Building Cost and Performance Metrics:
DATA COLLECTION PROTOCOL

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Pacific Northwest NATIONAL LABORATORY
FEMP

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Whole Building Cost and Performance Measurement: Data Collection Protocol

Revision 2

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Version 2 of the report was enhanced through the application of the protocol on U.S. General Services Administration and U.S. Navy buildings. The original version of the protocol was developed in 2004-2005 with assistance from a Technical Advisory Group of government sector sustainable design professionals.

Disclosure: The Fall of 2008, Kim Fowler became a member of the U.S. Green Building Council's Government Committee and Emily Rauch became a member of the Research Committee. Their recent involvement in these groups has confirmed the need for a whole building performance measurement protocol, but has not directly impacted the project.

Preface

This protocol was written for the Department of Energy's Federal Energy Management Program (FEMP) to be used by the public as a tool for assessing building cost and performance measurement. The primary audiences are sustainable design professionals, asset owners, building managers, and research professionals within the Federal sector. The protocol was developed based on the need for measured performance and cost data on sustainable design projects. Historically there has not been a significant driver in the public or private sector to quantify whole building performance in comparable terms. The deployment of sustainable design into the building sector has initiated many questions on the performance and operational cost of these buildings.

This protocol aims to generate high-level comparative measurement results of the performance of sustainably designed buildings. Originally developed in 2004-2005, this revised protocol reflects lessons learned from various studies and projects where the protocol was used as a primary tool for measuring whole building performance. This protocol includes two sets of metrics that need to be collected for each facility: building and site characteristics data and building cost and performance data. The metrics were selected for ease of collection, usefulness or relevance of the information to sustainability and the expected quality of the data to be collected. Each of the metrics identified in this protocol are considered important to offer a representative indication of building performance, however, due to anticipated data availability, some metrics have been identified as optional, and others have been removed from the list provided in revision 1.

The data analysis and communication of results target the financial decision makers' need for measured performance and cost data on sustainable design projects. This protocol was not intended to answer all questions regarding the performance of sustainably designed buildings, but rather to offer indicators of performance and cost to further the knowledge base for the sustainable design business case.

To date, the protocol has been used by the U.S. Navy to measure the performance of five sustainably designed buildings as compared to typically designed buildings in the same location and with similar use profiles. The protocol has also been used in a General Services Administration study to evaluate and compare the performance of twelve sustainably designed federal buildings located throughout the U.S. with both national and regional building performance averages. Other Federal agencies and private organizations are in the process or are considering using the metrics as well.

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Abbreviations and Acronyms

ANSI	American National Standards Institute
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
ASTM	American Society for Testing and Materials
BEMS	Building Energy Monitoring System
BIDS	Building Investment Decision Support
BOMA	Building Owners and Managers Association
Btu	British Thermal Units
CAA	Clean Air Act
CDD	cooling degree days
CDD65	cooling degree days at base 65°F
CO	carbon monoxide
CO_2	carbon dioxide
CO_2e	carbon dioxide equivalent
DOE	U.S. Department of Energy
ECM	energy conservation measure
EEM	energy efficiency measure
EERE	Office of Energy Efficiency and Renewable Energy
EMS	Environmental Management System
EPP	Environmentally Preferable Purchasing
ESCO	energy service company
ESP	energy service provider
EUI	energy use intensity
FEMP	Federal Energy Management Program
GHG	greenhouse gas
GPS	global positioning system
GSA	General Services Administration
GWP	global warming potential
HDD	heating degree days
HDD65	heating degree days at base 65°F
HVAC	heating ventilation air conditioning
IAQ	indoor air quality
ICLEI	International Council for Local Environmental Initiatives

IEQ	Indoor environmental quality
in.	inches
inH_2Oe	inches water equivalent
inHg	inches of mercury
IPMVP	International Performance Measurement and Verification Protocol
ISO	International Organization for Standardization
kg	kilograms
kW	kilowatts
kWh	kilowatt-hours
LEED™	Leadership in Energy and Environmental Design
M&V	measurement and verification
NAAQS	National Ambient Air Quality Standards
NO_X	nitrogen oxides
NREL	National Renewable Energy Laboratory
O&M	operations and maintenance
O_3	ozone
Pb	lead
PM_{10}	particulate matter less than 10 □m in diameter
$PM_{2.5}$	particulate matter less than 2.5 □m in diameter
PNNL	Pacific Northwest National Laboratory
PV	photovoltaic
sf	square feet
SO_2	sulfur dioxide
SO_2e	sulfur dioxide equivalent
SSV	Sustainable Silicon Valley
T&D	transmission and distribution
TAG	Technical Advisory Group
TMY	typical meteorological year
TSP	total suspended particulate
U	uranium
USGBC	United States Green Building Council
µm	Micrometers

Glossary

An *Indicator* is a qualitative or quantitative value that provides a proximate gauge of the effects of sustainable development on the state or condition of the environment. For this project, economic, environment and social equity indicators are used to evaluate sustainable development metrics.

A *metric* is a measurable characteristic, which for this project includes both building performance and cost.

Modeled refers to the representation of a building operations using calculations, usually using computer simulations, to estimate performance.

Performance, for this protocol, is the measurable value associated with building operations.

A *protocol* is the procedure for executing data collection and analysis. It guides what to do and when, and how to ensure quality.

Sustainably designed refers to a building project that seeks to minimize the negative environmental impact of a building by enhancing the efficiency and moderation in the use of water, energy, materials, and siting space. Sustainably designed buildings also prioritize the occupant comfort, and focus on minimizing the environmental impacts of the construction activities.

Typically designed refers to a building project that used standard design approaches during the development of a building. Commonly the building design did not incorporate integrated design strategies or innovative resource conservation features.

Whole Building Performance Measurement is the activity of documenting the operational metrics of a building. The general categories include water, energy, maintenance, waste generation and recycling, indoor environmental quality, and occupant commute.

1.0 Introduction

The purpose of this document is to provide a method and set of metrics (referred to as the "protocol") for the measurement of whole building cost and performance. The metrics identified in this protocol are intended to be indicators of whole building performance. They are not intended to measure all aspects of sustainably designed building performance, but rather provide some basic information about a building's comparative performance with respect to sustainable design. This protocol was developed for the Federal sector and has been applied to multiple buildings within the U.S. Department of the Navy, General Services Administration and the U.S. Army. Revision 1 of the protocol describes the protocol development in greater detail, where this revision focuses more on the details of applying the protocol to Federal buildings.[1]

1.1 Overview

Sustainable design professionals' intuition has been telling them for years that sustainably designed buildings result in better buildings with lower operating costs, more productive occupants, and a smaller environmental footprint than typically designed buildings. Without documented operations data it has been difficult to gain support for sustainable design with some key Federal decision makers.

At the same time, the number of sustainably designed buildings has been increasing, in part as a result of relatively easy to use industry standards such as the U.S. Green Building Council's (USGBC) Leadership in Energy and Environmental Design (LEED™) rating system for new construction. Plus, in recent years, many studies addressing the business case for sustainable design have been performed. These studies have provided data to address the perception of increased costs for sustainable design by using design assumptions, manufacturer assumptions, and modeling to forecast the costs and benefits of sustainable design.

In addition to the above, a number of performance measurement studies have been documented targeting energy use[2] and occupant productivity and satisfaction.[3,4] These studies tend to gather detailed information in the targeted area, and although useful for optimizing a building's operation in that area, the studies do not address other aspects of building performance.

The collection of sustainable design building case studies data has also been expanding. For example, FEMP has sponsored a Federal portal to the *High Performance Buildings Database* to increase the number of Federal projects included in this growing data set. These case studies provide quality anecdotal stories regarding the success of sustainable design practices and over time, expect to include a considerable set of building cost and performance data.[5]

Although each of these studies offers useful information for sustainable design professionals, they do not demonstrate the measured impact of existing sustainably designed buildings. They offer evidence that investment in sustainable design is a cost effective, long-term strategy; however, the data could be more convincing with measured building cost and performance data. [6, 7, 8, 9, 10]

The Building Cost and Performance Metrics project was initiated in fiscal year 2004 by FEMP to address the need for measured building performance data that captures the difference between sustainably designed and typically designed buildings. The scope was to develop a **relatively simple method** for measuring building cost and performance, which could be used to represent the life cycle costs and benefits of sustainable design to Federal decision makers. The primary product of the project was a data collection protocol published in 2005 that outlined a set of high-level metrics for comparing the cost and performance differences of sustainably designed and typically designed buildings. This document is a revision of the original protocol and includes updated information and lessons learned from real examples that utilized the Whole Building Cost and Performance Metrics.

1.2 Protocol Development

The information available at the beginning of the project pointed to the need for measured building performance data that could be translated into a cost value used to further explain the life cycle benefits of sustainable design to financial decision makers. To be useful to the Federal stakeholders, the data needed to be:

- Measured, not modeled;
- Relatively easy and inexpensive to collect;
- Representative of sustainable design principles, not just individual design strategies such as energy efficiency; and
- Translatable into cost values that could be shared with the financial decision makers to demonstrate performance in their language.

The project approach used a team of Federal sector leaders in sustainable design and performance measurement to develop a set of metrics, test the metrics, and finalize a data collection protocol that could be used to gather data (see Appendix A.1).

1.3 Applying the Protocol

Since the first publication in 2005, the protocol has been used in a variety of studies, including an assessment of post-occupancy building performance for a portfolio of 12 General Services Administration (GSA) buildings[11] and an evaluation of 5 U.S. Navy matched building sets[12]. Information from these real world examples, in addition to a pilot test conducted during the development of the protocol, was used to clarify the metrics data collection protocol and to aid in addressing potential data collection challenges. Lessons learned that apply to the overall protocol use include:

- Identifying and collecting data on sustainably designed buildings and an appropriate baseline takes time and persistence. Although the metrics included in this protocol are targeting relatively simple and common areas of performance measurement, it is recognized that the data are not always collected in a consistent manner and the information is often managed by different organizations, such as the building manager, human resources, waste management, and others.

- Engage building managers early in the process and keep them as leaders throughout the measurement process;
- Consider forming a building team to assist in the data collection effort;
- If buildings are not individually metered, assess whether the cost and effort to meter the buildings fit within the budget and time constraints;
- Hold teleconference(s) with each building team or point of contact to gather as much information as possible prior to the site visit;
- Bring a digital camera, measuring tape, and a trundle wheel on the site visit;
- Outsourcing of building related services may complicate data collection and interpretation efforts; and
- Significant data collection gaps between the sustainably designed buildings and baseline will need to be addressed.

These challenges to data collection and analysis are being shared to assist with the application of the protocol. Many of these challenges need to be addressed on a case-by-case basis. Issues identified pertaining to a specific metric are discussed in the chapters providing details on that metric.

2.0 Protocol

This protocol is intended to be used for high-level comparative analysis of sustainably designed buildings to typically built buildings or standards. The basic steps of this protocol are shown in Figure 1 and listed below:

- Project Initiation
  - Define target audiences and focus questions
  - Select buildings
  - Determine type of comparison to use
  - Identify baseline
  - Select and refine set of performance metrics
- Project Execution
  - Identify data collection system needs and collect data
  - Clarify data anomalies
- Project Analysis
  - Analyze data and compare to baseline
  - Report findings

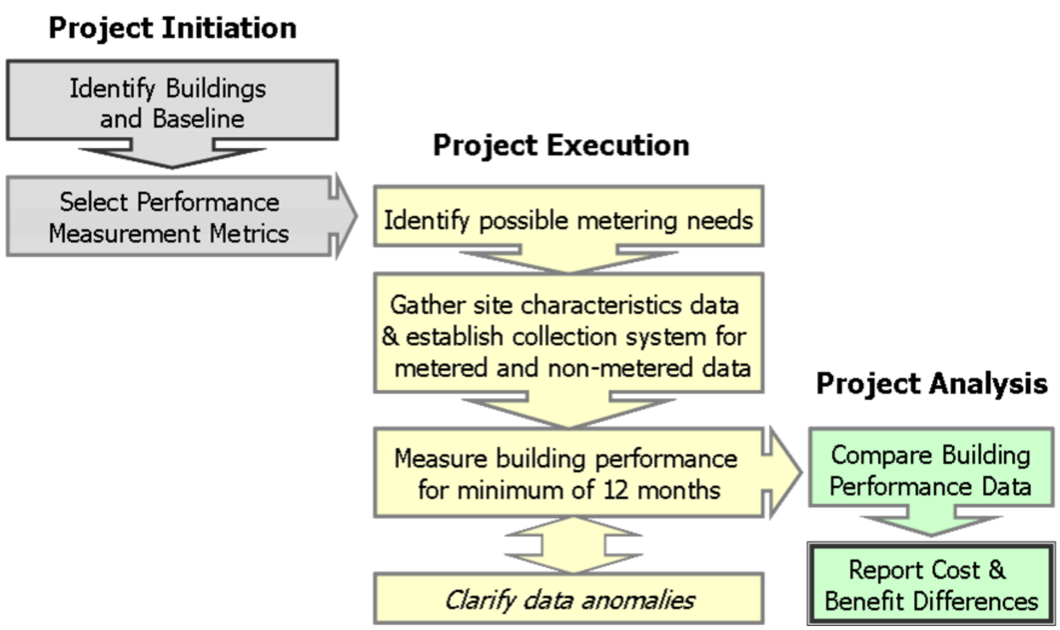


Figure 1. Whole Building Performance Measurement Protocol

2.1 Target Audiences

The primary audiences for the use of this protocol are building managers and sustainable design professionals. The primary audiences for the building performance and cost data (once it is collected and analyzed) are building managers, sustainable design professionals, and the financial personnel responsible for submitting or accepting budgets for design projects. Other key audiences include technical personnel responsible for designing new buildings and management responsible for approving design concepts and budgets.

The financial personnel within the Federal sector may include the Office of Management and Budget, Comptrollers, Asset Managers, Claimants, Chief Financial Officers, Third-Party Financiers and others with similar financial oversight roles. As trusted stewards of funding, these decision makers want to ensure that sustainable design offers a sound financial investment. The types of questions the metrics attempt to address for this audience include:

- How does the first cost of sustainably designed buildings compare to the first cost of typically designed buildings?
- How do the performance-based operating costs compare between sustainably and typically designed buildings?

These questions are likely to satisfy the interests of other key audiences as well. It is recognized that even when performance and cost data are provided to financial decision makers, they may still run into known business practice challenges such as rules of thumb for the cost of design and "lowest first cost" decision-making.

Depending on the audience of the cost and performance measurement data, the metrics attempt to address the following additional questions:

- How do sustainably designed buildings perform in comparison to typically designed buildings?
- What design features offered significant performance impact?
- Why did the building(s) perform the way it did?

2.2 Building Selection

Once the audiences and questions have been identified, it is time to select the buildings to be studied, which also involves determining deciding what type of comparative analyses can be performed given available buildings and baseline data. Because each type of comparative analyses requires different building data, finalizing these decisions will influence which metrics will be analyzed.

To perform any of the studies listed above, the definition of a sustainably designed building as compared to a typically built building must be established. Sustainably designed buildings are those that have environmental, economic, and social equity impacts incorporated into the design, construction, and operation considerations alongside life cycle costs. Quality sustainably designed buildings have often used an integrated design strategy. For the purposes of this project, a sustainably designed building could be anything from a LEED™ platinum certified building to a building claiming a considerable number of sustainable design features. The definition of sustainably designed buildings could also be restricted to the U.S. Green Building Council's Leadership for Energy and Environmental Design New

Construction (LEED-NC™) certified projects. While the number of LEED-NC™ Federal buildings is growing rapidly, this restriction would unduly limit the number of Federal facilities available for comparative analysis given not all sustainably designed Federal buildings apply for LEED certification.[13]

Typically designed buildings are those where minimal or no extra consideration was made to incorporate environmental or social equity impacts, and/or life cycle cost considerations into the design, construction, and operation of the building. Comparative analysis establishing useful baselines is a challenge for any of the potential study designs.

2.2.1.1 Potential Issues and Lessons Learned

- Buildings need to be fully functioning and occupied for a minimum of 6 months before performance and cost data are collected;
- Local involvement/ownership in this process is paramount to its success. Locations where local/site staff are not part of the process can make it difficult to obtain information or achieve required installation needs.
- Collecting data on individual buildings located on campuses may require new tracking systems to be put in place;
- When selecting buildings for a performance measurement study, the following criteria should be considered:
    - Existing metering for energy and water use
    - Access points for new metering and communications (as required)
    - Existing systems for collection of maintenance, waste generation and recycling data (as required)
    - Ability to perform occupant satisfaction surveys
    - System for clearly identifying the sustainable design features of the buildings, e.g., LEED certification
    - If using matched pairs analysis, careful consideration of design features to assess whether building performance will be comparable
    - Operational assessment of all systems, e.g., are they operating correctly?
    - Access to site operations and maintenance personnel for trouble-shooting during the study
- Depending on the type of study, it may be advantageous to offer a short training class for "engaged" site staff on study scope.

