Perspectives on SEM Evaluation
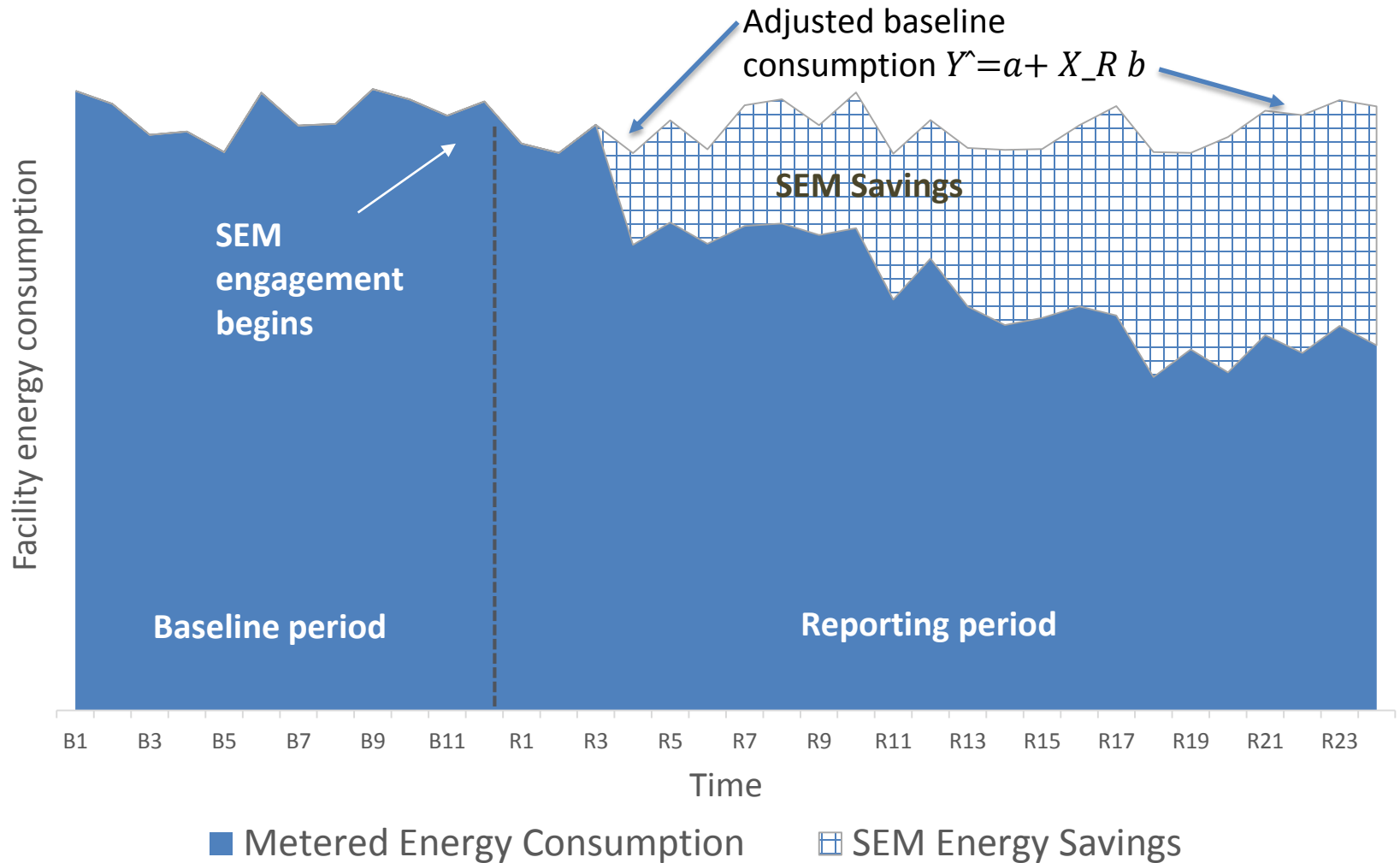**Northeast SEM Collaborative Workshop**

Jim Stewart, Ph.D.

