Suggested Guidance Criteria for Documentation and Acceptance of Whole-Building Savings Results

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Motivation

- Whole-building programs such as behavioral, retrocommissioning, operations, multi-measure retrofit hold promise for delivering deep savings
  - Represent sweet spot for whole-building M&V with existing conditions baseline
- Advanced whole-building M&V hold promise for capturing full program impact and tracking savings in near real-time
- But…. industry needs to ensure that results from using WB existing conditions are:
  - Rigorous
  - Well documented for 3rd party review

Purpose of This Document

- This is a living discussion document that may evolve over time as industry dialogue continues
- It is intended to be used as a starting point for region- or program-specific or pilot-specific considerations
- As appropriate and relevant, elements of this guidance may be adapted for use in existing or future processes that you may be exploring

Guidance is Based on Industry Best Practice

- Referenced documents
  - International Performance Measurement and Verification Protocol (IPMVP)
  - ASHRAE Guideline 14
  - Bonneville Power Administration Reference Guides
  - California Public Utility Commission guidance on M&V Plan development for M&V 2.0 applications

- Concepts are extended and complemented with:
  - Findings from the published literature
  - Discussions with industry stakeholders nationwide

Background Terminology and Metrics: Model Fitness

- How well do modeled values compare with actual baseline data?

- Guidance includes consideration of key metrics:
  - R^2:
    - Indicates the proportion of energy use explained by the model, use of the right independent variables
    - Scale 0 – 1, higher is better
  - CV(RMSE):
    - Quantification of the typical size of the error relative to the mean of the observations; reflects the model's ability to predict the overall energy use shape reflected in the data
    - 0-100%, lower is better
  - NMBE:
    - Represents the total difference between actual and modeled energy use
    - 0-100%, lower is better

Background Terminology and Metrics : Uncertainty Due to Model Error

- Guidance includes consideration of uncertainty of a savings estimate due to model error, at a given confidence level (Guidance suggests 80-90% confidence)

- Uncertainty can be expressed as a numerical value or fractional (percentage)

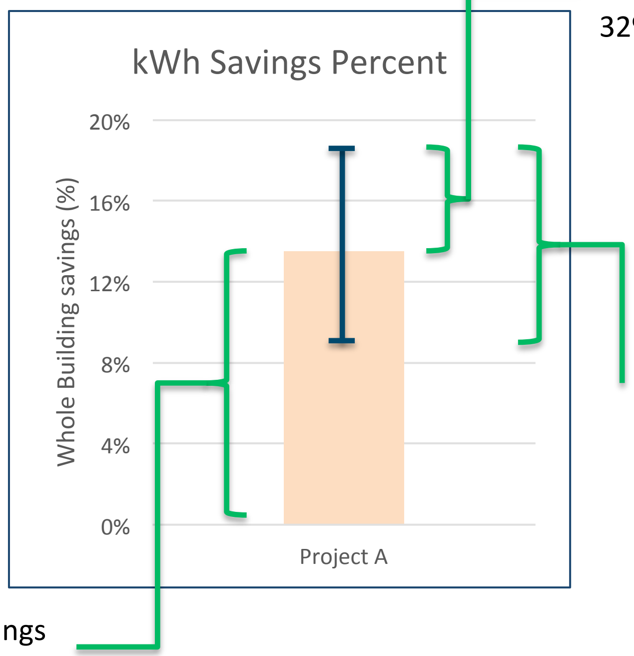
- In ASHRAE Guideline 14, derived from
  - CV(RMSE) of baseline model
  - # of data points in baseline and post periods
  - Savings (numerical or percentage)
  - Desired confidence level

- Provides understanding of impact of model fit on the final savings result – 30% CV(RMSE) may be tolerable if savings are large, whereas 10% may be needed if savings are small

Uncertainty Example

Fractional

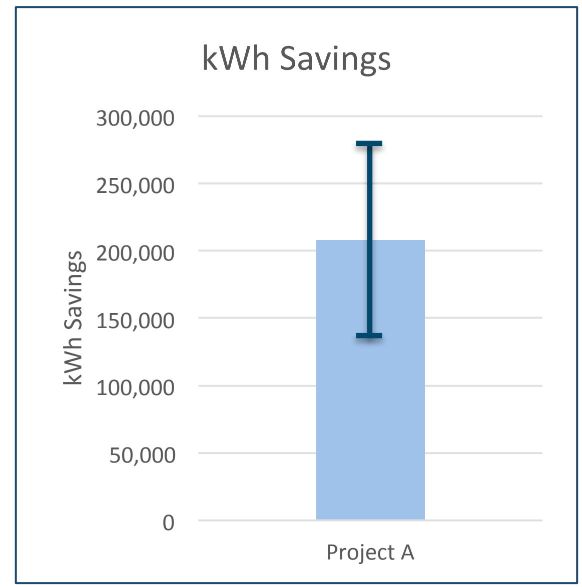
Fractional Savings
Uncertainty (FSU)
32%



