December 15, 2011

Office of Electricity Delivery & Energy Reliability

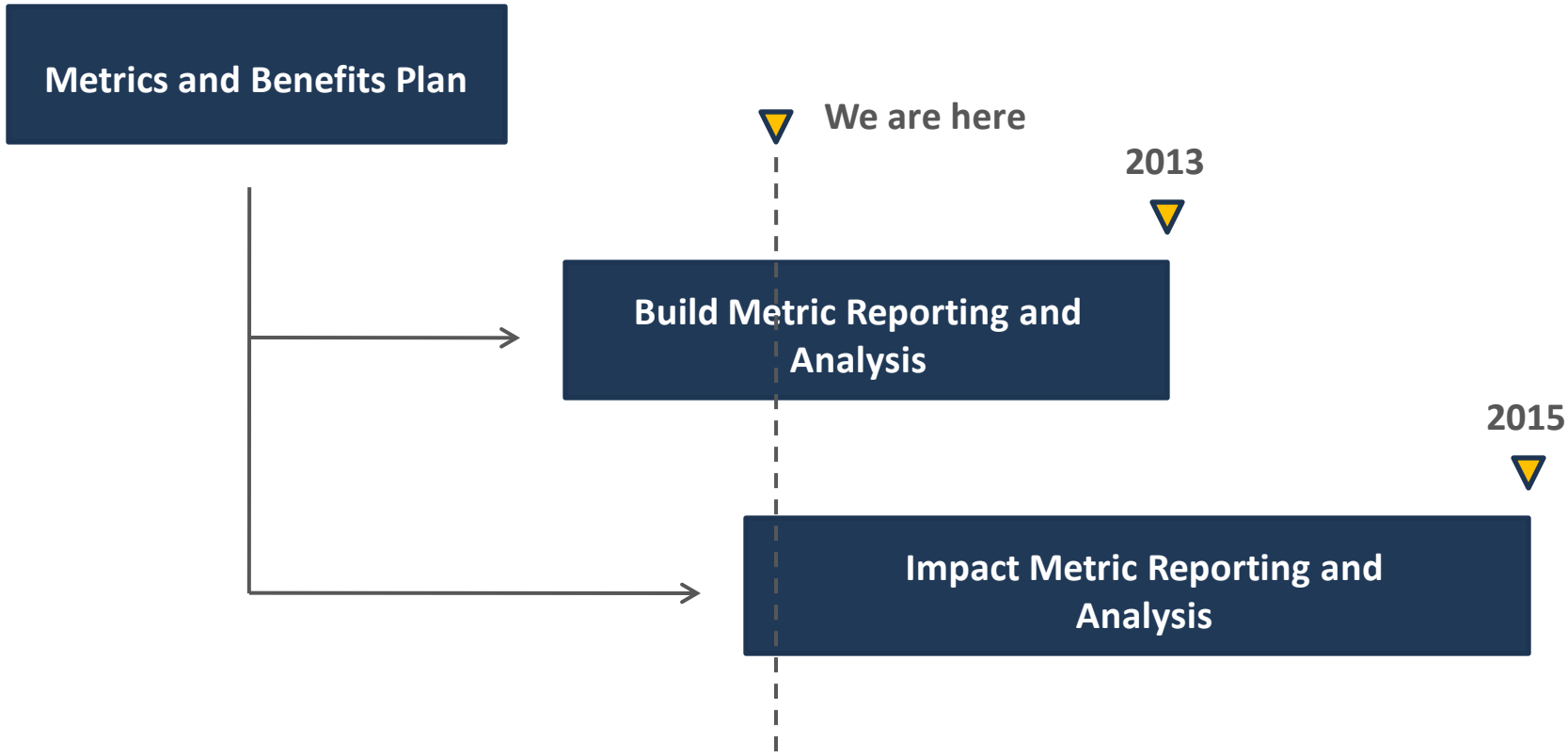
Peak demand and electricity consumption

DOE/Recipient Forum

SMARTGRID.GOV
RECOVERY ACT SMART GRID PROGRAMS

Introduction

The DOE Metrics and Benefits work is transitioning into the reporting and analysis of impact metrics. Build metric reporting and analysis will continue.



Six Primary Analysis Focus Areas

Today our discussion will focus on Energy Efficiency in Distribution Systems.

Peak Demand and Electricity Consumption

- Advanced Metering Infrastructure
- Pricing Programs and Customer Devices
- Direct Load Control

Operations and Maintenance Savings from Advanced Metering

- Meter Reading
- Service changes
- Outage management

Distribution System Reliability

- Feeder switching
- Monitoring and health sensors

Energy Efficiency in Distribution Systems

- Voltage optimization
- Conservation voltage reduction
- Line losses

Operations and Maintenance Savings from Distribution Automation

- Automated and remote operations
- Operational Efficiency

Transmission System Operations and Reliability

- Application of synchrophasor technology for wide area monitoring, visualization and control

DOE / Recipient Dialogue

DOE would like to establishing a forum to explore how AMI technologies affect peak demand and electricity consumption.

DOE's Interests	Recipients' Interests
1. Analysis Approach: Working through issues relating to measuring impacts a. Analytical methodology b. Baseline/control groups c. Underlying factors leading to results d. How to convey the results and to whom? 2. Lessons-Learned/Best-Practices: Internally and externally conveyed a. What can we learn from each other? b. How do we want to document lessons-learned and best practices for external communication? c. Are there detailed case studies that can be developed?	1. What would you like to address in a group setting? 2. What do you want to learn or share? 3. How would you like to exchange information? a. In smaller or more focused groups? b. How should we structure and support the discussion? 4. Are there issues you are NOT interested in addressing here?

