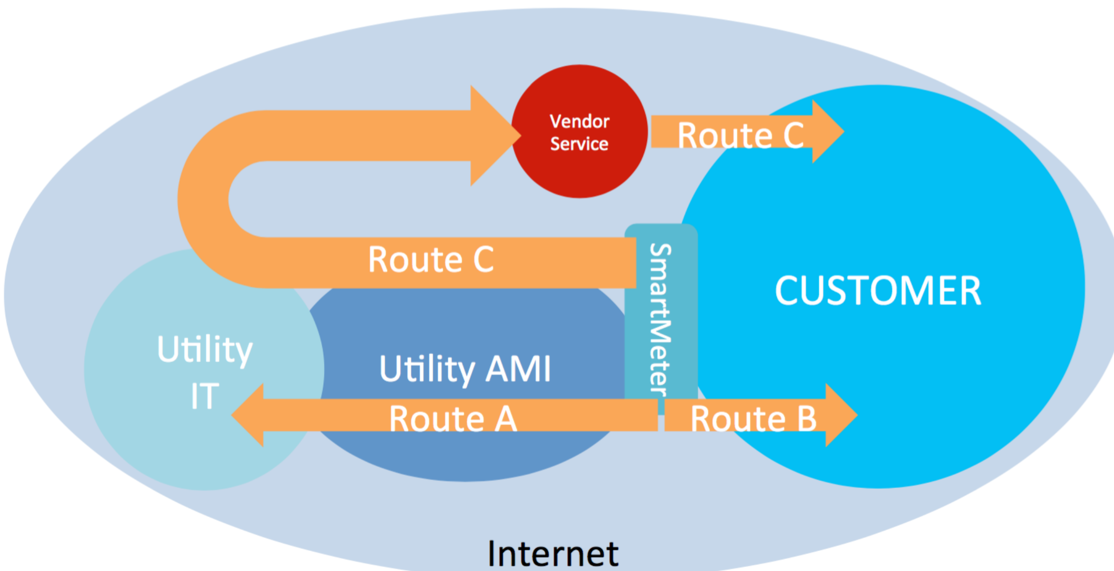
AMI Data routes

In general SmartMeter™ based systems can have three routes to extract and deliver electrical usage data to external parties.Table 9 and Figure 18 below shows the three routes and how PG&E implements the routes with data platform services.

Table 9 AMI Data routes

Route Name	Description	Utility Asset	PG&E implementation
Route A	SmartMeter™ to head end data delivery via AMI	AMI network	Vendor-specific proprietary network, usage data service through back end and onto PG&E databases for residential and LC&I customers.
Route B	SmartMeter™ to customer premise data delivery	Meter direct	ZigBee SEP1.0 service through "Stream My Data"
Route C	SmartMeter™ data delivered to customer through Internet (using Route A)	Back-end to Internet	Green Button Connect service through "Share My Data", "Download My Data" and "Green Button Download" for file downloads.

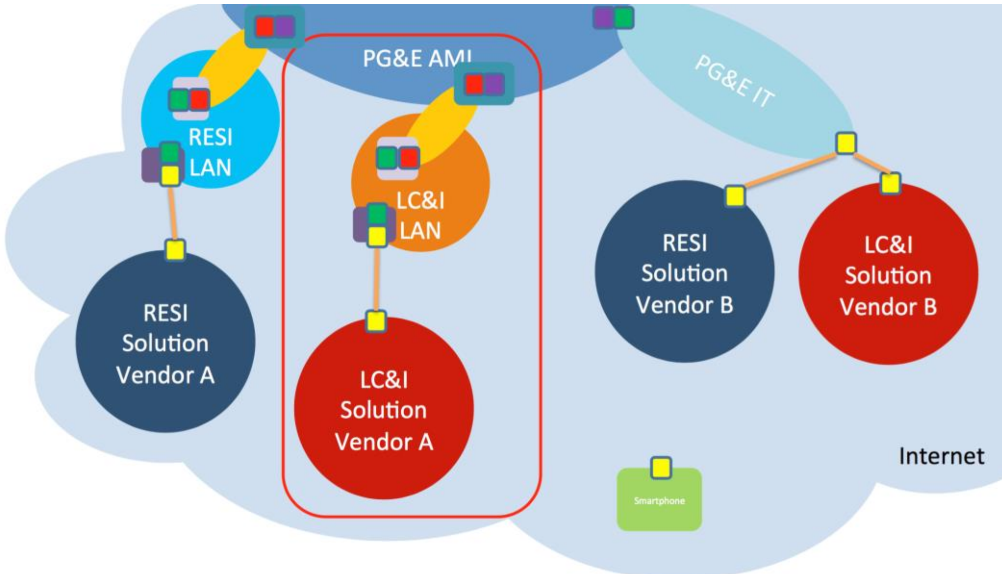
Figure 18 Three Routes of AMI Data



AMI Data related Network Zones

The diagram below illustrates the actual networks that the AMI data travels through the interfaces; the routes are enabled by the network interfaces within the SmartMeter™ or the HAN device as illustrated by the red, green, yellow and purple boxes. The network zones are shown in relation to the network interfaces that access the networks; these interfaces are present in Figure 19 and represent SSN, ZSEP1.0, and LAN modules enable the data to pass into the various networks available at the customer site, or utility AMI.