2.3 Comparative Analysis

Some general approaches to quantify and compare building performance include

- Matched Pairs Study – Two groups where each building is matched by a set of specific attributes to another building and the difference between each pair for each metric is compared.
- Two-sample comparison – The metrics from a sample of sustainably designed buildings are compared to a sample of typically built buildings
- Mean performance comparison to baseline – The metrics obtained from a sample of sustainably designed buildings are compared to a set of defined performance metrics.
- Trend Detection – A set of sustainably designed buildings are ranked according to the number of sustainably designed features (i.e. LEED ranking) and their ranking is compared to the performance metrics measured.

2.3.1 Matched Pairs

A building study which uses matched pairs attempts to match each sustainably designed building with a typically designed building of comparable attributes. Basic building and site characteristics data (see Section 4.0) are collected for each building in each pair of buildings to establish the pairing. The differences in performance between the matched buildings are then used to evaluate the performance. The buildings in a matched pairs design must be matched by the following criteria:

- Be the same building type or function (e.g., office, courthouse, training center, etc.) and have similar water, energy, waste, and maintenance needs;
- Be located near each other to minimize the impact of different weather considerations over the measurement period;
- House a similar occupant type (e.g., active military, government employees, contractors, etc.), to minimize differences in policies, procedures and work ethic; and
- Have been in operation for at least 6-months and for a comparable number of years. This reduces the impacts of equipment differences.

If these basic matching criteria cannot be met, then a different design should be selected.

For a matched pairs design it is recommended that the group of matched buildings be as large as possible. Comparisons can be made with a small number of matched pairs; however, larger data sets (at least 40 total buildings) provide enough support to have quality statistical analyses of the building cost and performance metrics. However, this approach would also require significant financial resources, as well as the need to acquire the willingness of 40 or more building managers to provide the requested data, which at a minimum would be a daunting task. Ideally, enough data will be collected through the building set approach to create a large data set over time.[14]

Another matched pairs design matches the building by following a set of building occupants from a typically designed building to a sustainably designed building which may provide an easier comparison of occupants and productivity. However, the data on building operation would need to be collected for a minimum of two 12 month time periods in succession and then normalized for differences in weather and other events that may have impacted the building costs and performance over that 2-year period. The occupant data would need to consider how productivity measurements might be affected by any change to occupant surroundings (e.g., the Hawthorne Effect). The final set of data would only involve one to two buildings (as a result of the rare situation being evaluated) and therefore, would offer more of a case study rather than a data set with multiple buildings.[15]

2.3.2 Two-sample comparison

If data from sustainably and typically designed buildings can be gathered but there is no clear way to match each building together for a matched pairs design, then a two-sample comparison can be performed. In this design the average performance of sustainably designed buildings is compared to the average performance of the typically designed buildings. With larger data sets (20 or more sustainably designed buildings and 20 or more typically designed buildings) the ability to identify a difference in average performance using statistics is improved. As noted previously a large sample size would require significant financial resources.

2.3.3 Mean Performance Comparison to Baseline

If the limits of the study restrict the sample of buildings to those that are sustainably designed, then this data set can be compared to an agreed upon baseline. Accurate baseline values are required for proper analysis of the sustainably designed buildings in the study. The final baseline values will require agreement from all the interested parties and their source should be well documented. Two potential methods to create baseline metrics are described in the following paragraphs.

Business case analysis based on modeled and estimated cost and performance data has been performed for sustainable design projects[16,17] and could be used to compare measured performance and cost data of buildings in operation. Modeled cost and performance data for a baseline building could be compared to measured performance and/or modeled performance of the sustainably designed building. This approach would offer a consistently prepared and documentable baseline. One challenge with this approach is that modeling data are not always understood by financial decision makers.

Comparing sustainably designed buildings to industry standards would provide a comparison to what is considered "normal" within the buildings industry. However, explaining how one actual building compares to an 'industry standard building' would likely encounter similar challenges as that of modeling data when the results are explained to the primary audience, financial personnel. Ideally, the industry standards could be used along with other methods to offer an additional benchmark for comparison.[18]

2.3.4 Trend Detection

If the limits of the study restrict the sample of buildings to those that are sustainably designed and there are no agreed upon baseline metrics, then the sustainably designed buildings can be compared to each other. This method requires an accurate method to evaluate the number or amount of sustainably built features in each building. The ranking of buildings based on sustainable features could use the LEED™ certified scores or some other criteria that identifies the number of sustainably design features in the building. After each of the buildings are ranked based on their features, then measured performance of each building over the lifetime of the study could be compared to the rankings. Care should be taken to control for building type, use, and occupants when evaluating the performance and ranking of each building.

There are many different factors which introduce error into the estimates for surveys. When using survey results care should be taken to examine the results in context of all of these possible factors. The primary sources of errors include measurement error, nonresponse error, and margin of error.

2.3.4.1 Measurement error

This error includes biases and variability associated with the wording of questions, the representativeness of those being surveyed and/or the manner in which the questions are asked (web, phone, live). Care should be taken to create an appropriate survey which does not present an in appropriate bias to the survey results.

2.3.4.2 Nonresponse error

Because there are always people that do not respond, no survey achieves a 100 percent response rate. If the persons which responded in the survey differ in meaningful ways from those who did not respond the survey estimates will include a bias. The size of the bias is related to the percentage of nonrespondents and the magnitude of the differences between the two groups. This error is often the most difficult to measure and understand.

It is important to remember that the nonresponse rate is not a direct measure of the nonresponse error. The academic literature is not clear on an appropriate standard response rate which should be achieved. In fact, many pollsters don’t believe response rates are low until they fall below 40 or 50 percent. Standard polling numbers used in the media have provided evidence that high-quality surveys with low response rates tend to do a good job at identifying the appropriate perceptions of the population.

2.3.4.3 Margin of error

The margin of error is the statistical term which represents the error in the estimate from taking a random sample of the population of interest. This is generally the only error that is quantified in typical random sample surveys. If the entire population is surveyed then there is no error associated with random sampling.

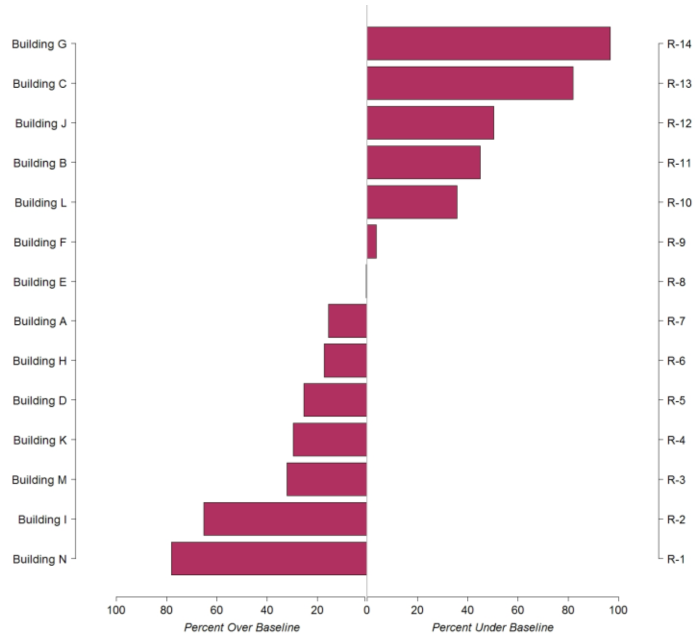
3.0 Data Analysis Visualization

After gathering and analyzing the essential building performance and cost metrics data, appropriate graphical depiction of the data can provide insight and understanding about the specific study. This section describes graphics which can be used to represent a multiple building study. However, many of the ideas presented could be used on a single building study. Most of the plots and charts presented here represent one year of data for each building that is summarized annually. Due to the difficulties of gathering this type of data, it is assumed that one year studies will happen more often than multiple year studies. Multiple year studies would provide the ability to measure the year to year variability of a building's performance for each of the metrics gathered and provide measures of variability (i.e. standard deviation or minimum and maximum) which could be represented on the graphics. The graphics detailed below provide examples of graphics to be used when representing annual metrics from a one year study as compared to industry standard baselines.

Each of the graphical representations below has unique features based on the metrics and baselines which are gathered. In general, the structure of bar charts (i.e. bar graphs or bar plots), time-series plots, or scatter plots (i.e. x-y plots) can convey much of the information about building studies. Additional features can be included on the plots and charts to provide as much concise information as possible. A few other types of plots are shown at the end of this section to provide additional examples.

3.1 Over/Under Baseline Bar Charts

Two options for over/under baseline bar charts are shown in Figures 2 and 3. The two plots in Figure 2 are examples of summarizing a metric for each building in the study. Both of these plots have the buildings ordered based on performance; however, the order of the buildings could be used to identify another important characteristic of the study (i.e. group buildings by building type, square footage, or region). In addition, each of the bars can be colored to identify a separate relationship. The upper plot shown in Figure 2 uses the sides of the plot to identify information about each bar. The left axis identifies the building and the right axis identifies each of these building's respective region. Region is just one example of many that could be included on the chart.



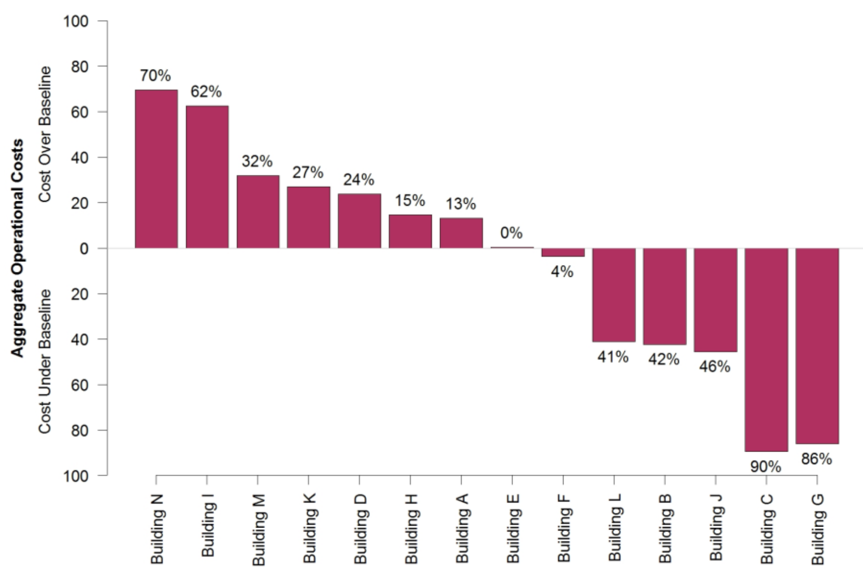


Figure 2. Examples of baseline bar charts representing one metric for all the buildings in the study. With a horizontal axis (above) or vertical axis (below).

The bar chart in Figure 3 represents all the primary metrics for an individual building. These two charts are examples of the costs for each metric. This chart shows the column to the furthest right in a separate color and represents the aggregate costs (sum of the annual costs for the other seven metrics) as compared to an overall aggregate cost baseline. These charts provide a snapshot of a building's annual cost performance.

Figure 3. Two examples of baseline bar charts representing all key metrics for an individual building.

3.2 Baseline Range Bar Charts

Often the current literature provides different baselines for the same metric. One method to represent each buildings performance for a specific metric as compared to the range of possible baselines is shown in Figure 4. These charts provide a clearer picture of the different assumed baseline values and are useful when used with over/under baseline charts. The baseline range charts provide a clearer picture of the uncertainty associated with the baseline selected.

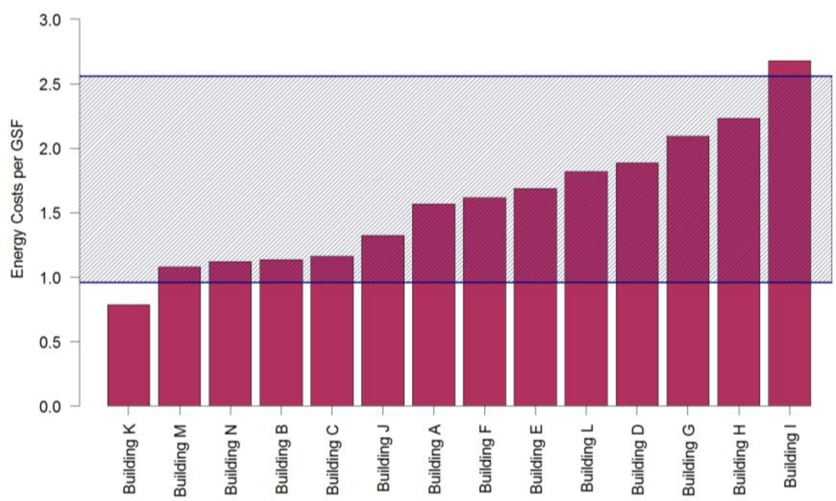
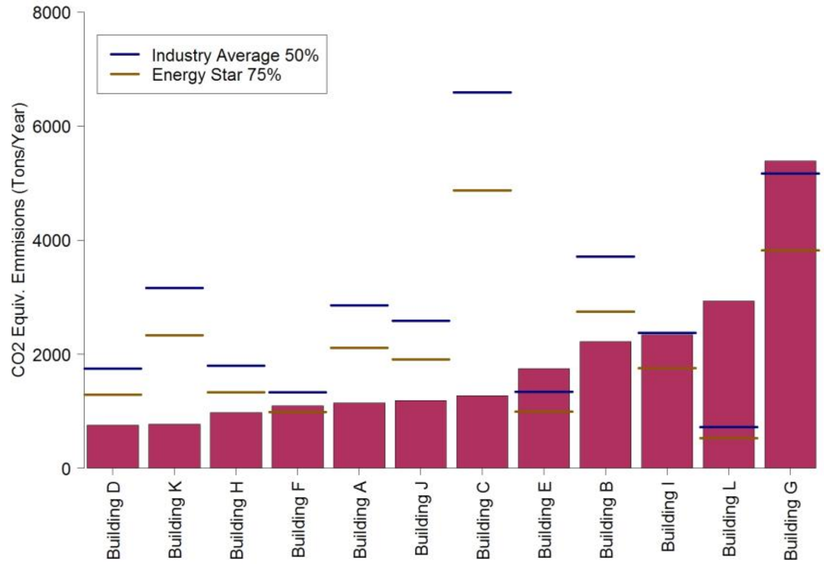


Figure 4. A baseline range bar chart for one measured metric with all of the buildings shown.

3.3 Multiple Baseline Charts

If there are multiple baselines for a specific metric and each of the baselines has features that make them unique (i.e. regional vs. national baselines), then each of them can be shown on a multiple baseline chart. Figure 5 provides two examples of these charts. The top chart shows the building specific baselines for two different baseline standards based on the square footage of each building. The bottom chart has unique baselines for each region and a national office space baseline for the buildings which are primarily office space.



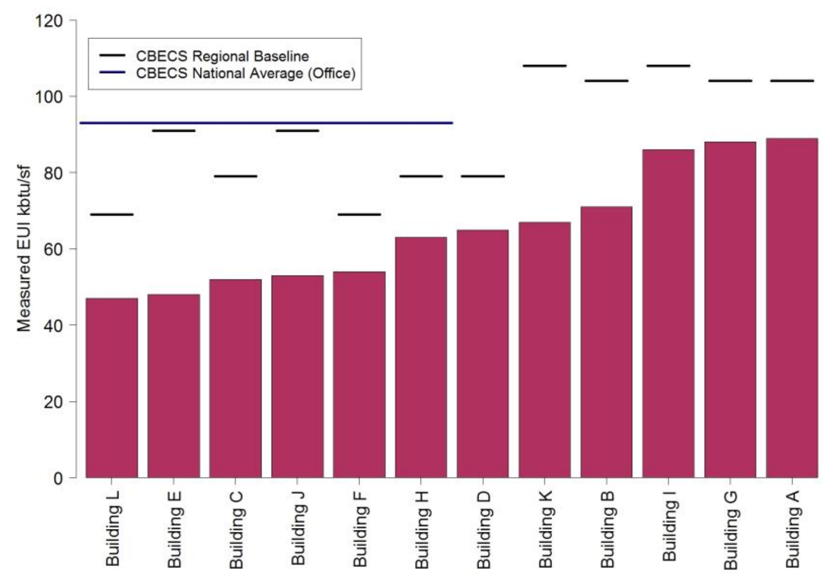


Figure 5. Multiple baseline charts.

3.4 Baseline Secondary Variable Plots

The plots shown in Figures 6 and 7 use the information from a typical bar chart together with a potentially influential variable to provide an improved picture of the data. Because the points are generally scattered over the entire plot region Figure 6 shows that the population per square mile appears not to be correlated with the roundtrip commute distance. However, Figure 7 shows a trend of decreasing CO_2 values as the population increases. There appears to be a much stronger relationship between the population per square mile and the metric tons of CO_2 metric for each building. This figure includes the regression line and the associated simultaneous confidence bands. The regression line shows the expected (average) metric tons of CO_2 for each population per square mile value and the simultaneous confidence bands are much like a confidence interval on the mean except that the amount of uncertainty varies along the regression line. If there appears to be a linear relationship between the two variables, the regression line along with the confidence bands provides a visual representation of the strength of the relationship between the two plotted variables. Some further examples and explanations are given in the next section.

