Commercial & Industrial Strategic Energy Management

Measurement & Verification Reference Guide v1.0

Commercial & Industrial SEM M&V Reference Guide

March 2022

BPA's New SEM M&V Guide

Commercial & Industrial SEM M&V Reference Guide

- – Added to BPA M&V Protocol Library

  https://www.bpa.gov/energy-and-services/efficiency/measurement-and-verification

- – Updated MT&R_Rev9 ☺

- – Questions or comments as we go

  - • Use Chat or

  - • Raise Hand

Agenda

– Todd Amundson, BPA
– Kevin Campbell, Energy 350

User's Overview of C&I SEM M&V Reference Guide

- Develop Whole-Facility Baseline Model

- Quantify Energy Savings

- Report Savings

Examples

- Non-routine adjustment

- Re-baseline

Overview

Section	Focus	Key M&V Action
1	**Develop Whole-Facility Model**	Characterize the Facility
2		Establish a Baseline Data Set
3		Develop a Baseline Energy Model
4	**Quantify Energy Savings**	Make Adjustments for Non-Routine Events
5		Calculate Energy Savings for the Reporting Period
6		Adjust for Data Gaps, if Needed
7	**Report Energy Savings**	Report Verified Savings
Appendices A – F	**Additional Technical Details**	Calculations and Examples

Develop Whole Facility Model

| Section	Focus	Key M&V Action
1	**Develop Whole-Facility Model**	Characterize the Facility
2		Establish a Baseline Data Set
3		Develop a Baseline Energy Model

1. Characterize the Facility

- Define the Measurement Boundary
  - Whole facility or Portion of facility
  - Includes all systems & equipment
  - Account for all energy crossing boundary

- Identify all Utility & Sub-meters
  - Understand areas served by each
  - One-line electrical drawings / Site walk

Whole-Facility Measurement Boundary

Retrofit-Isolation Measurement Boundary
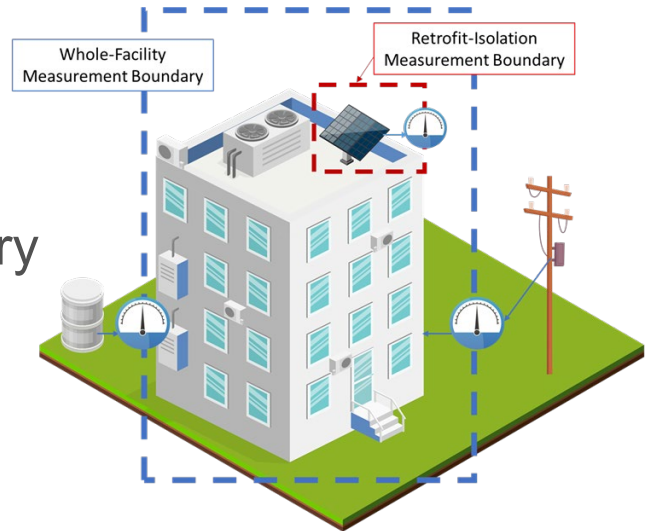
1. Characterize the Facility (cont.)

- ## Identify Energy Drivers

  – Independent Variables

    - Continuous (e.g., outdoor air temperature)

    - Categorical (e.g., operating mode)

  – Static Factors

    - Everything else impacting energy consumption



kWh/Day vs. Average Daily Temperatures
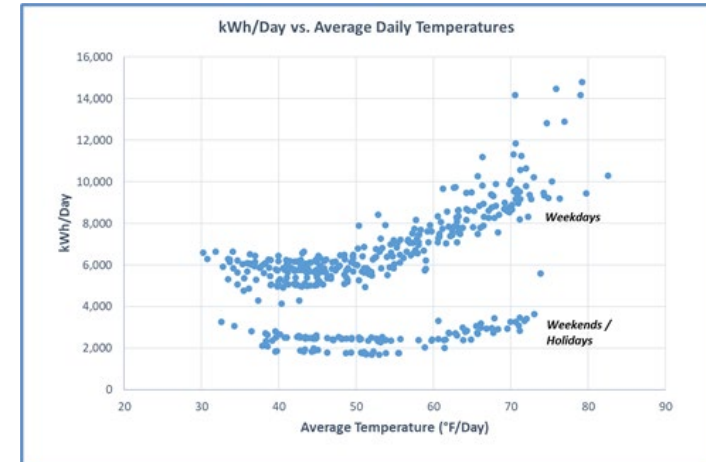
1. Characterize the Facility (cont.)

- Identify Key Independent Variables – Commercial
  - Outdoor air temperature
  - Site-specific operational data improves models

Possible Data Source	Examples of Potential Metrics
Control System Trends	A weighted average speed of significant motors; Average speed of the primary ventilation fan
Security Data	Number of scanned security badges; Total number of cars parked/day
Computer System Records	Number of computer user log-ins
Sub-Metered Data	Daily ton-hours of cooling and/or therms for heating; Tenant energy consumption
Management Data	Number of meals served; Number of classes on-site; Daily sales totals or number of transactions

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1. Characterize the Facility (cont.)

