The Current Flavors of M&V

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Reasons for Evolving M&V

1. More rapid data analysis
2. Improve programs during implementation cycles
3. Improve evaluations with little or no extra costs
4. Understand and manage demand curves
5. Evaluate GHG impacts of programs and measures
6. Efficiency as a grid resource
Integrated Resources

Can Energy Efficiency Compare with:

- Distributed Generation?
- Renewable Energy?
- T&D Upgrades?

Traditionally, system planners have deeply discounted energy efficiency at the grid level.
Retiring Power Plants

A host of U.S. nuclear power plants closed or closing

Even more coal plants offline

Source: Brookings analysis of EIA monthly electric generator inventory, September 2016
Dealing with SONGS Closure

2014 All Resources Procurement

- Implement portfolio solution to address local peak
- Demonstrate DSM can be used to meet capacity & reliability

- 125MW of Efficiency Projects

Providers of efficiency solutions are required to meter the savings delivered.
Efficiency for Capacity Needs

Demand Management Program (DMP)

Replacing Indian Point 2,000 MW

- 1,000 MW from Hydro-Quebec
- Renewables, CHP, other Generation
- Energy Efficiency
  - 100 MW of Efficiency Upgrades
    - Targeted 2-6 pm, Jun-Sep

Non-Wires T&D Solution: BQDM

- Install $200 million customer side resources to defer building a $1 billion substation
Most Desirable DSM

- Feasible
- Economical
- Marketable
- Desirable

100 MW
## Increased Value of Efficiency

A premium paid for targeted efficiency when it can be measured and confirmed.

### DEMAND MANAGEMENT PROGRAM

In addition to the current program offerings, increased incentive rates will be offered to eligible Con Edison electric customers for energy improvements that provide summer on-peak demand reduction.

<table>
<thead>
<tr>
<th>Project Type</th>
<th>Before DMP</th>
<th>DMP Offer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermal Storage</td>
<td>$600/kW</td>
<td>$2,600/kW</td>
</tr>
<tr>
<td>Battery Storage</td>
<td>$600/kW</td>
<td>$2,100/kW</td>
</tr>
<tr>
<td>DR Enablement</td>
<td>$200/kW</td>
<td>$800/kW</td>
</tr>
<tr>
<td>Chiller/HVAC/BMS/Controls</td>
<td>$0.16/kWh</td>
<td>$0.16/kWh + $1,250/kW</td>
</tr>
<tr>
<td>Lighting</td>
<td>$0.16/kWh</td>
<td>$0.16/kWh + $800/kW</td>
</tr>
</tbody>
</table>
Targeted Efficiency

- Real-Time, Near-Time M&V
  - Efficiency hits target window
  - No room for error

- Specific knowledge needed
  - Which measures where
  - In which sectors
  - Which incentives to adjust
  - Measures to add/delete
  - How to target marketing
Most Desirable DSM
The Evolving Grid...

Retiring Power Plants
It’s Really About Data

Retiring Power Plants
Defining Advanced M&V

Data Analytics
- Machine Learning & Artificial Intelligence
- People Learning & Real Intelligence
- Engineering & Statistical Analysis
- What is granular data?
- What is the value to the energy sector?
- The future of E and M and V?
Whole Building Data

The Role of AMI Data?

- Scoping and snooping?
- Billing analysis?
- What sectors?
- Is it really “big” data?

What about even more granular data?
Sources of Data
Real-Time, Near-Time, Full-Time

RESIDENTIAL

COMMERCIAL

EDGE gateway

Occupied Spaces

Systems

Cloud
NEBs: Building Health

Schools and learning outcomes...

THE 9 FOUNDATIONS OF A HEALTHY BUILDING

forhealth.org
### Who Owns Advanced M and V?

#### Possible Value Streams for M and V

<table>
<thead>
<tr>
<th>PROGRAMS</th>
<th>IMPLEMENTERS</th>
<th>OWNERS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temporal and locational targeting and confirmation of CDM/DSM</td>
<td>Contract performance monitoring</td>
<td>Better understanding of facility usage</td>
</tr>
<tr>
<td>Evaluation of projects and programs</td>
<td>Spot changes in use, impacts on usage, identify positive/negative shifts</td>
<td>Building health</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Workplace analytics, productivity analysis</td>
</tr>
</tbody>
</table>
THANK YOU!

