# ManagingEnergy.com

## Overview of ASHRAE Guideline 14-2002

**(American Society of Heating, Refrigerating and Air-Conditioning Engineers)**

## Measurement of Energy and Demand Savings

managing energy inc

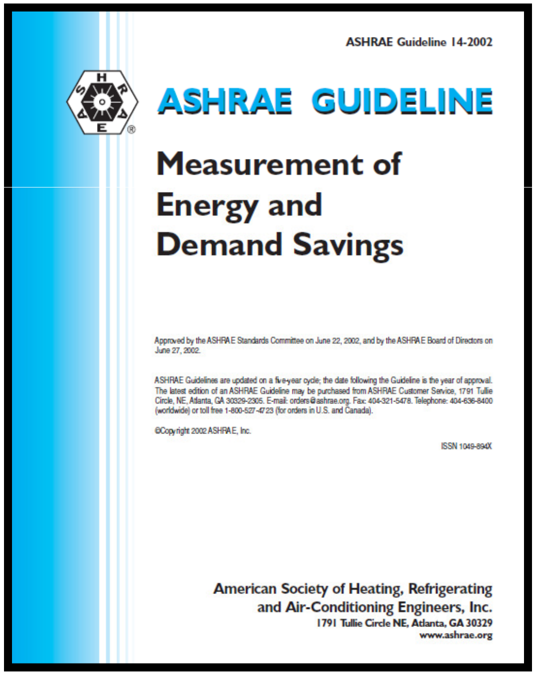
# ASHRAE Guideline 14-2002 Overview

## Measuring Energy Savings

**To assess the savings resulting from an Energy Conservation Measure**

- Must be able to compare before and after energy use while also accounting for non-ECM factors.
- ManagingEnergy.com provides a user-friendly interface to comply with the guideline, which is the de-facto international standard.

**"The purpose of ASHRAE Guideline 14-2002 is to provide guidelines for reliably measuring the energy and demand savings due to building energy management projects."**


ASHRAE Guideline 14-2002

ASHRAE GUIDELINE

Measurement of Energy and Demand Savings

Approved by the ASHRAE Standards Committee on June 22, 2002, and by the ASHRAE Board of Directors on June 27, 2002.

ASHRAE Guidelines are updated on a five-year cycle; the date following the Guideline is the year of approval. The latest edition of an ASHRAE Guideline may be purchased from ASHRAE Customer Service, 1791 Tullie Circle, NE, Atlanta, GA 30329-2305. E-mail: orders@ashrae.org. Fax: 404-321-5478. Telephone: 404-636-8400 (worldwide) or toll free 1-800-527-4723 (for orders in U.S. and Canada).

©Copyright 2002 ASHRAE, Inc.

ISSN 1049-894X

American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.
1791 Tullie Circle NE, Atlanta, GA 30329
www.ashrae.org

managing energy inc

# ASHRAE Guideline 14-2002 Overview

## Measuring Energy Savings

**There are no direct ways to measure energy savings**

- Instruments can only measure the presence of energy use and demand

**Energy savings can only be determined indirectly**

- The absence of energy use and demand can be calculated by comparing the energy use and/or demand from before and after the implementation of an energy conservation measure (ECM)
- Statistical methods are used – can be complex

$$Savings = (Use\ or\ Demand)_{Before\ ECM} - (Use\ or\ Demand)_{After\ ECM}$$

This simple comparison does not differentiate between the energy impact of the ECM and other factors such as weather and occupancy