- Energy Drivers as Independent Variables – Industrial
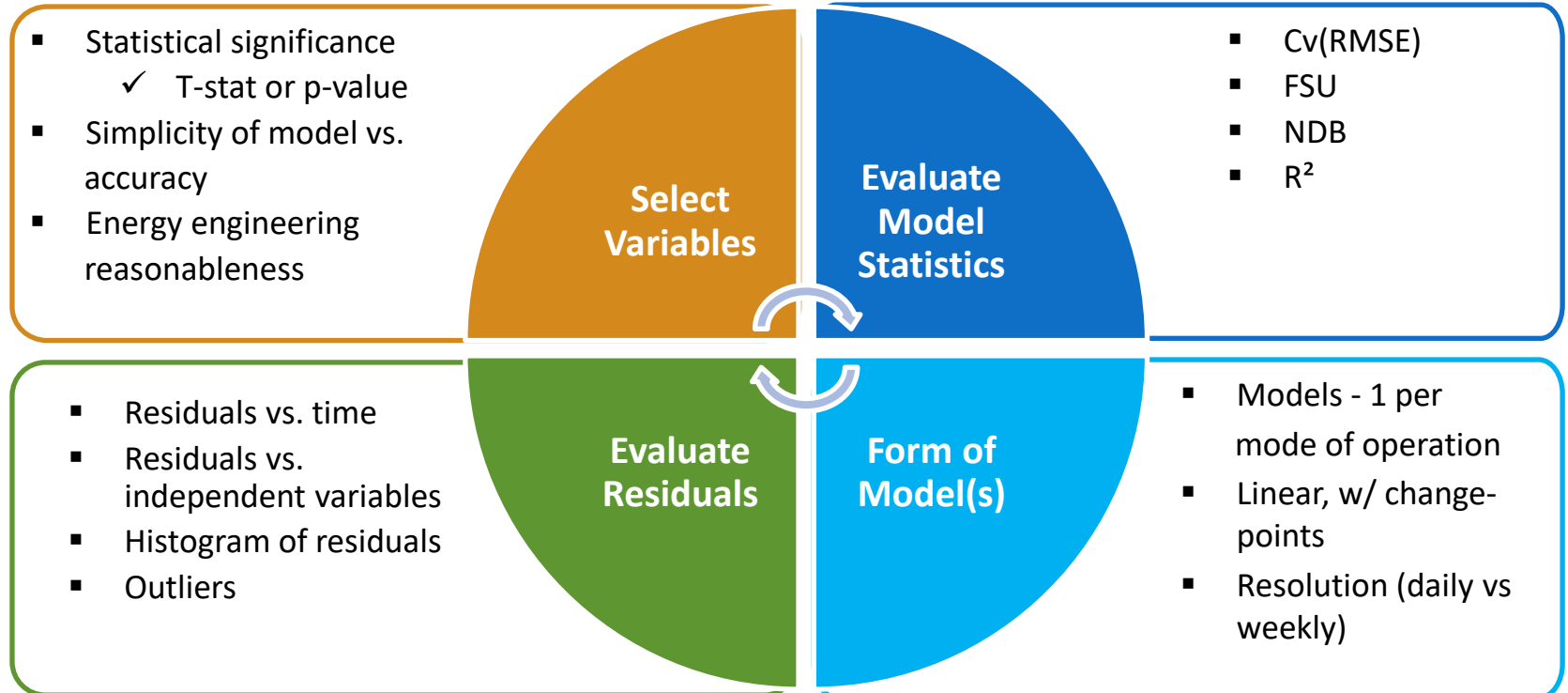 - Outdoor air temperature, HDD/CDD
  - Production related data
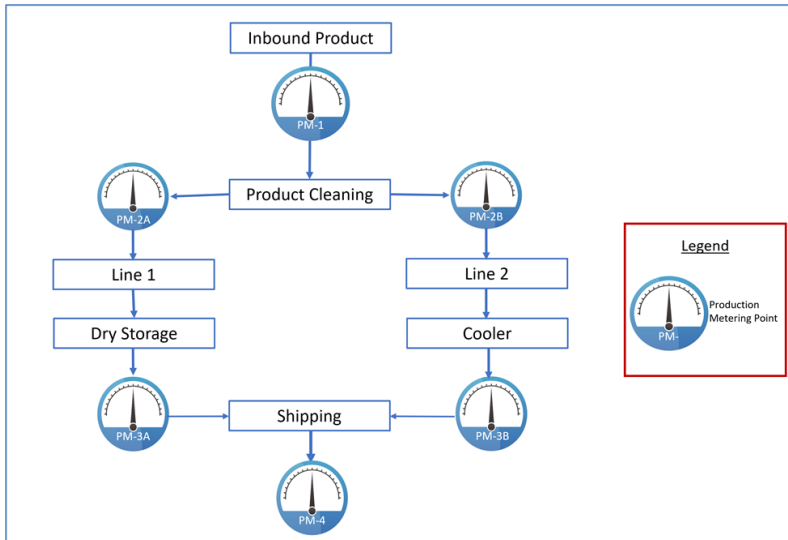
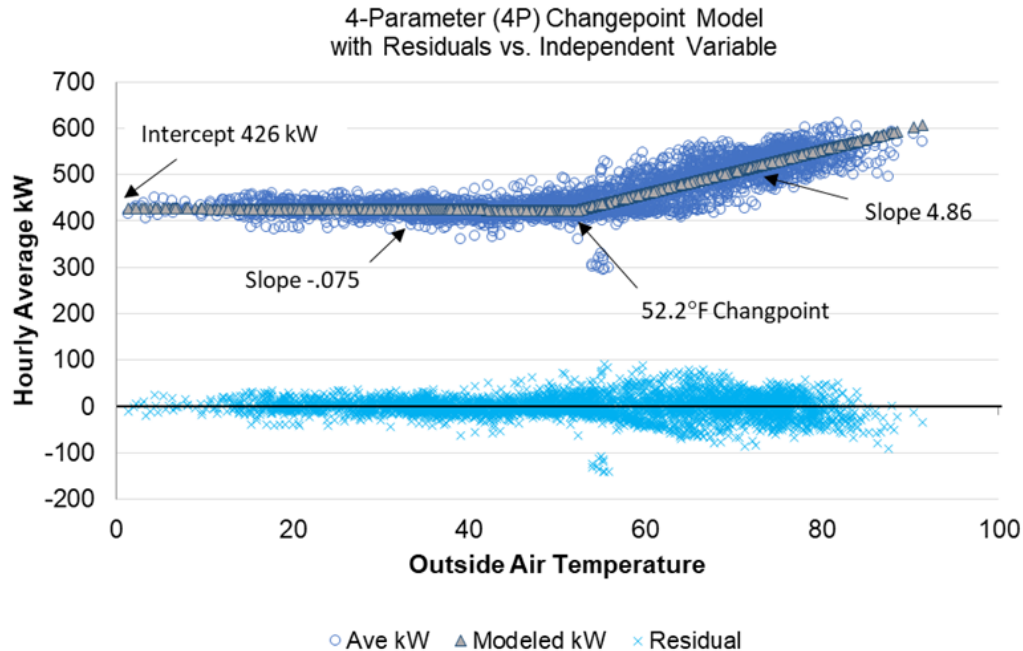| Measurement Location	Advantage
Raw material input	Provides a mechanism to capture the effects of different raw material types.
Work in progress	Allows selection of production variable at energy-intensive process step, thereby minimizing time series shift.
End of line metric	Provides mechanism for incentivizing energy impact of yield/productivity improvements.
Finished product shipped	Reliable data is typically available from business systems.

