Mark Rawson, Sacramento Municipal Utility District

SMUD
SACRAMENTO MUNICIPAL UTILITY DISTRICT
The Power To Do More.®

VALUE OF ENERGY STORAGE WITH PV – INITIAL FINDINGS

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NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Problem Statement

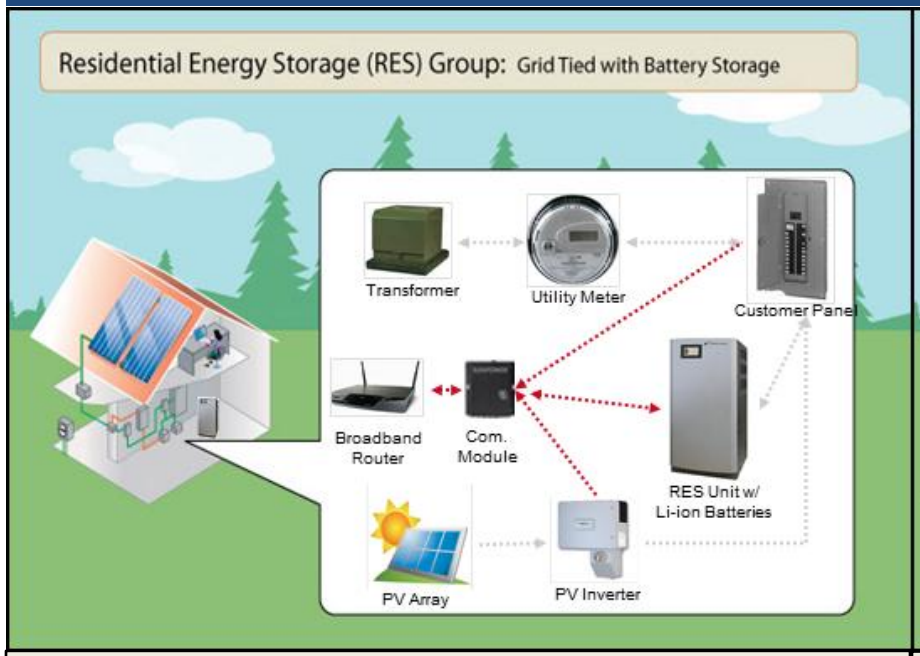
- Greenhouse gas regulations and renewable portfolio standards driving solar installations in SMUD's service territory
- Creates uncertainties with PV integration
  - Solar forecasting is not developed enough for minute ahead forecasts during variable weather
  - Solar peaks 4 to 5 hours before utility peak
  - Distribution system reliability could be impacted
  - Grid operation costs could increase
- To manage these issues, SMUD is studying energy storage at all levels of its electricity system.

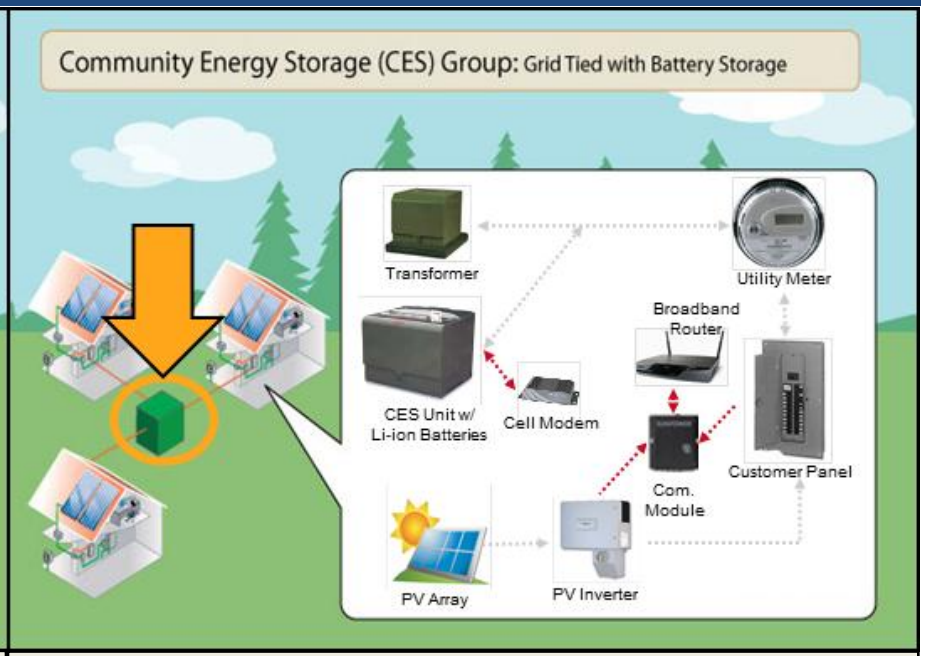
Project Objectives

- Understand how the integration of energy storage can enhance the value of distributed PV resources within the community.
- Determine if the addition of energy storage can add value for the utility
- Determine how to leverage SMUD's AMI Investment to manage a distributed PV/energy storage resource
- Determine if capacity firming and advanced pricing signals will influence the energy usage behaviors of customer