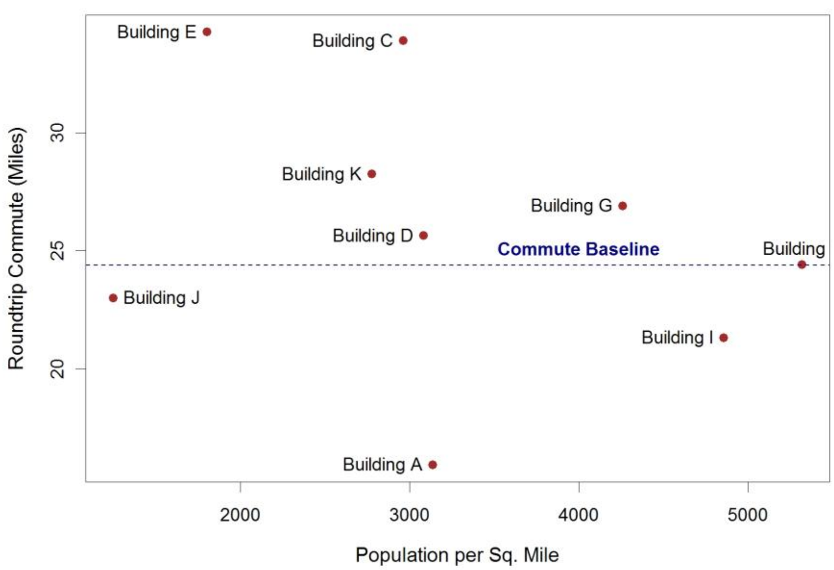


Figure 6. Baseline secondary variable plot identifying the relationship between roundtrip commute and population size. The dotted blue line identifies the commute baseline.

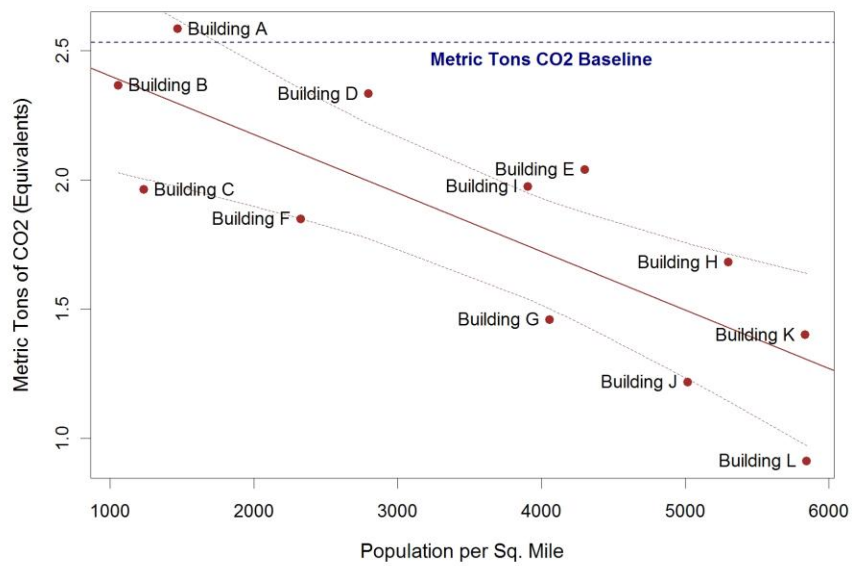


Figure 7. Baseline secondary variable plot with associated regression line and prediction interval.

3.5 Regression Comparison Plots

Similar to the baseline secondary variable plot shown in Figure 7, regression comparison plots (Figures 8 - 12) show the relationship between two variables for each of the buildings in the study. The primary difference is that these plots do not have an associated baseline for the measured metric.

Figures 8 - 12 are provided to show some different scenarios when fitting a regression line and calculating R^2 values. The first four figures are on the same scale for demonstration purposes. Typically the amount of white space shown in the plot is similar to those shown in Figures 6 and 7. The additional white space shown in these figures is not recommended in a final report.

As a general note, regression lines should not be use to estimate average values for points on the line which are far from any previously observed values. For example, because Figure 8 has observations shown for Energy star scores between 50 and 90 it would be inappropriate to use the calculated linear relationship to estimate MBTU per GSF for an Energy star score of 25.

A general summary of each of the regression plots shown is presented in Table 1. The figure is identified along with a general description of the slope (i.e. small, large), the R^2 value, if there is an outlier in the plot and the statistical significance of the relationship. Essentially, the final column identifies if the relationship between the two variables is appropriate to use to explain the relationship. Technically, statistical significance identifies if the correlation coefficient (R) occurred by chance if the true correlation is zero. Where the correlation coefficient is the square root of R^2

(the +/- is defined by the direction of the slope). Each of these figures provides an example of different possible scenarios which could occur when analyzing the linear relationship between two variables.

Figure 8 is an example of stronger R^2 value but a very small slope. In this case for every one point increase in a building's energy star score the MBTU per GSF changes very little, but based on the statistical test the change is significantly different than zero.

Figure 9 provides another example of a strong R^2 value; however, this example has a much larger slope which is statistically significant. In this case, for every one point increase in a building's Energy Star score the decrease in MBTU per GSF is much larger.

Table 1. Summary of each of the regression plots shown in Figures 8 - 12.

Figure	slope	R-squared	Outlier	Statistical Significance of Relationship
8	small	0.32	No	Significant
9	large	0.76	No	Significant
10	large	0.26	No	not significant
11	small	0.061	Yes	not significant
12	small	0.065	No	Significant

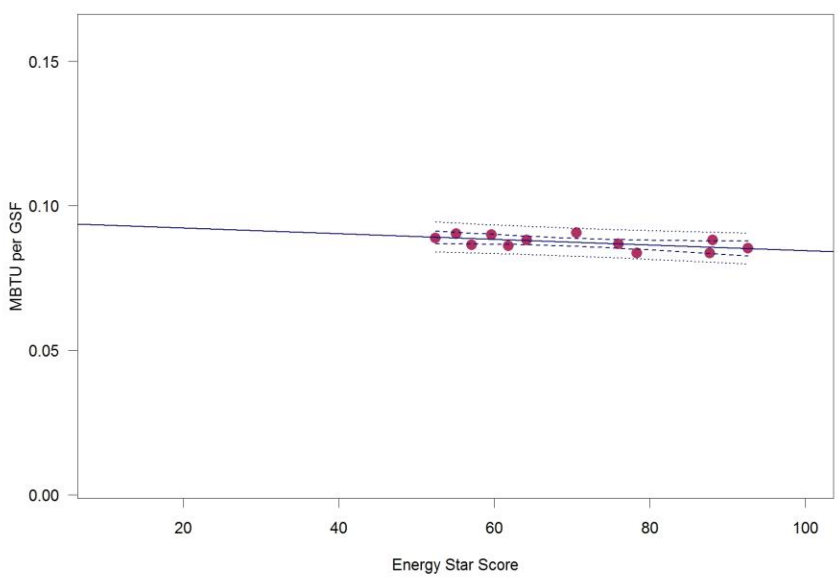


Figure 8. Statistically significant relationship between Energy star and MBTU per GSF with a 0.32 R^2 but very small slope.

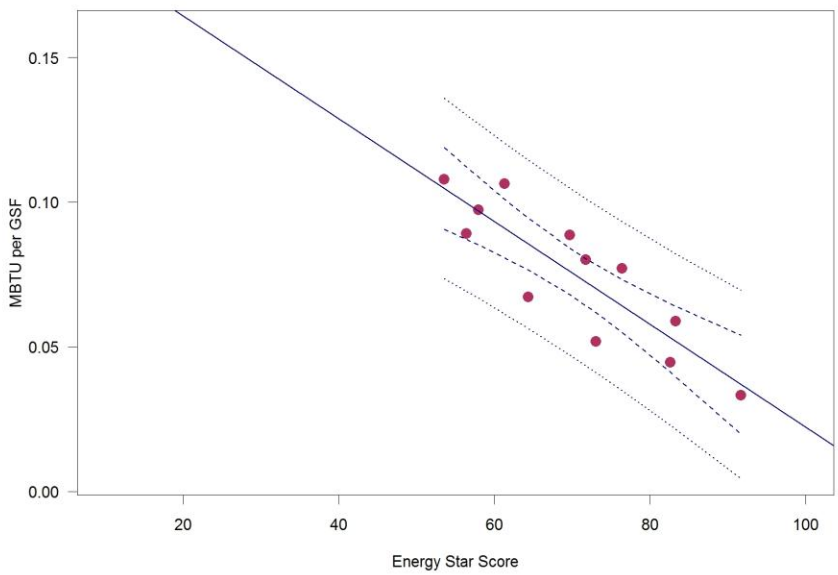


Figure 9. Statistically significant relationship between Energy star and MBTU per GSF with a 0.76 R^2 and a very large slope.

Figure 10 and Figure 11 have the same points plotted with one exception; Figure 11 has one influential point on the plot with an energy star score of 19 and an MBTU per GSF of 0.05. While it is clear from the picture that this point is much different from the other observations, the merits of including or excluding this point during the analysis must be made based on other information that identifies this point as distinctly different from the population of interest (i.e. the building was observed in the study but was a standard built building.). These two figures show how the regression model estimates can be influenced by extreme observations. This influence can weaken relationship estimated from the regression model (see Figure 10 and Figure 11) or strengthen it depending on the location of the extreme observation.

Figure 12 provides one final example where the slope and R^2 values are small, but the relationship between Energy star scores and Total LEED points is significant. This significance simply identifies that while the relationship between the two variables is weak, the line does correctly identify a relationship which does exist.

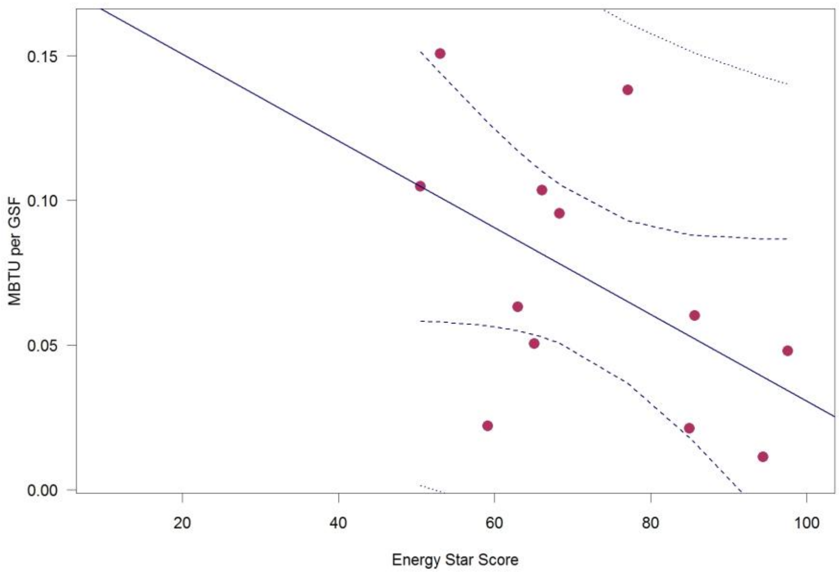


Figure 10. Relationship between Energy star and MBTU per GSF which is not significant. R^2 is 0.26 and the slope is big.

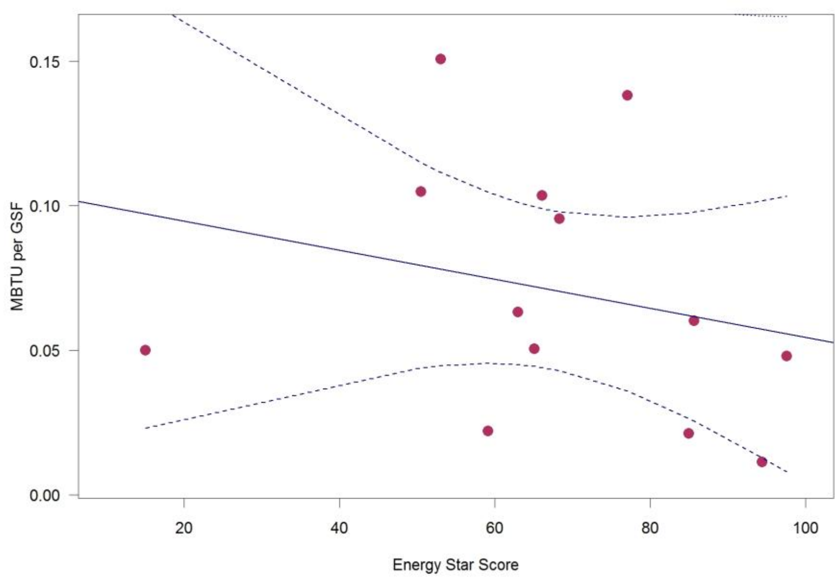


Figure 11. Relationship between Energy star and MBTU per GSF which is not significant. One outlier is present in this data as compared to the previous figure. This changes R^2 is 0.061 and the slope is small.

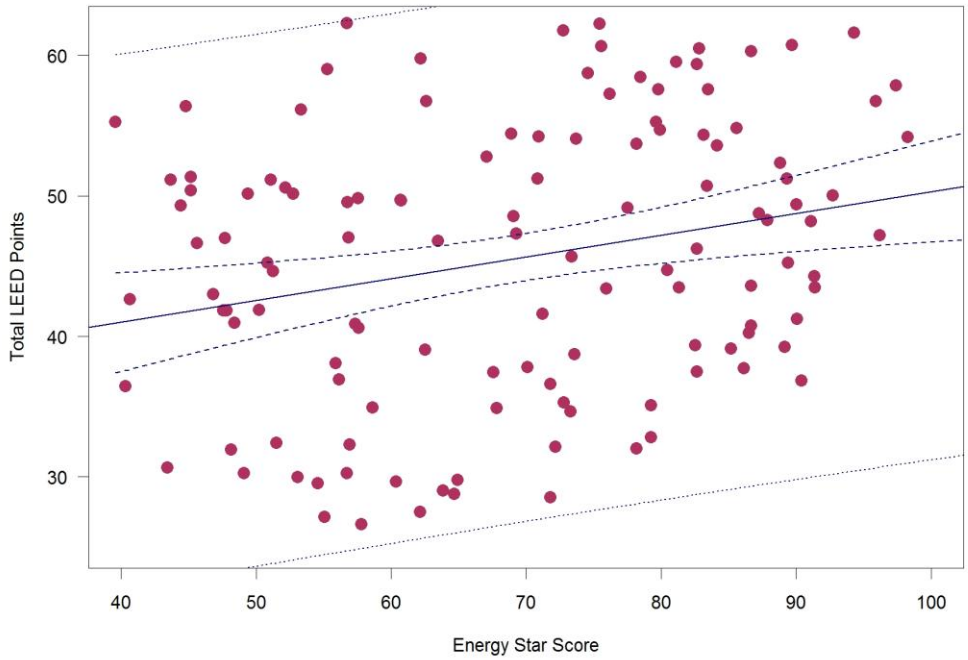


Figure 12. Statistically significant relationship with a small slope and a 0.065 R^2.

3.6 Quadrant Baseline Graphics

Figure 13 shows a quadrant baseline plot. This plot represents three different baseline values and one set of survey results for all of the buildings in a study. The quadrants identify four unique regions of building performance. These quadrants used together with the color scale and performance line associated with each point provide an overall summary of an individual building's performance as well as showing potential relationships among the four metrics represented among all the buildings.

Both the "X" and "Y" axis in Figure 13 are metrics in the form of over/under baseline values; however Figure 14 shows how a metric with a scale of 1 to 100 could be represented on one of the axes. In both figures the dotted lines which cross through the middle of the plot represent the assumed average score for the plotted metrics. As can be seen in Figure 13, the average performance for over/under baseline values is zero. The y-axis in Figure 14 represents a survey percentage where 50% is assumed to be the average values. These dotted lines create the four quadrants which represent the performance of the buildings based on the metrics on the "X" and "Y" axis. The lower left quadrant represents below average performance for both metrics. The upper right quadrant is where building with above average performance for both metrics would lie. Points in the other two quadrants perform well on one metric while falling short on the other.

Each of the points on the plot also displays additional information about two other metrics. Each point is colored based on the description shown in the legend. In this case an over/under baseline value is used for the aggregate maintenance metric. The points were separated into four color groups identifying the degree and direction of difference from the baseline. Finally, an additional performance line is attached to each point. The values from a fourth metric can be plotted such that the length of the line identifies the overall value of the metric for each building. The performance line in both Figure 13 and Figure 14 represent the values from the general satisfaction questions of the occupant survey.

These plots provide a concise manner to portray a "big picture" summary of a building performance study. For example, Figure 13 identifies how the buildings with above average WUI metrics also have higher maintenance expenses. Figure 13 also shows that the WUI, EUI and aggregate maintenance metrics are not good discriminators of the occupants' general satisfaction.