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2. Establish the Baseline Data

- Select period for baseline
  - 12 months continuous data typical
  - Review for energy projects and NREs

- Collect and review data
  - Energy & possible independent variable data
  - Establish sources & procedures
  - Review and clean data
  - Make any adjustments required

- Document key static factors

3. Develop a Baseline Energy Model

Select Variables
- Statistical significance
  - ✓ T-stat or p-value
- Simplicity of model vs. accuracy
- Energy engineering reasonableness

Evaluate Model Statistics
- Cv(RMSE)
- FSU
- NDB
- R^2

Evaluate Residuals
- Residuals vs. time
- Residuals vs. independent variables
- Histogram of residuals
- Outliers

Form of Model(s)
- Models - 1 per mode of operation
- Linear, w/ change-points
- Resolution (daily vs weekly)

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3. Develop a Baseline Energy Model(s)

4-Parameter (4P) Changepoint Model
with Residuals vs. Independent Variable

Intercept 426 kW
Slope -.075
52.2°F Changpoint
Slope 4.86

○ Ave kW   △ Modeled kW   × Residual

- Commercial facilities often driven by cooling / heating

- Industrial energy use follows process loads

- Form of models should match data and physics

- Review model residuals and statistics

3. Develop a Baseline Energy Model

Statistic for Variable	Guideline
T-statistic	Absolute value > 1.3
p-value	< 0.20

Statistic for Model	Guideline
Net Determination Bias Error (NDBE)	< 0.5%
Coefficient of Variation (C_V RMSE)[1]	< 20% for daily models < 10% for weekly models < 5% for monthly models
Coefficient of Determination (R^2)	> 0.5
Fractional Savings Uncertainty (FSU)	< 65%

- *Assumes 80% Level of Confidence*

- *Recommended* thresholds
  - Variables
    - T-stat or p-value
  - Overall Model
    - FSU, Cv(RMSE)

- Aligns with industry consensus

[1] See ASHRAE Guideline 14-2104 for discussion.

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Quantify Energy Savings

Section	Focus	Key M&V Action
4		Make Adjustments for Non-Routine Events
5	**Quantify Energy Savings**	Calculate Energy Savings for the Reporting Period
6		Adjust for Data Gaps, if Needed

4. Non-Routine Adjustments

NRAs account for changes in energy unrelated to SEM/EE

Category	Examples
Static Change	Installation of new equipment
Minor Facility Operations Change	Controls modifications Adjustments to ventilation rates Temporary facility closure Add tenant
Major Facility Operations Change	Variables consistently out of range Change in manufacturing or facility use Adjustment in operating schedules

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4. Non-Routine Adjustments

See *IPMVP Application Guide on Non-routine Events & Adjustments*

Category	Action Required
Static Change	NRA using Sub-metered data
Minor Facility Operations Change	NRA - add variables to redefine regression model, develop pre-post model NRA – create an adjustment model
Major Facility Operations Change	Modification of regression model(s), New baseline period

4. Non-Routine Adjustments

- Tracking non-SEM changes needed
- Non-routine event must be identified
  - Details of changes in static factors documented
- Proposed NRAs must be approved

5. Calculate Energy Savings

- Data collection
  - Review, clean-up data if necessary
  - Ensure data is in valid range for use in model
- Assess site changes unrelated to SEM
  - Interviews, Tracking Data, Review model residuals
  - Make any adjustments needed
    - NRAs
    - Non-SEM Energy Projects

5. Calculate Energy Savings

- Use regression model to predict energy use
  - input reporting period independent variable data

- Savings = Predicted Energy Use – Actual Energy Use +/- NRAs

- Establish statistical confidence in savings
 - E.g., FSU

5. Calculate Energy Savings

- Basic method is forecast model
- Other methods as needed:
  - Backcasting
  - Mean Model
  - Pre-Post
  - Engineering Calculations

5. Calculate Energy Savings

Measure Energy Savings	Data Requirements	Calculation Requirements	Supporting Documentation
< 50,000 kWh/yr.	Reasonable and documented assessments of the loads and hours for baseline and post-install	Simple calculations that account for the changes in kW and hours, key variables	Equipment specifications, photos
50,000 to 200,000 kWh/yr.	Align with BPA's ECwV Protocol; Measured values over time are used to determine kW and operating hours	System-level calculations accounting for interactive effects using data trends and regression analyses; Details of steps and calculations	Equipment specifications, photos; System description, operating parameters, supporting screen shots, logged data, drawings, or commissioning report
> 200,000 kWh/yr.	Meet with stakeholders and consider developing a custom M&V plan; Establish comprehensive baseline and post-install data	System level calculations (above) or energy simulation model	Documentation noted above, and as established in M&V Plan