Figure 19 LC&I Network Interconnect Scope

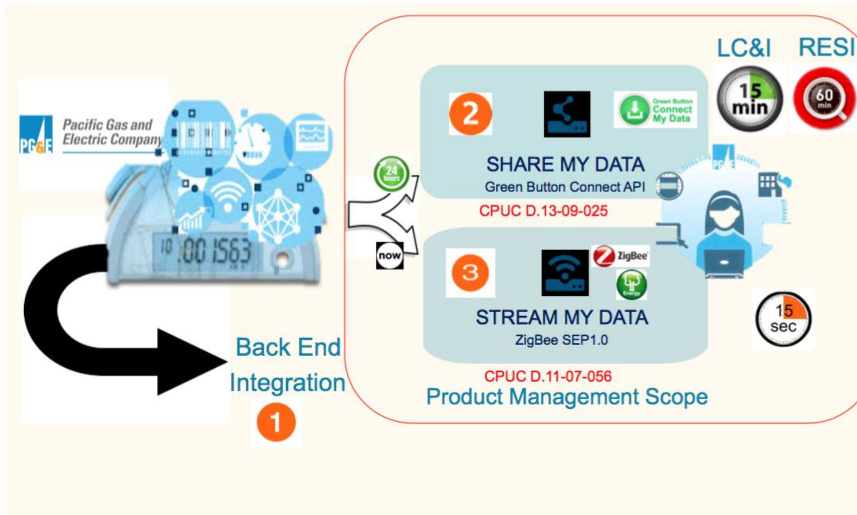


Note that Interface (I/F) nodes are represented in colored squares:
Red: ZSEP1.0, Purple: SSN AMI FAN, Green: LAN, Yellow: WAN

As illustrated in figure above, a variety network zones exist and are connected to various service providers and systems. Any data flowing from the SmartMeter™ to PG&E AMI is Route A; any data obtainable through the Residential customer (RESI) and LC&I LAN from the SmartMeter™ is Route B. Lastly, any data obtained through RESI and LC&I Solution Vendor B would be Route C. This Project concentrates on the RED outlined scope in particular.

B1.4 Characteristics of Data Delivery: Time Interval Granularity, Delivery Latency, and Accuracy
Electrical usage data from SmartMeters™ are delivered through the network interfaces, as previously mentioned. The particular network interface and the meter metrology readings are related in how frequently that data can be updated due to the capacity of the data carrying network. In the case of the AMI network realm, that system needs to carry all the traffic from individual SmartMeter™ nodes. In contrast, the ZSEP1.0 network is short range low power “Personal Area Network” (PAN) that can transmit data at throughputs that are not hindered very much by presence of other devices. As such, a more real-time usage data update and delivery is possible through the ZSEP1.0 communication path. The granularity, or the time interval between subsequent reads, is illustrated below in Figure 20, and individual meters are programmed differently for LC&I (15 minute interval read through AMI), RESI (60-minute interval read through AMI) and ZSEP1.0 (15 seconds in all cases).

Figure 20 PG&E Data service time scales



The delivery Latency and accuracy of the data are determined by the data route and service available through those routes. For ZSEP1.0, at 15 second reads for PG&E's Stream My Data service (service "3"), the data is "raw" and uncorrected through Route B. For LC&I and RESI data through the AMI FAN, in the case of PG&E's Share My Data service, (service "2") the data is delivered in 24-to-36 hours after collection (>1 day latency) but also cleansed and verified by the utility bank end systems (thus accurate) before delivery through Route C. Route A (service "1") is outside the scope of the present discussion.

B2.0 Data Model for Services

This Project concentrates on utilizing Route B real-time data for LC&I customers. The SmartMeter™ uses the ZigBee Smart Energy 1.0 Profile-based data model. As the data traverses interfaces beyond the PAN as depicted in Figure 15, each device and service transforms the data model according to its own needs. This means that very specific data structures that are prescribed and employed as industry standard changes to a vendor-specific data model by the time the data needs to be consumed by the LC&I Solution Vendor. ZigBee SE1.0 Data is sent in machine-readable form in a binary datagram of IEEE802.15.4 MAC data frames, and is processed internally by the HAN device within the ZigBee SE1.0 protocol stack and application layer. There is no specific data model to share the data beyond that application layer. As such, each device vendor solution defines a data model, Figure 21. Within this Project, and the data model is given below in one instance for demand data for our specific HAN device; the entire schema used in the data model can be derived from the vendor API documentation*.