November 8, 2017

AGENDA

- **Overview**

- **Best Practices**

- **Advances**

- **Measure Life**

OVERVIEW

SEM Energy Savings

Adjusted baseline consumption $\hat{Y} = a + X_R b$

SEM Savings

SEM engagement begins

Facility energy consumption

Baseline period

Reporting period

B1 B3 B5 B7 B9 B11 R1 R3 R5 R7 R9 R11 R13 R15 R17 R19 R21 R23

Time

■ Metered Energy Consumption ⊞ SEM Energy Savings

Savings = Adjusted baseline consumption – metered consumption

The Evaluation Problem

- **Baseline must be estimated**
  - **Accuracy of savings estimate depends on baseline validity**
- **How to estimate baseline?**
  - **How to assess validity?**

- **Why do we care?**
  - **Credibility and acceptance of SEM energy savings**

How is SEM Program Evaluation Different?

- Multiple energy end uses

- Small % savings

- Lifts EE program participation

- Uncertain measure life

BEST PRACTICES

SEM EM&V Protocols

PROTOCOLS

- IPMVP (2012) – Option C

- ASHRAE-14 (2014) Measurement of Energy, Demand, and Water Savings

- U.S. Department of Energy Superior Energy Performance Measurement & Verification Protocol (2016)

- BPA Monitoring, Tracking, and Reporting Reference Guide 6.0 (2017)

- CA Industrial SEM M&V Guide (2017)

- U.S. Department of Energy Uniform Methods Project SEM Evaluation Protocol (2017)

TOPICS

- Characterization of facility

- Data collection

- Methods for calculating adjusted baseline

- Baseline model validation

- Savings estimation

- Non-routine adjustments
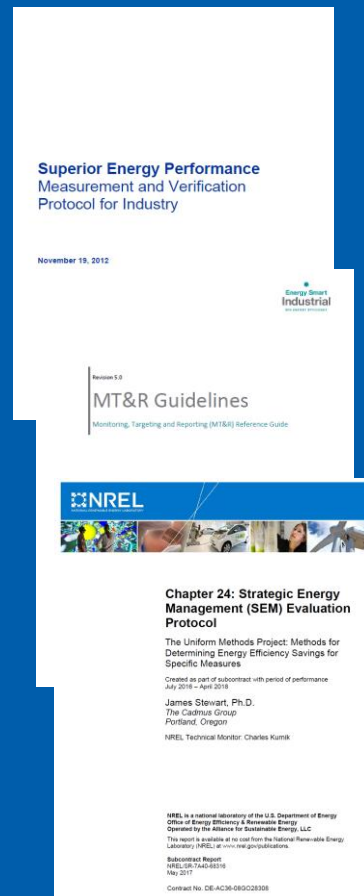
DOE UMP SEM Program Evaluation Protocol

