Acceptance Criteria:

What Accuracy Will We Require for M&V2.0 Results, and How Will We Prove It?

Quality, accurate results

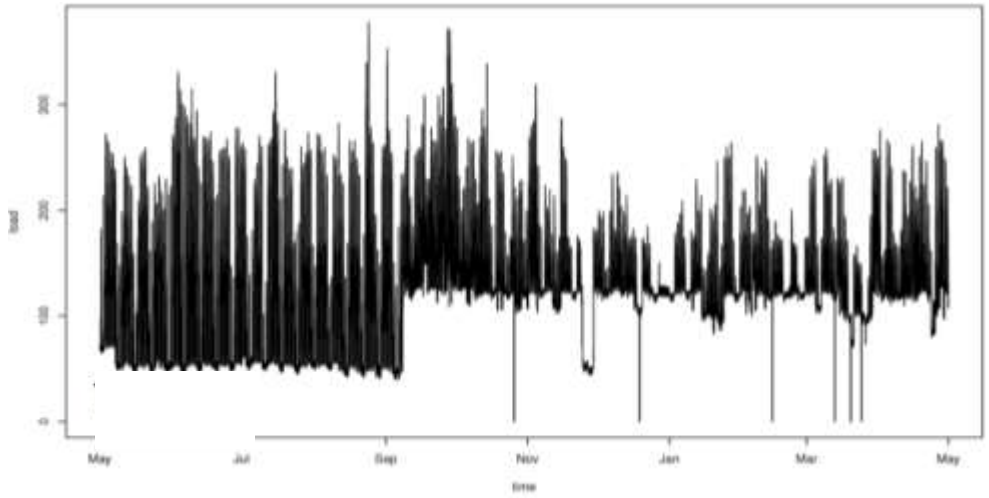
- Tool testing can tell us that 2.0 technologies are reliable – can model, predict energy use well over time horizons used for EE

- Once we have reliable tools, still have to verify that application generates a quality result

- Many, but not all buildings are 'predictable'/model-able
  - Uncertainty analysis can quantify *error due to modeling error in M&V2.0 tools*
- Gross savings at meter may not be gross savings due to the measure, i.e., non-routine adjustments may be needed
  - Transparent documentation especially of non-routine adjustments is needed

Non-routine events and adjustments

- Gross metered savings may not reflect gross program/measure savings
  - E.g. Occupancy may change or loads may be added/removed

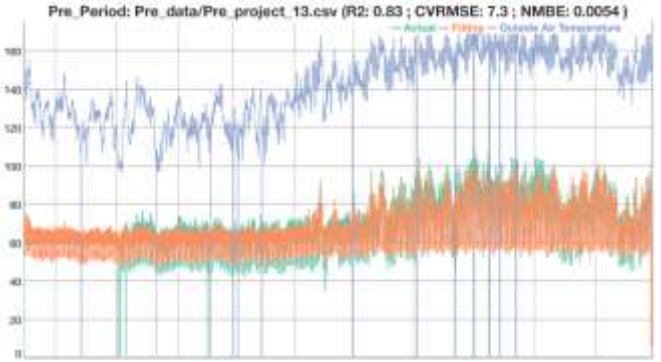


- Most 2.0 tools do *not* capture non-routine events, comparison group 2.0 tools may
  - Possible that 2.0 analytics can flag cases where savings drop or increase unexpectedly, so that implementers can flag events, make adjustment
  - Currently this is a manual process
  - If whole-building M&V were used at large scale, would these events cancel out?

Common sources of error savings estimation and evaluation

- Measurement error: is the instrument accurate
  - Often assumed negligible for revenue-grade utility meters

- Modeling error: does the model fit the data, characterize the phenomenon
  - Often characterized with 'goodness of fit' statistics



- Sampling error: is a selection representative of the population
  - Often considered in evaluation, not applicable to single site M&V

Uncertainty analysis

- ASHRAE Guideline 14 provides formulation to quantify savings uncertainty due to model error (no sampling)
  - Scope is individual buildings/projects
  - Negligible measurement uncertainty for revenue grade utility meters

- Add up each building's savings to get program-level result;
  - Use error propagation to get **aggregated savings** uncertainty (not covered in ASHRAE)