Figure 21 Vendor Energy Gateway Data API

(Example here depicted in XML; JSON is optional)


```
<InstantaneousDemand>
        <DeviceMacId>
                0x00158d0000000004
        </DeviceMacId>
        <MeterMacId>
                0x00178d0000000004
        </MeterMacId>
        <TimeStamp>
                0x185adc1d
        </TimeStamp>
        <Demand>
                0x001738
        </Demand>
        <Multiplier>
                0x00000001
        </Multiplier>
        <Divisor>
                0x000003e8
        </Divisor>
        <DigitsRight>
                0x03
        </DigitsRight>
        <DigitsLeft>
                0x00
        </DigitsLeft>
        <SuppressLeadingZero>
                Y
        </SuppressLeadingZero>
</InstantaneousDemand>
```


Note that other HAN vendors can and will employ different data model (Table 10) for the same demand data; standardized schema definitions exist for a variety of data use cases in energy, but they are not uniformly adopted in the industry.

Table 10 Data Models

Network Realm	Application	Data Model
ZSEP1.0 PAN	ZigBee Smart Energy 1.0 Device	ZigBee Smart Energy 1.0
LAN	Energy Gateway application	Energy Gateway Vendor defined XML and JSON

B3.0 Data Exchange Protocol

The communication connection needed to pass data from the SmartMeter™ to a HAN device and beyond depends on the compatibility of physical communication connectivity, access security, and prescribed message exchange processes. Each network realm differ in their physical connectivity requirements, where for the SmartMeter™/HAN PAN the physical connection is wireless 2.4GHz ISM band O-QPSK spread spectrum path, and in the LAN realm it is typically WiFi at 2.4GHz or 5GHz band OFDM; the WAN domain of Internet varies and access may be through any of DOCSIS, DSL, 3G/4G/LTE, etc., depending on the service provider.

Access security differs for each network realm; ZSEP1.0 utilizes a ZigBee Pro network security combined with CBKE APS layer mutual authentication for devices to join the network at the SmartMeter™. WiFi utilizes WPA/WPA2 security profile application level security depends on the particular service. Once a service is rendered typically through the WAN on the Internet, a TLS/SSL secure connection will exist with the service using server authentication.

Due to the fact that getting data from the SmartMeter™ to WAN involves three or more network realms and across non-IP to an IP-based network, each with its own application layer, even if there exists a path the application layer service logic must be able to parse and understand the data handled. This means that data model compatibility is critical to removing technical barriers to data utilization.

This Project selected a HAN solution vendor as a vendor with a device in PG&E's Validated Device certification process, and so the WAN side data model was dictated by the vendor and its API definitions. A successful use of real-time SmartMeter™ data meant that the LC&I Energy Solution vendor had to consume the SmartMeter™ at the vendor Cloud API based on vendors' data model and interaction definitions as an absolute implicit requirement.

Appendix C: Site Interview Logs

Site surveys were performed for the participant sites. The following Table 11 details the important interview/survey information retrieved from the participants

Table 11 Survey Log

Site Key	Discussion Points
CM – 1 CM – 2 CM – 3	Multiplier had to be applied Desire to see SA / SP / multiple meters in one dashboard Will not replace BEMS as it is used for control Advantage to know real-time for PDP days Normally sufficient to get 36 hour delayed data, to respond to property management to answer questions about billing Desire to see the BILL from PG&E and compare (note: unless AB802 fills this gap, the need will persist) Desire to control Demand Charge. Alerton's ASCEND system utilizes modBus submeters at 15 minute interval, and together with GAS and WATER, gives the facility manager ability to manage the property. Ability to scan past information is important
GOV – 1	Headquarters (supervising management)-should use the information Device sent, installed-- checked it one or two times but not afterwards; it worked first time, and installation was relatively easy. Multiplier had to be applied Not complicated if all the electrical/network there. No problem with downloading information.
T – 6 T – 1 T – 3 T- 5 T – 4 T –2	Multiplier had to be applied. Out of the box the HAN unit is not reporting anywhere close to the actual kW the meter is reading (dynamic range is too large for effective display on default application). Another issue is that when the HAN unit is paired with the SmartMeter™, the meter just shows "busy" instead of displaying the real-time kW. So that makes it even more difficult to do a calibration. This is probably the biggest issue I see with using these units - if they're not calibrated correctly in advance, dialing them in is difficult especially when you have no other reliable source for calibration. And the documentation itself is basically non-existent on what the Custom Multiplier and Divisor settings do. Having a hardwired Ethernet connection for the HAN unit can make deployment a challenge. In a couple of locations, there was simply no way to get an Ethernet connection at all, but I found a workaround by using this IOGear universal Ethernet to WiFi adapter. Another surprise: how robust the ZigBee connection is between the HAN unit and the meter. I have not had any trouble getting the two to connect even at 100+ yards, through multiple walls. We are currently using the vendor cloud capability to send data to a cloud SaaS, since we already have other devices using that platform. This is not currently our primary energy management system, but at least it is a way of storing the data in a platform where we can potentially do other things with, including visualizing it along with other building data. By sending the real-time data to SaaS, it can be integrated into real-time dashboards where we can graphically see up-to-date