Demonstration Overview

PV and Energy Storage Demonstration at Anatolia Subdivision





5.0kW/7.7kWh X 15 units	30kW/34kWh X 3 units

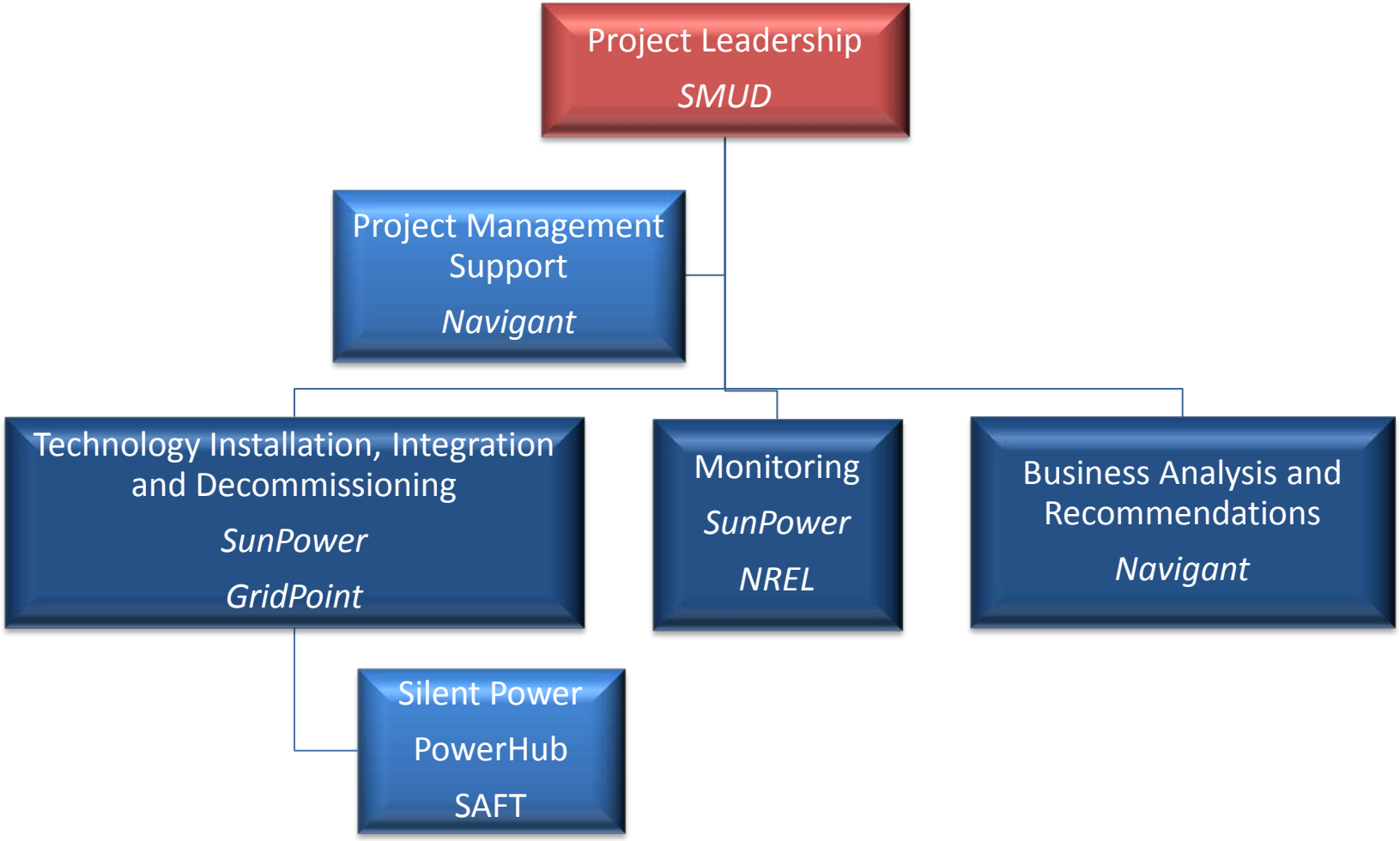
Storage deployed in all solar community with 300 homes built and an installed capacity of ~600 kW