Have you read Zondits today?
Non-regulated utilities
Pay-for-performance programs
“Fail Fast”
Valuation using actual costs, not “regulatory” costs
Increasing visibility into the data business
Continuous iterative M&V + faster cycles
Capacity cost increase: the set up for a perfect storm

Boston area utilities
3x capacity cost increase
~40% increase in procurement costs
2% - Negative energy prices
Capacity > Energy

*NEMA Boston. Includes required reserves. Excludes transmission capacity costs.
AMI meter analysis provides visibility into the business

“David was there all along, I just undressed the stone”

-Michelangelo

Reference load shapes
Individual customer level analysis
Modeled vs. actual load shapes by customer class

Reference load shape vs. Actual peak day load shape

Significant implications for:
- DSM valuation
- Rate setting
One customer, one week

Residential customer coincident peak load ranges from 0.1 kW to 40 kW! Does a residential customer “class” even exist?
Shape shifting amoeba: residential peak load distribution

Summer peak

Fall Saturday

Animation from **Sagewell SageSight™** AMI meter data analytics software
Result: EM&V will change
Continuous, iterative M&V

Principles:
Precision vs. accuracy
Look for obvious successes – do more
Look for obvious failures – stop
“Fail fast”
Continuous, iterative M&V

Case studies:
Weatherization
Heat pump impact measurement
Behavioral peak load reduction email program
Weatherization case study – peak reduction

Peak: 1.8 kW average summer coincident peak
0.1 kW peak reduction
5.6%
Weatherization peak reduction – Mass Save®

Reported reduction:
13,938 kW / 20,745 participants = 0.67 kW
37% peak reduction from weatherization?

Precise but not accurate?
Will “deemed savings” approach survive?

Q2 2017 Electric & Gas Summary Report
*Prior to 2016, benefits were only reported in Q2 and Q4. Benefits in the other quarters are shown as zero.

<table>
<thead>
<tr>
<th>As of Q2 2017</th>
<th>Participants</th>
<th>Total Expenditures</th>
<th>Annual MWh Savings</th>
<th>Lifetime MWh Savings</th>
<th>Summer Capacity (kW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential</td>
<td>3,593,671</td>
<td>$270,393,187</td>
<td>584,086</td>
<td>4,475,067</td>
<td>79,313</td>
</tr>
<tr>
<td>Residential Whole House</td>
<td>1,139,855</td>
<td>$162,093,278</td>
<td>232,877</td>
<td>1,157,469</td>
<td>37,935</td>
</tr>
<tr>
<td>Residential New Construction</td>
<td>5,134</td>
<td>$7,059,826</td>
<td>7,184</td>
<td>109,228</td>
<td>3,066</td>
</tr>
<tr>
<td>Residential Multi-Family Retrofit</td>
<td>19,417</td>
<td>$18,031,125</td>
<td>9,310</td>
<td>91,805</td>
<td>833</td>
</tr>
<tr>
<td>Residential Home Energy Services - Measures</td>
<td>20,745</td>
<td>$111,740,730</td>
<td>87,548</td>
<td>826,601</td>
<td>13,938</td>
</tr>
</tbody>
</table>

Source: Masssavedata.com
Heat pump peak impact

0.5-1 kW peak reduction over old equipment
Equivalent to high efficiency central AC
If you just look at AC impacts... no advantage
But...
Heat pump impact – beneficial electrification

2,000-6,000 kWh of “beneficial electrification”
Significant carbon reduction
$300 to $1,000 of additional contribution margin
Verdict: continue

Note: ductless systems vs. ducted systems outcomes
Change focus to favor ducted over ductless?
Decoupling still a good idea? Recouple?
Case study: emails & “fail fast”

2015, “great success” – 10-15% peak reduction
2016, 5-day heat wave – 2-3% reduction, fatigue
Daily evaluation of success

2016, at 3 other utilities: 5-10% increase!
Total failure; end program, celebrate, move on
The catch

1 = 100,000 data points/yr

5 million meters & 5 yrs = 2.5 Trillion

Traditional databases

New EM&V software firms will emerge

Analysis and analysts will evolve
Company Overview

- Sensor & software services platform company delivering total home intelligence
- Expertise in big data processing, thermodynamic modeling & consumer engagement
- HQ in Oakland, CA w/ lab in Germantown, MD - privately held, backed by top VCs
Thermodynamic Modeling

Our Thermostat Grey Box Model:

- Correlate indoor to outdoor conditions
- Unique for every house
- Uses minimal customer data
- Developed in collaboration with University of Maryland

3x more energy efficiency p/t-stat
15% more DR capacity per home

Connected Savings Intelligence DRMS
Granular Weather Data

Hyperlocal, real-time weather data for energy efficiency modeling & load forecasting

50% of your energy use is driven by the weather.
Today’s Home is Not Really Connected

<1% of all devices connected
Or Is It?
Whisker Labs Energy Sensor
Typical Energy Data
Our View of Energy Data

![Graph showing energy data]
Detecting Efficient vs. Faulty Window AC

Inefficient Systems Produce Less Cooling & Use More Energy

![Graph showing power and cumulative energy consumption for efficient and faulty AC systems.](image-url)
Connected Savings Programs & Pilots
Connected Savings Programs & Pilots