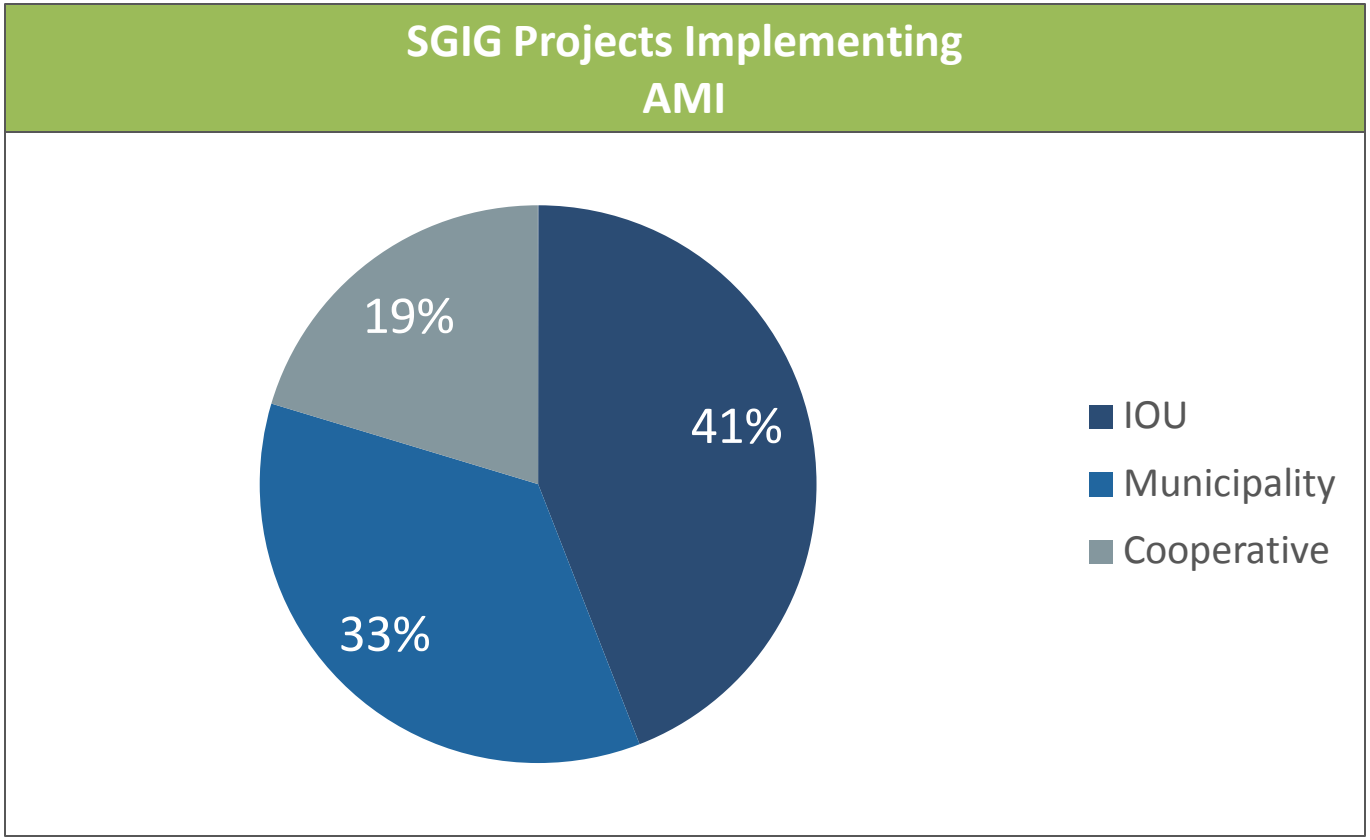
DOE's Analysis Objectives

The Metrics and Benefits Team is trying to determine how AMI technologies can affect peak demand, shift peak demand, and change electricity consumption.

Analysis Objectives
• Evaluate the influence of smart meters, pricing information, customer devices such as programmable controllable thermostats, in-home displays, and direct load control devices on: o Change in peak demand o Peak shift o Electricity conservation • Quantify how changes in electricity usage patterns and pricing affect consumer electricity bills, fuel mix for electricity generation, and power plant emissions.

SGIG Projects

57 SGIG projects and several SGD projects are implementing AMI assets to determine whether they reduce or shift peak, or achieve conservation.



Source: SGIG Build metrics and Navigant analysis

Technologies

Project teams are deploying a variety of different technologies.

Smart meter

- Provides foundation for two-way communications between utilities and customers
- Enables utilities to offer information, tools, and incentives for customers to reduce and shift electricity usage

Field area network

- Displays and communicates energy usage information to customers
- Interoperates with appliances, lighting, and HVAC based on grid conditions and time based rate

Backhaul and Head end server

- Collects customer meter data and transmits it to a central information center
- Options include broadband, cellular, wireless, and Ethernet networks
- Enables utilities to manage dispersed data collection

Other

- Activities related to planning and supporting AMI deployment
- Includes planning, engineering costs, consulting, management, and security

Applications that affect peak demand and electricity consumption

DOE has seen three general applications within projects that are conducting smart grid projects related to peak demand and electricity consumption.

Time based rate program

Offering electricity rates ($/kWh) that vary by time of day or year, such as a critical peak pricing program, might cause customers to change electricity consumption.

Customer systems

Customers gain information about and control over electricity consumption. For example, web portals provide insight into electricity consumption and programmable controllable thermostats offer control over electricity consumption.

Direct load control program

Customers enter an agreement with a utility to reduce demand by controlling selected appliances, such as air conditioners and pool pumps, during peak demand periods. Direct load control equipment can be supported by AMI communications infrastructure.

Build and Impact Metrics

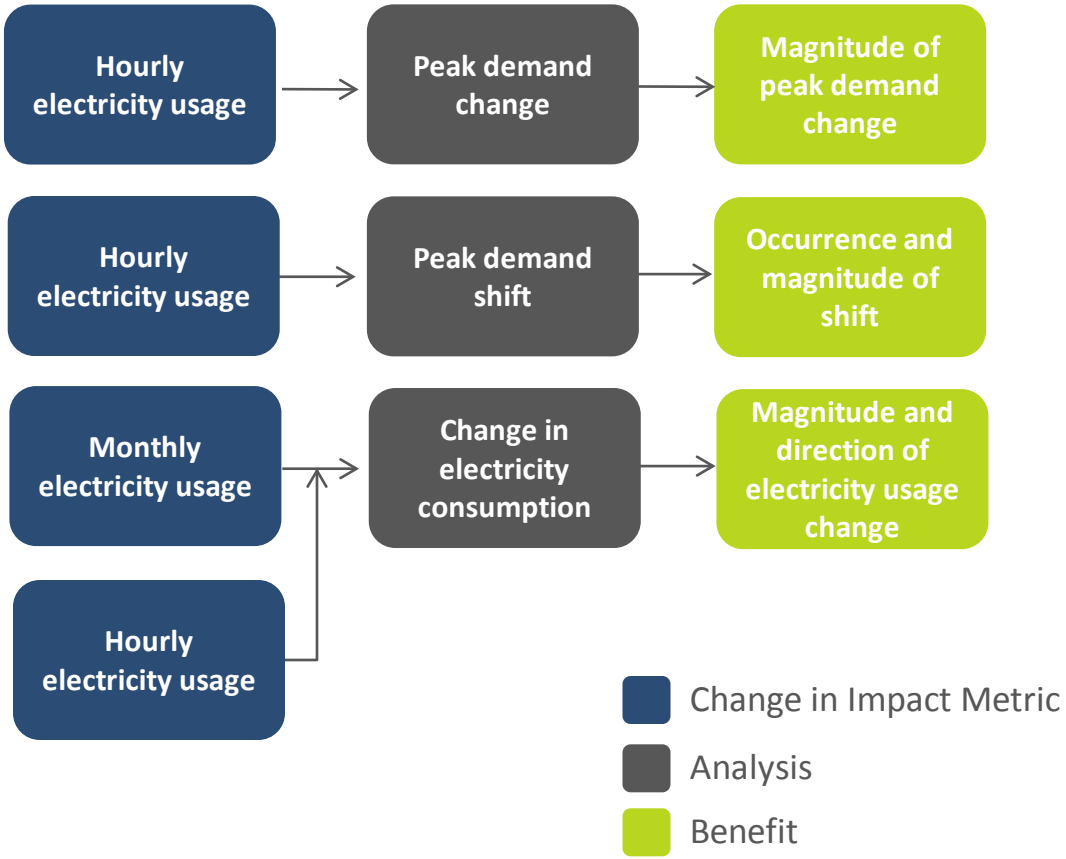
Build and Impact metrics will track the deployment of technology and how it affects peak demand and electricity consumption.