5. Calculate Energy Savings

- ## Track Savings over time
  - ### CUSUM

- ## Change in savings
  - ### EEMs
  - ### NREs
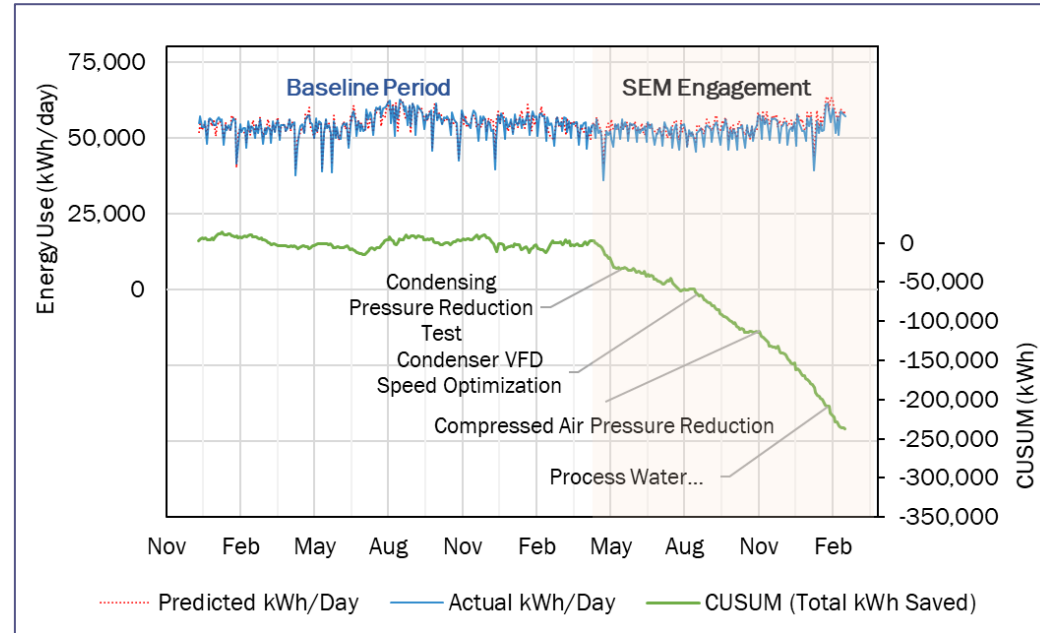
6. Adjust for Data Gaps

- Alternate ways to estimate energy savings
  - Gaps in data (e.g., utility meter failure)
    - Engineering Calculations
  - "Annualize" savings when less than 1-year of data

- Rarely used due to avoided savings accounting

Report Energy Savings

Section	Focus	Key M&V Action
7	**Report Energy Savings**	Report Verified Savings

7. Report Energy Savings

- Multi-Year Savings Reporting
  - Incremental year-over-year savings used for payments
  - Defines terms

- Backsliding or Negative Savings
  - Actual savings to be reported to BPA

- Re-Baselining
  - Only required when major operations change

7. Report Energy Savings

Savings definitions:

– Cumulative

– Annual Achieved

– Verified

Six-year Example

SEM Savings Methodology - Annual Reporting
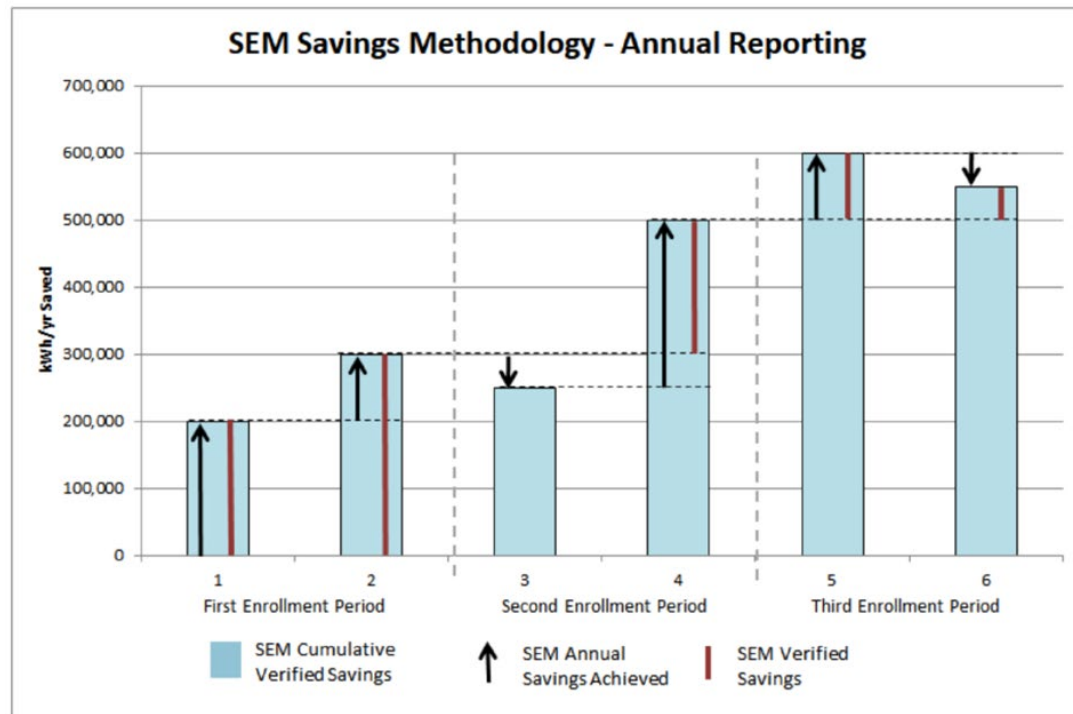
Other Technical Details

Section	Focus	Key M&V Action
Appendices A – F	Additional Technical Details	Calculations and Examples

Appendices

Appendix	Key M&V Action
A	Treatment of Incentivized EEMs During the Baseline
B	Treatment of Incentivized EEMs During the Reporting Period
C	Overview of Regression Output
D	Glossary of Terms
E	Models with Irregular Time Interval
F	Opportunity Register

Appendices A & B: Energy Projects

- Non-SEM Incentivized EEMs
  - During the Baseline Period
  - During the Reporting Period

- Adjust energy data based on reported savings
  - Distribute annual savings over-time
  - Pro-rate for partial years

Appendix E: Irregular Data

- Appendix E - Models with Irregular Time Intervals
  - Substantial and detailed content
  - Using weighted regressions
    - Monthly billing data
    - Missing data

Appendix F: Opportunity Register

→Defines EEMs identified & implemented

→ States the existing conditions & specific subsystems

→ Describes the new conditions of EEM (setpoints, added capability, ect.)