Usual interpretation of uncertainty

- Establish range of values (uncertainty), and likelihood (confidence) that savings lie in that range
- Lower uncertainty, smaller confidence interval, smaller range
  - 95% confident that savings are between [4,000, 12,000], i.e. 8,000 +/- 4,000, i.e. fractional savings uncertainty is 50%
  - 68% confident that savings are between [6,000, 10,000], i.e. 8,000 +/- 2,000 , i.e. fractional savings uncertainty is 25%

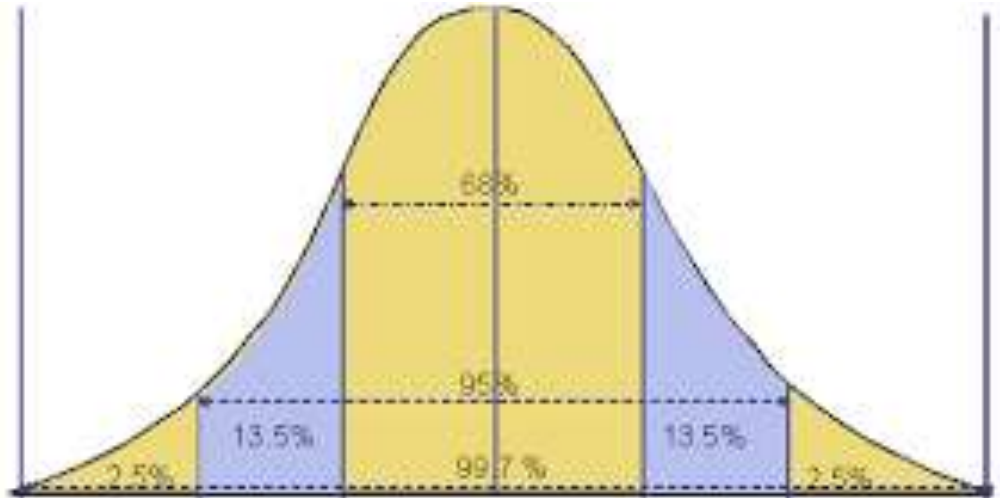
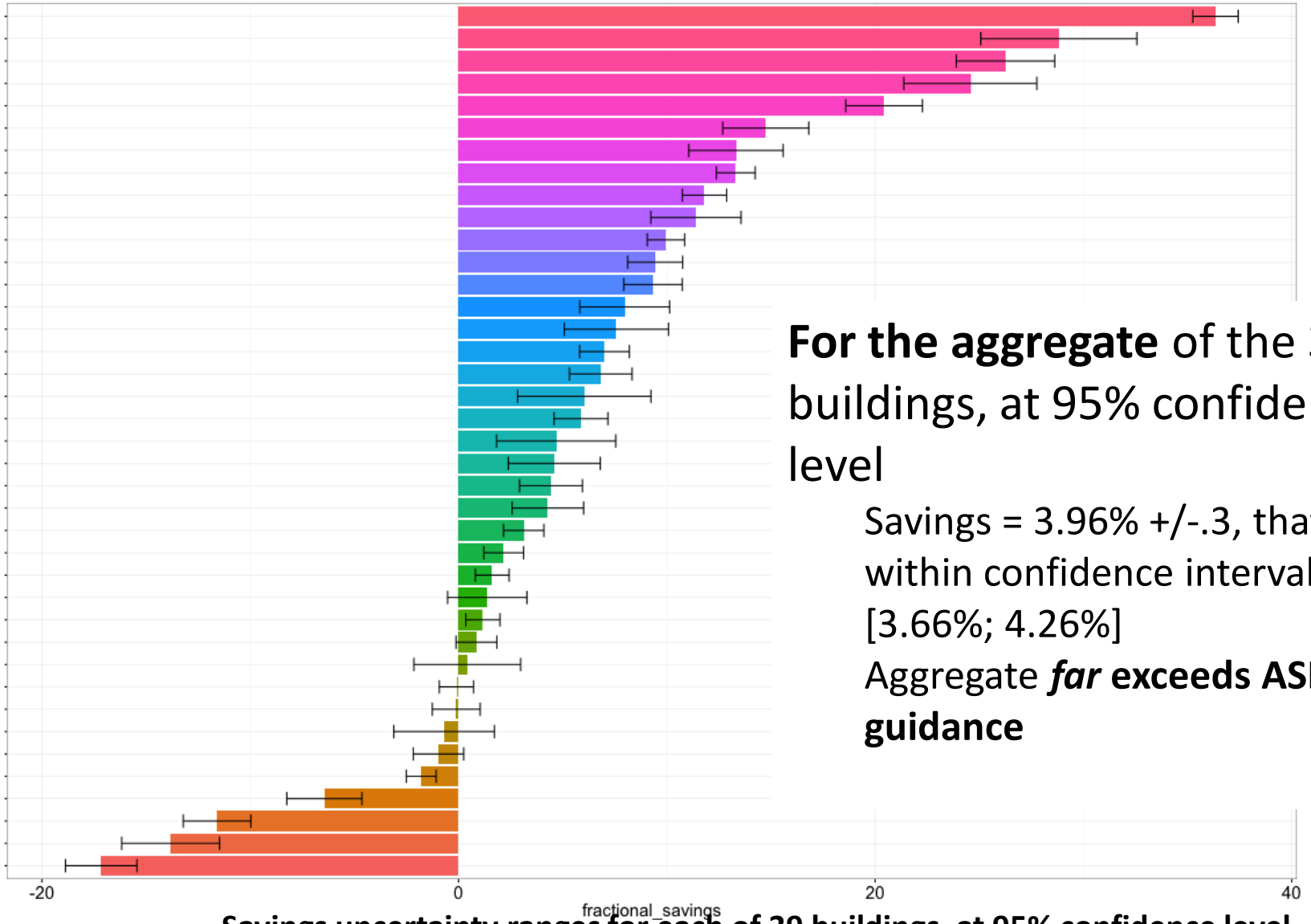