Key Build Metrics (Technologies)
• Smart meters • Communications system • Customer EMS/Display/Portal • Time-based rate programs • Direct load control devices

Key Impact Metrics
• Hourly customer electricity usage • Monthly customer electricity usage • Peak load and mix (direct load control) • Peak generation or supply and mix (generation fuel and technology) • Annual electricity production or supply • Annual electricity production cost • Ancillary services cost • CO_2, SO_2, NO_X, and PM emissions, generation or supply

Logic for Analyzing Peak Demand Change, Peak Demand Shift, and Electricity Usage Change

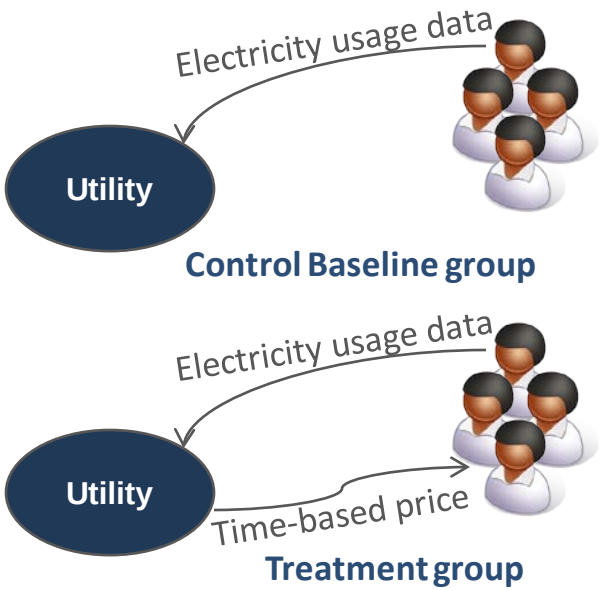
Analyzing hourly and monthly electricity usage provides insight into peak demand changes, peak demand shifts, and overall electricity usage changes.



Electricity usage data should be collected for representative customer classes.

Hourly electricity usage data

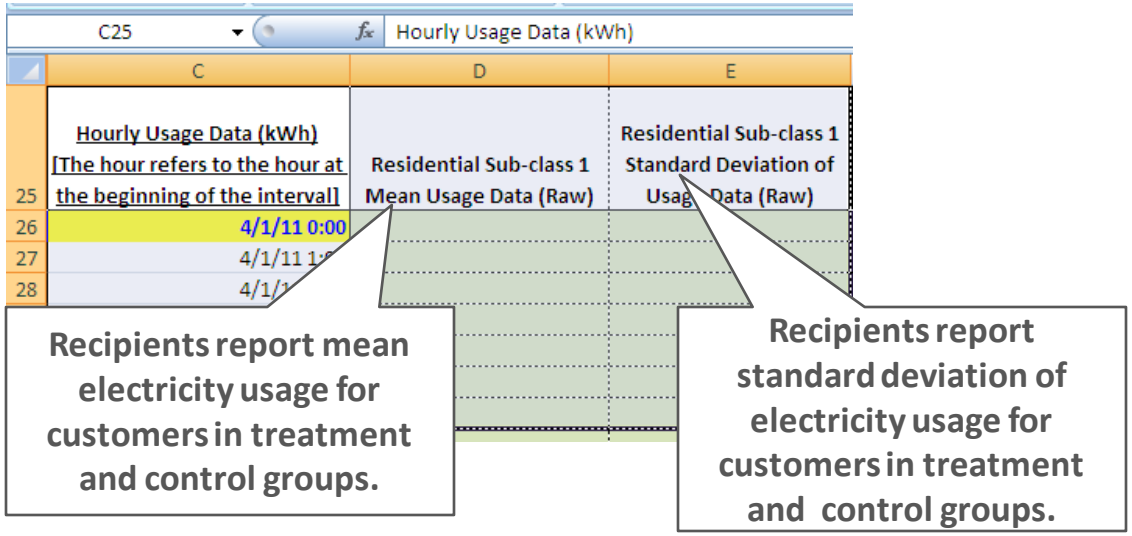
Recipients report the hourly electricity usage mean and standard deviation for all customers in treatment or control groups.



Recipients collect electricity usage data from N control baseline group customers, and N project customers under treatment. N can be small, or it could be thousands of customers.

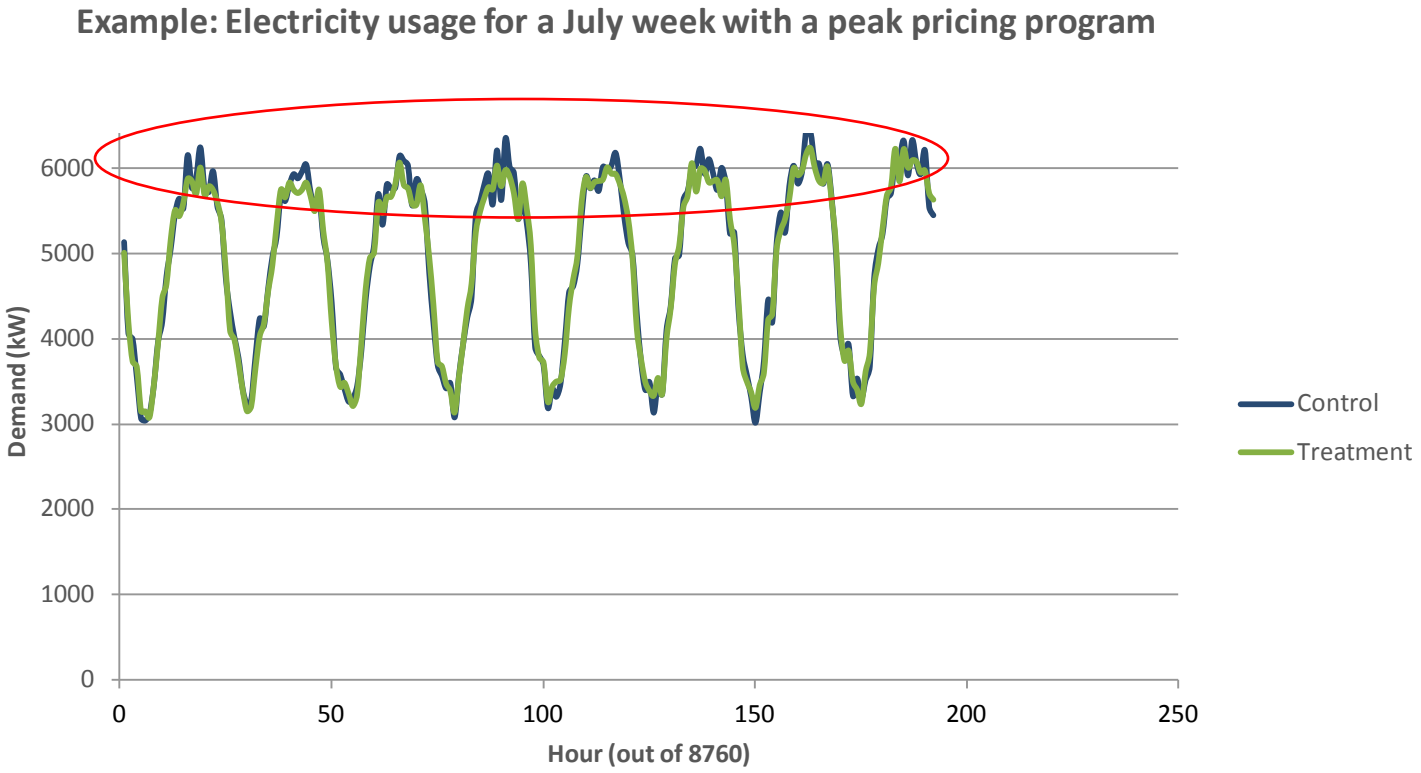
Reporting electricity usage for each customer requires more computing capacity than many recipients have.