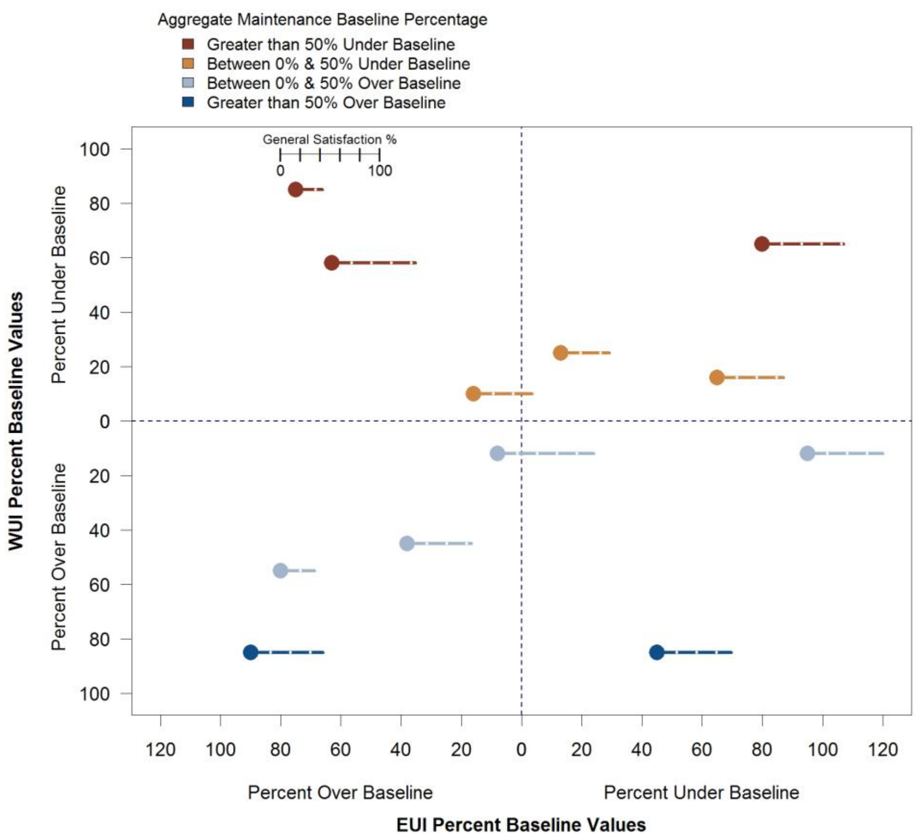


Figure 13. Example of a quadrant baseline plot.

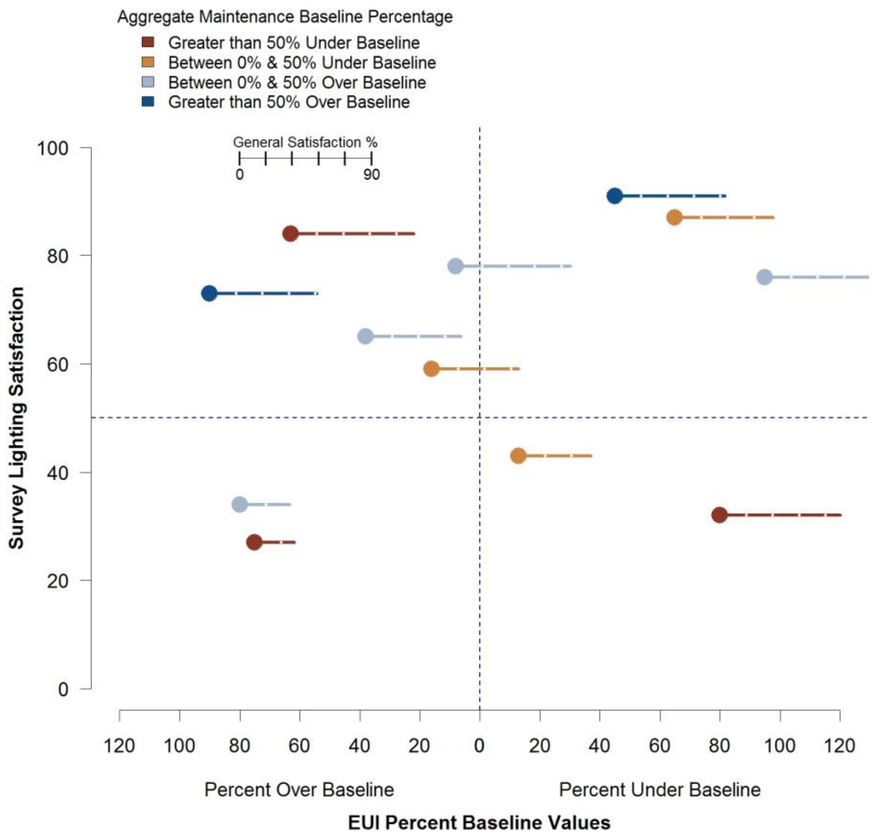


Figure 14. Second example of a quadrant baseline plot with a y-axis that is not an over/under baseline value.

3.7 Time Series Plots

If monthly data are gathered for each of the buildings in the study then the plots shown in Figure 15 and Figure 16 provide two examples of how this data can be visualized. Figure 15 provides a time series plot of the gallons of water per square foot for a building with one year of monthly data. Multiple lines could be included on the graph for other buildings as necessary. Figure 16 has a similar structure to Figure 15; however, this plot represents multiple years of data for an individual building. In this plot a "box plot" is used to represent the variability of the building data for each month recorded over the multiple years. A box plot (see example in Figure 17) displays five measures of the data; the lower whisker (-1.5 x Interquartile range (IQR)), 25th percentile, median, 75th percentile, upper whisker (1.5xIQR) and any extreme observations.

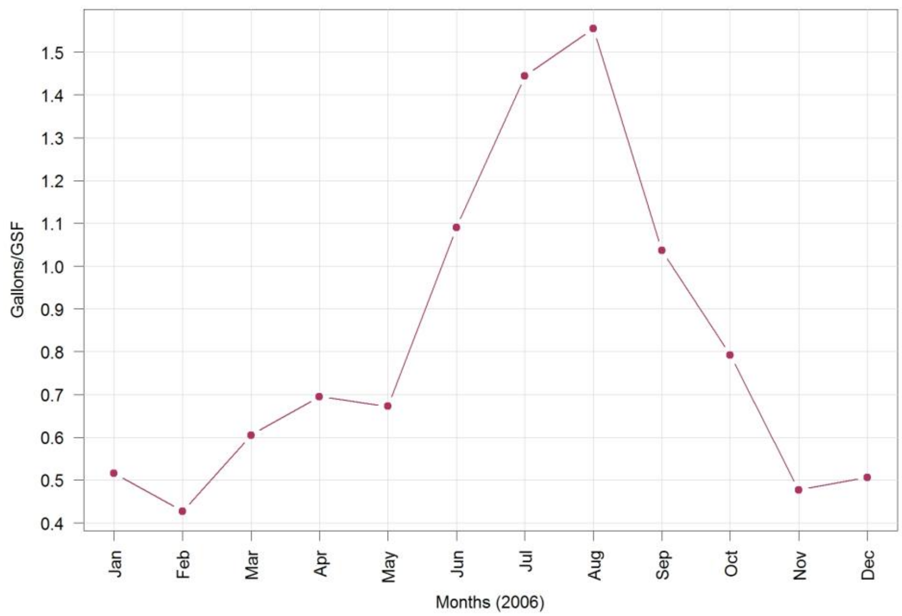


Figure 15. Time series plot of one buildings monthly water usage.

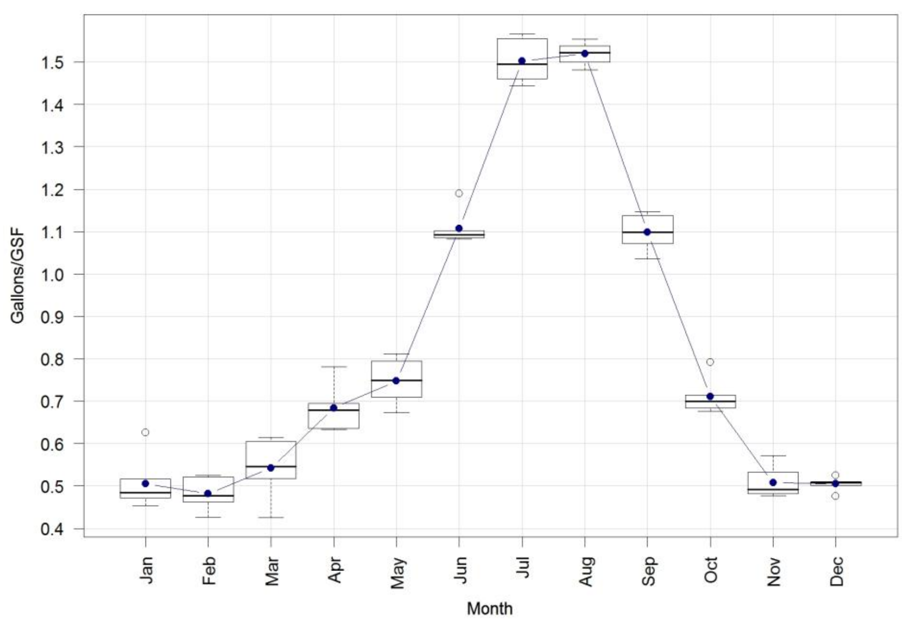


Figure 16. Time series plot for a study with multiple years of monthly data.

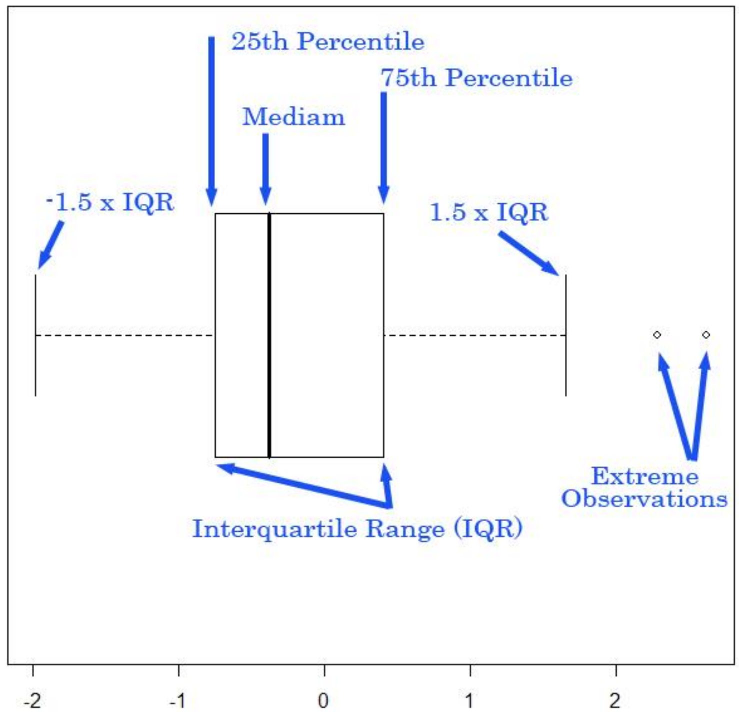


Figure 17. Example of a box plot with all of the important features labeled.

3.8 Additional Plots

Some additional plots which can be included in a building study report are shown in the following figures. Figure 18 is an example of what can be used to display matched pairs data for any metric of interest. In this example, the buildings (1 and 2) are matched by their location (A-O). Each rectangle displays the difference between each pair with the building label associated with the observed values marked on the respective end of the rectangle. In this plot the difference between the two values is shown in the rectangle and the blue rectangle identify those locations where building 2 had a lower cost per GSF than building 1.

There are many ways to represent data in a clear and concise manner. What has been presented here is intended to provide insight for representing building study data. Often there are unique features to each study that need to be highlighted graphically. Any of the plots presented can be modified to include those features or new plots can be used if necessary.

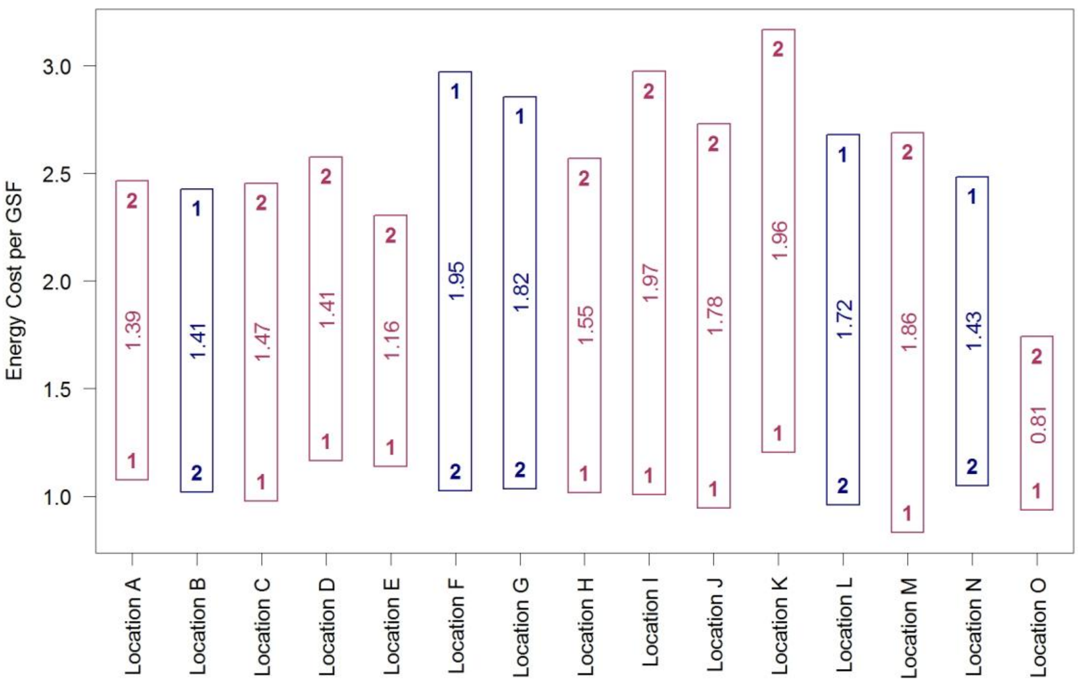


Figure 18. Matched pairs plot identifying the difference between buildings at each location.

3.9 Metric Selection

The metrics provided in this protocol, and summarized in this section, were finalized using the selection criteria defined in the first version of this protocol. The selection criteria were also used to determine whether or not the metrics should be considered required or optional. All of the metrics identified in this protocol are preferred for a complete comparable analysis of building cost and performance, however, if it was determined that some may be more difficult than others to collect consistently, they were identified as optional. Considering the question(s) to be answered, the audience interests, and the available baseline and building data, the performance metrics can be selected from the lists provided in this document.

The *metrics*, or measurable characteristics, were developed, reviewed, and tested to ensure they were technically feasible and defensible. The information that needs to be collected from each building to produce comparable measurements has been broken into two groups:

1. Building and Site Characteristics and
2. Building Cost and Performance Metrics.

The building and site characteristics are used to provide a valid comparison between buildings. The building cost and performance metrics are used to measure the actual performance of the building over time. The performance of the individual buildings will be measured with a minimum of 12 months of data.

3.9.1 Site and Building Characteristics

The building and site characteristics describe the uniqueness of a building. These data will be collected one time and used to normalize the data collected from the building performance metrics. Some data are required to complete the analysis; optional data provide a more complete picture but are not necessary to accurately compare building performance. These data will be collected from the building owner, manager, and/or others as needed, and should be completed prior to the analysis of building cost and performance metrics. Table 2 offers a summary list of the required and optional building and site characteristics data needs.

Table 2. Summary of building and site characteristics

	Required	Optional
Building Specifications	Building Location	Gross Ground Floor Footprint/Number of Floors
	Building Function	Gross Conditioned Floor Area
	Key Building Features/ Design Intent	Parking Area
	Year Building First Occupied or Year of Last Major Renovation	Ratings or Awards
	Gross Interior Floor Area	Landscaped Area
	Operational Concerns	Total Building Site Area
Occupancy	Type of Occupant	Key Policies (e.g. sick leave, holidays/vacations, recycling, transportation, etc.)
	Hours of Operation	
	Total Number of Regular Occupants	
	Number of Regular Visitors	
	Occupant Gender Ratio	
First Costs	Total Building Cost	Design Cost
		Construction Cost
		Unusual Cost Elements

3.9.2 Performance Metrics

Building cost and performance metrics provide quantitative measures of building operations over a minimum of 12 months. Most of these data will be collected monthly and summarized into annual performance data. For each of the following categories of metrics, the specific data points that will be collected are described in Table 3.

- Water
- Energy
- Maintenance and Operations
- Waste Generation and Recycling
- Indoor Environmental Quality and
- Transportation.

Many of the metrics are required in order for the analysis of the building performance to be representative of sustainable development. However, some of the metrics, for example stormwater sewer output, are considered optional because they may be too difficult and/or costly to measure, but have the potential of significant environmental, social, and economic impact. It is left to the discretion of those performing the analysis to determine whether the effort to collect those data is feasible.

Table 3. Summary of building cost and performance metrics

Metric	Required	Optional
Water	Total Building Water Use	Indoor Water Use Outdoor Water Use Process Water Use Total Storm Sewer Output
Energy	Total Building Energy Use	Source Energy Peak Electricity Demand On-site Renewable Energy Special Equipment
Maintenance & Operations	Building Maintenance Preventative Maintenance	Grounds Maintenance Janitorial Maintenance Churn Costs
Waste Generation and Recycling	Solid Sanitary Waste	Recycled Materials Hazardous Waste
Indoor Environmental Quality	Building Occupant Satisfaction	Self-rated Productivity Absenteeism Turnover Rate Indoor Air Quality
Transportation	Regular Commute	Business Travel

3.10 Data collection

This section offers three strategies for data collection of the building metrics. All three are reasonable strategies for accurate data collection. Consider the location and working relationships between those involved the study when determining the best strategy for a particular project.