Location of Community

Substation

Solar Community

Partner Roles and Responsibilities



Key Deliverables

- **Installed Equipment**
- **Recruited Customers**
- **Monitoring and Testing Plan**
- **Internal Advanced Pricing Workshop**
- **Quarterly Data Analysis Reports**
- Final Benefits Analysis
- Strategic Analysis for SMUD
- Smart Inverter Testing and Strategy
- Decommissioning Equipment

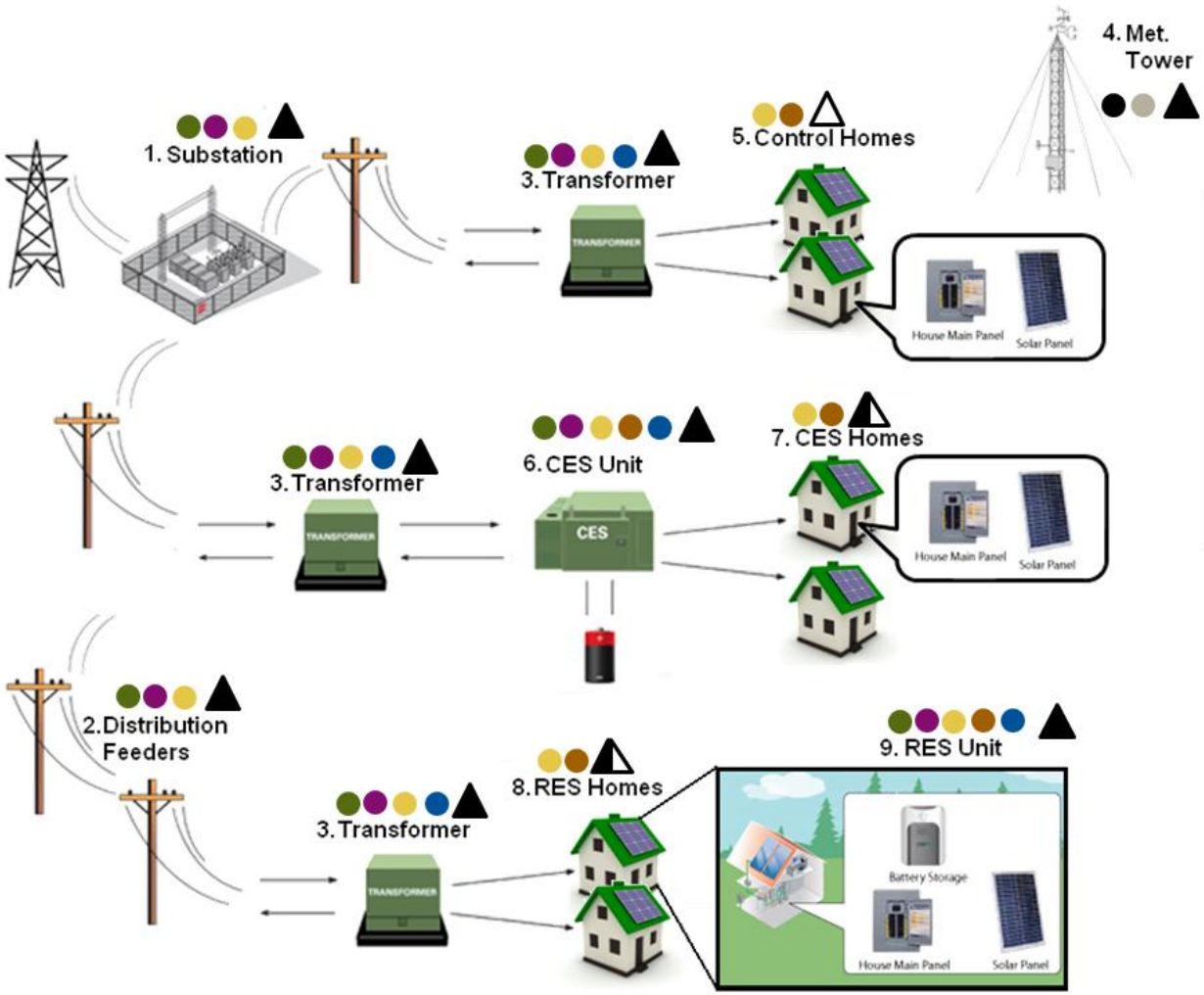
Bold indicates completion

Progress to Date Examples

Progress

- Residential storage units received UL Listing
- Marketing campaign developed/launched
- Residential sites recruited/contracts signed (15)
- Community sites recruited/contracts signed (3)
- 15 of 15 installed and commissioned (11 Operating)
- 3 of 3 CES installed and commissioned (3 Operating)
- IEEE testing of CES units completed by NREL
- Home Energy Management Portal launched
- TOU rates applied to RES customers (May 2012)
- Monitoring/Testing underway(16 Op Modes)
- Enhanced scope by testing potential impact of electric vehicles
- Project extended through 30 Sep 2013
- Resolved multiple bug/fixes (Batteries/CES/RES/BMM/telecom etc…)