To accommodate this limitation, calculate electricity usage statistics: the mean and standard deviation of electricity usage (kWh) for the N customers at every hour i (i = 1,…,8760).



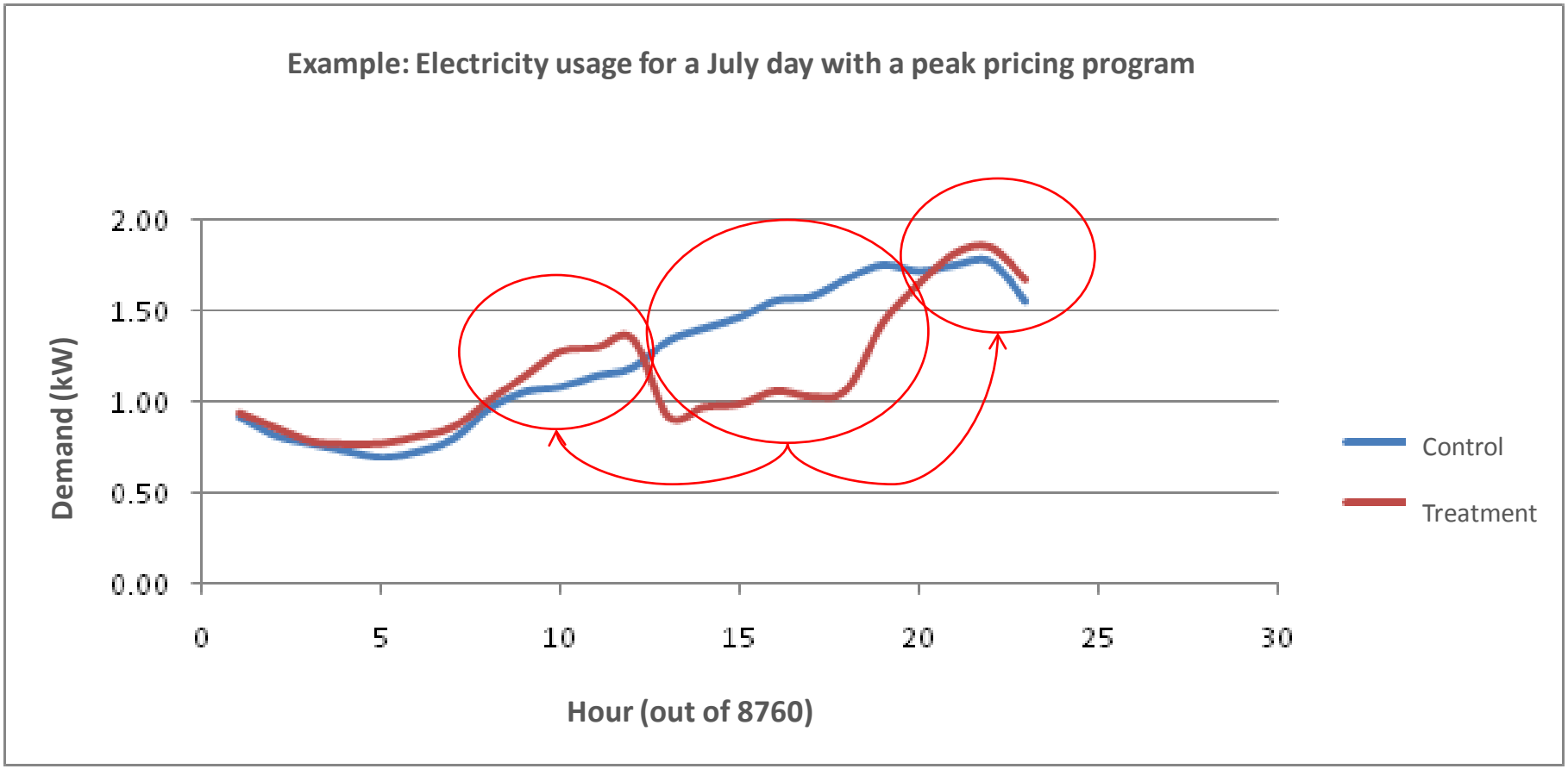
Peak reduction calculated from hourly electricity usage data

Many projects are reporting hourly electricity usage data, that can be used to calculate change in peak demand.



Peak shift evaluated from hourly electricity usage data

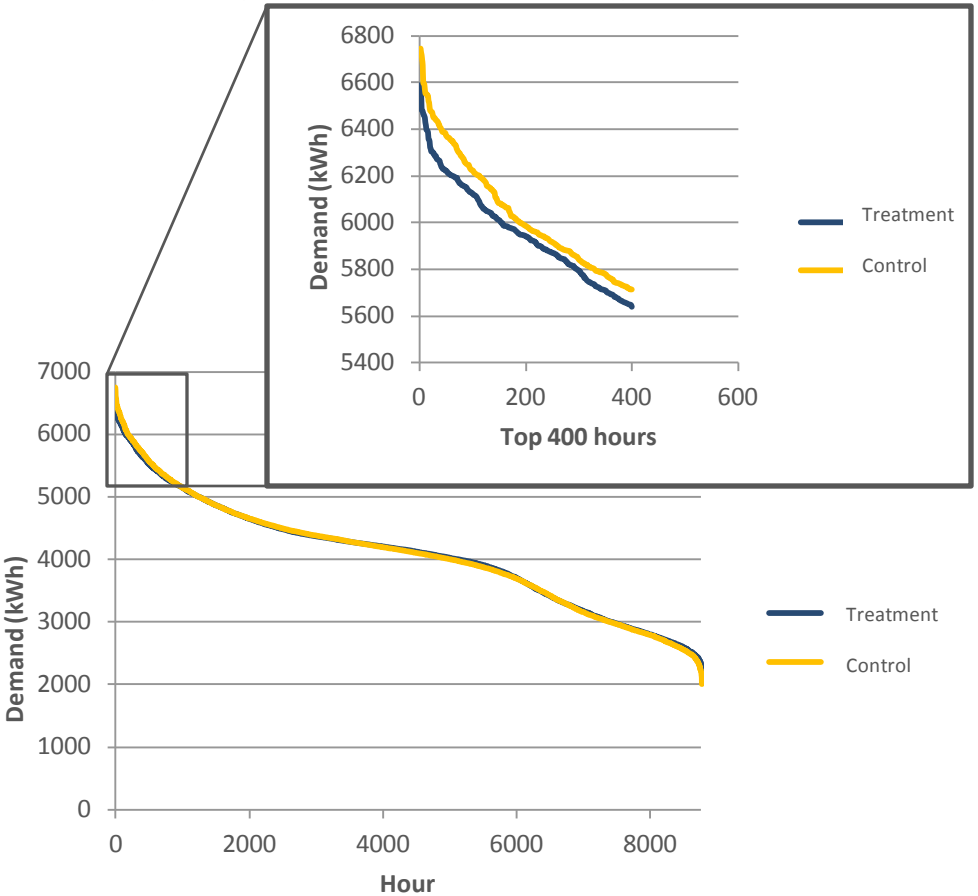
Many projects are reporting hourly electricity usage data, that can be used to evaluate peak shift.