- **Published in 2017**
  - **https://www.nrel.gov/docs/fy17 osti/68316.pdf**

- **Goal: provide guidance about best practices for estimating savings**

- **Development**
  - **Technical Experts and TAG**
  - **Public comment**

CADMUS
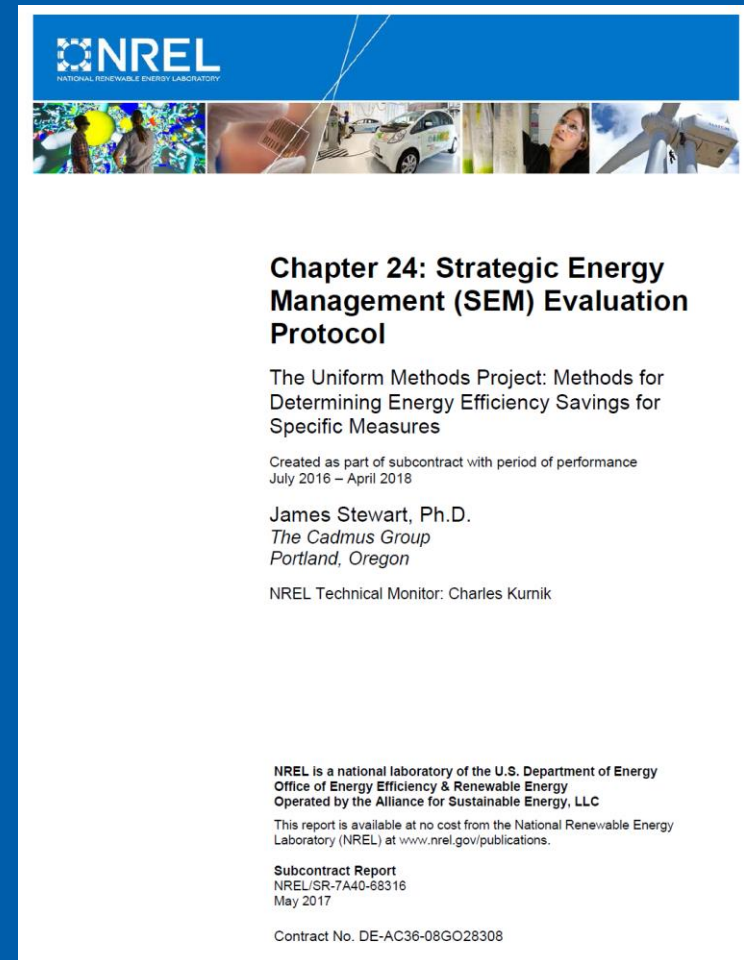
UMP Measure Description

- **Strategic Energy Management (SEM)**
  - Continuous improvements in energy efficiency
  - Systematic and planned changes in facility O&M, behaviors, and capital upgrades
- **Energy Management Systems (EnMS)**
  1. Establish management support, policy, and goals
  2. Identify and implement savings opportunities
  3. Track progress
  4. Update goals and plans
- **CEE Definition and Minimum Elements**

Application Conditions of Protocol

- **Estimating energy savings is the goal**
- **Facility-level data are available**
  - **Baseline and reporting periods**
- **Possible to construct a valid facility energy consumption model**
  - **Predictive accuracy**
- **Expected savings can be detected statistically**

UMP Savings Calculation Approach

- Facility ≡ unit of analysis
- Estimate savings for individual facilities
- Define facility boundary
- Collect data
  - Full year of baseline data
- Multivariate regression analysis
  - Validate model
- Non-routine adjustments
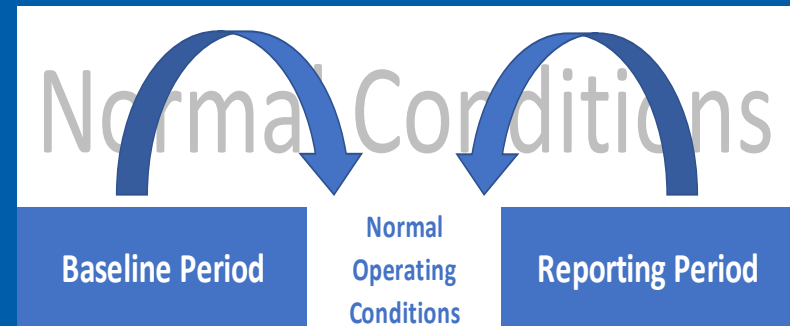 - Use sparingly and should be based on engineering calculations
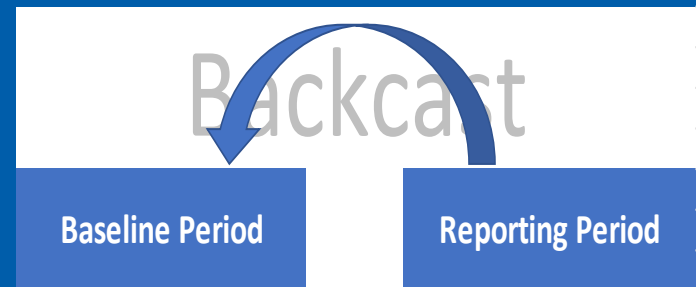
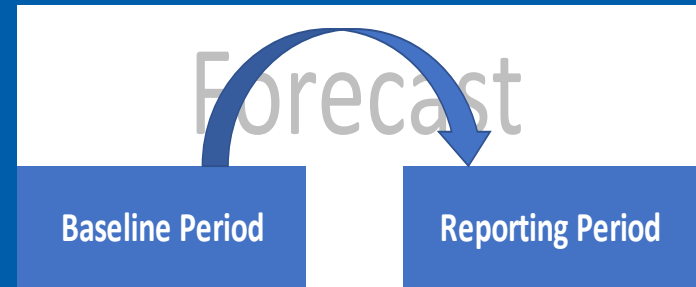# UMP Measurement and Verification Methods