High Fidelity Data Monitoring



Highest Frequency at which Data is Collected

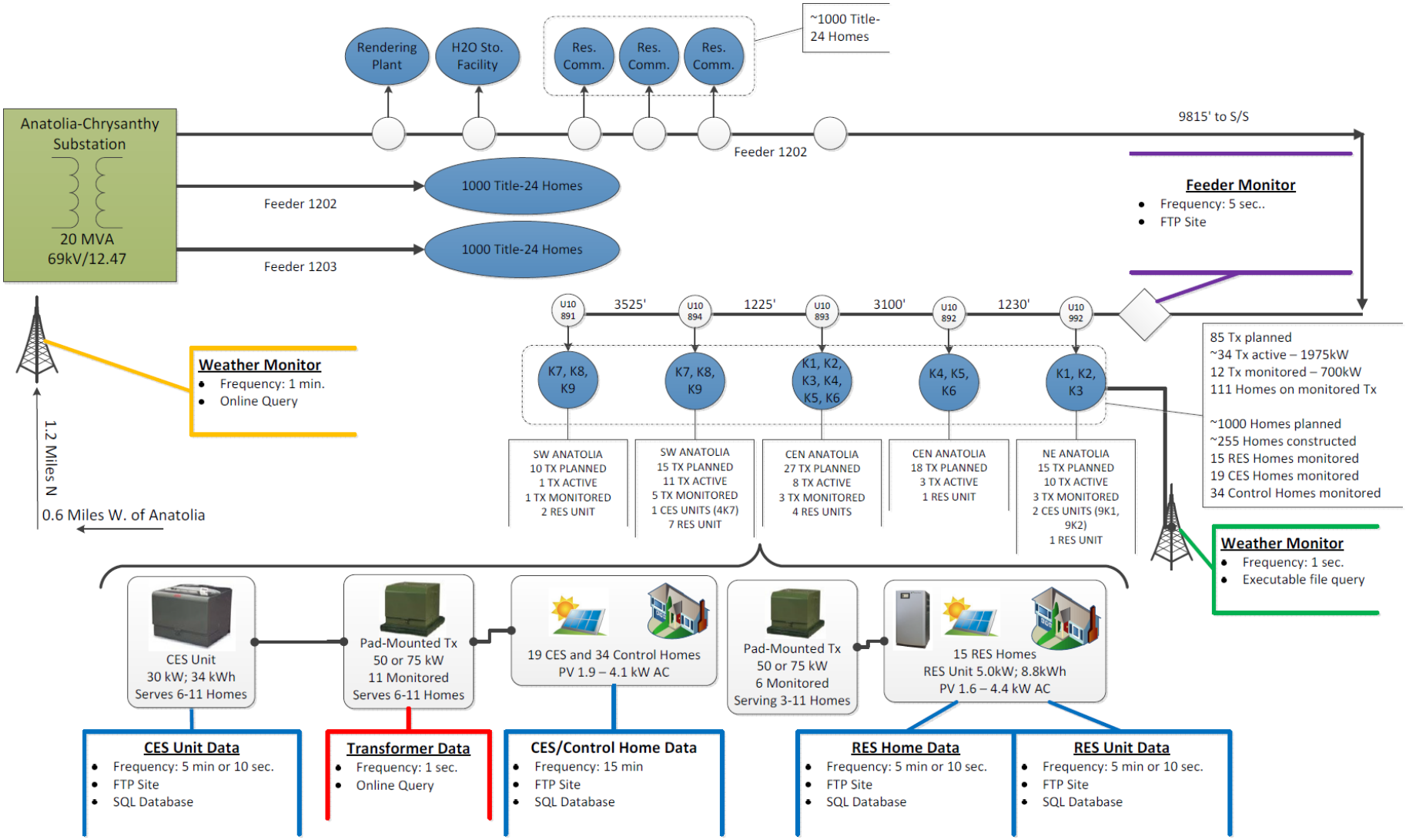
- ▲ ≤ 10 seconds
- ◭ 5 minutes
- △ > 5 minutes

The longest data collection interval is 15 minutes.