Conservation evaluated from hourly or monthly electricity usage data

Many projects are reporting hourly or monthly electricity usage data, that can be used to evaluate change in overall electricity consumption.

Example: Hourly electricity usage for one year with a peak pricing program in July and August



Example: Monthly electricity usage (MWh) from May – August with a peak pricing program in July and August for 2008 residential customers

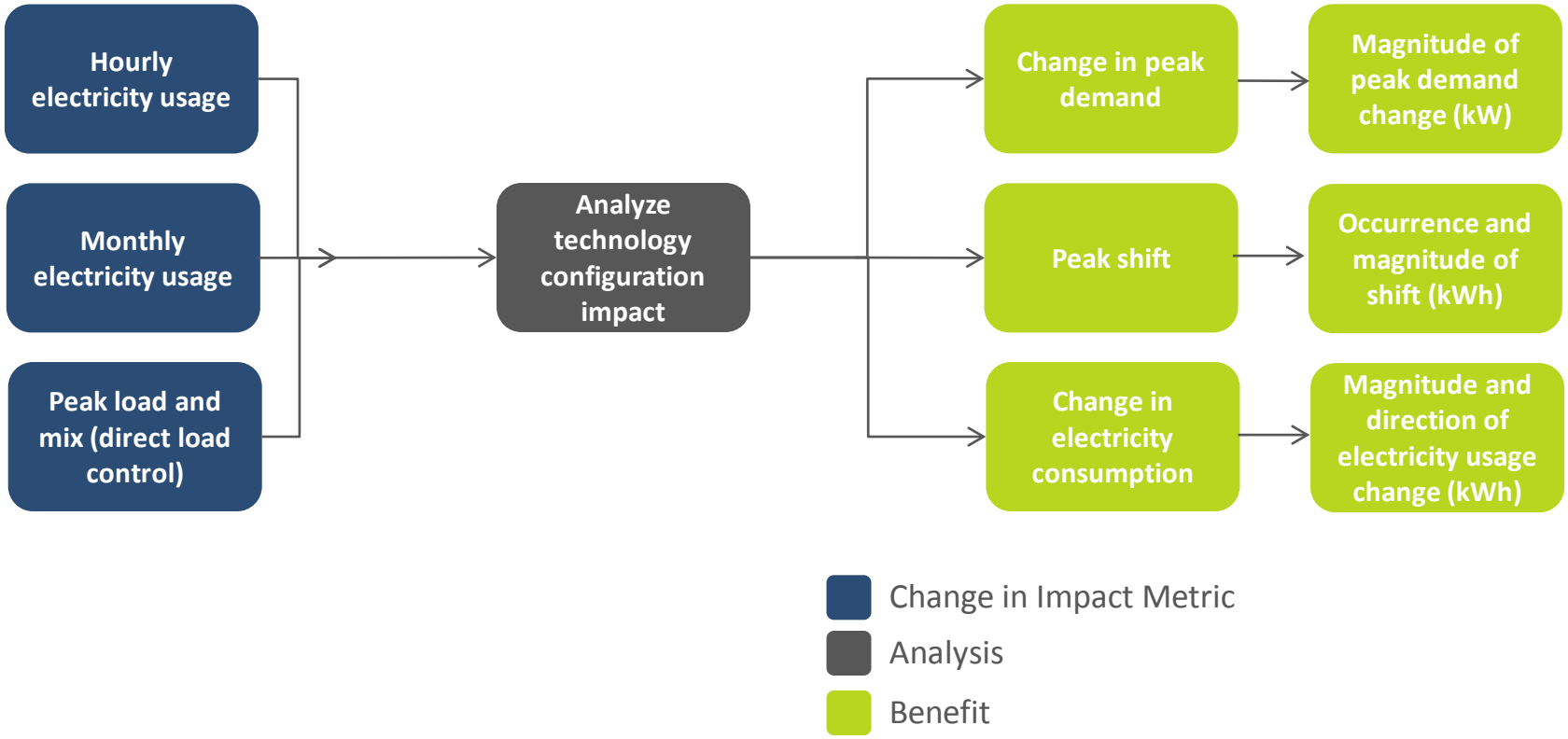
	Control	Treatment
May	2806.483	2803.074
June	3165.189	3162.555
July	3768.887	3749.27
August	3426.765	3408.821
Total	13167.32	13123.72

Conservation =Total Control – Total Treatment
Conservation = 13167.32 – 13123.72
= 43.6 MWh

Assuming change only occurred when time of use pricing was in affect, such that the price was $0.10/kWh higher than the base rate, customer savings are $2.18/customer.

Logic for calculating peak change, peak shift, and change in overall electricity consumption

We will work with projects to examine affect of technology configuration on peak demand, peak shift, and electricity consumption.



Moving Forward

Additional Questions	Logistics
• What other kinds of impacts are project teams expecting, and how should we be looking for them in the metrics data? • What other kinds of data or information can be shared to help the group understand impact? • How are utilities operating the AMI, time based pricing programs, direct load control programs, and customer systems, and how can that shared? • How are baselines and customer control groups being established? • How might service area and technology configuration affect results? • What kinds of “experiments” can the forum projects perform together?	• What type of format should we use for future meetings? • Who should participate in these meetings? • What type of schedule should we follow? • Suggested topics for the next discussion?

Appendix

Customer behavior studies

There are 9 customer behavior studies (CBS) that are taking a deeper look into factors that affect electricity usage.

- NV ENERGY
- OGE
- MARBLEHEAD MLD
- VERMONT TRANSCO
- MINNESOTA POWER
- FIRSTENERGY OHIO
- SACRAMENTO MUD
- DETROIT EDISON
- LAKELAND ELECTRIC

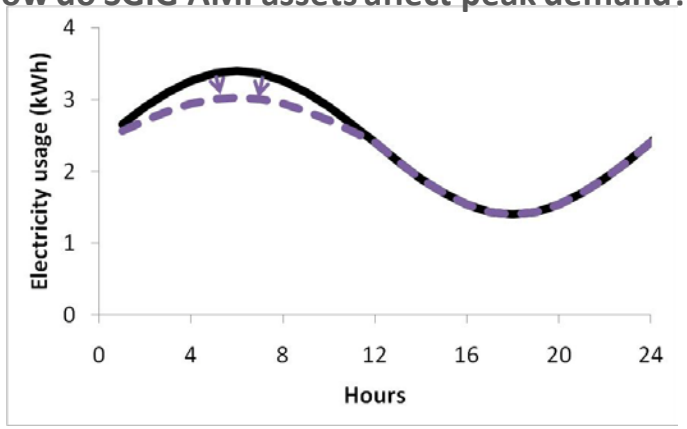
Research questions

1. **Customer Acceptance**: What motivates customers to accept time-based rate programs?
2. **Customer Retention**: What motivates customers to remain on time-based rate programs?
3. **Customer Response**: Will customers respond, and if so by how much will they respond, to time-based rate programs?
4. **Role of enabling technology and information/education**: Will customers respond, and if so by how much will they respond, to control and/or information technology and/or education alone?