→ Documents the implementation dates, when the savings start

→ Clearly documents parameters that changed

Appendix F: Opportunity Register

ID Number	Description	Subsystem	Measure Type	Identified	Completion Date	Estimated Savings (kWh/yr)	Priority (1 -3)
1	Replace outside air damper actuators in all AHUs	HVAC	O&M	12/1/2020	3/1/2021	115,000	1
2	Adjust lighting controls to match occupied hours in office areas[33]	Lighting	O&M	12/1/2020	12/7/2021	5,000	1
3	Turn down plant air pressure, was 110 psi, now 100 psi. Monitoring stations - goal in the future is 95 psi[34]	Compressed Air	O&M	2/7/2021	2/25/2021	72,000	2
4	Install occupancy sensors in South Building's 5 conference rooms	Lighting	Capital	3/1/2021	5/5/2021	12,000	3
5	Standardize all thermostat temps to heating 70, cooling 75[35]	HVAC	O&M	4/24/2021		10,000	1
6	Shut off transfer pumps when mix chest is full. Currently the pump dead heads against a fully closed valve.	Pumping	O&M	6/1/2021		Low	1
7	Install 2-ton ductless heat pump in IT room and schedule off AHU-4 with other AHUs.	HVAC	Capital[36]	6/1/2021	8/2/2021	55,000	1
8	Replace weather stripping on front doors	Doors	O&M	7/1/2021		Low	3

[33] Occupied hours are 8 am to 6 pm on weekdays.

[34] See plant supervisor for trend data prior to making further adjustments.

[35] See running list of completed t'stats in O&M office.

[36] Note incentive provided from prescriptive program.

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Other BPA M&V Resources

BONNEVILLE POWER ADMINISTRATION

BPA's M&V Protocol Library

- Extensive & detailed
  - ✓ 12 M&V Protocols

- Basis for all BPA's M&V

- Great supporting resources for SEM
  - 12_
  - 10_
  - 07_
  - 03_

BPA M&V Documents
01_Measurement and Verification Protocol Selection Guide
02_BPA_MV Sampling Reference Guide
03_Regression for M&V Reference Guide
04_Verification by Equipment End-Use Metering Protocol
05_Verification by Energy Use Indexing Protocol
06_Engineering Calculations with Verification Protocol
07_Verification by Energy Modeling Protocol
08_Existing Building Commissioning
09_End-Use Metering Absent Baseline Measurement
10_Glossary for M&V Reference Guide
11_Estimating Peak Demand Impacts
BPA Implementation Manual 2022
12_BPA C&I SEM M&V Reference Guide

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Examples Follow:
1. Non-Routine Adjustment
2. Re-baseline

Questions? Comments?
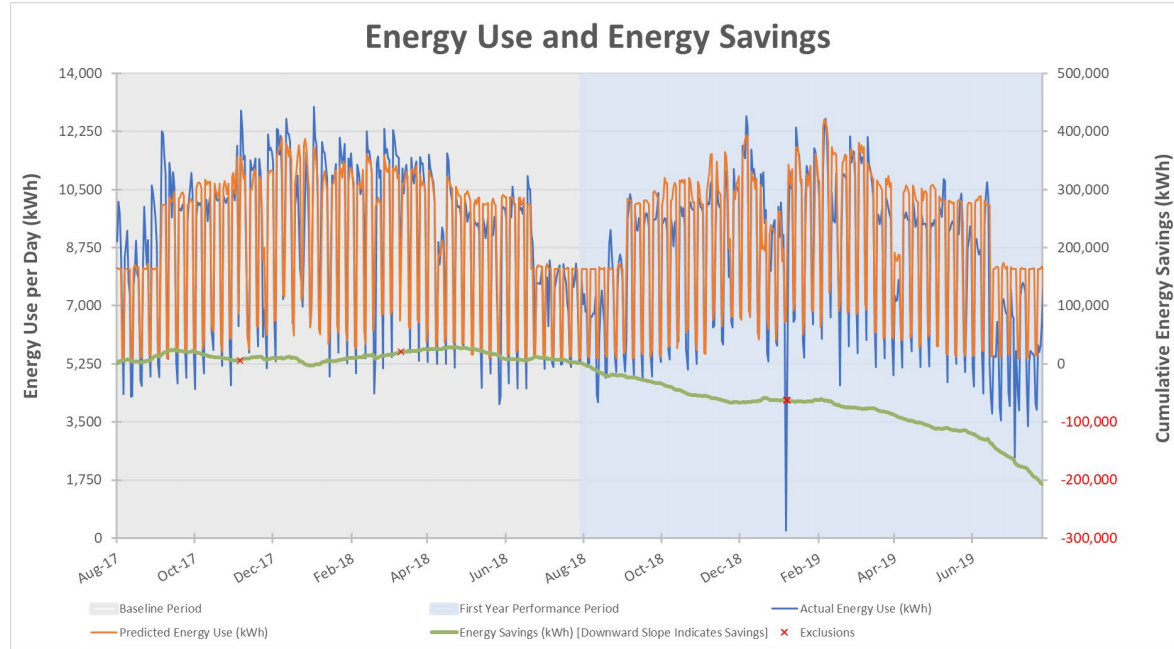
Thank you!