3.10.1 Three Data Collection Methods and Strategies

Option 1: Collect All Data by Phone

This option is based on execution of the study solely by phone, fax, and e-mail. Good relationships between the building owners, building management, utilities and tenants must be formed in order to execute the data collection task in this manner accurately and timely. This method requires clear communication of the expectations of all parties involved. The individuals collecting the data must be very clear on exactly what is needed and ask questions that would otherwise be apparent if they were physically visiting the site.

Collecting all of the data by phone and electronically can be the right choice for a study that is only collecting the minimum metrics, or that has a very good working relationship with the building management and tenants. The downside to this approach is that the depth of analysis into how the buildings' characteristics, operations, tenant work habits, occupant satisfaction, and general issues connect to the metric values may not be as comprehensive as if a site visit had been done.

Option 2: Collect Data by Phone and Site Visit

This option is based on execution of the study through a site visit and phone/electronic gathering of information. The project would be initiated by phone and/or email to gather the majority of the details. After a cursory review, a site visit would be scheduled. Generally this site visit would be scheduled through the building manager/s who would coordinate with the other appropriate individuals (e.g. building engineer, janitorial lead, tenant representative). This visit generally lasts 2-8 hours depending on the building size and the amount of information still needed to be collected.

The site visit is the time where data that was not originally provided can be collected, items that were collected can be confirmed, and a building walk-through can take place. During the building walk-through general observations on the building characteristics can be made and unusual building uses can be identified. For example looking for items such as; if the building has a restaurant/deli, are all of the lights on/off, do the spaces seem empty/fully occupied, are there a large amount of computers or other electronic equipment? Many of the questions can and should be asked prior to the visit, but it is generally easier to identify unusual items through a site visit than an email questionnaire.

The site visit can also be a good time to initiate the occupant survey. In some owner/tenant situations the tenant may initially be wary of participating in a survey and generally their concerns can be addressed during the site visit face to face.

The primary benefit to this approach is a deeper understanding of the relationship between the buildings' characteristics, operations, tenant work habits, occupant satisfaction, its general issues, and the resulting metric values. Other benefits include data consistency if the same person is collecting the data at all of the buildings in the study. The downside is that site visits may require significant travel time.

Option 3: On-Site Personnel Collect Data

This option is based on execution of the study through a site team member gathering information. Ideally this person would be the property owner, building manager, or building engineer. Data collection can take a moderate amount of time, and this person would need to be able to allocate a portion of his/her schedule to accurately collect the data. A sample on-site data collection tool can be found in Appendix A.2

There are many benefits to having an on-site individual collect the data. In many cases they can easily connect with the right individuals to request information, can easily describe what is and is not included in contract costs and utility bills, and can implement the survey easier than an outsider can. The downside is that on-site personnel juggle multiple projects and this data collection effort may not be completed as timely as it may otherwise.

3.10.2 Metering Specific Potential Issues and Lessons Learned

Performance measurement projects that can avoid the need to install new metering and communications equipment are the recommended approach for future studies of this type. On projects were additional metering and communications equipment is needed, the following is recommended based on lessons learned from the Navy project:

Using different metering equipment, subcontractors, and metering specialists can mean that data is collected and summarized using different methods. This can result in considerable effort during the report generation stage to compile the data into one format for analysis. Recommended metered data collection protocols include:

- If possible, standardization the time-steps in which the data is collected
- Data downloads and quality assurance checks scheduled for weekly
- Schedule monthly meetings to identify, investigate, and resolve irregular events, curious operations, and equipment malfunctions
- Develop software to automate flagging of data anomalies and data collection success

The organization that will be receiving the data needs on-site oversight to achieve proper installation. It is a time consuming process to troubleshoot malfunctioning equipment remotely, which can result in time gaps in the data if equipment failures occur.

- Subcontractor for metering and communication devices should be required to provide both installation and calibration (i.e., system commissioning) services as part of the award. Subcontractors need be held accountable for not only the installed equipment (meters) but for making sure it is properly interfaced and calibrated with the surrounding equipment. This can be a contracting challenge because it may require an open-ended contract or some level of service support activity as part of the agreement.

- Standardization of metering equipment and outputs is recommended as it assists in the ease of set-up, troubleshooting, and any need for replacements.

- Communications capability (e.g., telephone, cell phone, or network) needs to be approved and tested prior to installing the metering equipment.

3.11 Report findings

This section offers examples of the reporting options for the building cost and performance data and a brief status report on the protocol development project. The metrics were selected, in part, for their versatility in reporting ability. The collected data can be manipulated in variety ways to express the results in a format that meets the audience's needs.

3.11.1 Data Analysis and Reporting

Throughout the collection of data, it is recommended the data be reviewed and compared to ensure it will be usable. Sorting the building and site characteristics data as well as the monthly building cost and performance data in one table is recommended for facilitate data analysis.

Once a minimum of 12 months of data have been collected for the building set, the building performance and cost data can be compared. First summarize the metric data for each of the buildings. Next, compare the data between the sustainably designed building and baseline side-by-side to identify the key findings. Depending on the target audience for the key findings, the data could be shared in a variety of ways. An existing communication tool for the sustainably designed building performance data is the U.S. Department of Energy's Federal Energy Management Program's Federal portal to the *High Performance Buildings Database*.[19] It is recommended that case studies be included in the *High Performance Buildings Database* and shared with the FEMP Interagency Sustainability Working Group.

For the purposes of the protocol development project, the selected the primary audience of the findings was Federal financial decision makers. A report format with some sample data was prepared to address the following communication needs:

- Focus on measurable costs;
- Provide background, more detailed cost data to support summary costs;
- Share building related performance, environmental impact, and productivity data for further explanation of the findings; and
- Share as much information as possible in a small, easy to understand fashion.

Figure 19 offers a snapshot of the four-page sample report. The report was kept intentionally brief and cost focused in order to capture the attention of the financial decision maker audience. The chart considered key to the communications with the financial decision maker is the cost avoidance summary chart on page one of the sample report. Additional information could be prepared from the collected data to address different audience needs or to supplement and explain the building performance comparisons. Data representation possibilities not shown in the sample report include:

- water use data (monthly or annual),
- storm sewer data (monthly or annual),
- source energy impact,
- grounds maintenance costs and requests (monthly or annual),
- sanitary waste disposal and costs (monthly or annual),
- hazardous waste disposal and costs (monthly or annual),
- recycled materials quantity (monthly or annual),
- environmentally preferable purchasing results (monthly or annual),
- occupant turnover rate,
- absenteeism, and
- transportation environmental impact and costs.

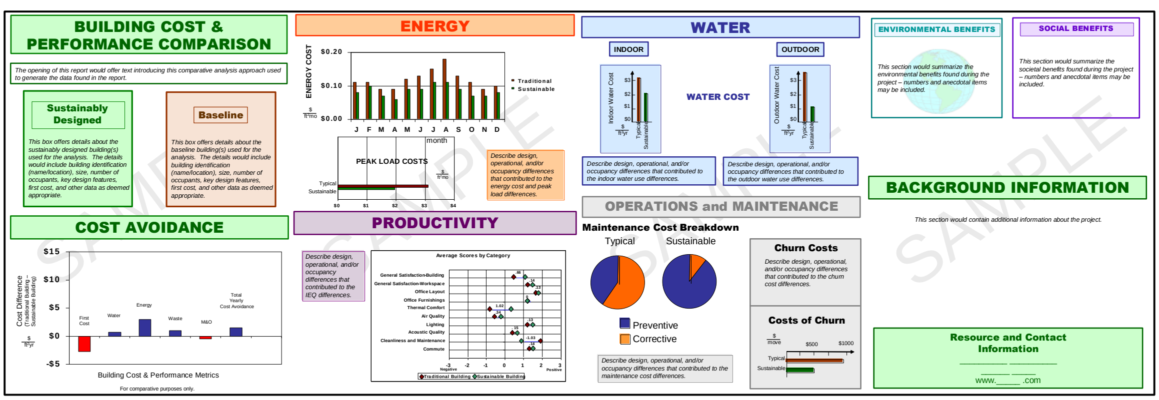


Figure 19. Sample Report

The purpose for developing this protocol was so that measured data could be communicated to key stakeholders. Currently the mechanisms for sharing the data gathered are the High Performance Buildings Database and the FEMP Interagency Sustainability Working Group. Protocol users are encouraged to share their findings with these existing forums.

4.0 Building and Site Characteristics

As mentioned previously, this protocol offers performance indicators of sustainably designed buildings using a comparative analysis. To be able to use the protocol, there must be the ability to collect the same data from both a baseline and a sustainably designed building in operation. The building and site characteristics data offer the basis for comparing the monthly and annual cost and performance data.

The building and site characteristics are organized by

- building specifications,
- occupancy, and
- first cost data.

These data form the basis for normalization between a sustainably designed building and a baseline to compare the annual cost and performance data.

4.1 Building Specifications

The building specifications data are critical to the comparative analysis. The required and optional building specifications data needs are outlined in Table 4.

Table 4. Building specifications

Metric	Required	Optional
Building Specifications	Building Location	Gross Ground Floor Footprint/ Number of Floors
	Building Function	Gross Conditioned Floor Area
	Key Building Features/ Design Intent	Parking Area
	Year Building First Occupied or Year of Last Major Renovation	Ratings or Awards
	Gross Interior Floor Area	Landscaped Area
	Operational Concerns	Total Building Site Area

The required metrics must be collected consistently for each building being used for the comparative analysis. Optional metrics may be considered essential given certain building characteristics; for example, if the building has interior parking, it would be essential to know the area of the interior lot.[20]

4.1.1 Required Metrics Definitions

4.1.1.1 Building Location

The building location is used to address any potential weather differences. The key building features provide the differentiation between the sustainably designed building and the baseline.

4.1.1.2 Building Function

The building function must be similar for the analysis to continue; otherwise building performance data would be too difficult to compare using the selected cost and performance metrics.

4.1.1.3 Key Building Features

The key design features of the sustainably designed buildings will be the means to differentiate from the baseline. Based on the experience of applying this protocol to building sets, it is much easier to compare the buildings when a structured, externally recognized system for differentiating design has been used, such as the U.S. Green Building Council's Leadership in Energy and Environmental Design rating system. However, when a third-party system is not available, it is necessary to differentiate based on the design feature descriptions. When identifying the building design features, organize them by areas of measured performance impact, such as water, energy, maintenance and operations, waste and recycling, occupant satisfaction, and occupant transportation.

4.1.1.4 Building Occupation Date

The year of first occupation or last major renovation is used to compare potential maintenance and operations differences.

4.1.1.5 Gross Interior Floor Area

One of the key building and site specifications metrics are the geometry metrics. These require standardized collection to provide for consistent analysis of the cost and performance metrics.

Building and site geometry metrics provide information about the resource efficiency of space and other resource use and are used to normalize water use, energy use, maintenance, purchasing, and waste cost and performance indicators. These cost and performance indicators are also normalized by occupancy and first cost.

Geometry metrics specifically developed for use with energy analysis and measurements have been developed by the National Renewable Energy Laboratory (NREL)[21] and are largely referenced here. These are based in part on building geometry definitions set out in the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Standard 90.1 for energy requirements.[22] Floor area definitions developed by Building Owners and Managers Association (BOMA)[23] are American National Standards Institute (ANSI) approved for use in negotiating contracts of leasing, space use, and expense allocations. Geometry definitions for building management, space use planning, classification of functional space, and occupant requirements have been developed by the American Society for Testing and Materials (ASTM).[24]

Gross interior floor area is measured from the *inside* surface of the exterior walls on a floor-by-floor basis and consists of all enclosed spaces.[25] Resource use and cost values that are relevant to the building interior will be normalized according to gross interior floor area. Resource use quantities include materials purchasing, waste output, indoor water consumption, energy consumption, and maintenance costs. The performance and cost metrics will also be normalized to occupant density (occupants/square feet).

4.1.1.5.1 Potential Issues and Lessons Learned

Other floor area characteristics may need to be collected as well depending on the type of building and the baselines that are being compared against. For instance, it may be appropriate to normalize the maintenance costs by rentable area instead of gross interior floor area.

4.1.2 Optional Metrics Definitions

4.1.2.1 Building Footprint

Gross ground floor footprint and the number of floors are metrics that can be useful when comparing buildings of various sizes. There will be times when the number of floors will be a necessary metric to consider, for example when considering the energy impact of a daylighting design of a high-rise building, the number of floors would be a relevant normalization factor.

4.1.2.2 Landscaped Area

Landscaping includes non-parking developed area associated with the building. Parking areas that require landscaping maintenance such as permeable vegetated surfaces and vegetated islands are included. Other non-parking development including patios, walkways, decorative fountains, and water treatment pools are included. Green roofing is not included in landscaping area unless it can be considered a garden for occupant use. Undeveloped site areas including conserved or restored wetland, prairie, or other habitat are not included.

Landscaping area will be used to normalize exterior water use and grounds maintenance costs. The intent is to determine how sustainable landscaping strategies affect material costs, time spent, and water use.

4.1.2.2.1 Potential Issues and Lessons Learned

Make sure to gather information on how the landscaping is being maintained (e.g. typical upkeep, hand weeding, pesticide applications etc.) and what type of water is used to irrigate the area (e.g. potable water sub-metered, potable water-not sub-metered, irrigation water, rainwater, greywater, no irrigation).

4.1.2.3 Total Site Area

Total site area includes areas for the building, landscaping, parking, and undeveloped land primarily associated with that building (*Total Site Area = Building Footprint + Undeveloped Site Area + Landscaped Area*). For stand-alone facilities, the site area is equal to the lot area. For campus buildings, exterior areas are assigned by on-site personnel. Clear space divisions such as streets, streams, hedges, and fences can be used to apportion grounds areas to the extent possible. Other considerations include what site area needs to be considered for collection of other metrics, such as grounds maintenance, water use, and stormwater outflow.

Building exterior area includes all exterior landscaped area whose irrigation water use is considered part of the building. Inseparable stormwater outflow routes associated with the building can be included if stormwater is going to be measured. Parking areas serving more than one building are assigned proportionally according to building occupancy at peak time.

Total site area will be used to provide overall site comparison for selected resource use metrics. It supports the analysis of the storm sewer metric for the calculation of site related runoff. Note that the storm sewer metric is optional.

4.1.2.4 Gross Ground Floor Footprint

Gross ground floor footprint is the surface area covered by the building's enclosed spaces at grade level, measured from the *outside* face of exterior walls.

Subdividing total building site area into components allows alternative normalization options for resource and cost measurements.

4.1.2.5 Gross Conditioned Floor Area

Gross conditioned floor area is all of the conditioned spaces measured from the inside surface of the exterior walls. A conditioned space is an enclosed space within the building that is cooled, heated or indirectly conditioned. This area is equal to the gross interior floor area minus the floor area of unconditioned spaces and the exterior walls.[26]

Conditioned floor area allows for a more precise determination of energy use intensity (EUI) in terms of functional conditioned space.

4.1.2.6 Parking Area

Parking area includes all usable capacity including underground lots and parking garages. This is measured on a floor-by floor basis from the interior wall, excluding stairwells, elevators, and any other areas not usable for parking. Include information on permeable and impermeable parking area, when appropriate.

Parking area may be used for a maintenance cost per unit area or for a parking area per occupant. Impermeable surface area information along with measured stormwater runoff data will help evaluate the impact of surface area types and stormwater management efforts.

4.2 Occupancy

Building occupants are the most significant factor in sustainable building operations. Occupants that choose to work in a sustainable manner regardless of their facility surroundings can greatly impact the performance and operating cost of a building. For example, a building that has occupants who take advantage of daylighting rather than turning on lights will be impacting the energy use, maintenance and waste generation metrics. Occupants committed to recycling will be impacting the waste generation metric through reduced waste disposal and increased recycling. And, occupants that chose to commute to work using mass transit, carpools, fuel efficiency vehicles or bicycles will be impacting the transportation metrics. The occupancy metrics will not address all the potential impacts occupants will have on building performance. However, they were selected to characterize the occupants in order to normalize the building cost and performance data for comparative analysis purposes. The required and optional occupancy-related data needs are outlined in **Table 5**.

Table 5. Occupancy

Metric	Required	Optional
Occupancy	Type of Occupant *Military, civilian, etc.*	Key Policies (e.g. sick leave, holidays/vacations, recycling, transportation, etc.) *Summary of key policies*
	Hours of Operation $\frac{hrs}{week}$	
	Total Number of Regular Occupants $\frac{occupants}{day}$	
	Number of Regular Visitors $\frac{visitors}{day}$	
	Occupant Gender Ratio *Number of male and female occupants*	
	Number of Computers	

In the Federal sector, type of occupant refers to whether the occupant is active military or is considered a civilian. This is considered relevant because of the anticipated difference in occupant expectations and the potential for different turnover rates and churn costs. The hours of building operation will be used to normalize the energy and water consumption. The total number of building occupants and the number of regular visitors will be used to assist in the comparative analysis of resource use. The occupant and visitor density will also be used to normalize the cost and performance metrics as appropriate. The occupant gender ratio is necessary to normalize building water use. The policies of the organizations in the building will be used to normalize the observed occupant behavior. For example, if sick leave policies are different for the occupants in the sustainably designed building than for those in the baseline, the absenteeism metric may be impacted. An example that could impact the transportation metric could be when an organization offers incentives for using mass transit. These policy differences will be used to normalize and/or anecdotally note how the policy impacted the building cost and performance comparative analysis.