Site Key	Discussion Points
	graphing (by hour/day/week/etc.) of energy consumption or renewable energy production I believe we have the ability to aggregate the meter feeds into a single dashboard view - so we can see everything in a single view rather than having to view the devices individually… may be possible to do deeper analytics on the energy data (with the EMS platforms used)
SM- 1	Multiplier had to be applied. Installation was successful; vendor worked on API to integrate with existing EMS
SM – 2	Corroborate data: Revenue grade meter and data from it helps to verify the installation and operation. Installing submeters is more expensive. Currently the system is used for Permanent Load Shift (PLS) by shifting peak to off-peak periods. A second important use case is DR (not yet implemented), to implement at peak times. PLS is reactive control and needs real-time; future real-time data will be used for predictive calculations. Set up- Once PG&E was involved in the back end, swapping the meter and adding HAN, it was straight forward. Data is observed every 15 seconds to 30 seconds. Currently a separate submeter at 5 second interval is used in parallel for the study Disadvantage of HAN is the relative small selection of vendors Submeters each cost $1100, and $400 for electrician to install (best case). Furthermore, MAIN power needs to come down--this is a big concern. Main building being turned off is not feasible Several thousand dollars in other issues. By relying on revenue grade meter from utility, $ is less expensive. KW values at 5 second period used; HAN device longer 15s period being correlated... Installation happened October, operation started November. Running intermittently but will go constant in April once the strategy is worked out. Peak is 12pm - 6pm-- this is shifted to off-peak hours. System is thermal shifting...Charge by ice making in off-peak, use it to cool building peak hours. Cooling- temperature/flow sensors are being used. Heat transfer vs. electrical usage being investigated.
SCH – 1	Multiplier had to be applied Critique of default HAN vendor dashboard: -Looking at history, it doesn't provide the calendar date you are observing on the dashboard. -It would be nice to select which periods (start date to end date) to look at. -As far as application, it's nice to see the real-time and periods sooner than waiting for the electric bill. -PG&E Interact provides more reporting and data, and except for the real-time, I'm not sold on the product at this point.

Appendix D: Laboratory Test (Stage I)

PG&E laboratory tested SmartMeter™ models consistent with PG&E's SmartMeter™ deployment throughout its service territory, including commercial customer sites. Testing (Table 12) verified connectivity capability, and that results read from a HAN device were consistent with the metrology reading of the meters themselves.

Test cases for meter types: 9S KV2CE-H, 9S KV2CE-HN, 9S KV2CE-HV, 9S FOCUS-H, 3S I210+H, 3S I210+HN, 4S I210+H, 4S I210+HN, 45S KV2CE-H, 45S KV2CE-HN, 45S KV2CE-HV

Table 12 Test Script

Step	Description	Expected Result
1	Obtain required model SmartMeter™	Required model SmartMeter™ obtained
2	Setup SmartMeter™ with required NIC GMI Program and Meter Program	SmartMeter™ setup with required NIC GMI Program and Meter Program
3	Energize SmartMeter™ and apply load	SmartMeter™ energized and load applied
4	Join vendor device through HCM	Vendor device joined
5	Setup account vendorcloud.com	Vendor Cloud account started
6	Add Gateway using '+ New Gateway' link	Gateway added
7	Navigate to Settings, vendor, Settings on Gateway	Vendor settings are displayed
8	Set multiplier with register constant value in CC&B	Multiplier set
9	Navigate to Meter on Gateway	Note Current Usage value
10	Note meter read on SmartMeter™ and multiply by the multiplier to obtain usage	Usage value calculated
11	Compare usage value calculated to current usage value from Gateway	Usage values are very close
12	For kVAR Meter Program note meter read on MeterMate 5.51 software and multiply by the multiplier to obtain usage	Usage value calculated
13	For kVAR Meter Program compare usage value calculated to current usage value from Gateway	Usage values are very close

Test Results: All PASS.

Please contact PG&E for specific result data.