- **Regression models for estimating savings:**

$$\widehat{Y}_t = a + X_t\, b$$

- – **Forecast models**
- – **Backcast models**
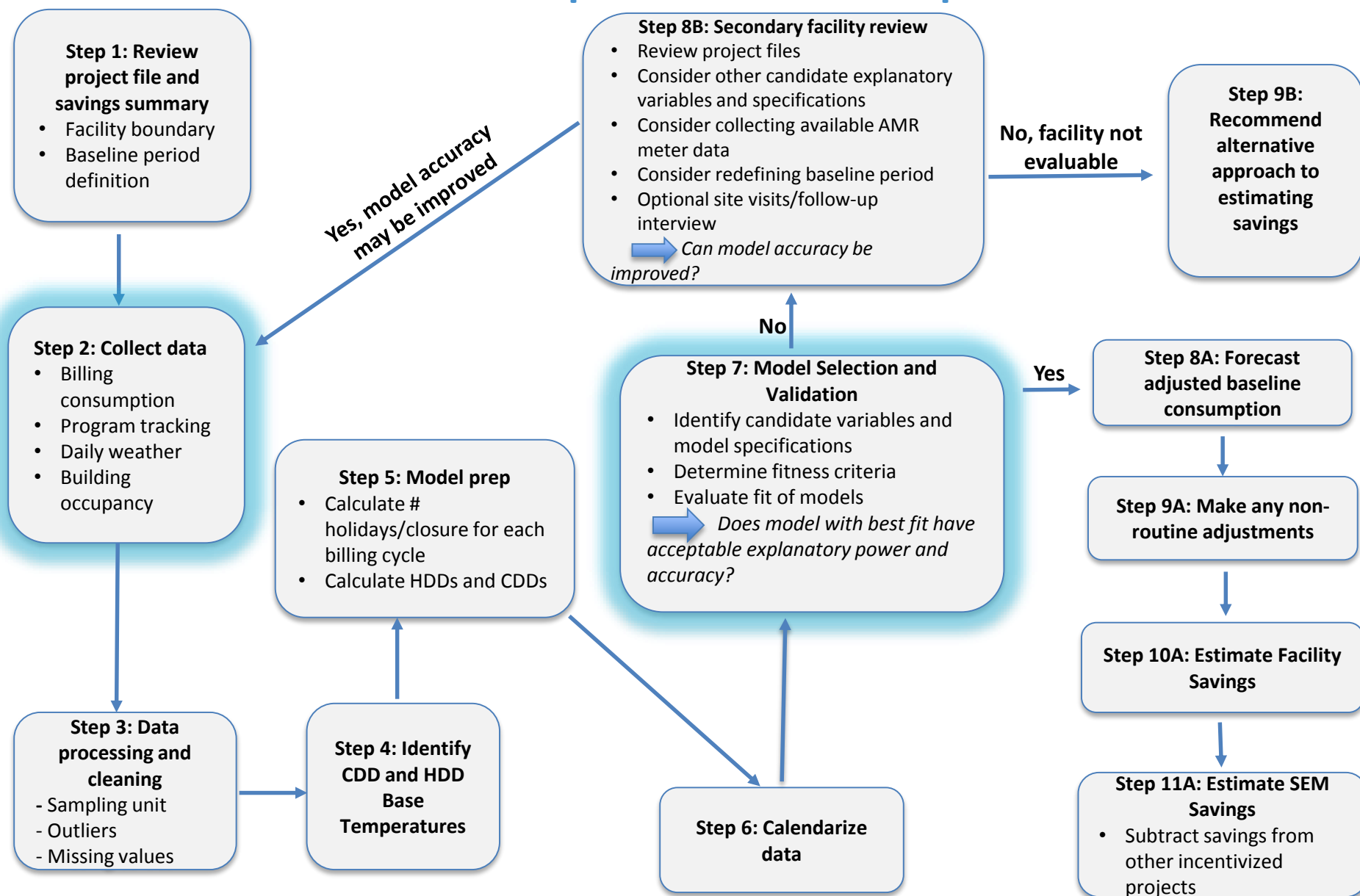- – **Normalized operating conditions models**