managing energy inc

# ASHRAE Guideline 14-2002 Overview

## Measuring the impact of an Energy Conservation Measure

**Requirements**

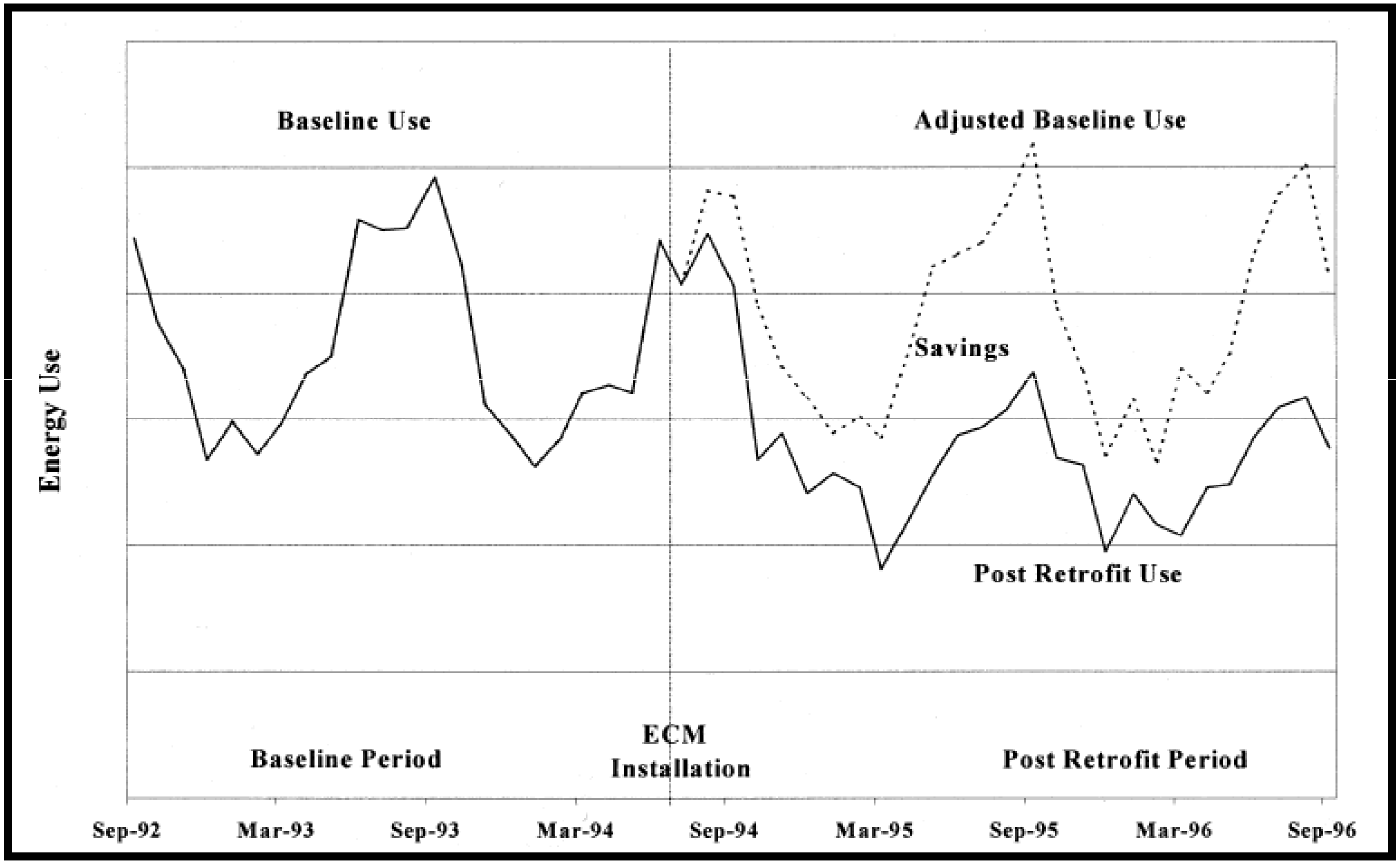
- Must be able to project the energy use or demand patterns from the pre-retrofit (baseline) period into the post-retrofit period.
- Projection must take into account all major energy-governing variables.

$$\boxed{\begin{aligned} \boldsymbol{Savings_{ECM}} = {} & (\boldsymbol{Projection\ of\ baseline\ energy\ use\ or\ demand\ to\ post\ ECM\ conditions}) \\ & - (\boldsymbol{Post\ ECM\ energy\ use\ or\ demand}) \end{aligned}}$$

managing energy inc

# ASHRAE Guideline 14-2002 Overview

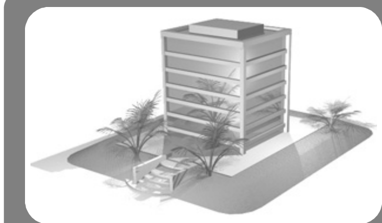
## Measuring the impact of an Energy Conservation Measure




managing energy inc

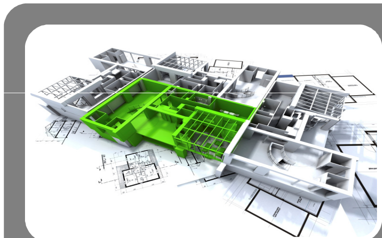
# ASHRAE Guideline 14-2002 Overview

## Approaches for Measuring Savings – Circumstances suggest best option



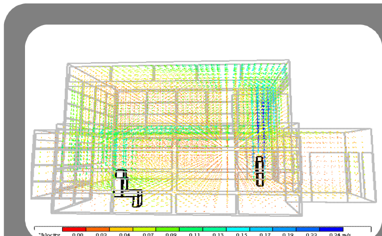
### Whole Building Approach

- Uses a “main” meter to measure energy flow
- ECMs may be applied to one or more of the systems served by the meter
- Might involve the use of monthly utility bill data
- Option of two paths (prescriptive or performance)



### Retrofit Isolation Approach

- Uses meters to isolate the energy use and/or demand of the subsystems affected by the ECM pre and post-retrofit