Illustration: savings uncertainty at building and aggregate level, due to model uncertainty (no sampling)



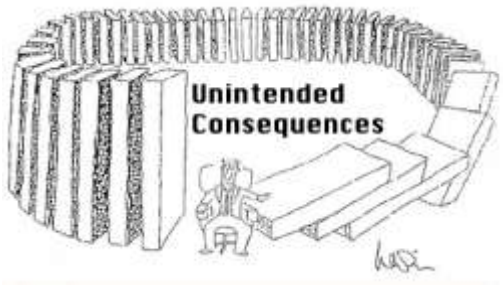
For the aggregate of the 39 buildings, at 95% confidence level

- Savings = 3.96% +/-.3, that is within confidence interval of [3.66%; 4.26%]
- Aggregate ***far*** **exceeds ASHRAE guidance**

Savings uncertainty ranges for each of 39 buildings, at 95% confidence level

Some cautions on certainty analyses

- If accuracy concerns are issue for M&V2.0, we should establish what bar for rigor must be met
- For 2.0 tools, use same standards for sufficiency applied to "1.0"
  - Consider whether 2.0 can give equivalent or higher levels of certainty
- Not suggesting we quantify *every source* of uncertainty in EE savings estimations
- Avoid double standard for existing cond. whole building approaches vs. deemed, custom, simulation-based approaches
  - Currently, often treat gross savings as point values -- no uncertainty
  - Uncertainty *is* considered for program evaluation, often in sampling



Existing confidence-uncertainty guidance

- ASHRAE puts bar at 68-50 for building-level gross M&V
  - Propagating gross uncertainty from building to aggregate multi-building level reduces uncertainty for the total
- Forward capacity markets have used 80-20 for portfolio-wide savings EM&V
- These criteria arise from separate use cases - what will we require of M&V2.0 tools applied to a program?

Certainty/uncertainty wrap up

- Savings uncertainty may be useful framework to consider M&V2.0 accuracy associated with imperfect ability to model/predict consumption
- Non-routine adjustments to attribute meter-level savings to measures are currently manual, can be more automated, well documented for evaluation review
- Collective question:
  - How to set the uncertainty target to accept 2.0 tool results
  - What do we require for non-routine event documentation?