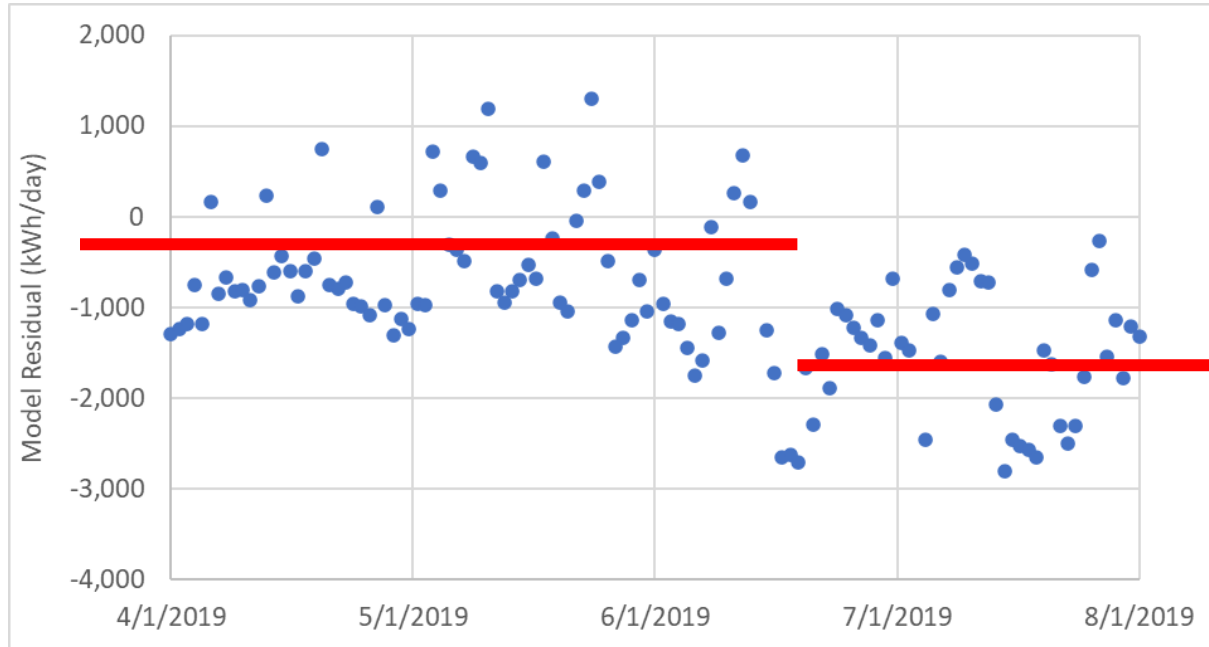# 1. Non-Routine Adjustment

Example at a **High School**

High School – Baseline Period
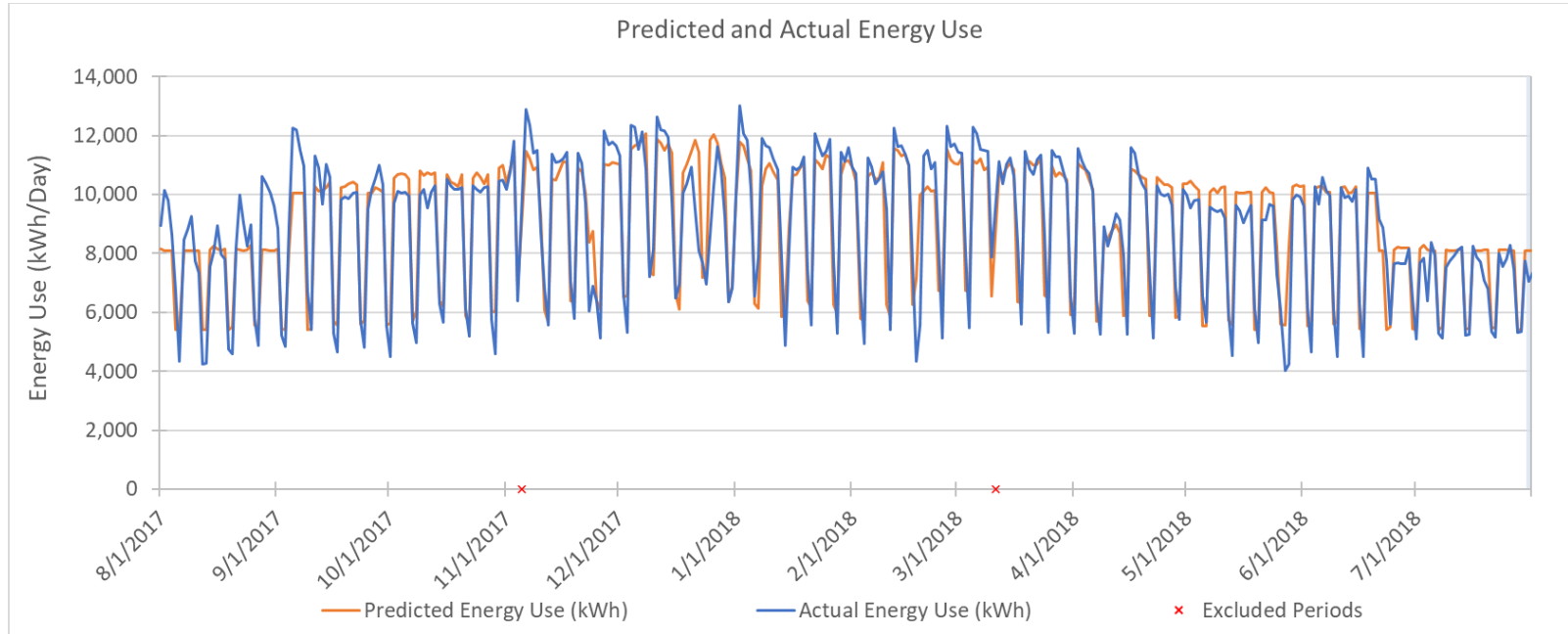
High School – Hybrid CUSUM