### Whole Building Calibrated Simulation Approach

- Uses computer simulation software to model facility energy use and demand
- Model is calibrated against actual energy use and demand data
- Calibrated model is used to predict energy use and demand of the post-retrofit period

managing energy inc

# ASHRAE Guideline 14-2002 Overview

## Selecting an Approach

Most typical
me method

| Considerations | | Best Applications for Each Path | | | |
|---|---|---|---|---|---|
| | | Whole Building | | Retrofit Isolation | Whole Building Calibrated Simulation |
| | | Prescriptive | Performance | | |
| 1 | Ability to determine savings of individual ECMs | No | No | Yes* | Yes |
| 2 | Nature of possible future baseline adjustments | Minor but can be estimated adequately | Minor but can be esti-mated adequately | Complex, or effect on ECM performance is simple to estimate adequately | Many or complex |
| 3 | Impact of ECMs | Any component of the facility | Any component of the facility | No reduction of building envelope losses | Any component of the facility |
| 4 | Understanding by nontechnical personnel | Can be simple | Can be simple | Can be very simple | Difficult |
| 5 | Special skills of personnel | | | Metering systems | See Table 5-2 |
| 6 | ECMs' interaction with the energy use of the rest of the facility | Can be complex | Can be complex | To be ignored or measured | Can be complex |
| 7 | Best length of post-retrofit period | Multiyear | At least one year | Representative periods | Maybe none |

managing energy inc

# ASHRAE Guideline 14-2002 Overview

## Approaches: Common Considerations

**Selection of Relevant Independent Variables**

- Variables which represent forcing functions of the energy-using system
- “t-test” should be used to determine which variables are significant
- The most significant variables should be measured over the period of interest
- Unaccounted for variables are the primary source of uncertainty in any computed savings

**Examples of Relevant Independent Variables**

- Weather (temperature, humidity, cloud cover and wind)
- Occupancy (floor area rented, sales, hotel vacancy rates)
- Production (items produced, shifts)

# ASHRAE Guideline 14-2002 Overview

## Approaches: Common Considerations

**Documenting Baseline Conditions**

- Changes in the design or use of the building may lead to an invalid/outdated baseline model
- Recording baseline conditions can aid in model revisions
- Common conditions include
  - Occupancy patterns, densities, schedules, and type for each typical season.
  - Average throughput or plant loads in each operating mode
  - Operating schedules and key set points of energy-using systems for all operating modes
  - Non-routine functions of the facility, their dates, and impacts on operation
  - The nature and timing of any breakdown of significant energy-using equipment
  - Equipment nameplate data

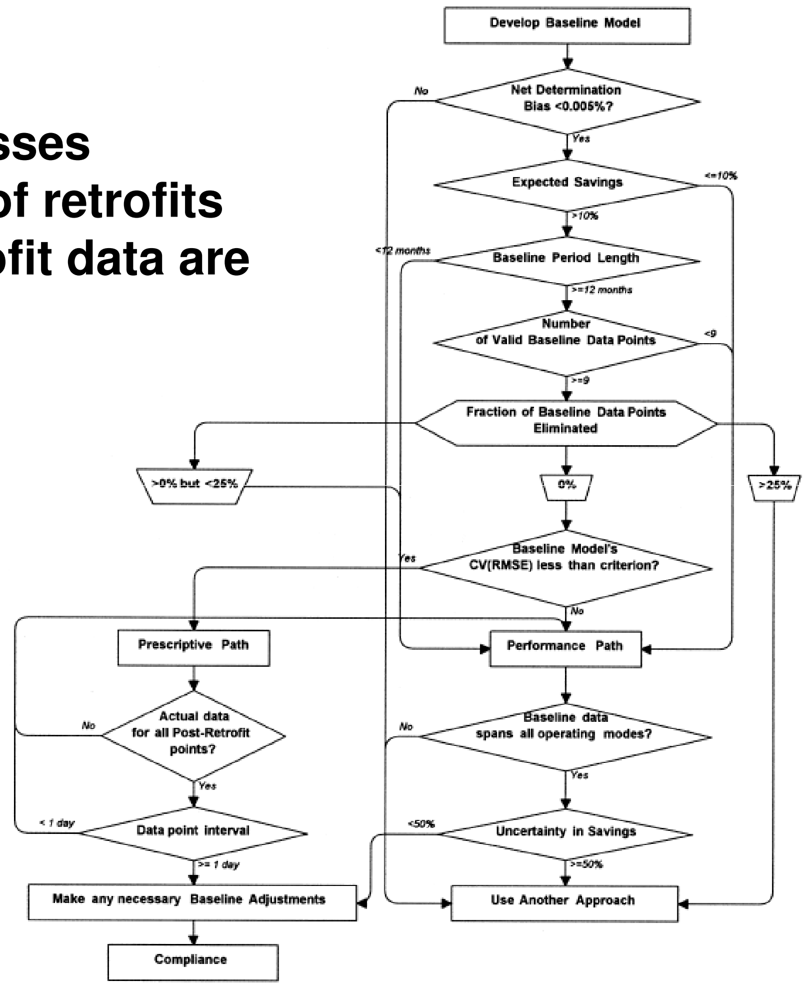
Me energy auditing and document management features provide key process support.

managing energy inc

# ASHRAE Guideline 14-2002 Overview

## Whole Building Approach

The *Whole Building Approach* encompasses procedures that verify the performance of retrofits where whole building pre- and post-retrofit data are available.