Fractional Savings
Range
9.2%; 13.5%; 17.9%

Fractional Savings
13.5%

Numerical



Savings 207,967kWh
Savings Uncertainty 67,109
Savings Range 140,858; 207,967; 275,076

Documentation Guidance and Examples

Documentation of the Savings Estimate Should Enable the Following Questions to be Answered

- Did baseline model characterize baseline energy use well?
- Is savings uncertainty due to model error acceptable?
- Is coverage factor sufficient for a reliable counterfactual?
- Were non-routine adjustments identified and quantified appropriately?

Documentation Guidance: Summary of Recommended Content (1 of 2)

- Modeling narrative
  - The mathematical form of the model, e.g. piece-wise linear regression, or artificial neural network
  - The dependent variables and the independent variables used to predict consumption. Describe how missing or erroneous data was handled.
  - Time resolution
  - Start/end dates and duration of baseline and performance periods (include # of data points)
  - Modeling software used
- Metering information: mapping to accounts/premises; measurement boundaries; on-site generation if applicable; if utility meters not used, describe meters, calibration, etc.
- Spreadsheet of dependent & independent variables, and modeled values (consistent format, determined by program)
- A list and description of measures implemented, including dates and any other data collected to support the project

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Documentation Guidance: Summary of Recommended Content (2 of 2)

For each meter-based savings calculation, results should include:

- A plot of the baseline period that shows
  - Metered baseline data
  - The fitted baseline model
  - The independent variables
  - The model CV(RMSE), NMBE, and R^2

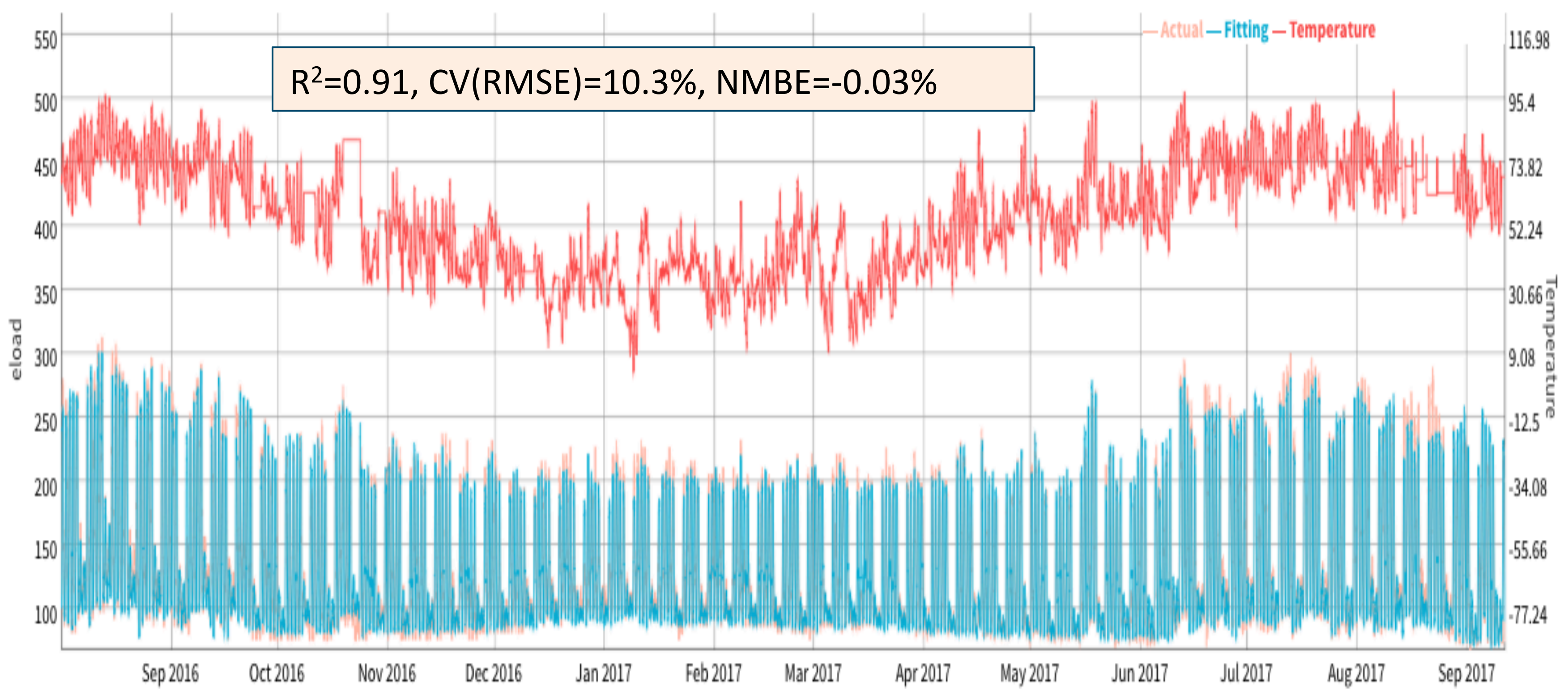
- A plot of the post-measure performance period that shows
  - The projected baseline model
  - The metered data
  - The independent variables
  - Fractional savings
  - Fractional savings uncertainty