SEM Evaluation in Practice
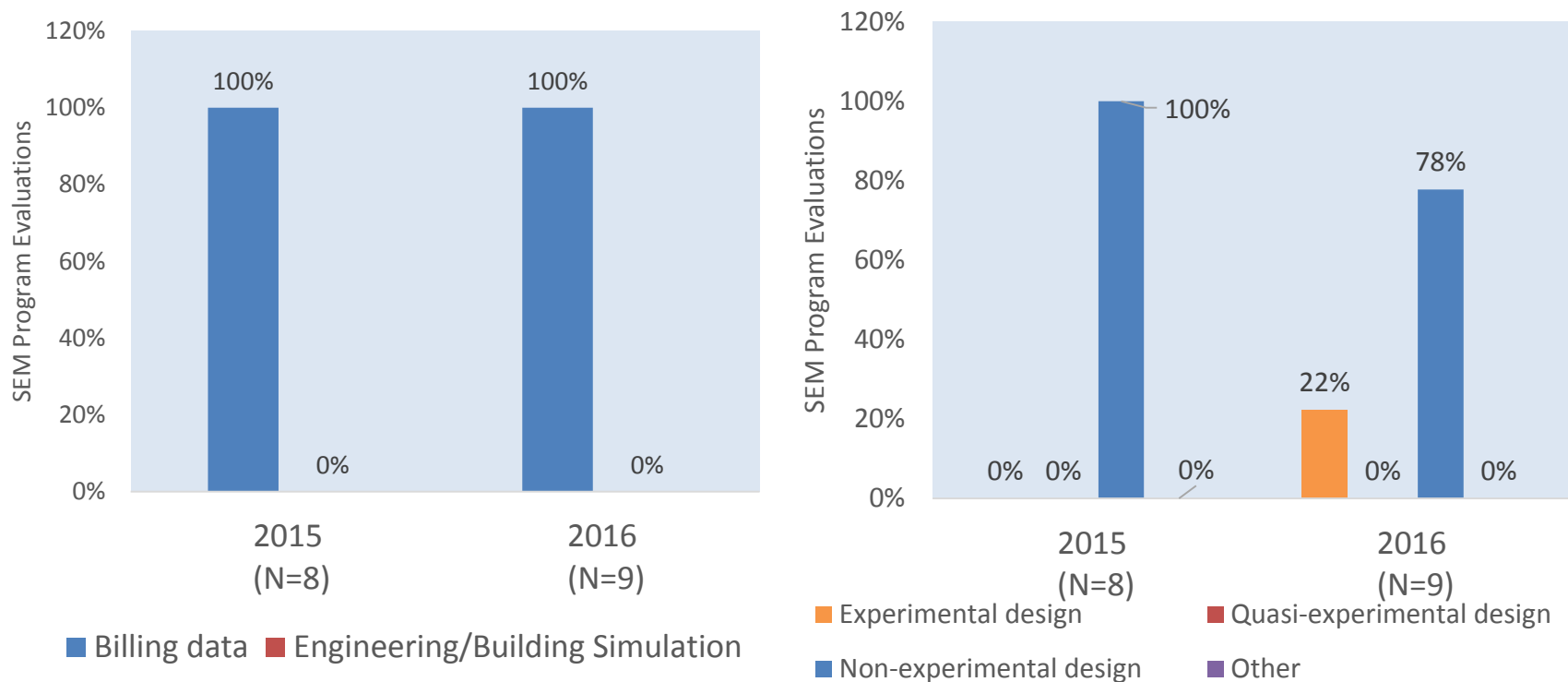
Source: CEE Behavior-based program database for 2015 and 2016. Utility SEM or CEI programs that estimated or planned to estimate energy savings.

ADVANCES

SEM Impact Evaluation Steps

Step 1: Review project file and savings summary
- Facility boundary
- Baseline period definition

Step 8B: Secondary facility review
- Review project files
- Consider other candidate explanatory variables and specifications
- Consider collecting available AMR meter data
- Consider redefining baseline period
- Optional site visits/follow-up interview
  - *Can model accuracy be improved?*

No, facility not evaluable

Step 9B: Recommend alternative approach to estimating savings

Yes, model accuracy may be improved

No

Step 2: Collect data
- Billing consumption
- Program tracking
- Daily weather
- Building occupancy

Step 7: Model Selection and Validation
- Identify candidate variables and model specifications
- Determine fitness criteria
- Evaluate fit of models
  - *Does model with best fit have acceptable explanatory power and accuracy?*

Yes

Step 8A: Forecast adjusted baseline consumption

Step 5: Model prep
- Calculate # holidays/closure for each billing cycle
- Calculate HDDs and CDDs

Step 9A: Make any non-routine adjustments

Step 10A: Estimate Facility Savings

Step 3: Data processing and cleaning
- Sampling unit
- Outliers
- Missing values

Step 4: Identify CDD and HDD Base Temperatures

Step 6: Calendarize data

Step 11A: Estimate SEM Savings
- Subtract savings from other incentivized projects