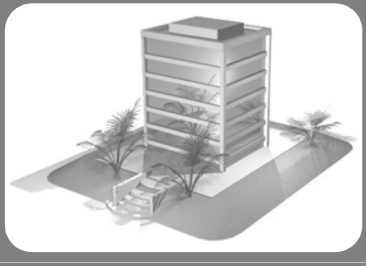

Appropriate for complex, multi-phase projects as opposed to one or two contained retrofits.

managing energy inc

# ASHRAE Guideline 14-2002 Overview

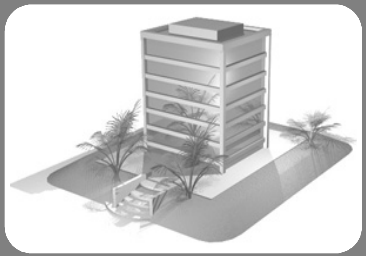
## Whole Building Approach: Paths

**There are two possible paths which can be taken**



### Whole Building Prescriptive Path

- Expected Savings > 10%
- Energy data is continuous (no exclusions) in pre- and post-retrofit data



### Whole Building Performance Path

- Energy data is not continuous
- More forgiving of data availability
- Statistical methods assess validity

Normal me
method.

Managing Energy uses the **Whole Building Performance Path**

managing energy inc

# ASHRAE Guideline 14-2002 Overview

## The Baseline Model

**The regression process yields a statistical model in the following form**

$$E = C + B_1V_1 + B_2V_2 + B_3V_3 + \ldots \qquad (6.1\text{-}1)$$

where

$E$ = energy use or demand estimated by the equation,

$C$ = constant term in [energy units/day] or [demand units/billing period],

$B_n$ = coefficient of independent variable $V_n$ in [energy units/driving variable units/day] or [demand units/driving variable units/day],

$V_n$ = driving variable.

managing energy inc

# ASHRAE Guideline 14-2002 Overview

## Baseline Adjustments

**Needed when changes to the facility occur during the post-retrofit period.**

**Option 1 (preferred)**

- Sub-meter the effect if possible
- Post-retrofit data is then simply the total metered amount less the sub-metered quantity

**Option 2**

- Account for the adjustment in the model

Managing Energy supports option, with either an actual submeter or virtual (calculated) submeter.

$$E = C + B_1V_1 + B_2V_2 + B_3V_3 + \; A_1V_n + \ldots \qquad (6.1\text{-}2)$$

where

$A_1$ = coefficient of the independent variable for the adjustment,

$V_n$ = independent variable for the adjustment.

managing energy inc

# ASHRAE Guideline 14-2002 Overview

## Identifying an Optimal Baseline Model

**The guideline recommends the optimal model be selected based on a measure of the goodness of fit.**

### $R^2$: Coefficient of Determination

- Indicates the proportion of response variation "explained" by the regressors

### CV(RMSE): Coefficient of Variation of the Root Mean Squared Error

- Indicates the uncertainty in the model

managing energy inc

# ASHRAE Guideline 14-2002 Overview

## Identifying an Optimal Baseline Model

### $R^2$: Coefficient of Determination

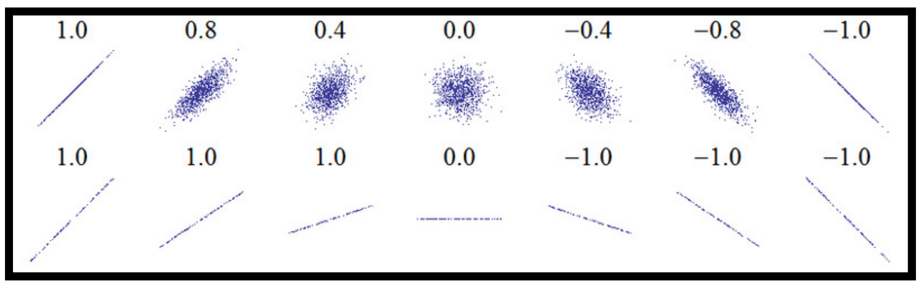
**$R^2 = 1$**
- All variability in the response variable can be explained by the regressors.

**$R^2=0.8$**
- Approximately 80% of the variation in the in the response variable can explained by the regressors.

**$R^2=0$**
- None of the variation in the response variable can be explained by the regressors.
- No relationship

Ideally you want **$R^2$** > 0.8
**BUT NOTE:**
**"Correlation does not imply causation"**

**R=**



# ASHRAE Guideline 14-2002 Overview

## Identifying an Optimal Baseline Model

**CV(RMSE): Coefficient of Variation of the Root Mean Squared Error**

- **A measure of uncertainty in the model**
- **Whole Building Prescriptive Path**

| Post-Retrofit Period | Criteria |
| --- | --- |
| < 12 months | • CV(RMSE) < 20% for energy use<br>• CV(RMSE) < 30% for demand |
| 12→60 months | • CV(RMSE) < 25% for energy use<br>• CV(RMSE) < 35% for demand |
| > 60 months | • CV(RMSE) < 30% for energy use<br>• CV(RMSE) < 40% for demand |