- Assessment of sufficient coverage factor

- Documentation of non-routine adjustments

- **Data, calculations, models, and tools must be sufficient to enable replication of results and review by a third party**

Example of Suggested Baseline Data Documentation



Above: Example of a plot showing metered baseline data, a fitted baseline model, the independent variable (temperature), and the baseline model goodness of fit metrics R^2, CV(RMSE), and NMBE.

CV(RMSE) < 25%
NMBE < 0.5%
R^2 > 0.7

Recommended guidance values; not a pass/fail – can be considered in light of uncertainty

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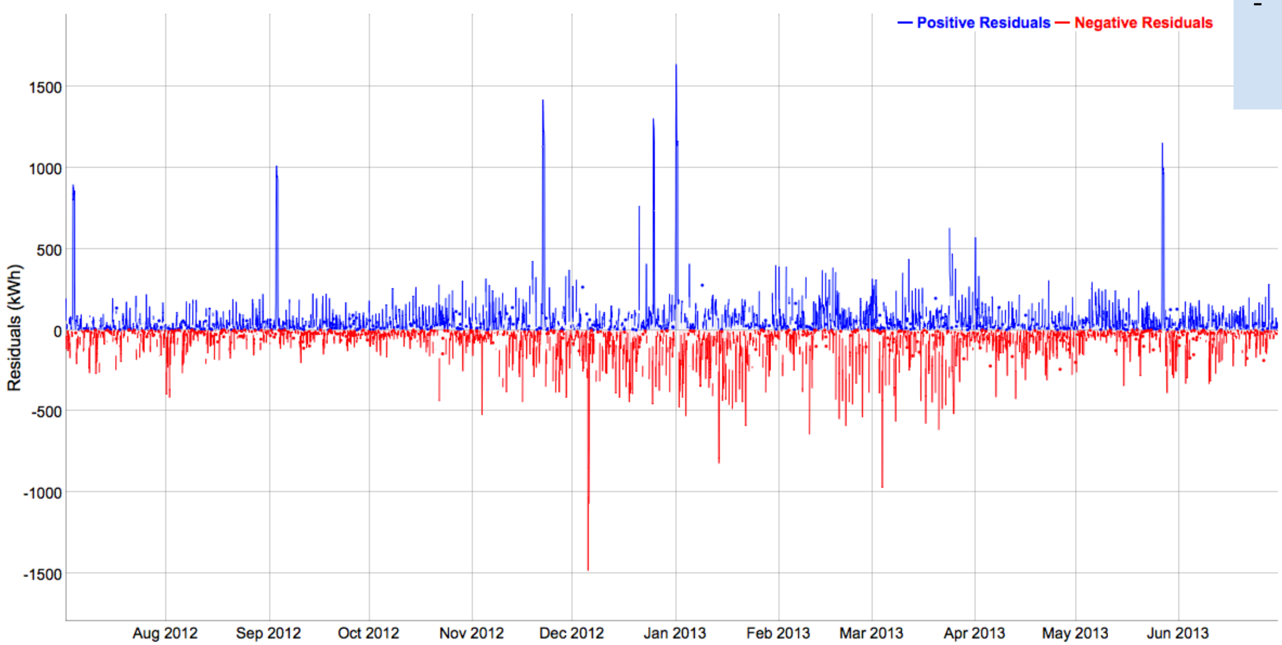
Other Documentation