Questions on Uncertainty

Program Evaluation Perspective

Sue Haselhorst,
Vice President of Project Analytics

Scaling site results to a program evaluation

The results of an impact evaluation are high-stakes

- Drive shareholder incentives
- Large factor in cost-effectiveness

Best practices specifies impact evaluations that will yield unbiased results.

- A precise value in-and-of-itself does not insure an unbiased result

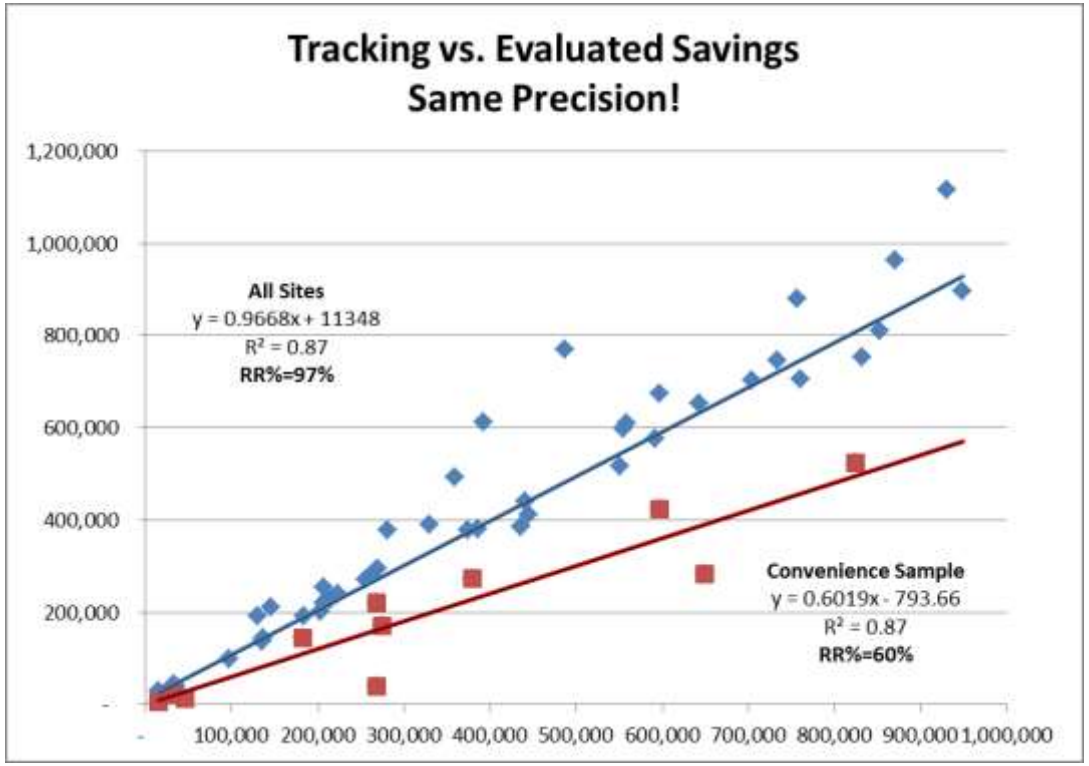
Considerations in scaling to a full impact evaluation

Accurate but biased …

- In 1948, the opinion polls projected Dewey would beat Truman based on telephone surveys. The newspapers were so confident, they printed the results before all the results were in.
  - It turns out Republicans owned telephones, Democrats not so much

A precisely biased result

- Hypothetical
  - In blue: Evaluated results for all sites yields a 97% RR with equivalent precision of ±5% (includes red marker sites as well)
  - In red: Sub-sample not selected randomly yields 60% with similar precision.