Managing Energy supports the **Whole Building Performance Path** but **CV(RMSE)** can be used interchangeably with $\mathbf{R^2}$

$$CVRMSE = 100 \times [\sum (y_i - \hat{y}_i)^2 / (n-p)]^{1/2} / \bar{y}$$

managing energy inc

# ASHRAE Guideline 14-2002 Overview

## Identifying an Optimal Baseline Model

**A well correlated model is not always a good model**

- **Compliance indicators can be helpful in assessing whether a model is sound**

**ASHRAE 14-2002 Compliance**

**CV(RMSE):** 7.81%
**Regression:** 0.9938
**CV(STD):** 0.9933
**NMBE:** 0.0000
**Net Determination Bias:** 0.000%
**Includes all Operating Modes:** True
**Balanced Representation:** True
**Data Elimination < 25%:** True

**Complies with ASHRAE 14-2002:** True

managingenergy provides a quick compliance check in the modeling view

managing energy inc

# ASHRAE Guideline 14-2002 Overview

## Compliance: CV(STD)

**Coefficient of Variation of the Standard Deviation**

- Another measure of model uncertainty
- Used to compute savings uncertainty when the baseline energy use or demand is essentially the same in all periods

**ERRATA SHEET FOR ASHRAE Guideline 14-2002**
**Measurement of Energy and Demand Savings**

**October 10, 2008**

The corrections listed in this errata sheet apply to all copies of ASHRAE Guideline 14-2002.

| Page | Erratum |
| --- | --- |
| 15 | **Section 5.2.11.3 Modeling Uncertainty.** In Section 5.2.11.3 replace the existing Equation 5.3 with the following: |

$$CVSTD = 100 \text{ x } [\sum (y_i - \bar{y})^2 / (n-1)]^{1/2} / \bar{y}$$

managing energy inc

# ASHRAE Guideline 14-2002 Overview

## Compliance: NMBE

**Normalized Mean Bias Error**

- Yet another measure of model uncertainty
- A compliance criteria for the Whole Building Simulation Approach

$$\boxed{NMBE = \frac{\sum (y_i - \hat{y}_i)}{(n-p) \times \bar{y}} \times 100}$$

managing energy inc

# ASHRAE Guideline 14-2002 Overview

## Compliance: Net Determination Bias

### Definition

- The net determination bias test shall apply the baseline independent variable data to the algorithm for savings determination to re-compute an algorithm-determined baseline energy usage or demand for each of the *n* baseline data points (*i*). These re-computed quantities are then compared to the actual baseline energy usage or demand (*i*) in the baseline period to derive the *net determination bias*.

$$\text{Net Determination Bias} = \frac{\sum^{n} (e_i - \hat{e}_i)}{\sum^{n} e_i} \times 100$$

To comply with the guideline: **net determination bias ≤ 0.005%**

managing energy inc

# ASHRAE Guideline 14-2002 Overview

## Compliance: Net Determination Bias

Natural Gas Meter    NET DETERMINATION MEAN BIAS TEST

Buildings: 1 Main Hospital
Meters: 2 Main Natural Gas Meter

| Month | Original [Mcf] | Projected Base Year [Mcf] | Base Year [Mcf] | Energy Savings | % Energy Saved |
|---|---|---|---|---|---|
| Sep | | 1,353 | 1,412 | 59 | 4.37 |
| Oct | | 1,435 | 1,477 | 42 | 2.91 |
| Nov | | 1,901 | 2,050 | 149 | 7.86 |
| Dec | | 2,198 | 2,324 | 126 | 5.73 |
| Jan | | 2,721 | 2,719 | -2 | -0.09 |
| Feb | | 2,721 | 2,715 | -6 | -0.22 |
| Mar | | 2,260 | 2,138 | -122 | -5.38 |
| Apr | | 2,218 | 2,061 | -157 | -7.08 |
| May | | 1,597 | 1,566 | -31 | -1.95 |
| Jun | | 1,448 | 1,412 | -36 | -2.48 |
| Jul | | 1.357 | 1,367 | 10 | 0.71 |
| Aug | | 1,445 | 1,412 | -33 | -2.27 |
| | | 22,654 | 22,653 | -1 | 0.0044% <============= |

# ASHRAE Guideline 14-2002 Overview

## Compliance: Includes All Operating Modes

**Baseline periods, which span all modes of system operation are needed to reduce uncertainty in computed savings**

- A facility which operates on a annual cycle in response to weather should have a baseline period of a least one full year
- Period immediately prior to retrofit is preferred
  - Operations are most likely representative of post-retrofit period
  - Easily remembered by facility staff and thus least likely to introduce bias or error due to unaccounted significant variables

Managing Energy determines if the baseline model contains data from each month of the year.