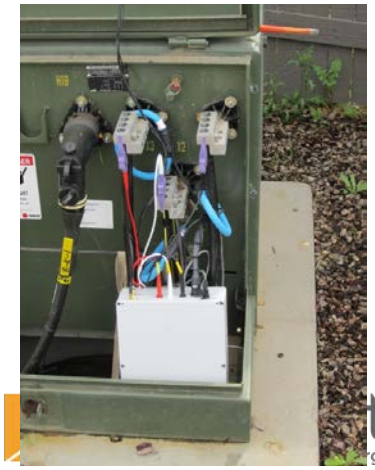
Key

- ● = Voltage
- ● = Current
- ● = Power
- ● = Energy
- ● = Temperature
- ● = Solar Insolation
- ● = Weather Data

High Resolution Data Collection



NREL Transformer Monitoring



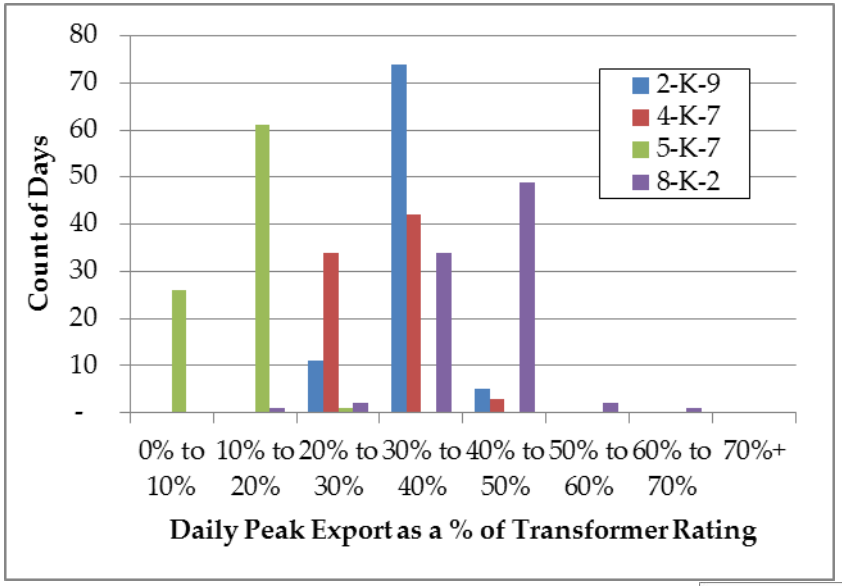
Twelve Distribution Monitoring Units (DMU) installed at 50 and 75kVA transformers are collecting 1 second data

- Custom built with off-shelf hardware
- Timing and location accuracy via GPS receiver
- Real-time measurements transmitted via cellular modem
- Uses phasor calculations similar to PMUs
- Communicates using IEEE Std. C37.118 for synchrophasors
- Voltage channels sample two 120V legs and neutral of transformer
- Current measured on each 120V leg and neutral
- Output includes RMS and phasor info for all sampled wave forms
- Includes frequency of secondary voltage
- Apparent, real and reactive power flows are calculated
- Power factor and displacement power factor derived from power and phasor values
- Includes PQ calculations
- Internal DMU and external transformer temperature monitored

Example of Data Analysis – Tracking RES Unit Efficiency

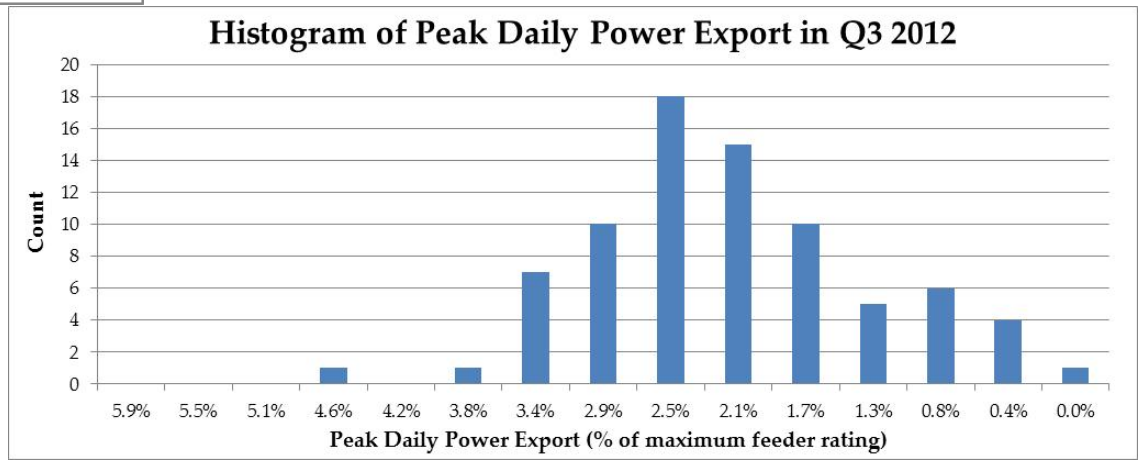
Unit	Round Trip Efficiency on 11/1 and 11/2	Round Trip Efficiency on 7/4 and 7/5	Round Trip Efficiency on 6/15
RES 2	84%	83%	82%
RES 3	81%	83%	85%
RES 5	80%	79%	83%