Detail on building occupants might be available from the human resources manager, organizational line manager, or equivalent. Building managers are typically the best source for building occupancy hours. Local area network managers may have information regarding the average number of workers and typical weekly operating hours if the data are not available from the building manager.[27]

4.3 First Costs

As mentioned previously, the primary audience for the data generated from the building metrics is financial decision makers. The questions that the primary and secondary audiences want to have answered include a comparison of the first cost investment to the on-going operating costs. To compare the operational costs to the initial investment, first cost data need to be collected. The required and optional first cost related data needs are outlined in **Table 6**.

Table 6. First costs

Metric	Required	Optional
First Costs	Total Building Cost $\$ \quad \frac{\$}{ft^2}$	Design Cost $\$ \quad \frac{\$}{ft^2}$
		Construction Cost $\$ \quad \frac{\$}{ft^2}$
		Unusual Cost Elements *$/activity*

The protocol uses the total building cost to compare the sustainably designed building to the baseline. For the comparison to be useful, both the sustainably designed building and the baseline need to include the same items in their total cost number. Ideally, design cost, construction cost, and any other relevant cost data would be collected to allow for a detailed comparison.

A study by Davis Langdon demonstrated that the first cost of the sustainably designed buildings varied tremendously based on the clarity of design objectives and many other causes that weren't always correlated with sustainable design.[28,29] Notations on reasons for specific cost elements will be taken when available to assist in the building cost comparison.

5.0 Building Cost and Performance Metrics

The building cost and performance metrics are the core of this protocol. Once buildings and comparison scenarios have been selected, these data are collected for both the sustainably designed building and baseline for a minimum of one year. These metrics are intended to be used as indicators of the comparative performance in order to provide additional data for the business case for sustainable design.

The building cost and performance metrics are collected on a monthly basis, normalized using the building and site characteristics data, and then used to compare the performance of the sustainably designed building to the baseline. These metrics include water, energy, maintenance and operations, waste generation and recycling, indoor environmental quality, and transportation.

The metrics are designated as required or optional. The required metrics must be collected consistently for each building to allow for a valid comparison. The optional metrics are still considered important to the cost and performance comparison and should be collected whenever possible.

Prior to initiating a comparative analysis, use the building and site characteristics to determine if comparable buildings exist. For the sustainably designed building and the baseline ensure you can collect monthly whole building water use and cost, whole building energy use and cost, building maintenance activity and cost, sanitary waste quantity and cost, and occupant satisfaction data. This will require access to utility bills, metering equipment, and/or internal tracking systems. This section provides definitions, suggests data collection and calculation strategies, and shares potential issues and lessons learned for each of the building cost and performance metrics.

5.1 Water

Potable water consumption is the building utility cost that is second only to energy use. Therefore, there is a direct monetary incentive to track and decrease water consumption. Stormwater management is a water use topic gaining more attention as local or regional governments are confronted with infrastructure and environmental costs caused by stormwater outflow volumes and quality.

Table 7 provides the summary of the required and optional potable water and stormwater metrics. This chapter offers an explanation of the water metric selection and relevance, guidance on how to collect and analyze data for each metric, and identification of potential issues and lessons learned that may be encountered with data collection or analysis.

Table 7. Water

Metric	Required	Optional
Water	Total Building Water Use $\frac{gal}{month}$ $\frac{\$}{month}$	Indoor Water Use $\frac{gal}{month}$ $\frac{\$}{month}$
		Outdoor Water Use $\frac{gal}{month}$ $\frac{\$}{month}$
		Process Water Use $\frac{gal}{month}$ $\frac{\$}{month}$
		Total Storm Sewer Output $\frac{gal}{month}$ $\frac{\$}{month}$

5.1.1 Metric Discussion

To determine which water metrics would best represent a building's cost and performance, a water use hierarchy was developed (see Figure 20). The hierarchy guidance along with the technical review recommendations resulted in the water metrics found in Table 7. Total building potable water use is the required metric because not only does it represent costs and resource use, but it is also a local government issue in many places. The optional water metrics are important and data should be gathered whenever feasible; however, they are more difficult to collect in a consistent manner, which is why they have been listed as optional.

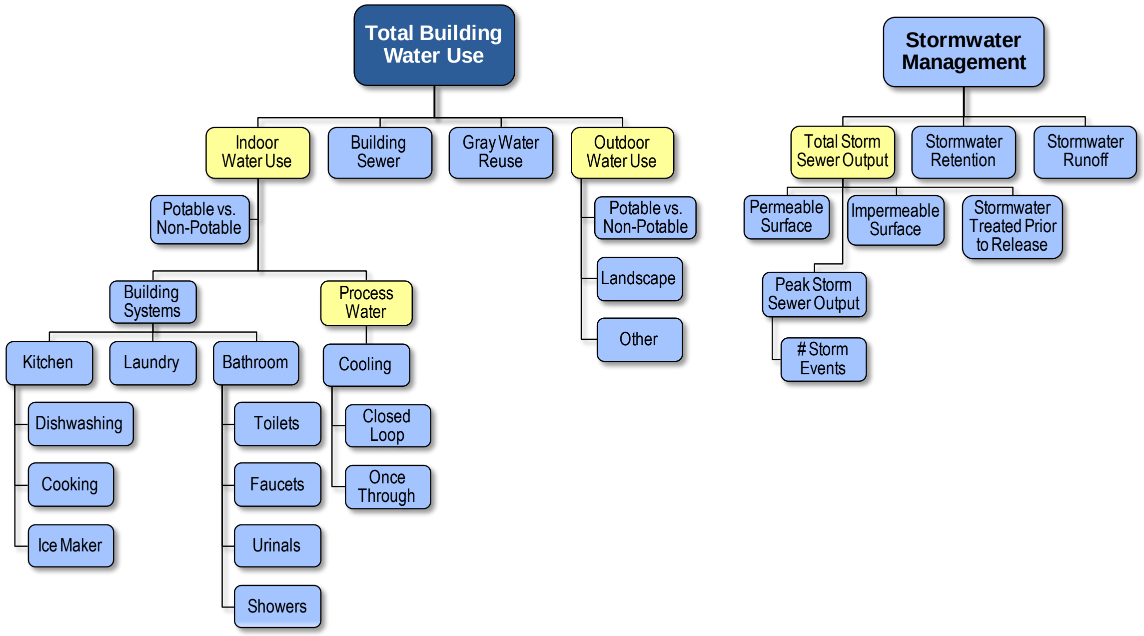


Figure 20. Water use hierarchy

5.1.1.1 Total Building Potable Water Use

Building water use includes all indoor and outdoor water use taken from a well or centralized water distribution. The potable water use *volume* metric does not include captured stormwater or reused gray water. Potable water use cost can include costs assessed for sewage treatment as long as both buildings in a set are measured the same way. Varying regional price structuring and metering may alter what data are readily available via utility bills. *Measurement and Verification Guidelines for Federal Energy Management Projects* offer detailed concepts in quantifying water consumption and cost.[30]

Water consumption allows for a building systems performance comparison; water use cost allows for an economic comparison. The total potable water use metric is likely not as instructive as values given when indoor and outdoor water use are separated, resulting in uncertainty regarding the reasons behind a more efficient water system. However, if separate metering is not available, this metric will be used, and individual uses may be calculated based on this total consumption.

5.1.1.2 Indoor Potable Water Use *(optional)*

Building interior water consumption includes that portion of potable water use used in the building interior, including bathrooms, mechanical systems, laundries, and kitchens. Water used and discharged for cooling through once-through or cooling tower systems is included here. It does not include irrigation or other exterior water use that is routed through the interior building plumbing system.

Building interior planning efficiency and fixture efficiency are represented by this metric. Comparisons of this indoor water use will likely be very meaningful because they are evaluated among buildings with similar functions on both per unit area and per occupant basis.

5.1.1.3 Outdoor Water Use *(optional)*

Exterior water use includes potable and irrigation water use. Captured rainwater and reused gray water are not included in the volume metric, but estimated volumes should be included in the key building features metric.

Comparison of area-normalized outdoor water use will allow an evaluation of the relative cost and performance efficiency of sustainable landscaping strategies.

5.1.1.4 Total Storm Sewer Output *(optional)*

Total storm sewer output is the metric being used to represent the volume of stormwater directed off the building site. Stormwater fees are generally assessed through taxes based on area, urban density, or impermeable surface area because outflow volumes are rarely metered.

Total storm sewer output is an indicator of the effectiveness of site related stormwater management.

5.1.2 Data Collection and Calculations

Water use data will be collected from utility bills and/or through installed metering.

5.1.2.1 Total Building Potable Water Use

Total building potable water use will generally be collected from one water use utility bill that includes sewer costs. If outdoor, indoor, sewer, and storm sewer costs are itemized in billing, they can be used separately for the optional metrics as well as be combined for this metric.

5.1.2.2 Indoor and Outdoor Water Use

Ideally indoor, outdoor, and primary end uses would be metered separately and the information would be available in 1-hour increments. Advanced building management systems may have collected end use information including irrigation, cooling tower, or chilled water use, which can be used if individual building or utility metering is not available. If no detailed metering data are available, utility bills that provide the indoor, outdoor, and sewer measurements separately can be used.

Not all utilities measure indoor use, outdoor use, and sewer output separately but rather use a seasonal variance method of determining water use. The seasonal variance method will generally assume that indoor water use remains constant during the course of the year, but cooling tower and irrigation water uses fluctuate with season. The accuracy of this method can be increased with specific building information on when these seasonal consumers actually operate.

If neither measured nor seasonal variance data are available, outdoor potable water use may be calculated from timed irrigation data or regular scheduling, along with sprayhead flow rates. Sprayhead information may be available through the building manager, online, or by contacting the manufacturer.

Time and flow information may also be used to calculate water consumption in once-through cooling, ice makers, cooling towers, or other end uses that need to be separately estimated. Water use volume and costs will sum to the total values determined in the previous metric.

5.1.2.3 Process Water Use

Many buildings use cooling systems such as water-cooled chillers with cooling towers and evaporative cooling systems because they are very efficient in terms of energy use, but these systems can account for over 25% of the building's water consumption. If a building does have these types of cooling systems the process water should be reported separately. If separate metering is not available process uses may be calculated based on the total consumption.

5.1.2.4 Total Storm Sewer Output

Stormwater costs will be determined for the site in the manner that they are assessed for taxation or otherwise. This metric measures the extent to which stormwater cost assessments represent actual site performance.

Storm sewer output is generally not metered by any government or utility, even in regions where storm sewer volumes are of specific local concern. Therefore, these values must be determined through installed metering. Metering should begin by determining at how many points stormwater leaves the property, and whether the stormwater outflow can be meaningfully separated from neighboring properties. Metered information should be used if at all possible, but a small amount of proportional calculation may be used to separate the contribution of neighboring properties. Combined stormwater outflows will be assigned proportionally to calculated impervious areas from the contributing property regions.

If site stormwater is managed such that no stormwater is directed off-site, or that the site is designed to approximate natural conditions with no evidence of erosion or sedimentation of local waterways during storm events, the storm sewer outflow may be estimated as zero.

5.1.3 Potential Issues and Lessons Learned

Through the pilot test of the metrics, technical review by water management experts, and applications of the first version of this protocol, the following potential data collection and analysis issues have been raised.

- The building set's "Total Potable Water Use" needs to include the same uses, or additional uses must be factored out. For example, if only one of the two buildings has a water-cooled chiller, that additional water use would need to be metered to remove it from the Total Potable Water Use metric.
- Many buildings do not have separately metered process water (due to cooling towers and evaporative cooling). Additional calculations may need to be made in order to account for process water usage.
- Occupancy gender may impact water use results, especially if water free urinals are in place.
- Many buildings on a government campus setting do not have individually metered water use. Installation of building-specific water meters would require additional time and resources.
- Utility bills may not include the same measurements and charges for each building (e.g., sewer, outdoor, chiller, taxes, fees, etc.).

5.2 Energy

Energy consumption and reduction is a widely studied category of building performance. High economic and environmental costs of energy drive resource efficiency and conservation.

Table 8 provides the summary of the required and optional energy use metrics. This chapter offers an explanation of the energy metrics selection and relevance, guidance on how to collect and analyze data for each metric, and identification of potential issues and lessons learned that may be encountered with data collection or analysis.

Table 8. Energy Use

Metric	Required	Optional
Energy	Total Building Energy Use $\frac{kWh_{delivered}}{year}$ $\frac{Btu}{year}$ $\frac{\$}{year}$	Source Energy $\frac{kWh_{source}}{year}$ $\frac{kg_{CO_2}}{kWh_{source}}$
		Peak Electricity Demand kW $\frac{\$}{year}$
		On-Site Renewable Energy
		Special Equipment

Measurement and verification (M&V) of energy consumption is often conducted according to three complementary documents, ordered here from most general to most specific. These resources provide a structure for quantifying energy and water savings from energy conservation measures (ECMs).

1. *International Performance Measurement and Verification Protocol (IPMVP)*: IPMVP has produced a series of broad documents with general information regarding M&V contracting and strategies.[31]

2. *Measurement and Verification Guidelines for Federal Energy Management Programs (M&V Guidelines)*: The *M&V Guidelines* offer more specific M&V information relevant to Federal agencies working with energy service companies (ESCOs) for facility energy conservation and efficiency.[32]

3. *ASHRAE Guideline 14*: ASHRAE has developed specific data collection and analysis information for whole building and end use metering. The format is tailored for use in energy savings contracts with ESCOs including specific options for baseline development and data normalization.[33]

Metering and normalization approaches in the FEMP protocol are generally taken from *Guideline 14*.

The National Renewable Energy Laboratory (NREL) is developing building energy performance metrics as part of the Office of Energy Efficiency and Renewable Energy (EERE) Performance Metrics Research Project.[34] Standardization of energy metrics is meant to facilitate meaningful benchmarks and comparisons via alleviation of discrepancies between source and delivery energy values.

Quantification of emissions outputs is done within a variety of software programs and public protocols including the California Climate Action Registry (The Registry)[35], the Sustainable Silicon Valley Project (SSV)[36], the Greenhouse Gas Protocol (GHG Protocol)[37], and the International Council for Local Environmental Initiatives (ICLEI).[38] Most applicable for calculating emissions from building energy use are The Registry's *General Reporting Protocol* and the GHG Protocol's automated worksheets for calculating CO_2 emissions from stationary combustion and electricity consumption. Calculation approaches developed in these sources are largely followed in this chapter.

5.2.1 Metric Discussion

To determine which energy use metrics would best represent a building's cost and performance, an energy use hierarchy was developed (see Figure 21). The energy use metrics hierarchy was adapted from the NREL energy use measurement protocol.[39] This hierarchy, along with the technical review recommendations, resulted in the energy use metrics found in Table 8. Total Building Energy Use is the required metric because it is typically the highest building cost and has an environmental impact based on the energy sources used. The optional metrics, peak electricity demand, and source energy are important as they provide increased detail on the resource use and environmental impact analysis. These data should be gathered whenever feasible. Given the campus setting of many Federal facilities, it may not be practical to collect these data for every building, and therefore, they have been listed as optional.

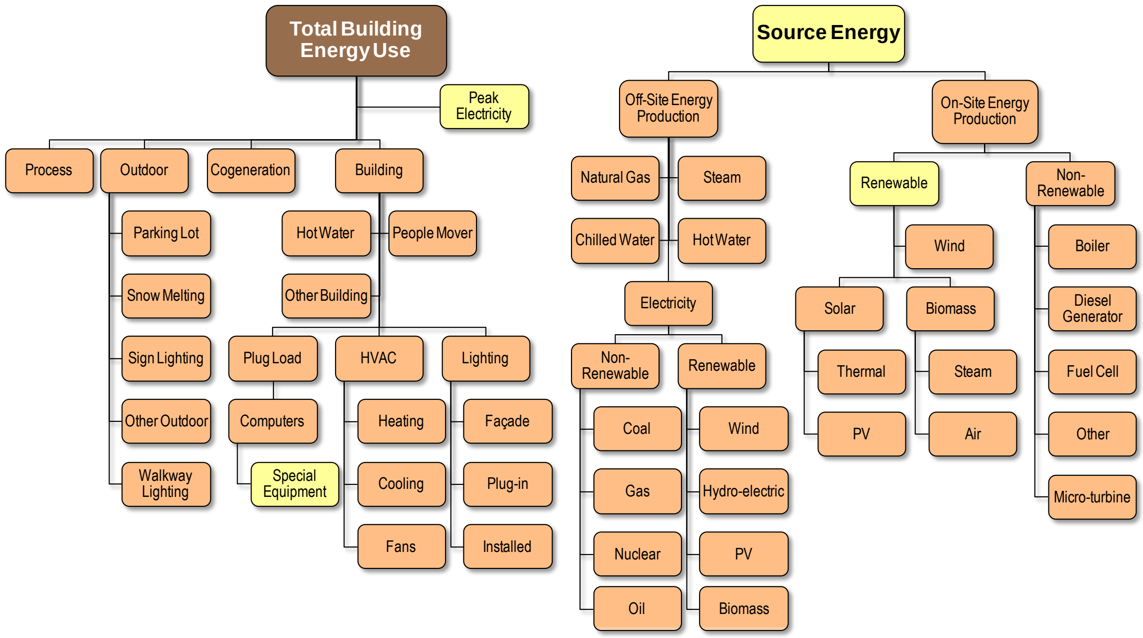


Figure 21. Energy use hierarchy

5.2.1.1 Total Building Energy Use

Building energy use includes all energy consumed in the building. Building energy consumption includes any exterior building illumination, but does not include parking garage or parking lot lighting.