High School – Residual Plot

High School – NRE/NRA

Energy Use and Energy Savings
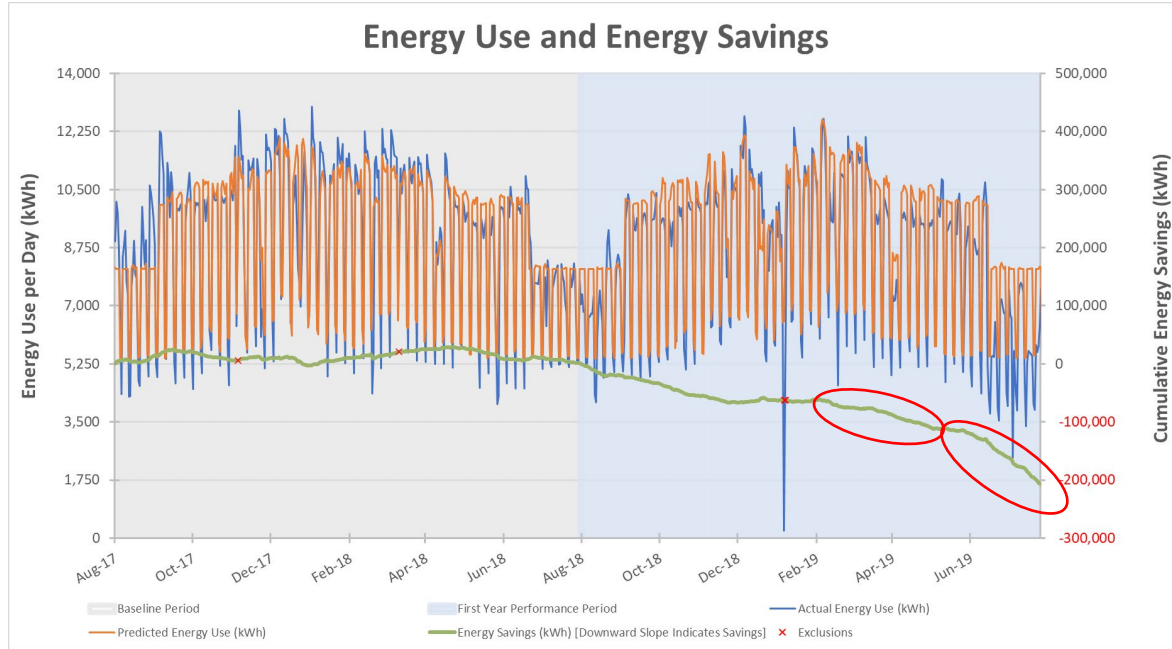
High School – NRE/NRA

| Impacted Pool Equipment							
Equipment	Item	Voltage	Phase	RLA	Power Factor	Load Factor	Input Power (kW)
Pool HVAC Unit	Comp Mtr 2	460	3	26.9	0.80	0.75	12.9
Pool HVAC Unit	Comp Mtr 3	460	3	26.9	0.80	0.75	12.9
Pool HVAC Unit	Comp Mtr 4	460	3	26.9	0.80	0.75	12.9
Pool HVAC Unit	Comp Mtr 5	460	3	26.9	0.80	0.75	12.9
Pool HVAC Unit	Blower Mtr 1	460	3	34.9	0.80	0.75	16.7
Pool HVAC Unit	Blower Mtr 6	460	3	4.3	0.80	0.75	2.1
Pool HVAC Unit	Blower Mtr 7	460	3	4.3	0.80	0.75	2.1
Pool Pump	Pump Motor	460	3	36	0.80	0.75	17.2
Total							89.4