Example of Data Analysis – Studying Export Levels



Export at transformer is high….

…. Yet low at feeder



CES Installation Lessons

- Units shipped and assembled onsite by GridPoint, PowerHub and SMUD personnel
- Crew, Operations and Safety personnel were trained at warehouse dock prior to field installation
- Installation by crew completed in one day each
- Commissioning took approximately 2 days - mostly IT integration and operator interface work
- Design changes made for lift points on top corners to enable existing distribution crew procedures for transformer installs versus slinging

Demonstration Lessons Learned

- Allow more time for UL and IEEE compliance testing
- Close frequent customer contact is essential to success
- Incentives need to be robust to attract participation
- Engaged city of Rancho Cordova permitting office early in project. Helped expedite plan check and approvals.
- Pro-actively engaged local fire service regarding technology
- Application of Time of Use rates has been a challenge with the introduction of energy storage and PV
- Relying on customer broadband for communications is unreliable

Challenges

- Equipment maintenance efforts more complex than expected
- Data analysis required extensive development support
- More time required to coordinate/resolve issues
- Marketing for CES customers was difficult
- Data acquisition more complex than expected
- Testing delay due to manufacturing defect in one RES unit
- Troubleshooting more complex than expected

Unit Downtime

Unit #	Q2 Total Downtime (%)	Q3Total Downtime (%)	Q4 Total Downtime (%)
RES1	25%	14%	38%
RES2	27%	48%	36%
RES3	25%	14%	38%
RES4	84%	100%	37%
RES5	25%	75%	35%
RES6	27%	92%	100%
RES7	89%	29%	100%
RES8	26%	14%	38%
RES9	27%	14%	38%
RES10	25%	14%	50%
RES11	69%	65%	100%
RES12	25%	12%	38%
RES13	34%	14%	38%
RES14	98%	14%	38%
RES15	22%	14%	51%
CES 1	23%	27%	1%
CES 2	21%	7%	27%
CES 3	49%	29%	51%

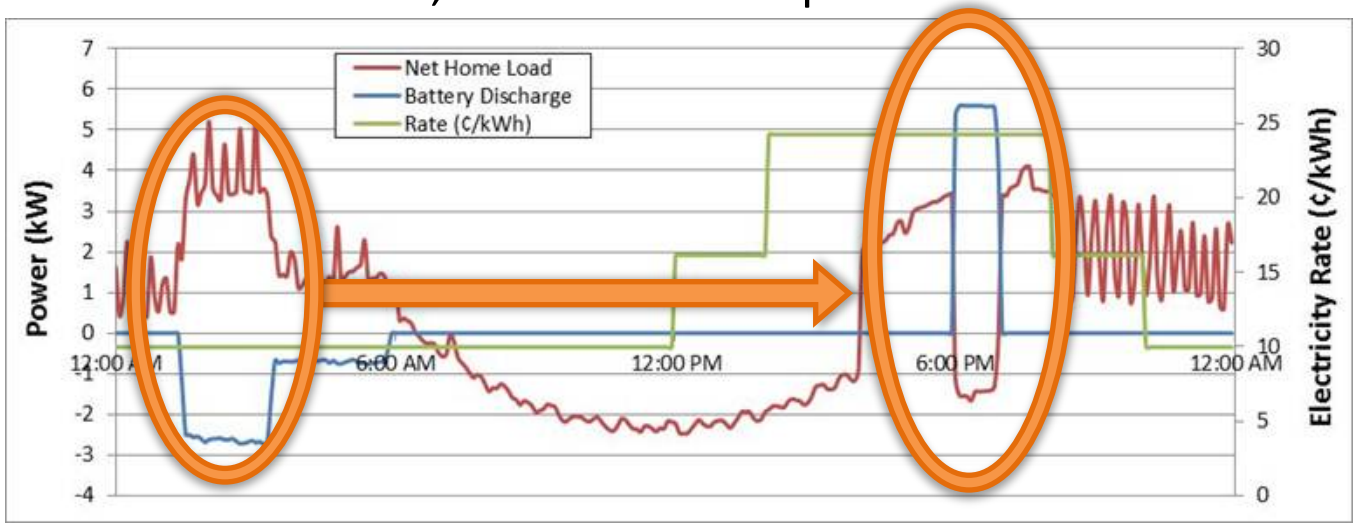
Preliminary Value Analysis of Applications