• Residential DR as a reliability product
• Residential DR, HVAC optimization, and behavioral EE for peak load reduction
• Whole home energy monitoring & HVAC fault detection
• Risk mitigation and short-term supply/demand optimization for residential electricity retailers
• Persistent virtual energy auditing & optimized measure implementation*
EM&V is Critical to Everything We Do

But No Single EM&V Approach Works for Everything We Do

• Our customers have differing objectives & preferences

• Rules, data sources and data access differ by program type, by jurisdiction and by customer

• Programs are designed to do different things and can’t always be measured the same way
  • Mile markers vs. micrometers vs. measuring cups

• Program budgets are always tight
  • There may not be sufficient program-level benefit to warrant the cost of collecting, storing, analyzing, and protecting large amounts of customer data
Advanced M&V
NEEP 2017 EM&V Regional Fall Meeting
Hartford, CT
October 3, 2017
Trade-offs in M&V

- Claimed Savings
- Desk Review
- Advanced M&V
- Pre/Post Metering
- Post Metering
- Evaluation
- Financial Due Diligence

Accuracy vs. Cost
Claimed Savings

• Project Summary
  – Custom lighting project
  – Replaced metal halides with LEDs, added staged dimming
  – Assumed 7,200 lighting hours of use (HOU)

• Energy Savings
  – Annual savings of ~266,000 kWh
Desk Review

• Personnel Interview
  – Confirmed installation of proposed measures
  – Adjusted HOU from 7,200 to 6,935

• Energy Savings
  – Annual savings of ~255,000 kWh
Advanced M&V

• Modeling Approach
  – Split AMI data into pre and post-installation periods
  – Merge with data from additional sources (weather, occupancy, schedules, etc.)
  – Fit separate models to pre and post dataset
  – Apply models to typical year conditions
  – Take difference in response
Utility Tracking
- Project ID
- Measure Type
- Installation Date
- Business Hours

AMI
- Hourly Energy Usage

Local Climatological Data (LCD)
- Historical temperature, RH, and wind speed

Typical Meteorological Year (TMY)
- Normal temperature, RH, and wind speed

Cleaning, merging, interpolating, splitting by site

Pre-Installation
- Energy, temperature, RH, and wind speed

Post-Installation
- Energy temperature, RH, and wind speed

Randomized split, training, testing, residual analysis

Baseline comparison

Typical Year Measure Savings

Pre and Post-Installation annual, weather normalized energy usage

NREL

NOAA

Final Data

Model Validation

Typical Meteorological Year (TMY)
- Normal temperature, RH, and wind speed

Pre-Installation Model

Post-Installation Model

Results

Process

Sources

Raw Data

Processing

Model Validation

Cleaning, merging, interpolating, splitting by site

Pre-Installation
- Energy, temperature, RH, and wind speed

Model, feature, and parameter selection

Baseline comparison

Pre- and Post-installation annual, weather normalized energy usage

Typical Year Measure Savings

Post-Installation Model

Pre-Installation Model

Results

Cleaning, merging, interpolating, splitting by site

Pre-Installation
- Energy, temperature, RH, and wind speed

Model, feature, and parameter selection

Baseline comparison

Pre- and Post-installation annual, weather normalized energy usage

Typical Year Measure Savings

Post-Installation Model

Pre-Installation Model

Results
Advanced M&V

Pre-Installation Usage: 9521 Hours Measured
Post-Installation Usage: 2186 Hours Measured
Assumed Installation Period

Energy [kWh]

2016-01 2016-03 2016-05 2016-07 2016-09 2016-11 2017-01 2017-03 2017-05

Time
Advanced M&V

- Annual savings of ~186,000 kWh
Post Metering

• Metering
  – Summer only (August, early September)
  – May skew low

• Energy Savings
  – Annual savings ~173,000 kWh
Post Installation Metering
## Results

<table>
<thead>
<tr>
<th>Method</th>
<th>kWh Savings</th>
<th>Realization %</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Claimed Savings</td>
<td>266,000</td>
<td>NA</td>
<td>7,200 hour claimed operation</td>
</tr>
<tr>
<td>Desk Review</td>
<td>255,000</td>
<td>96%</td>
<td>Hours reduction</td>
</tr>
<tr>
<td>Post Metering</td>
<td>173,000</td>
<td>65%</td>
<td>May be skewing low for summer</td>
</tr>
<tr>
<td>Advanced M&amp;V</td>
<td>186,000</td>
<td>70%</td>
<td>108% of metered</td>
</tr>
</tbody>
</table>
Closing Thoughts

• Use of AMI (advanced analytics) versus traditional approaches is not a binary choice
• Traditional M&V varies from not so accurate to very accurate (and expensive)
• Some other businesses have lower or different M&V requirements
• Even 1-hour AMI data can give great results for simple C&I projects