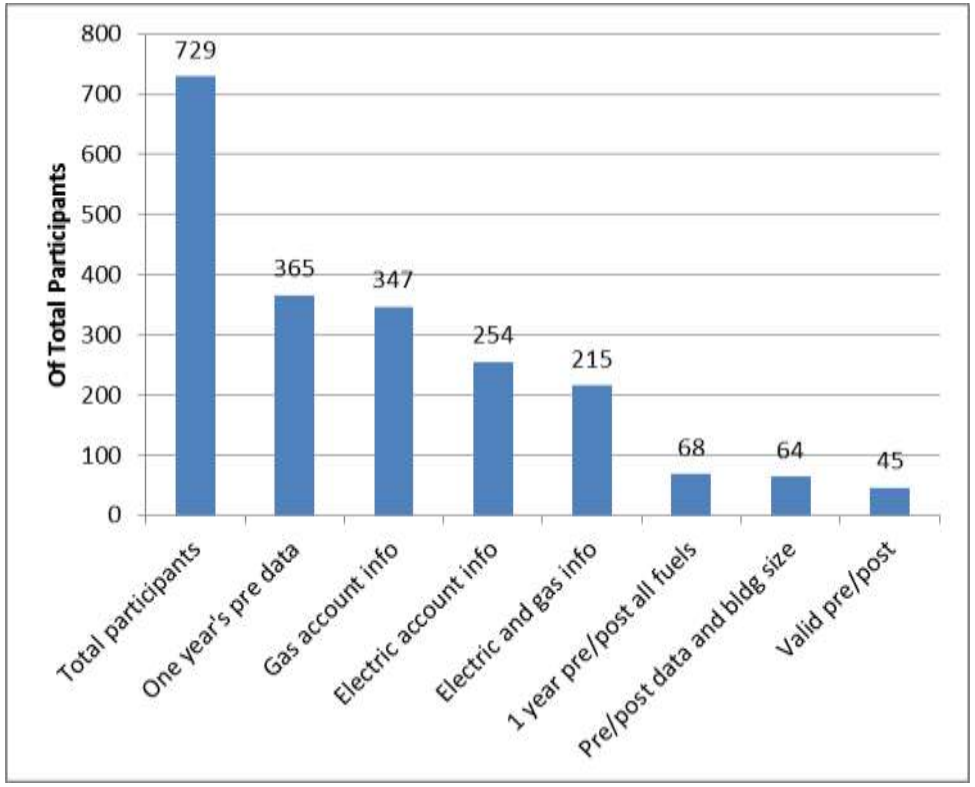


Uncertainty and bias

- On-site M&V: sampling error, unknown measurement error, but minimal bias
  - Sites are selected for on-site M&V introducing sampling error
  - Sampling error is often prescribed to meet ± 10% at the 90% confidence level
    - If the sample was redrawn 10x
      - All but one of the ten result would fall within ±10% of the others
  - The results are unbiased, **as long as the sample has been selected randomly**
  - This error value does not account for *measurement* error – that is the uncertainty associated with individual sites
- Billing analysis: no sampling error, some assessment of measurement error, unknown bias
  - Billing analysis starts with a census of sites – so no sampling error
  - However, **bias is potentially introduced by dropping of sites that are not suitable for billing analysis** (insufficient data, too many estimated reads, badly behaved)
  - Some measurement error (although attribution of technology contribution to savings within this band has uncertainty)

SMUD Example

- Direct install small business whole building evaluation billing data attrition



- What is your confidence in savings estimated using a non-random sample of 45 sites?
  - *Deep Savings for Small CDI ACEEE Summer Study 2016*

Systematic confounding factors

- Billing analysis works well in the residential sector
  - One-to-one correspondence between the measure and the meter serving the measure
  - Savings is often a large fraction of bills (i.e. weatherization savings in the order of 20%)
  - Similar order of magnitude of stable usages (500kWh – 20000 kWh)
  - 10s of thousands of accounts in the analysis often
- Less successful in non-residential sector
  - Multi-meter accounts occur frequently
  - Correspondence between the measure and the meter serving the measure is uncertain
  - Small savings fractions
  - Orders of magnitude range in usage (20,000 – 200,000,000 kWh)
  - Relatively small number of participants
- NY and MA have recently tried and failed to conduct a billing analysis, in some part attributed to meter mismatch problems

Potential Pilot Features

- Collect data through out the pilot of the account attrition
  - How many and why were accounts excluded from analysis
- Within the confines of the pilot
  - Track screening processes and number of sites that meet screening and those that do not
  - Track reasons for attrition
    - Did not meet initial screening
    - Insufficient pre or post billing data
    - Missing or estimated meter reads
    - Poorly performing individual models
    - Model fails other tests
  - At the conclusion of the test, estimate potential impact of the excluded sites on the outcome