managing energy inc

# ASHRAE Guideline 14-2002 Overview

## Compliance: Balanced Representation

**Care should be taken to ensure all modes of system operation are represented equally.**

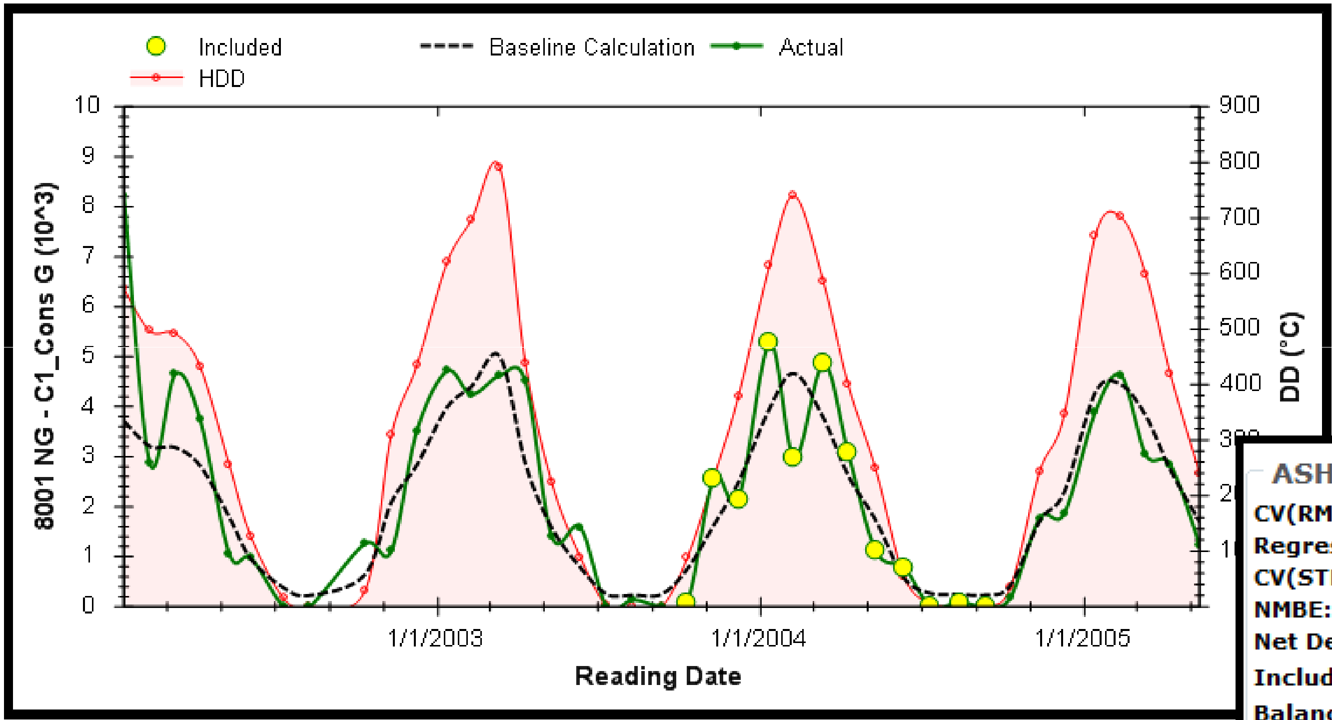
- Failure to do so may result in over representing one operational mode and thus introducing bias into the model (e.g. summer months than winter months)
- Most easily achieved by using an integral number of continuous 12 month periods (e.g. 12, 24, 36 months), not partial years (e.g. 7, 15, 30 months)

Managing Energy computes the “amount” of data within each of the 12 months and ensures that all months are approximately balanced.