- Additional charts that may be useful in assessing the suitability of the baseline model
  - Time series of residuals plot

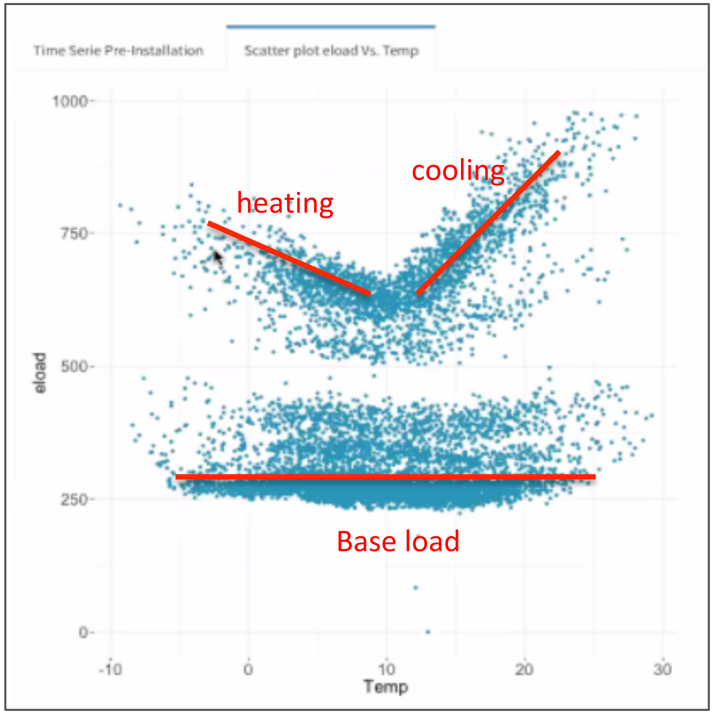
Visual quality check:
- Residuals closer to zero indicate better model fit
- Large offset from zero could indicate bias
- Patterns can indicate autocorrelation, which impacts uncertainty analyses and can suggest missing independent variables