- Today we will be presenting preliminary values for three applications:
  - > Time of Use Energy Cost Management
  - > Electric Energy Time Shift
  - > T&D Upgrade Deferral
- Our analysis is based upon results thus far from our demonstration and scaled up to assess broader implications for SMUD.

APPLICATION #1 – TIME OF USE ENERGY COST MANAGEMENT

Definition

- A customer uses storage to shift between super peak prices and off peak prices during summer months with peak pricing.
- We analyzed the RES units discharging to optimize across rates, load and PV output.



Input	Assumption
Storage Location	Customer Home
Storage Owner and Operator	Customer
Operation	**1000 batteries discharge for a 3 hour Super Peak period from 5 PM to 8 PM for 80 days a year at 1.8 kW each.**

Energy Use Shifted From High Cost to Low Cost Times

APPLICATION #1 – TIME OF USE ENERGY COST MANAGEMENT, VALUE

Technical Assumptions

Item	Assumption
Number of Units	1000 RES Units
Power Capacity	3.0 MW
Energy Capacity	5.4 MWh
Project Lifetime	10 years
Round-trip Efficiency	82%
Discount Rate	8%

Costs and Results

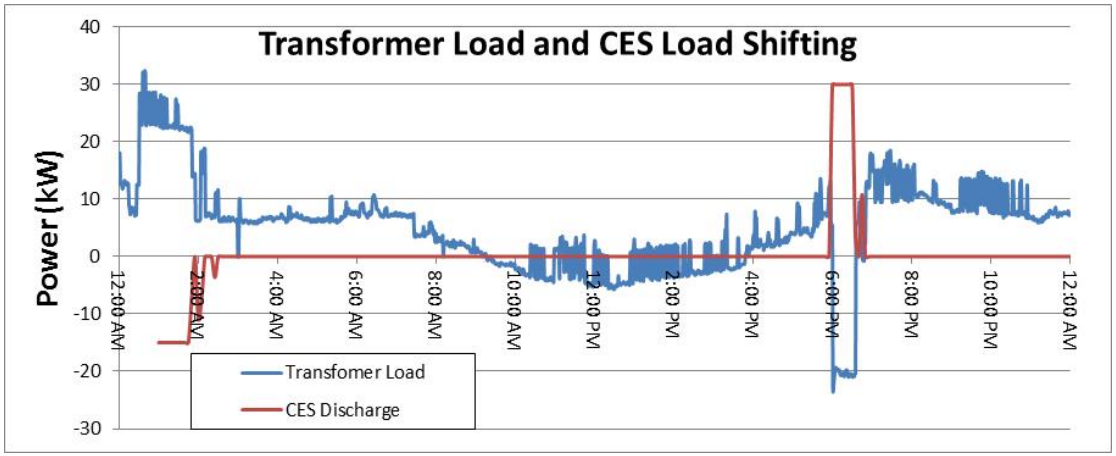
Item	Assumption
Summer Super Peak Rate (2 PM to 8 PM)	24.24 ¢/kWh
Summer Peak Rate (Noon to 2PM and 8 PM to 10 PM)	16.14 ¢/kWh
Summer Off Peak Rate	9.97 ¢/kWh
NPV of Benefits over Project Lifetime	***$386,000***
Normalized Benefit	***$129/kW***

In this application, a SMUD Solar Smart customer that added energy storage could save $390 over a 10 year period by shifting energy usage from periods of high cost to periods of low cost.

APPLICATION #2 – ELECTRIC ENERGY TIME SHIFT

Definition

- A utility that charges ES when demand is low, and discharges the devices when demand is high may decrease their energy costs by allowing the utility to run a more cost effective mix of generation.
- We looked at the CES units discharging in the early evening after PV output falls off.