managing energy inc

# ASHRAE Guideline 14-2002 Overview

## Compliance: Balanced Representation




**ASHRAE 14-2002 Compliance**

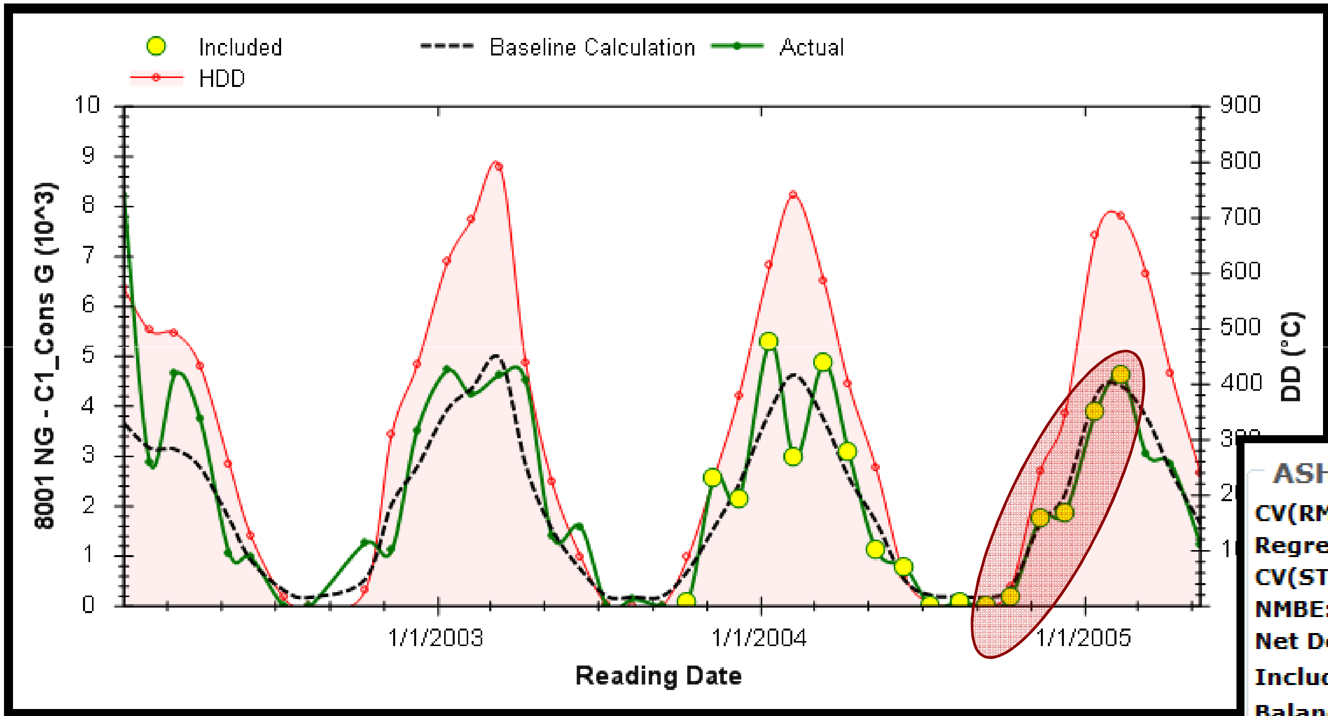
**CV(RMSE):** 42.84%
**Regression:** 0.7751
**CV(STD):** 0.9021
**NMBE:** 0.0000
**Net Determination Bias:** 0.000%
**Includes all Operating Modes:** True
**Balanced Representation:** True
**Data Elimination < 25%:** True

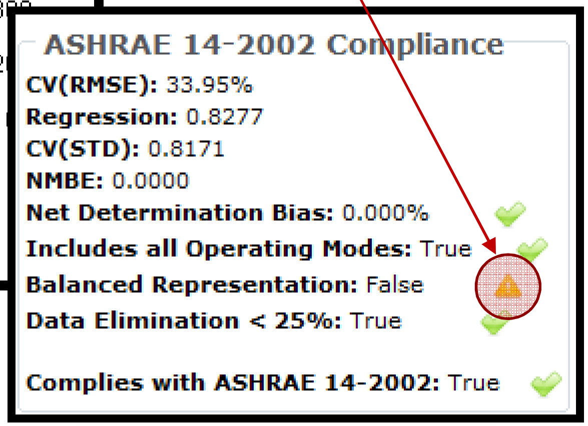
**Complies with ASHRAE 14-2002:** True

managing energy inc

# ASHRAE Guideline 14-2002 Overview

## Compliance: Balanced Representation



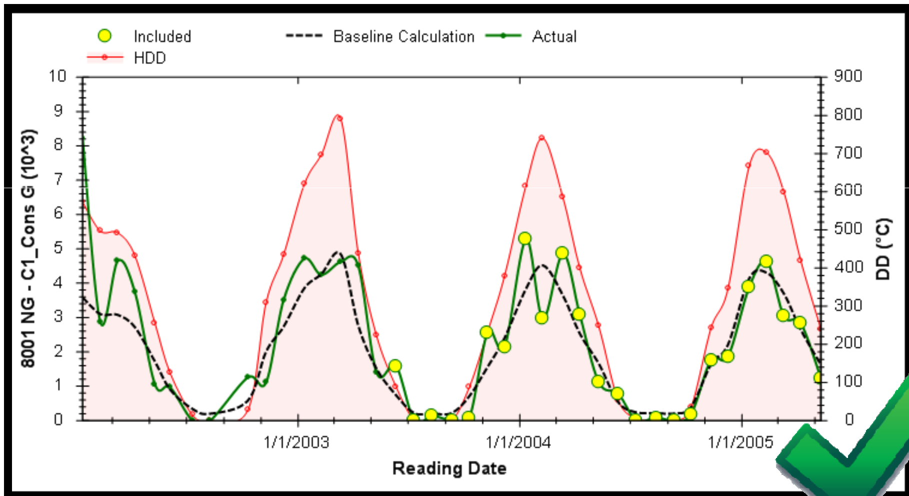

managing energy inc

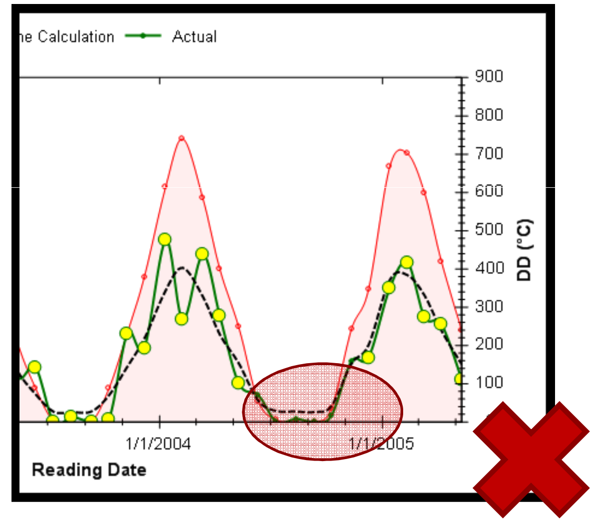
# ASHRAE Guideline 14-2002 Overview

## Compliance: Data Elimination

**“No more then 25% of measured data shall be excluded”**

- Reasons should be given for data gaps, data elimination or estimations of any measured data in the baseline or post-retrofit period