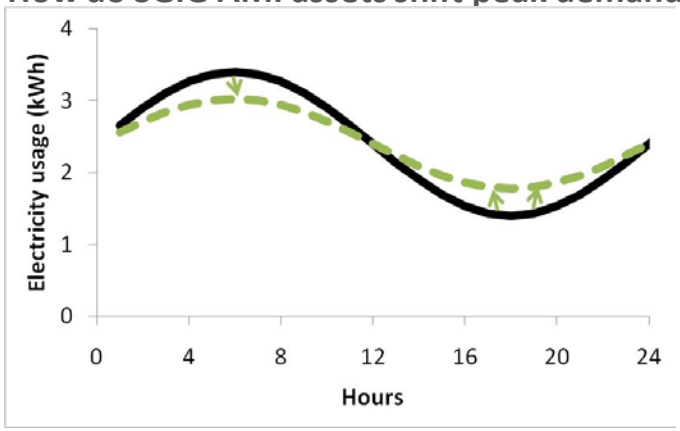
DOE wants to examine AMI affect on demand and consumption

Utility AMI deployment affects electricity consumption and peak demand

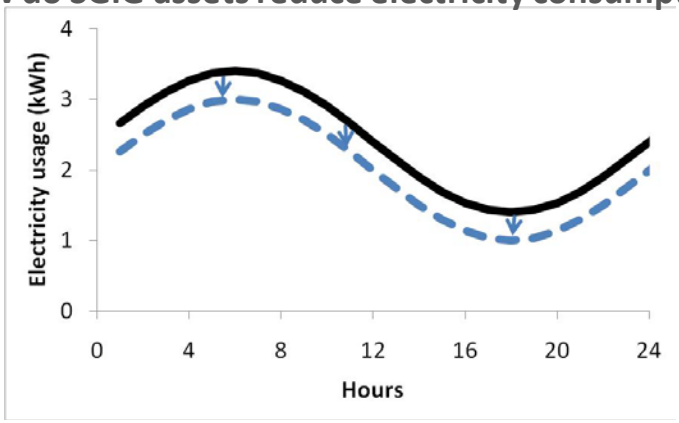
How do SGIG AMI assets affect peak demand?



How do SGIG AMI assets shift peak demand?



How do SGIG assets reduce electricity consumption?



Two special definitions for baseline and project metrics

Before we discuss analysis, there are a two terms to define.

1. "**Treatment**" refers to any equipment or demand management program offered to customers. Treatments can include but are not limited to:
   - Time based pricing program
   - Direct load control program
   - Home area network
   - Information feedback to the customer (e.g., text messaging)
2. "**Contemporaneous**" project and baseline data is collected at the same time. Contemporaneous data ensures that customers in the treatment and control groups are experiencing the same conditions, such as weather and economy. The following are example characteristics they might share:
   - Economic status
   - Geographic location, such as Census tract
   - Service area location, such as feeder or substation

We will explain the contemporaneous concept a little further on the next slide. It lends itself to a special definition of "baseline," which is a control group for hourly electricity and monthly electricity usage data.

SGIG Guidance A-001

The Metrics and Benefits team has provided general guidance on defining baseline impact metrics for customer electricity usage data.

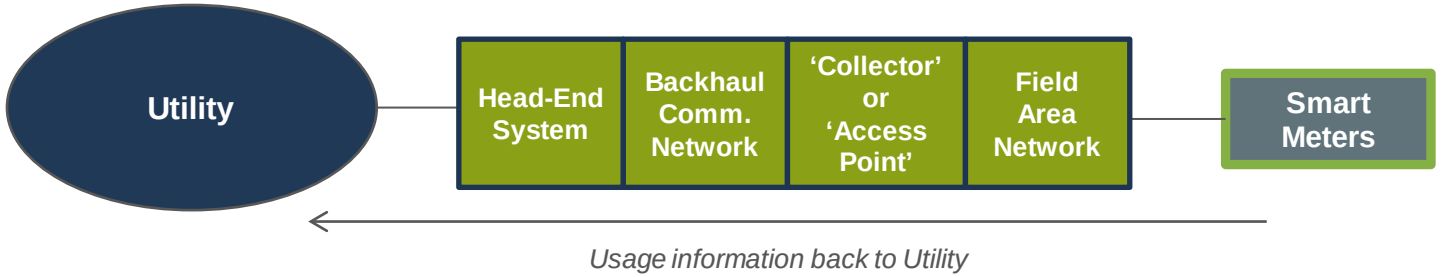
1. **Control group baseline (Preferred).**
   - This baseline type will be explained further on the following 2 slides
   - Recipients define a set of customers who receive the same device as the treatment group but do not receive a treatment, e.g., time based rate.
2. **Customer profile, where the recipient has projected hourly data for customers similar to those in the treatment group.**
   This is a suitable substitute for a control group, because the recipient accounts for external factors such as weather and the economy in its projection. This data can be directly compared to a treatment group.
3. **Historical baseline, where the recipient has historical hourly data.**
   A recipient would use this baseline because all their customers receive a treatment.
   This is not preferred because data collected in the past was subject to different conditions that affect demand, such as weather. If the weather differs in the historical or reporting periods, the demand for those periods are not directly comparable.
   - Case 1: it has an existing smart meter deployment, so that they recorded hourly electricity usage before the SGIG program.
   - Case 2: it has a time lag before deploying a treatment. These customers serve as their own control, except for external factors such as weather.

Project v. Baseline customers

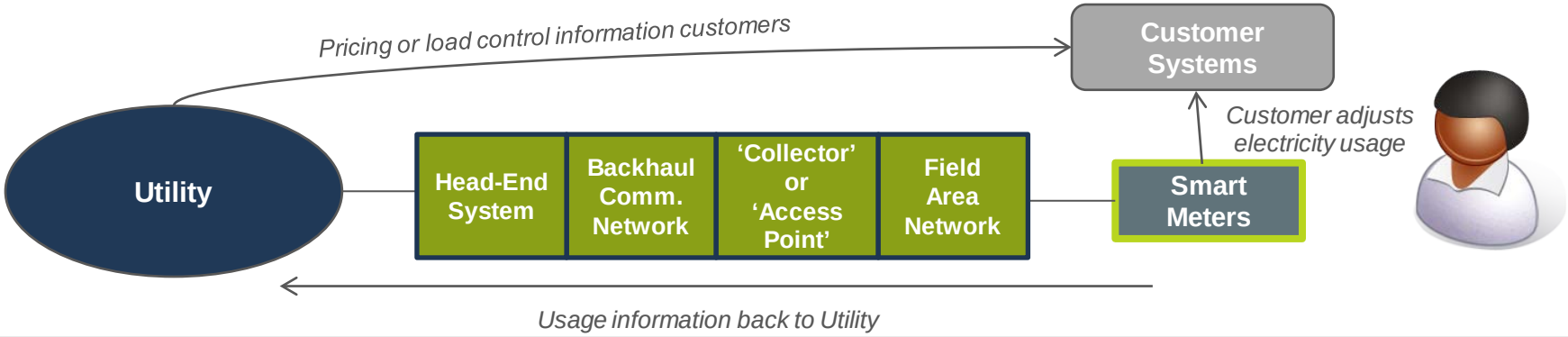
Hourly electricity usage and monthly electricity usage are collected in real time for baseline and project impact metrics.