2. Re-baseline

Example at **Medium Industrial** Facility

Medium Industrial – Baseline Period

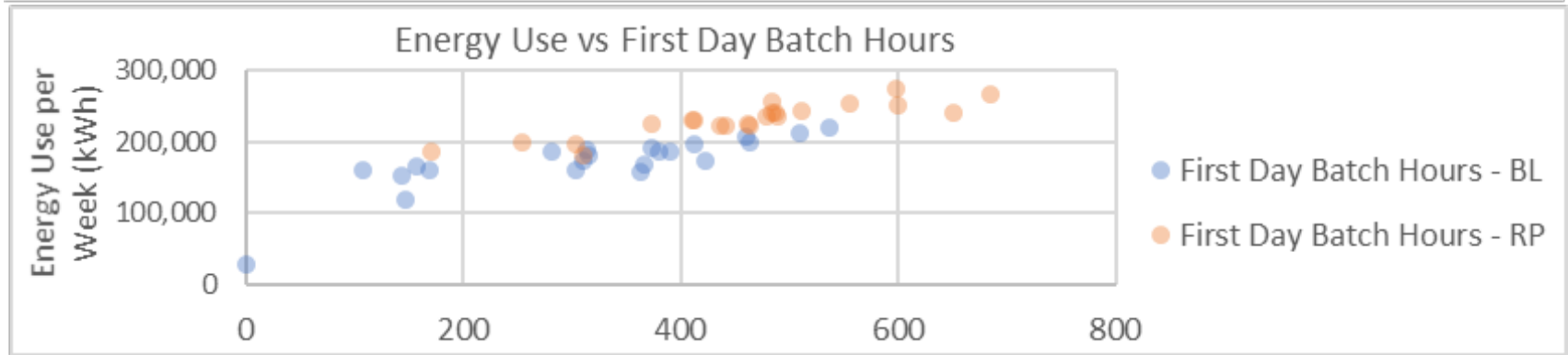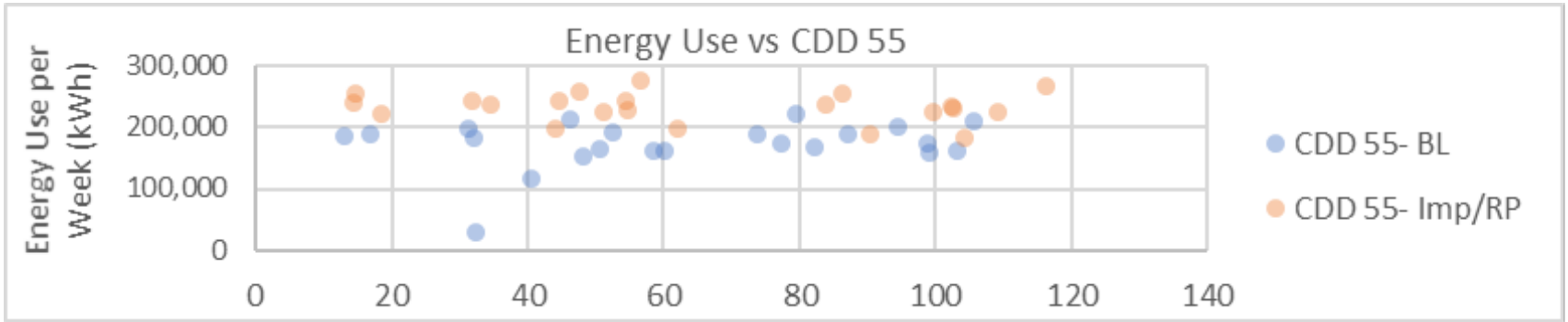Predicted and Actual Energy Use
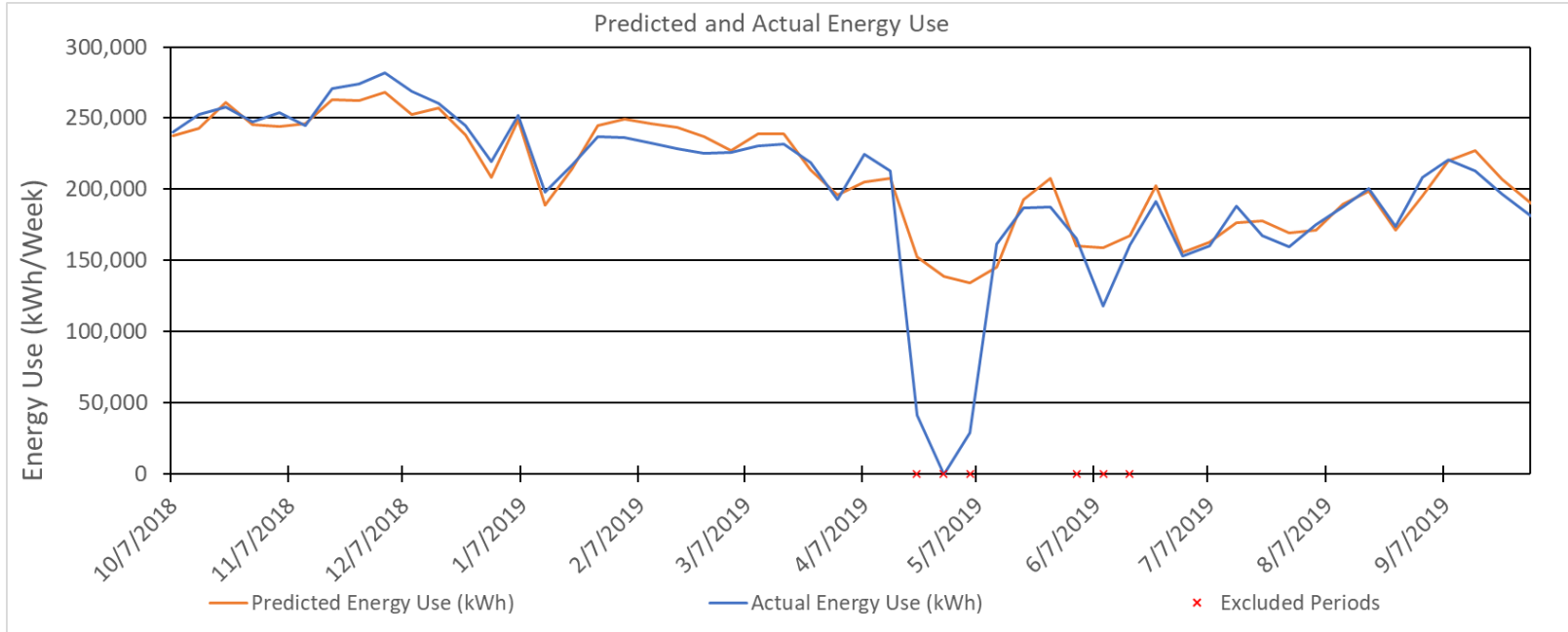
Medium Industrial – Hybrid CUSUM
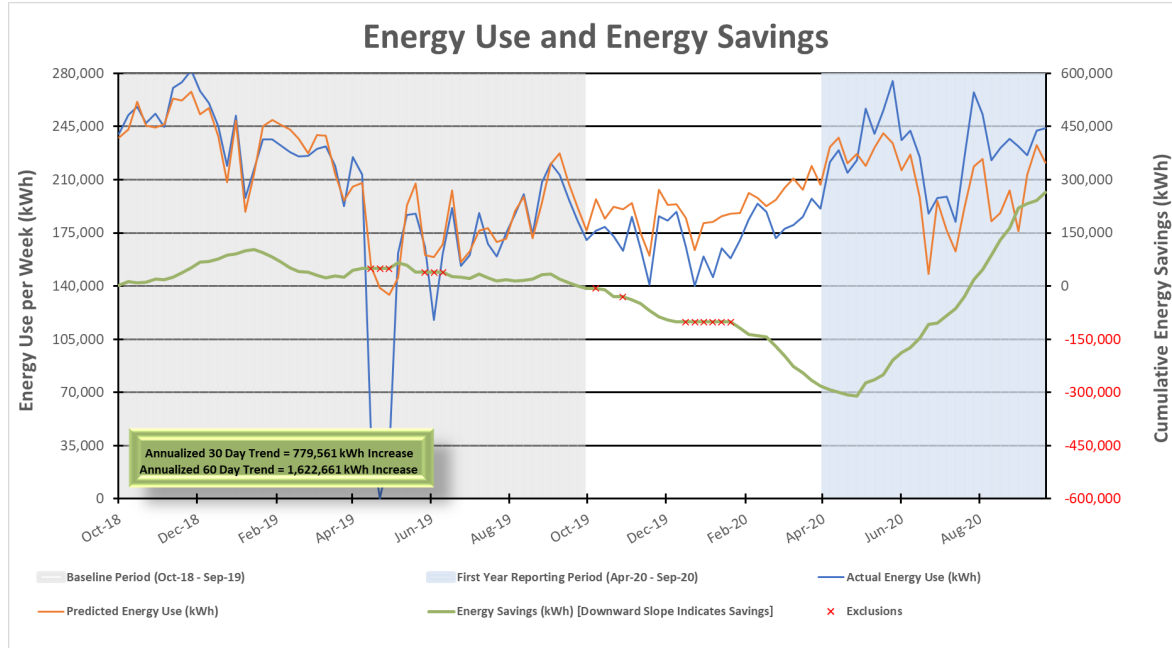
Medium Industrial – Energy Impacts

Medium Industrial – M&V Method

- ## Whole-Building models may stop working
  - ### Major Facility Operations Change

- ## Consider using engineering calculations
  - ### Suggested rigor in Section 5.5.5
  - ### Follow BPA's *Engineering Calculations with Verification Protocol*

- ## Re-baseline once new energy patterns are established over time

Thank you!

SEM C&I M&V Reference Guide

2022