Application of Machine Learning to SEM Evaluation

- **True model is unknown and may be complex**
  - **With AMI data, large number of candidate variables and functional forms to choose from**

- **Evaluation benefits of machine learning**
  - **Can improve prediction of baseline consumption**
 - **Uncover generalizable patterns**
  - **Avoids overfitting**

| Partition baseline period data | → | Select predictor variables using training data | → | Test out-of-sample prediction using test data | → | Final baseline model |

Barriers to Use of Machine Learning Methods

- **Data availability**
  - AMI meter data
  - High frequency output data for industrial facilities

- **Regulator and program administrator acceptance**

- **LBNL studies**
  - Granderson et al. (2016)

- **Evaluation of EE in schools**
  - Burlig, Knittel, Rapson, Reguant, and Wolfram (2017)
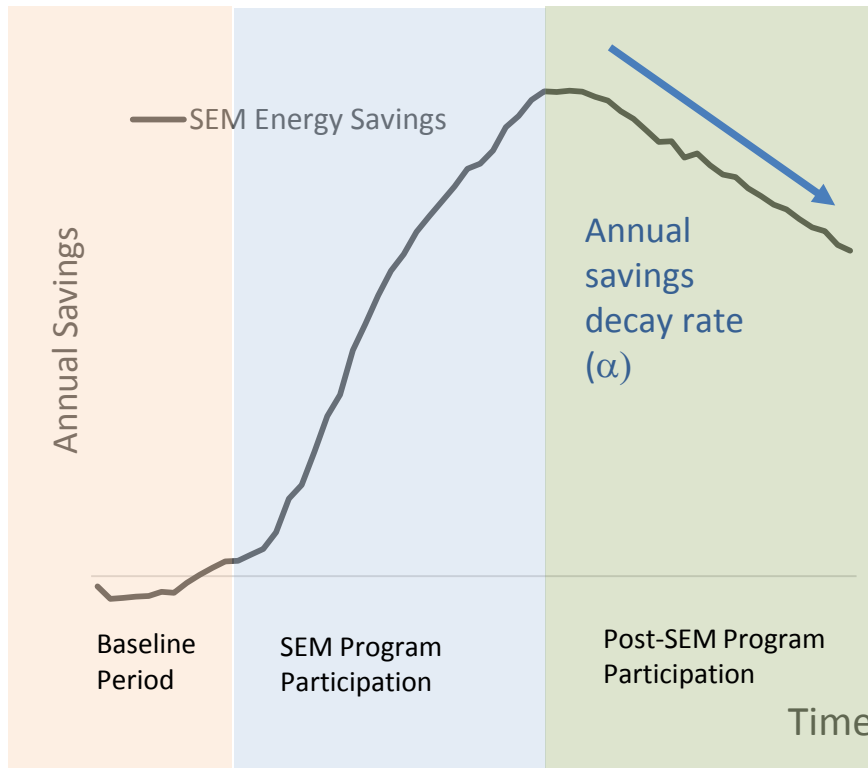
SEM MEASURE LIFE

SEM Measure Life

- Cost-effectiveness
- Long-term goal of SEM programs is lasting change in facility energy management
  - Do SEM savings persist?