Control and project group customers receive the same technology, except that project customers receive a "treatment". Concurrent data collection controls for weather, economics, and other factors.

AMI customers **WITHOUT** a treatment are a control group (or baseline)



AMI customers **WITH** a treatment, such as a demand management program, are the treatment group



Electricity usage (kWh) variables

Electricity usage (kWh) variable names used in calculations

P (Real Power Delivered) is the raw electricity usage data reported by recipients.

P represents the mean electricity usage for the treatment or control group for a specified period.

Variable	Description
P_{peak} (kWh/h)	Electricity usage at peak hour. Peak is determined one of two ways: 1. Preferred: Peak is electricity usage at the peak hour reported (date) by the recipient. 2. Alternative: If recipient doesn't report peak hour, Peak is the maximum P reported for the period.
P_i (kWh/h)	Electricity usage for hour i, i = 1,…, 4380 (for a 6 month period)
P_{month} (kWh/month)	Electricity usage for month m, m = 1,…, 6 (for a 6 month period)

Peak Reduction calculated from hourly electricity usage data

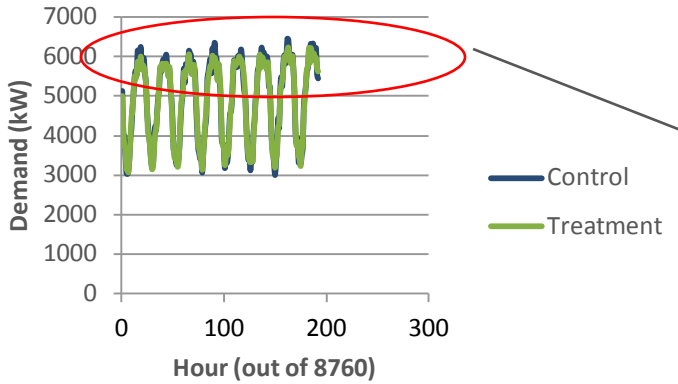
Change in peak demand can be calculated with hourly electricity usage data.

Magnitude of peak demand change

Some projects are reporting time of peak hours with their hourly electricity usage data. If they are not reporting the peak, we can determine peak hours by finding hours of maximum demand. The change in peak demand is calculated for peak hours:

$$\Delta P_{Peak} = P_{Peak,treatment} - P_{Peak,control} \text{ kWh/h}$$

Example: Electricity usage for a July week with a peak pricing program



We calculate the difference between hourly electricity usage at the peak to determine change in peak demand ΔP_{Peak}

Peak shift calculated from hourly electricity usage data

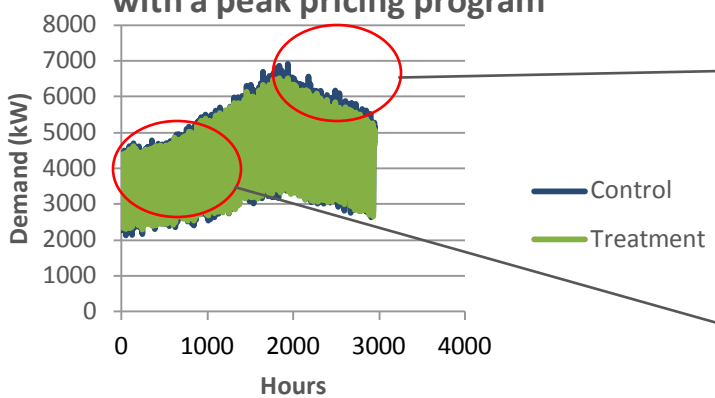
Peak demand shift can be detected and calculated from hourly electricity usage data.

Occurrence and magnitude of shift

Peak shift is determined by:

1. Calculate change in electricity usage ΔP_i per each hour i:
   $$\Delta P_i = P_{i,treatment} - P_{i,control} \text{ kWh/h}$$
2. For each hour where $\Delta P_i \neq 0$, a change in electricity consumption occurred. We anticipate $\Delta P_i \leq 0$ at peak hours and $\Delta P_i \geq 0$ at off-peak hours when a shift occurs.

Example: Electricity usage for a July day with a peak pricing program



In peak shifting ,we expect change in hourly electricity usage at peak hours to be less than 0 because treatment should be smaller than control: $\Delta P_i \leq 0$

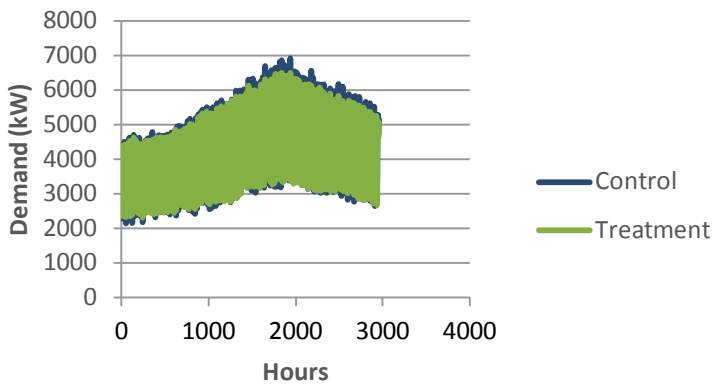
In peak shifting ,we expect change in hourly electricity usage at off-peak hours to be greater than 0 because treatment should be greater than control: $\Delta P_i \geq 0$

Electricity conservation calculation from hourly or monthly data

Change in overall electricity consumption can be calculated from hourly *or* monthly electricity usage data.

Magnitude and direction of electricity usage change

Example: Hourly electricity usage from May – August with a summer peak pricing program



If a recipient reports hourly data for the 4 month period, we calculate total change:

$$\Delta P_{i,Total} = \sum_{i}^{2952} \left(P_{i,control} - P_{i,treatment} \right) kWh$$

Example: Monthly electricity usage from April – September with a summer peak pricing program (MWh)

	Control	Treatment
May	2806.483	2803.074
June	3165.189	3162.555
July	3768.887	3749.27
August	3426.765	3408.821
Total	13167.32	13123.72