Building energy use allows for building systems performance, cost, and resource use comparisons.

5.2.1.2 Source Energy *(optional)*

Source energy is the energy directly consumed at the building and the energy consumed at the source or production point used to deliver the quantity of energy to the building site. Source energy includes site consumed energy, transmission and distribution losses, and conversion inefficiencies. Combusted fossil, biomass, and refuse-derived fuel (RDF) source energy is equivalent to stored chemical energy; nuclear source energy is calculated as the thermal energy released in the fission reaction; hydroelectric source energy is the potential or kinetic energy contained within dammed water.

Source emissions will be calculated in terms of the mass of the seven primary pollutants as defined by the National Ambient Air Quality Standards (NAAQS) of the Clean Air Act (CAA)[40,41]

- ozone (O_3),
- particulate matter less than 10 µm in diameter (PM_{10}),

- particulate matter less than 2.5 µm in diameter ($PM_{2.5}$),
- carbon monoxide (CO),
- sulfur dioxide (SO_2),
- nitrogen oxides (NO_X), and
- lead (Pb)

They will also be reported in terms of mass carbon dioxide (CO_2) and rolled up into global warming potential (GWP) as carbon dioxide equivalent (CO_2e), and acidification potential as sulfur dioxide equivalent (SO_2e). Where electricity is generated by a nuclear utility, the mass of radioactive waste (kg U) associated with site energy consumption will be collected. Other emissions data will be collected as determined available and relevant upon contacting the power utility.

Source energy is a more detailed means of determining building resource use efficiency performance than site energy because it accounts for the imbedded inefficiencies of transmission, distribution, and conversion.[42] Building designers and managers can change the impact of a building by installing on-site renewable energy and/or purchasing "green" energy from the utility.

Source emissions offer an environmental impact indicator. Relative global warming, acidification, and radioactive waste impacts are estimated from the collected values.

5.2.1.3 Peak Site Electricity Demand *(optional)*

Peak electricity demand is the maximum power demand and the associated cost premium assessed over a period of one calendar month. Typically, peak demand is measured in 15-minute intervals. Only electricity drawn from the grid is included in this metric; electricity consumed from on-site generation is not included here.

Peak electricity demand has associated economic and environmental impacts. Utilities generally charge additional fees based on monthly peak demand, sometimes including clauses that can affect an entire year's bills as a result of high electric consumption over one 15-minute period. Additionally, large demand variations force utilities to vary outputs, wasting energy because of startup and shutdown inefficiencies when making adjustments to match the required load. Utility and infrastructure capacity must keep pace with demand, and therefore, effective electricity load management can also reduce the need for additional construction.

5.2.2 Data Collection and Calculations

Energy use data will be collected from utility bills, installed metering, and/or utility interviews.

5.2.2.1 Total Building Energy Use

Energy use will be reported in kWh for electricity and Btus for all other sources. The primary source of energy data will be from monthly utility bills. Utility providers and/or building management will be contacted to determine the availability of additional timed data, to ensure continued consistent data availability during the study, and to collect historical building data.

If reliable utility bills are not available, whole building or end use meters may need to be installed. Submetering helps to compare buildings on a consistent basis, as well as to determine which systems are operating efficiently versus which are consuming large amounts of energy.

5.2.2.2 Source Energy

Source energy and emissions will be determined by tracking each type of energy delivered to the building. Site energy consumption, as collected above by type, will utilize transmission and distribution (T&D) efficiencies and combustion efficiencies to determine source energy consumption. Utilities may be able to provide these efficiency data; if not, T&D efficiencies can be determined based on type of fuel and distance from the building to the source. Combustion efficiencies of off-site sources can be determined based on average rated efficiencies, taking into account local and Federal equipment efficiency requirements, age of equipment, and type of equipment. For on-site energy sources, conversion efficiencies will be collected from manufacturer's data or periodic maintenance tests, like boiler combustion analyses.

When a power utility produces district heating or cooling along with electricity, the conversion efficiency and source energy varies among each outputted energy distribution medium. Source energy is assigned proportionally to working fluid enthalpy drops associated with each medium.

Emissions associated with each quantity of source energy, if not directly available from the utility, can be determined using tools found online, such as the GHG Protocol's tool to calculate CO_2 emissions from stationary combustion.[43, 44] The Energy Star® Portfolio Manger is another online tool that calculates total metric tons of CO_2 equivalent emissions per building. The program follows a methodology based on the GHG Protocol and uses data available through the U.S. Environmental Protection Agency's (EPA) Emissions & Generation Resource Integrated Database (eGRID) to calculate emissions associated with both on and off-site energy generation.[45]

5.2.2.3 Peak Site Electricity Demand

Peak site electricity demand will be collected from monthly electric utility bills in kW as measured by the electricity provider. Because the metric is defined in terms of 15-minute fixed window intervals, varying utility methods[46] of determining peak electricity demand may alter the precise meaning of the quantity and reduce the value of the comparison.

Metered data can be used to determine peak electricity demand, if peak demand is not provided on the utility bill or tracked by the utility. The same equipment used to meter or submeter electrical consumption can also record demand values. When possible, measurements should be made in 15-minute fixed window intervals.

5.2.3 Potential Issues and Lessons Learned

Through the pilot test of the metrics and technical review by energy management experts, the following potential data collection and analysis issues have been raised.

- To measure "Total Building Energy Use" functional meters and/or detailed utility bills must be available for all buildings included in the study.
- Peak demand on Federal campuses tends to be measured at a site level rather than a building level, which is why this metric is considered optional. Ideally peak demand would be measured for every building because it is an important metric with cost and performance implications as they contribute to the site total.
- Source energy provides data representing the environmental impact of energy use; however, it is likely to be the same for each building if you are comparing buildings using the same utility. Differences would occur when building integrated renewable energy generation or a building-specific purchase of green power has occurred.
- Electricity mixes can change often for the utilities, so when requesting information, be clear on what the study dates are to be able to accurately report the source energy mix. Utilities often report this as an annual average.
- Energy end use metering with data collected electronically every 15 minutes is preferred to assess and optimize the building performance in addition to measuring it.

5.3 Maintenance and Operations

A primary aim of high-performance or sustainable design is occupant comfort and productivity. Achieving high performance might equate to monitoring water, energy, ventilation, and conditioning equipment and increasing preventative maintenance to avoid potential future problems, thus shifting operations and maintenance (O&M) expenditures from reparative to preventative activities.

Table 9 provides the summary of the required and optional O&M metrics. This chapter offers an explanation of the selected O&M metrics and their relevance, guidance on how to collect and analyze data for each metric, and identification of potential issues and lessons learned that may be encountered with data collection or analysis. Performance metrics for operations maintenance were initially identified from the DOE FEMP *O&M Best Practices: A Guide to Achieving Operational Efficiency* and then adapted based on technical review feedback.[47]

Table 9. Maintenance and Operations

Metric	Required	Optional
Maintenance and Operations	Building Maintenance $\frac{Service\ Calls}{year}$ $\frac{\$}{year}$	Grounds Maintenance $\frac{jobs}{year}$ $\frac{\$}{year}$
	Preventative Maintenance $\frac{jobs}{year}$ $\frac{\$}{year}$	Janitorial Maintenance $\frac{Service\ Calls}{year}$ $\frac{\$}{year}$
		Churn Costs $\frac{moves_{construction}}{occupant \cdot year}$ $\frac{moves_{furniture}}{occupant \cdot year}$ $\frac{moves_{box}}{occupant \cdot year}$ $\frac{\$}{churn}$

Some studies have documented reduced O&M costs for sustainably designed buildings[48], while others claim O&M costs increase but are offset by other savings such as worker productivity[49].

Interdependence in building systems means that a cost effective and highly-performing O&M program may cost more in training, monitoring, and preventative maintenance, but reduces the costs of occupant satisfaction and productivity, energy, water, and materials costs, and repair costs. The metrics for occupant satisfaction and productivity are discussed in Section 5.5, Indoor Environmental Quality. A holistic measurement of building performance and costs, such as this protocol, will provide indicators of the impact of sustainable O&M practices.

5.3.1 Metric Discussion

To determine which O&M metrics would best represent a building's cost and performance, an O&M hierarchy was developed (see Figure 22). The result of this analysis along with the technical review recommendations resulted in the metrics found in Table 9. Building maintenance costs and service requests are required metrics because they represent building costs and impact occupant productivity. The optional metrics include grounds maintenance and janitorial costs. These metrics are considered optional because of the difficulty to measure data consistently across building sites.

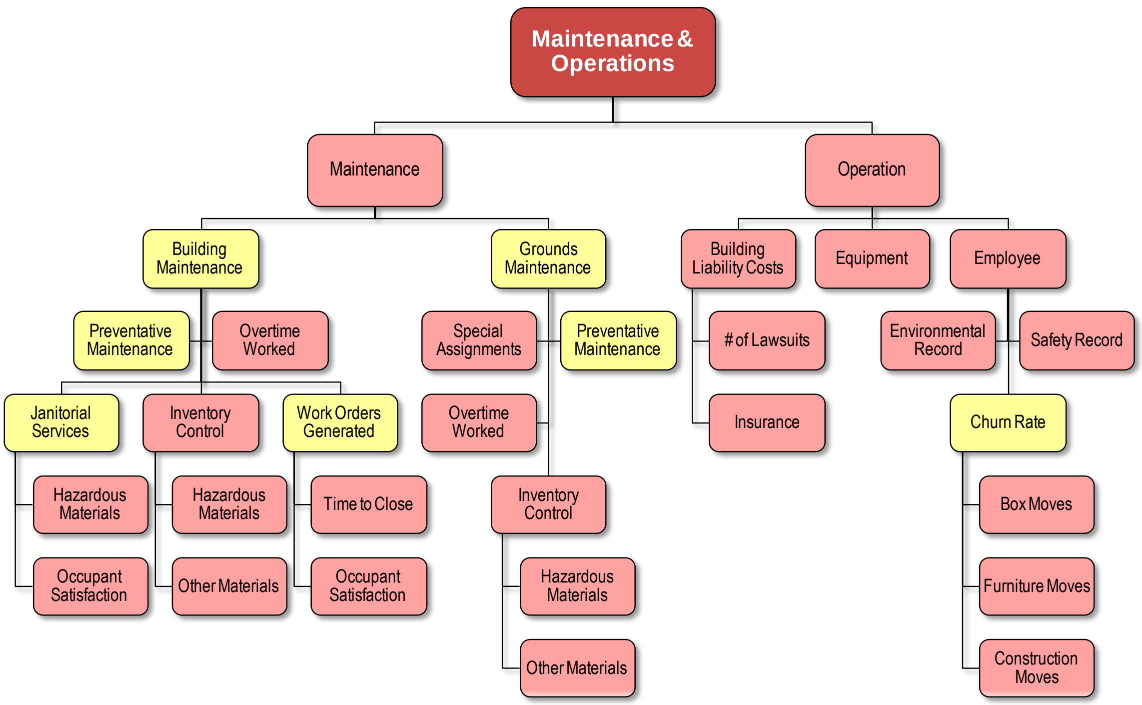


Figure 22. Maintenance and operations hierarchy

5.3.1.1 Building Maintenance

Building maintenance includes in-house and contracted resources expended for building monitoring, repair, preventative maintenance, training, and response to service requests. It does not include grounds work or major renovations. Costs do not include O&M staff overhead. The number of maintenance personnel will also be used as a reference point.

The requests include service requests as well as complaints. They are the building occupant requests to building personnel that require some action. Examples include temperature complaints and repair requests.

O&M expenditures are direct building costs that may also impact energy and water utility costs. Studies have shown that the quality and consistency of building operation, especially thermal comfort, impacts the productivity of the building occupants.[50] Quantity of service requests indicates how well the building is performing from an occupant's perspective as well as how much O&M personnel time is needed to maintain the building. Preventative maintenance regimes may decrease the number of service calls and increase the life of the equipment resulting in avoided life cycle costs. Training may increase as a result of managing more advanced building equipment.

5.3.1.2 Grounds Maintenance *(optional)*

Grounds maintenance includes in-house and contracted labor and resources expended for landscaping, stormwater management, and parking lot/garage upkeep. Costs include labor, training, and materials. The hazardous materials used also need to be documented separately and reported in the hazardous waste metrics. If training costs can be separated from other O&M costs, it will allow for a more detail comparative analysis of O&M related costs.

Sustainably designed grounds may incur fewer costs because of hardy native planting, reduced chemical application, and on-site rainwater infiltration. However, it may incur greater costs as a result of permeable surface maintenance or training needed to maintain new types of landscaping. The design differences will be noted in the key building features metric.

5.3.1.3 Churn Cost (optional)

Churn costs include resources expended in box, furniture, and construction moves including materials and O&M staff time. The comparison of these types of moves is used to demonstrate the impact of flexibility-targeted design strategies.

Box moves typically involve packing and unpacking when moving from one work station or office to another.

Furniture moves are box moves that also include moving desks, partitions, bookshelves, and other office equipment. Removing and replacing floor panels or carpet squares and redirecting wiring are considered furniture moves if these items were designed for removal and replacement.

Construction moves involve not only the activities of box and furniture moves, but also activities such as painting, minor construction/remodeling, and rewiring.

Sustainable design strategies incorporating flexibility into building and office accommodations claim to reduce the cost of churn. Raised floors with removable panels and carpet sections allow under-floor electrical and telecommunications wiring to be moved without construction work and movable partitions can replace constructed walls for ease in altering spaces. Quantifying churn costs will provide a relative measure for evaluating strategy effectiveness.

5.3.2 Data Collection and Calculations

Building managers will be interviewed to determine the best information sources such as work orders, service requests, or a computerized maintenance management system. Every effort should be made to assess incurred costs as opposed to budgeted costs, which may not directly reflect the O&M costs of a building.

Note that churn cost values are better determined over a period of several years; therefore the meaningfulness and comparability of gathered data will be evaluated on a case by case basis.

If the sustainably design building and the baseline have identical O&M policies, such as landscaping, pest control, cleaning, or monitoring practices, it may be difficult to demonstrate a difference in O&M costs with these metrics.

5.3.3 Potential Issues and Lessons Learned

Through the pilot test of the metrics and technical review by operations and maintenance experts, the following potential data collection and analysis issues have been raised.

- Outsourced building maintenance may make it difficult to collect information.
- Comparing buildings may be difficult when they are maintained in different ways and/or their maintenance is tracked in different ways (i.e. some programs track the number of preventative maintenance jobs, while others track the number of hours).
- Adjustments made to a new facility may or may not be included consistently in the service request tracking system. Daily service calls may not be included consistently in the service tracking system as well. It is important for the building management to explain what types of information is being tracked consistently.
- Grounds maintenance for shared landscaping areas may need to be addressed.
- 1-year of churn cost data may not be representative of the building performance, as moves occur for various reasons.

5.4 Waste Generation and Recycling

Waste disposal is a utility cost incurred by buildings that is an indicator of resource use by the building occupants. Table 10 provides the summary of the required and optional waste generation metrics. This chapter offers an explanation of the selected waste generation metrics and their relevance, guidance on how to collect and analyze data for each metric, and identification of potential issues and lessons learned that may be encountered with data collection or analysis.

Table 10. Waste Generation and Recycling

Metric	Required	Optional
Waste Generation and Recycling	Solid Sanitary Waste $\frac{ton}{year}$ $\frac{\$}{year}$	Recycled Materials $\frac{ton}{year}$ $\frac{\$}{year}$
		Hazardous Waste $\frac{ton}{year}$ $\frac{\$}{year}$

Most waste data collection methodologies have been developed for the purposes of targeting effective waste reduction strategies rather than for collecting standardized data sets for multiple buildings[51]. Utilities or municipalities often set waste rates based on the volume of compacted waste, number of pickups, or dumpster size, but landfill tipping costs are on a unit mass basis. Because regional costs of recycling and waste disposal vary widely, volume, mass, and cost values are collected and analyzed for this metric.

5.4.1 Metric Discussion

To determine which waste generation metrics would best represent a building's cost and performance, a hierarchy was developed (see Figure 23). The result of this analysis along with the technical review recommendations resulted in the waste generation metrics found in Table 10. Solid sanitary waste is the required metric because it is the easiest to collect of the metrics in this category and it represents costs and resource use within the building. The optional recycling and hazardous waste metrics offer useful information about the performance and cost of the building, however were determined to be more difficult to collect.