Input	Assumption
Storage Location	Distribution Transformer
Storage Owner and Operator	Utility
Operation	**Assume that 100 batteries discharge for a 3 hour Super Peak period from 5 PM to 8 PM for 152 days a year at 6.7 kW .**

APPLICATION #2 – ELECTRIC ENERGY TIME SHIFT, VALUE

Scaling the deployment of our CES units to shift energy usage could save SMUD $126,000.

Technical Assumptions

Item	Assumption
Number of Units	100 CES
Total Power Capacity	3 MW
Total Energy Capacity	3.4 MWh
Project Lifetime	10 years
Round-trip Efficiency	82%
Discount Rate	6.17%

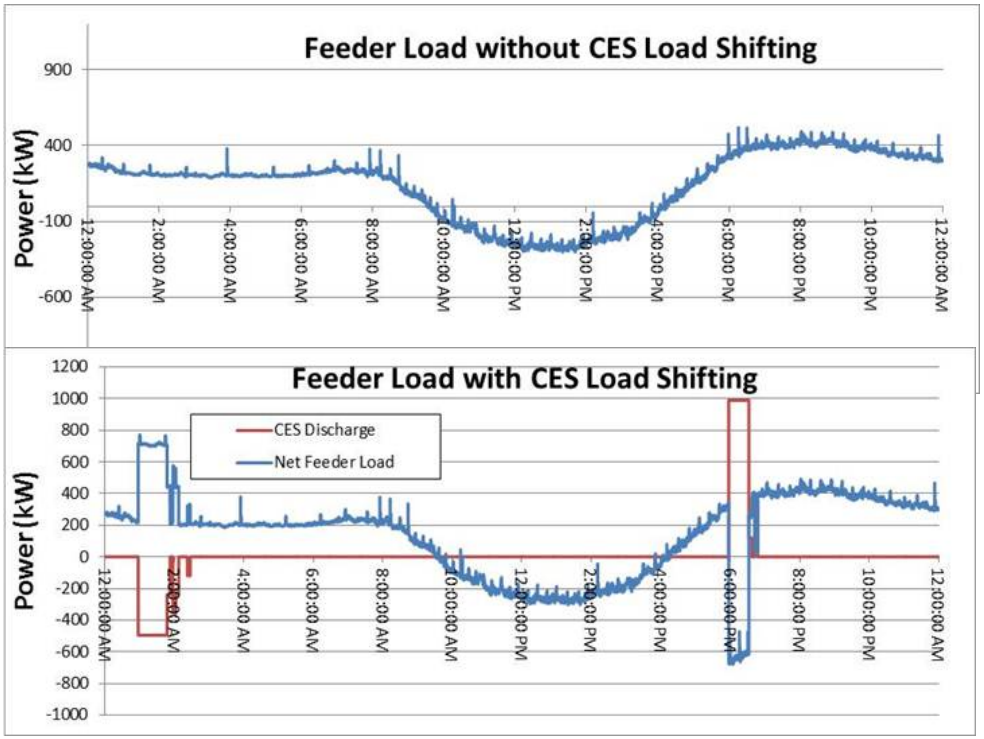
Costs and Results*

Item	Assumption
Average Arbitrage Value of Energy	$15/MWh
Average Deferred Capacity Value	$23/kW-Year
NPV of Benefits over Project Lifetime	***$126,000***
Normalized Benefit	***$41/kW***

APPLICATION #3 – T&D UPGRADE DEFERRAL

Definition

- Use energy storage to reduce peak load which can delay upgrades to existing equipment or specify smaller equipment when building a new distribution system. This can also result in avoided or reduced T&D O&M costs.



Input	Assumption
Storage Location	Distribution Transformer, Customer Home
Storage Owner and Operator	Utility
Operation	**Assume that 50 batteries discharge at 20 kW for a 1 hour peak period.**

APPLICATION #3 – T&D UPGRADE DEFERRAL, VALUE

Installing energy storage to defer distribution upgrades in SolarSmart communities could be worth $176/kW to SMUD.

Technical Assumptions

Item	Assumption
Number of Units	50
Power Capacity	1.5 MW
Energy Capacity	1 MWh
Project Lifetime	3 year deferral
Round-trip Efficiency	82%
Discount Rate	6.17%

Costs and Results*

Item	Assumption
Deferred Distribution Capacity Benefit[1]	$100/kW-Year
NPV of Benefits over Project Lifetime	***$264,000***
Normalized Benefit	***$176/kW***

1. Source: Benefit Analysis of Energy Storage: Case Study with the Sacramento Utility Management District, 2011 Technical Report, EPRI

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Next Steps

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PROJECT WEBSITE:
https://solarhighpen.energy.gov/project/sacramento_municipal_utility_district

Q &A AND DISCUSSION