Alternatively, if a recipient reports monthly data for the 4 month period, we calculate total change:

$$\Delta P_m = \sum_{m}^{4} \left(P_{m,control} - P_{m,treatment} \right) kWh$$

$$\Delta P_m = 43.6\,MWh = 43{,}600\,kWh$$

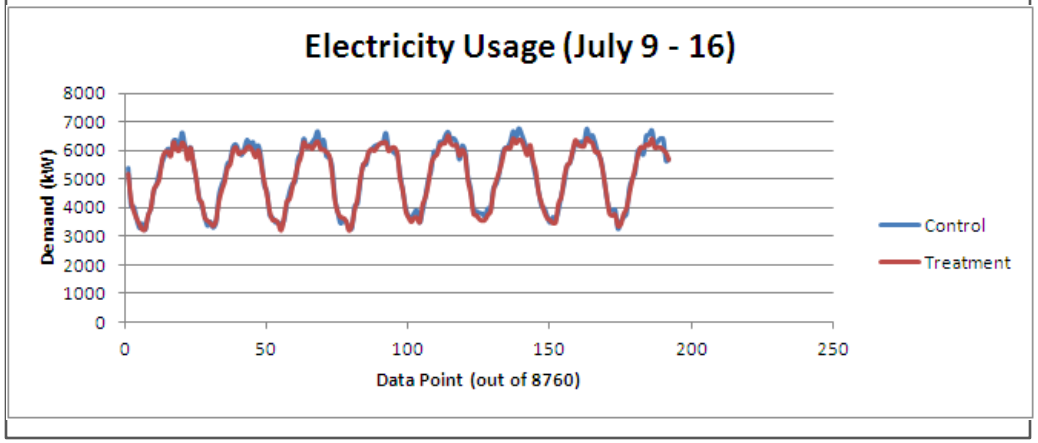
Peak Reduction: Example Analysis – Hourly Electricity Usage Data

Example: A recipient deploys smart meters and a seasonal time of use pricing program.

Customers might reduce their peak electricity demand, or shift demand from peak to off-peak hours.

The chart at right shows that there is some reduction at the peak, but our analysis can provide quantitative insight into hourly electricity usage changes.

Reported hourly electricity usage data (July week)



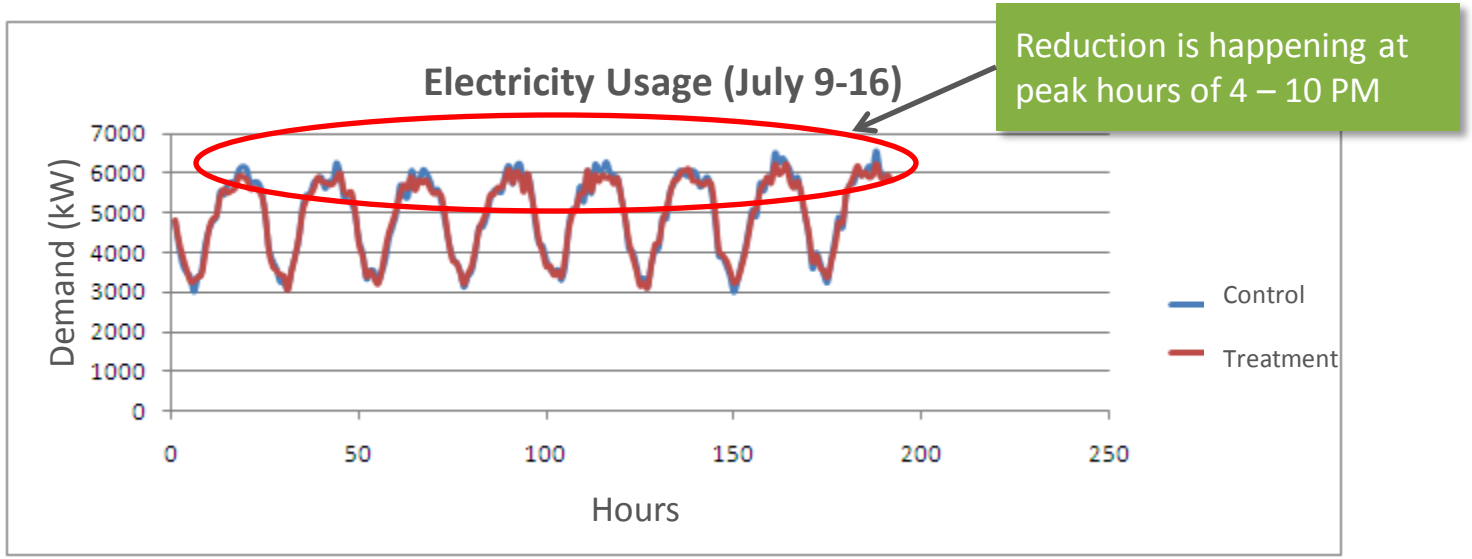
Pricing program description

- 2000 residential customers
- 8 commercial customers.
- Peak rate is $0.10/kWh higher than the base rate, in effect from 4 pm – 10 pm every day in July and August.

Example Analysis – Calculation of peak reduction

This example project reduced electricity usage by 0.6% for one week, July 9-16. Because the pricing program is effective for July through August, it reduced electricity usage by 0.1% for the whole year.

	SELECTED DATA (July 9 - 16)				FULL YEAR DATA			
	Control	Treatment		Change	Control	Treatment		Change
Usage Energy	949.3	943.5	MWh	-0.6%	35712.1	35680.5	MWh	-0.1%
Peak power usage	6451.30	6218.4	MW	-3.6%	6806.2	6551.2	MW	-3.7%



Source: Illustrative results from Navigant analysis

Example Analysis – Calculation of Monetary Value

Assuming average wholesale prices and a value for CO_2 emissions, potential benefits were calculated for the utility, society, and the customer for this 0.1%/year electricity consumption reduction (2,000 residential customers, 8 commercial customers).

Value of electricity consumption reduction: accrues to utility

Annual $\Delta P_{\text{pricing program}}$ = 35680.5 MWh –35712.1 MWh = -31.6 MWh

Utility cost savings, at an average wholesale market price of $56/MWh [1]:

Value($) = -31.6 MWh × $56/MWh = -$1,770

Value of avoided capacity

Annual capacity change = 6806.2 MW –6551.2 MW = -45 MW

Utility cost savings, based on ISO-NE average capacity clearing price $4.5/kW-month [2]:

Value($) = -45 MW-year × 12000 kW-month/MW-year × $4.5/kW-month = -$2.4 million

Value of CO_2 reduction, accrues to society and utility

Assuming 1.3 lbs/kWh for electricity generation and a CO_2 emissions price of $1.86/ton [3], we calculate the value of emissions reduction:

Value($) = 1.3 lbs/kWh × (-31,600 kWh) ×$1.86/ton CO_2 ÷ 2000 lbs/ton = -$38

Value of customer cost avoided: accrues to customer, assuming all electricity consumption change occurs during the seasonal time of use pricing program

Value($) = -31,600 kWh ×$0.10/kWh [4] = -$3,160

Given 2,008 customers, the value of avoided customer cost is $1.57/customer.

1. Average 2010 wholesale New England ISO price is $55.86, calculated from EIA data. NEPOOL Mass Hub New England wholesale ahead prices. http://www.eia.gov/electricity/wholesale/archive/2010/nepool10.xls, accessed 11/15/11.
2. ISO New England Forward Capacity Market Auction (FCA 2010-2011) Results report.
3. $1.86/ton is the Regional Greenhouse Gas Initiative 2010 clearing price. Source: Potomac Economics. *Market Monitor Report for Auction 9.* September 10, 2010.
4. Recall that our example assumes a $0.10 peak rate increase over the base rate.