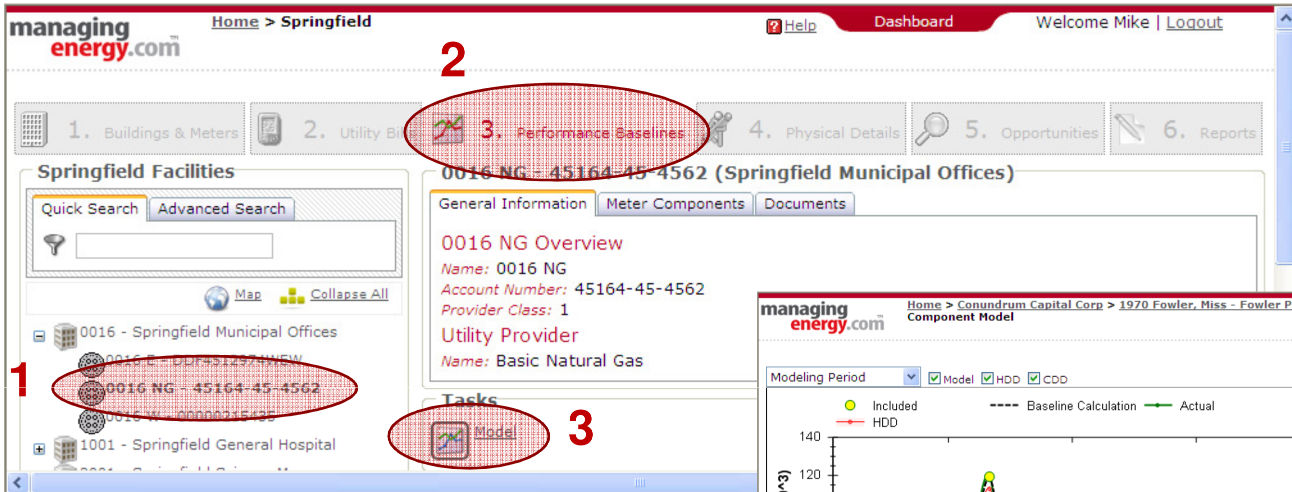



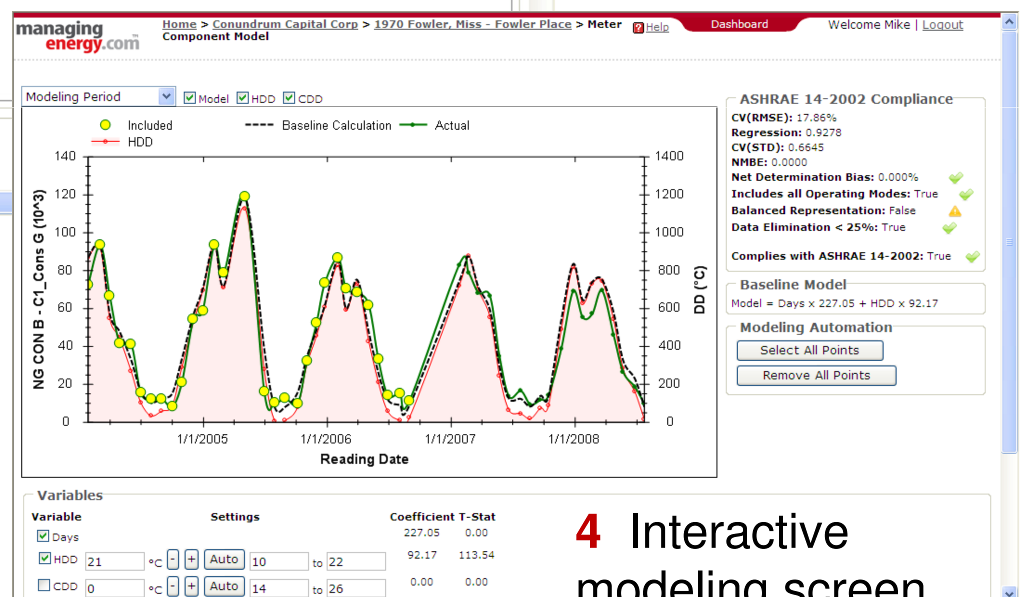

The period in which Managing Energy computes eliminated data begins with the most historic data point and ends with the most recent

managing energy inc

# ASHRAE Guideline 14-2002 Overview

## Getting there in mec




1 Pick the meter
2 "Performance Baselines" tab
3 Model button

4 Interactive modeling screen

managing energy inc