SEM program measure life assumptions
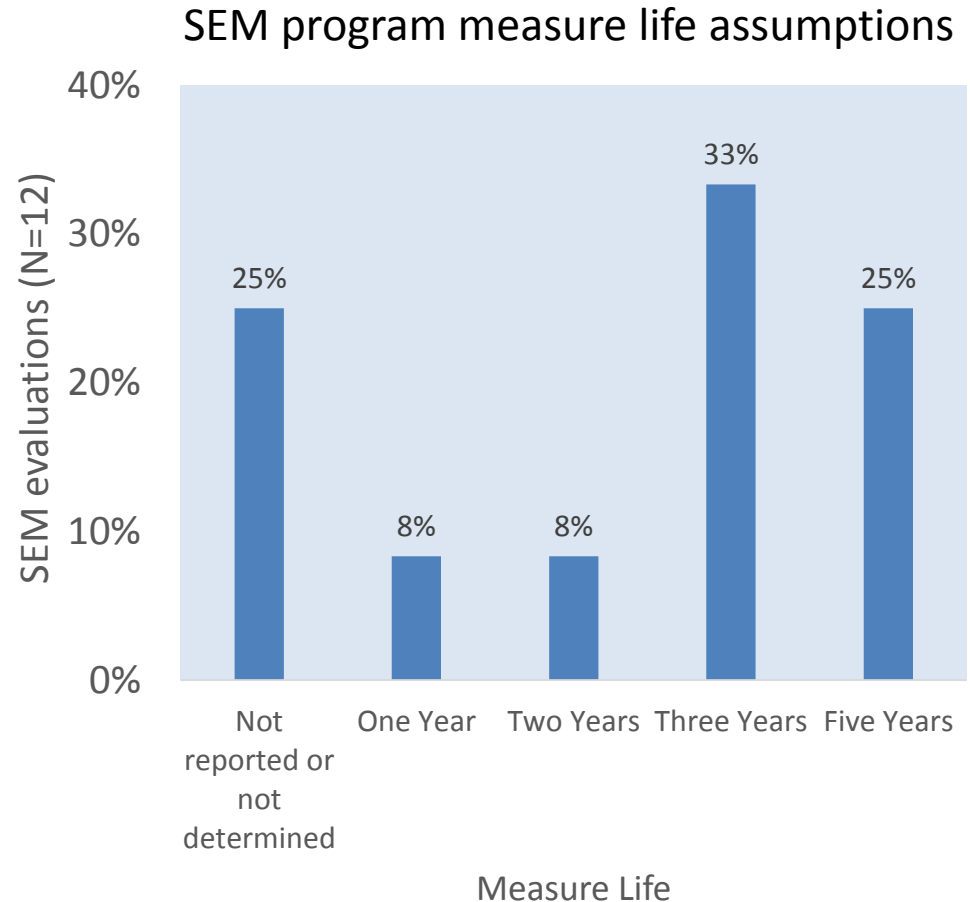
Source: 2014 CEE database for SEM programs that estimated energy savings

Framework for Estimating SEM Measure Life

Annual savings decay rate $(\alpha) = \dfrac{s_t - st_{+1}}{s_t}$

$$\text{Measure life} = \frac{Lifetime\ Savings}{Annual\ Savings}$$

<u>Example</u>

Annual savings s

Savings decay rate $\alpha = 25\%$

Lifetime savings = s + s(1-0.25) + s(1-0.25)^2 + ...

= s/0.25 = 4s

Measure life = 4s/s

= 4 years

Estimating SEM Measure Life

- **Estimate SEM energy savings after program engagement ends**
  - **Multiple years and facilities**
- **Calculate SEM savings decay rate and measure life**

- **Challenges**
  - **Measure life depends on length of engagement and facility type**
  - **Facility closures**
  - **Collection of post-participation data**

Thank You

Jim Stewart, Ph.D.
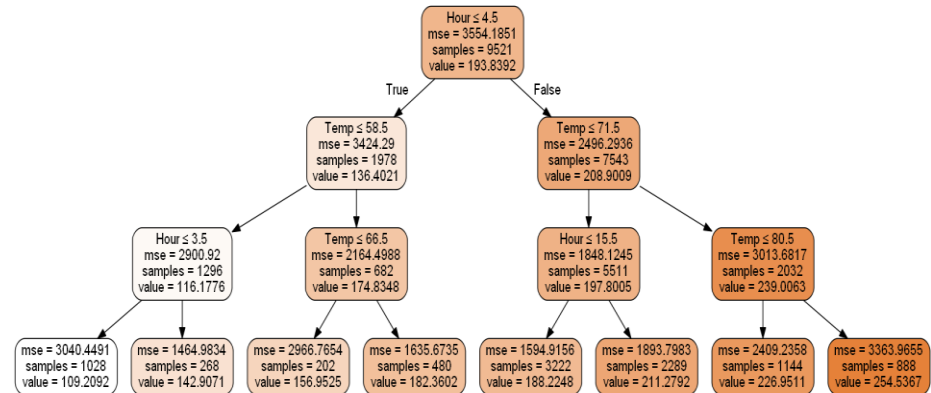
Principal Economist

Cadmus, Energy Services

jim.stewart@cadmusgroup.com

503-467-7184

Automated Baseline Example

- Project summary
  - Custom lighting project
  - Replaced metal halide with LEDs, added staged dimming
  - Sub-metering of lighting load

- Compared savings estimates from sub-metering with those from regression tree and OLS regression

Two Variables: Temp and Hour of Day, Max Depth of Three, Response is Hourly Energy Usage in kWh

Annual Savings