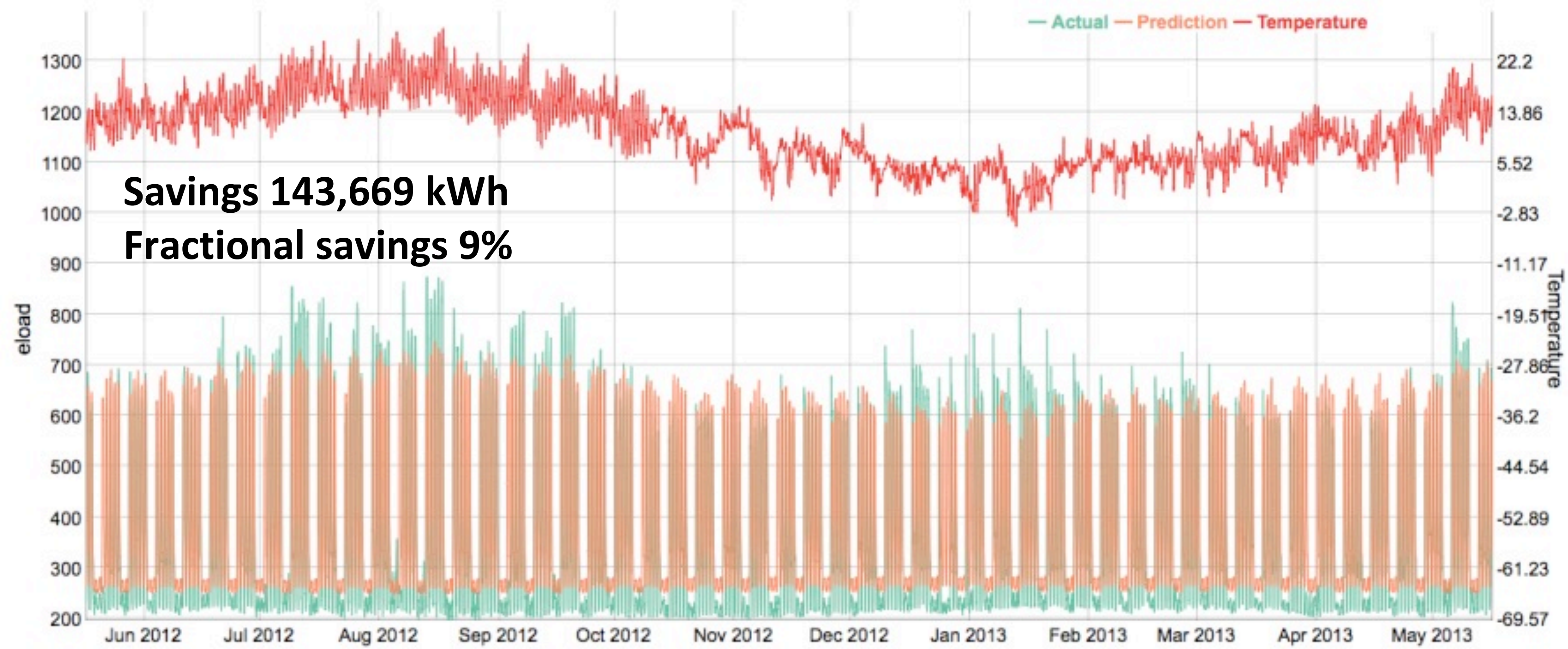
Other Documentation

- Additional charts that may be useful in assessing the suitability of the baseline model
  - Scatter plots of consumption vs. independent variables

Visual quality check: Scatter plot of load vs. temp shows strong & consistent relationship with weather – the chosen independent variable looks appropriate.



Example of Suggested Savings Documentation



Above: Example of a plot showing metered data, the projected baseline model, the independent variable (temperature), the fractional savings, and the fractional savings uncertainty at 90% confidence.

Guidance on Savings Uncertainty

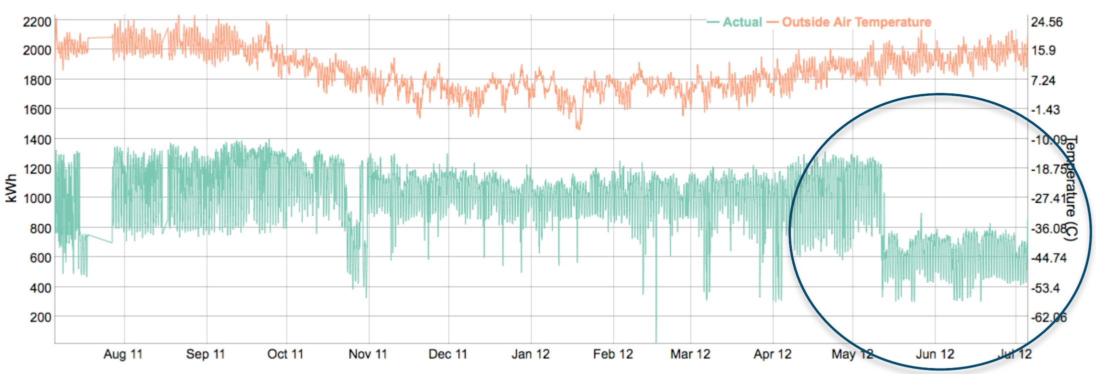
- Confidence Level: 80-90%

- Fractional Savings Uncertainty (FSU)
  - ≤ 25% is good
  - 25-50% may be acceptable

- Considerations:
  - **ASHRAE formulation to estimate uncertainty was developed with monthly models in mind; it may not be appropriate for more granular or non-linear models
  - If making interim analysis after short post-implementation period, higher FSU may be acceptable (not a final savings claim; more data to be collected)
  - Savings being claimed for single site or aggregated portfolio?
  - Pay-for-performance incentive structure and magnitude of incentive being paid

Documenting Non-Routine Events/Adjustments

- Description of how event was identified
- Description of non-routine event
- Data used to quantify impact of event
  - E.g. Start & end date, systems affected, info from staff interview, data from spot measurement or BAS trends, etc.
- Accounting of non-routine adjustments
  - Annotated plots of data are encouraged (see below)
- Adjusted savings, after accounting for non-routine events



Building was verified to have been shut down for 2 months

Example of an annotated plot showing a non-routine event

Examples of Non-Routine Event Types

Services	# of rooms/beds
	food cooking/preparation
	# of registers
	#of workers
Equipment loads	# of computers
	# of walk-in or standard refr. units or open/closed cases
	# of MRIs
	# or capacity of HVAC units
Operations	hours of operation
	weekend operations
	heating and cooling setpoints
	system control strategies
Site characteristics	size
	% of building heated and cooled
	envelope changes

Guidance for Addressing Non-Routine Events

Framework for assessing non-routine events may include:

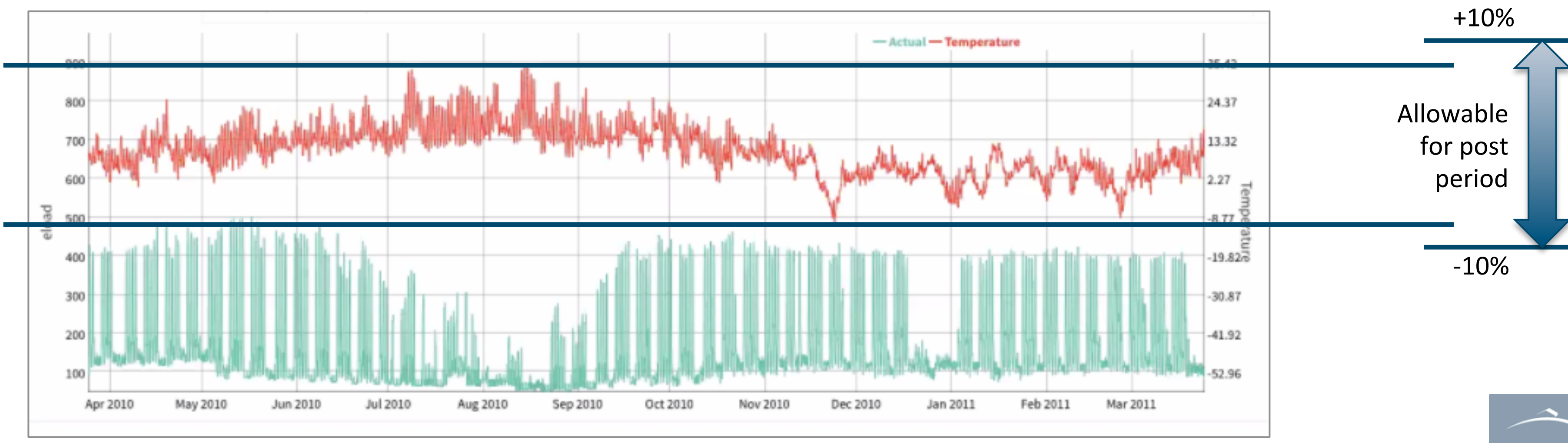
1. Determine whether an event is present
2. Determine whether the impact of the event is material, meriting quantification and adjustment
3. Determine whether the event is temporary or permanent. Temporary events may removed from the data set, however no more than 25% of the measured data should be removed, per ASHRAE Guideline 14, provided that a justifiable reason is provided.
4. Determine whether the event represents a constant or variable load
5. Determine whether the event represents added or removed load
6. Based on #3-5, the approach to measuring and quantifying the impact of the event may be determined.

Coverage Factor

- Coverage factor refers to the range in observed values of independent variables during the baseline period
- Models may not be projected to predict consumption for conditions far different than those observed in the baseline period
- For example, if a baseline model is constructed with data that spans 50-75°F, it may not prove reliable in predicting consumption for 90°F conditions in the performance period

Specific Guidance Draws From Guideline 14

"Apply the algorithm for savings determination for all periods where independent variables are no more than 110% of the maximum and no less than 90% of the minimum values of the independent variables used in deriving the baseline model."



Coverage Factor: Example

Month	Baseline Load	Average OAT	Performance Period Baseline Prediction	Performance Period Average OAT
1	394383	53.0	269831	54.1
2	355120	57.0	264236	57.4
3	400758	61.9	277054	58.1
4	423004	63.6	284204	61.2
5	408421	61.1	274539	59.9
6	421076	67.2	281134	67.1
7	433731	67.1	299625	69.5
8	452230	67.0	314535	70.2
9	406071	67.0	306156	69.1
10	411741	60.3	303321	66.3
11	385556	55.5	267428	53.0
12	385027	47.5	274512	50.6

Baseline period max: 67.2°F
110% of max: 73.9°F

Baseline period min: 47.5°F
90% of min: 42.8°F

Post period range: 50.6°F – 70.2°F

All post period data falls within coverage factor requirements

Baseline/post data period: 12 months
Independent variable: monthly average OAT

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Considerations for Your Region/Programs

- How might this guidance be integrated into your existing processes?
- How do you currently assess the quality of whole-building Option C savings analysis?
- What fitness and uncertainty thresholds are acceptable for your context?
- What additional requirements might complement those in this guidance?
- What stakeholders should be involved in developing/reviewing guidelines for your region?
- Opportunities to integrate guidance?
  - Existing programs that allow for whole building approach?
  - Pilot programs?

Questions?

Thank You!

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