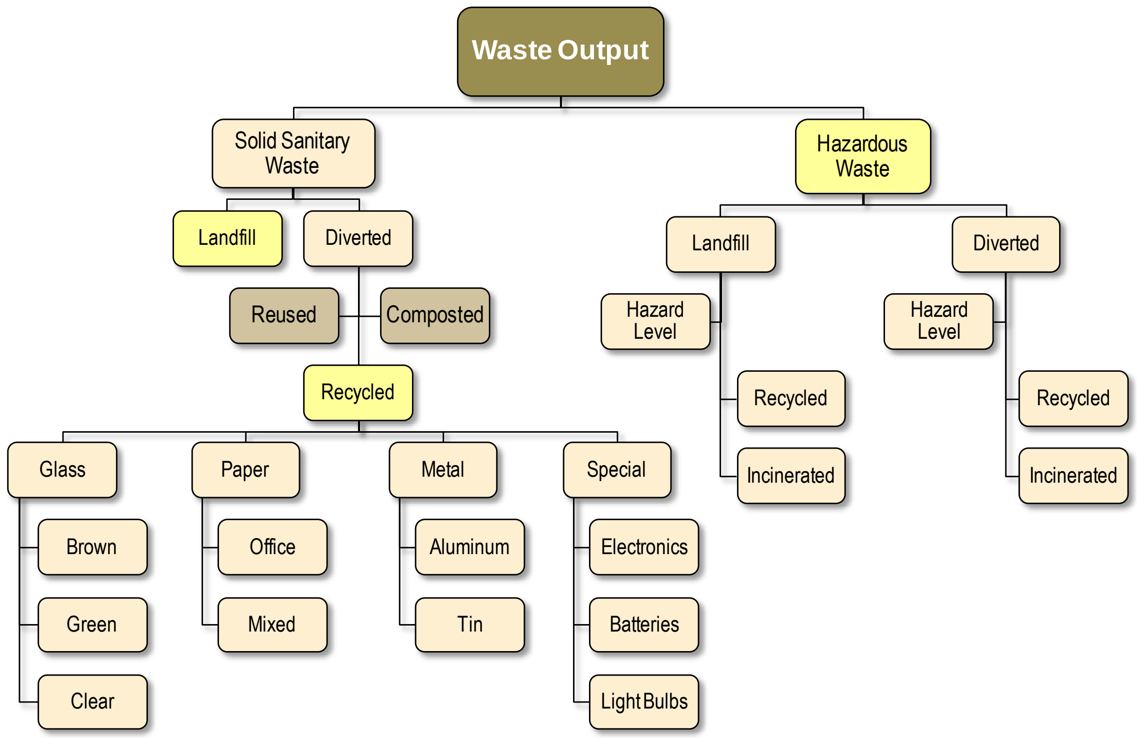


Figure 23. Waste generation hierarchy

5.4.1.1 Solid Sanitary Waste

The sanitary waste metric measures non-hazardous waste, also known as garbage, generated by building occupants and disposed of in a dumpster for pickup and delivery to a landfill or incinerator. Solid sanitary waste output will be reported in volume, mass, and dollars. Values will be normalized both on an occupant basis and on a gross building interior area basis.

Low amounts of sanitary waste disposal may represent greater access to recycling containers, occupant values, or policies of reducing material use, reusing materials, or aggressive recycling within the building.

5.4.1.2 Hazardous Waste *(optional)*

Building-specific hazardous materials may include cleaning, pest management, and landscaping chemicals. The purchase of these materials will be tracked in the environmentally preferable purchasing metric, but disposal of the materials, typically because of cleanout or overstock of supplies, would be included here. Hazardous waste output will be reported in volume, mass, and dollars. Values will be normalized both on an occupant basis, and on a gross building interior area basis.

Most building functions can be maintained at a high level of quality with non-hazardous materials. Having hazardous materials at a building site increases human health risks, disposal costs, and chemical maintenance costs.

5.4.1.3 Recycled Materials *(optional)*

Recycled materials are items diverted from waste disposal for reuse, recovery or reclamation. A list of types of materials recycled at the building site needs to be included. These items may include aluminum, tin, glass, cardboard, paper, batteries, electronics, and chemicals. Recycled waste output will be reported in volume. Values will be normalized both on an occupant basis, and on a gross building interior area basis.

Recycling can reduce sanitary and hazardous waste output, thus reducing the environmental impact and cost.

5.4.2 Data Collection and Calculations

5.4.2.1 Solid Sanitary Waste

If volume, mass, and cost data are readily available on a building-specific basis through utility bills, that is the preferred method of data collection. When utility data by building are not available, the waste quantity may need to be calculated from visual estimations or collected from waste haulers.

5.4.2.2 Hazardous Waste

Hazardous waste volume, mass, or cost will generally be tracked through environmental program reporting requirements. The environmental, health, and safety representative should be able to assist in identifying the viability of collecting hazardous waste by building.

5.4.2.3 Recycling

Recycling volume, mass and cost values will be collected through waste management data and utility bills. Some locations may have extensive information available through hauler data similar to that available for solid sanitary waste measures. Some Federal agencies, such as the GSA, also track recycling values for year-end reimbursement purposes. Data availability and format will dictate how it is used for calculations.

5.4.3 Potential Issues and Lessons Learned

Through the pilot test of the metrics and technical review by waste management experts, the following potential data collection and analysis issues have been raised.

- Some organizations have policies against the storage of hazardous materials in office buildings, but they still use the materials in the facility.
- The study participants may not know what a hazardous material is and say they don’t have any until pressed further and given examples.
- Recycled materials tend not to be measured by building.

- Depending on the location, cost of disposal and quantity of waste generated may not correlate and may not be measured by building.
- For collection of waste data, request that appropriate staff participate in teleconferences and the site visit.
- The cost of recycling materials may be included in the M&O contract.

5.5 Indoor Environmental Quality

Indoor environmental quality (IEQ) of a workplace reflects the interaction of air, lighting, and surroundings with occupants in a holistic sense. Effects include occupant health, productivity, and satisfaction. Table 11 provides the summary of the IEQ metrics. This section offers an explanation of the IEQ metric selection and relevance, guidance on how to collect and analyze data for each metric, and identification of potential issues and lessons learned that may be encountered with data collection or analysis.

Table 11. Indoor environmental quality

Metric	Required	Optional
Indoor Environmental Quality 	Building Occupant Satisfaction $\frac{occupant\ rating}{survey\ metric}$	Self-rated Productivity $\frac{occupant\ rating}{survey\ metric}$
		Absenteeism $\frac{absentees}{occupant \cdot year}$
		Turnover Rate $\frac{turnover}{year}$
		Indoor Air Quality

5.5.1 Metric Discussion

A variety IEQ methods and measures have been developed for building evaluations and case studies. The National Australian Built Environment Rating System (NABERS)[52] specifies a set of IAQ metrics as part of their scoring. The Post Occupancy Review of Buildings and their Engineering (PROBE)[53] has employed occupant satisfaction benchmarking along with indoor air pollutant levels. A LEED™ building evaluation being conducted for The City of Seattle by Paladino & Co, Inc.[54] is simultaneously evaluating productivity-related metrics from human resources records, daylighting study results, and survey responses.

American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE) Standards 62 and 55[55] have defined building performance characteristics for indoor air quality (IAQ) and thermal comfort, respectively. Optimal lighting levels are indicated the by the Illuminance Selection Procedure of the Illuminating Engineering Society of North America's (IESNA) Lighting Handbook[56]. IEQ conditions outlined in these standards are largely followed in building industry practice.

IEQ metrics can include continuous or spot measures of conditions such as temperature, relative humidity, and luminescence and levels of indoor air pollutants such as carbon dioxide, carbon monoxide, ozone, formaldehyde, total or individual volatile organic compounds (VOC), airborne viable bacteria, fungi, mold, and respirable dust. Occupant surveys, maintenance data, and human resource records can give additional information about the occupant response to the working environment.

Effects of changes in specific building conditions on occupant performance have been extensively studied. Many of these studies have been reviewed by the Advanced Building Systems Integration Consortium (ABSIC) at Carnegie Mellon University and used to develop the Building Investment Decision Support (BIDS) tool.[57, 58] BIDS can be used to guide strategic investments into the built environment to improve occupant productivity and satisfaction. Most of these metrics related to IEQ and productivity have a variety of influencing factors, only some of which are related to sustainable building design and operation.

To determine which IEQ metrics would best represent a building's cost and performance, a hierarchy was developed (see Figure 24). Both the building occupant and survey data are required metrics because they will be used to represent the impact of the building on its occupants.

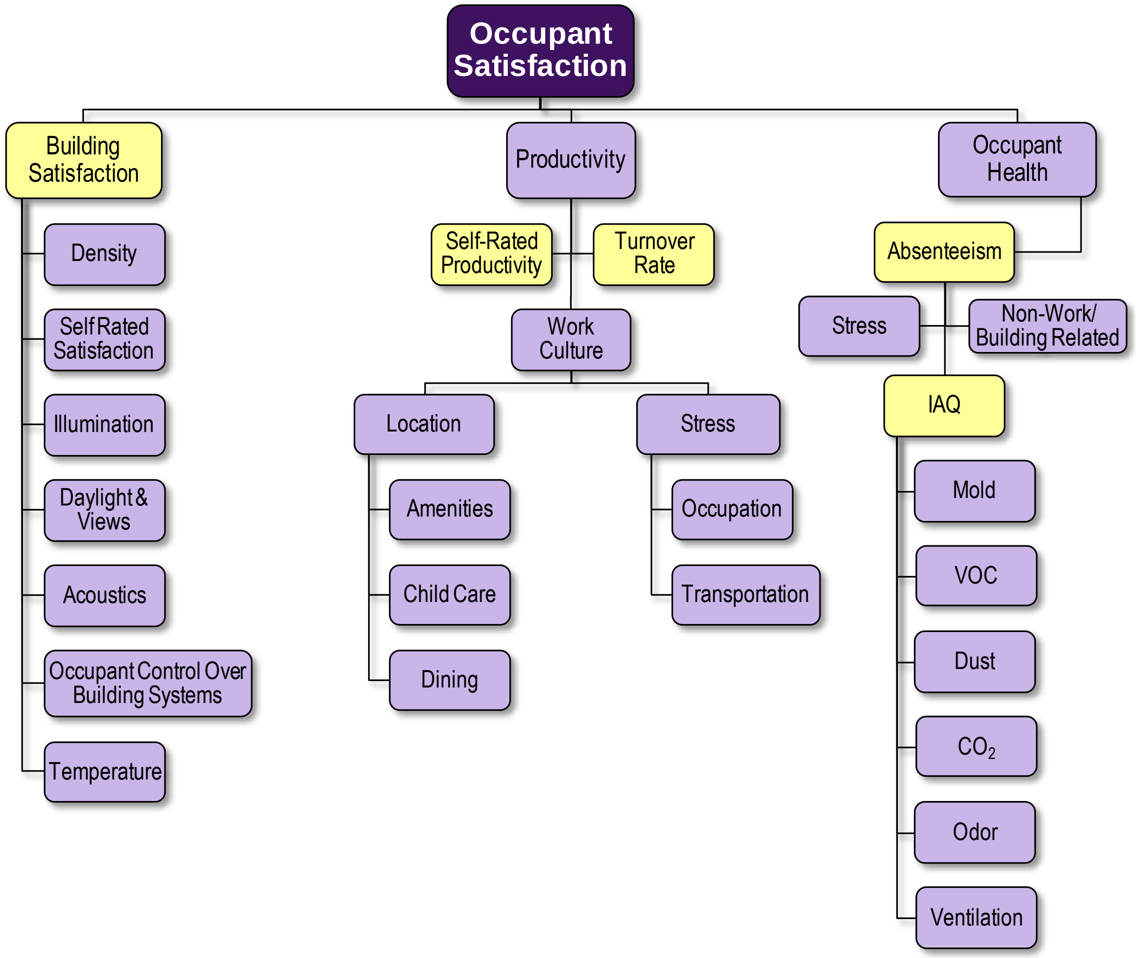


Figure 24. Indoor environmental quality metrics hierarchy

Indoor environmental quality will be evaluated using resulting indicators that should improve or deteriorate with the quality of the space. However, each IEQ metric will be reviewed in conjunction with building characteristics, organizational management, and other performance measures to evaluate differences among buildings.

5.5.1.1 Building Occupant Satisfaction

Building occupant satisfaction is a relative measure of comfort, environment, and indoor air quality as determined with a survey. Ratings range from low to high satisfaction.

A satisfying work environment has been correlated with staff retention and increased productivity.

5.5.1.2 Self-Rated Productivity

Self-rated productivity is a relative measure of an occupant's productivity. Ratings range from low to high productivity.

Employee costs are the largest organizational costs over time. Occupant perception on how a building's IEQ affects productivity and the quality of work offers an indicator of potential building-related organizational costs.

5.5.1.3 Absenteeism

Absenteeism is the number of days that an occupant is away from work for health reasons.

A healthy, satisfying, and productive work environment may be reflected in low absenteeism rates. Occupant absenteeism is an indicator of productivity. Absenteeism information along with occupant pay information can be used to determine a cost for work days lost.

5.5.1.4 Occupant Turnover Rate

Occupant turnover rate is the number of building occupants that leave the organization over the course of a year. If possible, designate whether the occupants left because of resignation, termination, or retirement and provide further detail on reasons for resignation. The ratio of turnover to total number of occupants is a retention indicator that will be used as part of the comparative building analysis.

Employee turnover costs time and money. Increased costs associated with training, churn, recruitment, severance, and downtime are impacts of turnover. The occupant satisfaction survey, the turnover rate, and absenteeism will be used to indicate the cost and performance impact of IEQ.

5.5.2 Data Collection and Calculations

5.5.2.1 Building Occupant Satisfaction

Satisfaction and other occupant-reported IEQ values can be gathered using surveys of building occupants. Core IEQ survey questions are related to office layout, office furnishings, thermal comfort, air quality, lighting, acoustics, cleanliness and maintenance. The rule of thumb for a reliable survey response rate is 60% for meaningful results. However, reasonable data can be gathered with as low as 20% response from very large building populations on the scale of 1000 occupants or necessitate 100% response from very small populations.

During the pilot phase of the protocol and in subsequent applications of the protocol, these data were collected using an online survey conducted by the Center for the Built Environment (CBE) at the University of California Berkeley.[59] CBE compiled the survey data with an existing reporting tool and provided a summary data report.

5.5.2.2 Self-Rated Productivity

Self-rated productivity and other occupant-reported IEQ values can also be gathered using data surveys of building occupants.

5.5.2.3 Absenteeism

Absenteeism rates for the occupants of the building will be gathered on a monthly basis from management records. Details regarding specific building occupants must be kept confidential.

5.5.2.4 Occupant Turnover Rate

Turnover rates for the occupants of the building will be gathered on a monthly basis from management records. Details regarding specific building occupants must be kept confidential.

5.5.3 Potential Issues and Lessons Learned

Through the pilot test of the metrics and technical review by IEQ experts, the following potential data collection and analysis issues have been raised.

- Organizational policies and procedures may impact the differences between buildings.
- Attributing a cost savings to the building satisfaction and productivity may be difficult for audiences to understand.
- Survey return rate needs to be high enough to provide statistically relevant results.
- For collection of indoor environmental quality data, recognize that there may be a need to address union officials, security, management, and/or senior organization officials.
- If the CBE survey is not used, compilation of survey data will be difficult if the questions and data collection methods vary greatly (e.g. electronic versus paper surveys).
- To ensure an accurate sample, confirm that all of the occupants permanently located at the building are offered the chance to take the survey.

5.6 Transportation

Transportation to a building reflects the impact of siting and the building occupant environmental ethic. Table 12 provides the summary of the required and optional transportation metrics. This chapter offers an explanation of the transportation metric selection and relevance, guidance on how to collect and analyze data for each metric, and identification of potential issues and lessons learned that may be encountered with data collection or analysis.

Table 12. Transportation

Metric	Required	Optional
Transportation	Regular Commute $\frac{miles}{gallon}$ $\frac{miles}{week}$	Business Travel $mode\ of\ transportation$ $\frac{miles}{trip}$

5.6.1 Metric Discussion

Transportation metrics have been investigated primarily to estimate carbon emissions associated with building occupant choices. The National Australian Building Environmental Rating System (NABERS) has an approach for determining transportation mileage and associated emissions.[60] The NABERS approach uses paper surveys distributed to occupants to determine weekly number of trips, mode of transportation, and distance of trips. From standard fuel economy values for each transportation type, carbon emissions per occupant are calculated.

Other methods for determining emissions from travel are employed by the California Climate Action Registry, Greenhouse Gas Reporting Protocol, International Council for Local Environmental Initiatives (ICLEA), and the Sustainable Silicon Valley.[61, 62, 63, 64] Some of these efforts are related to calculating emissions from company fleets, from work-related travel, or from whole-community sources. These employ available documentation such as logged miles and purchased fuel for a company or Department of Motor Vehicles (DMV) traffic estimates and local fuel sales for a community.

For determining CO_2 emissions, the most relevant information is the quantity of fuel consumed; for determining CH_4 or N_2O, the most relevant data are vehicle specifications and distance traveled. Fuel economy and GHG emissions information can be found for most passenger vehicles.[65]

To determine which transportation metrics would best represent a building's cost and performance, a hierarchy was developed (see Figure 25). The result of this analysis along with the technical review recommendations resulted in the metrics found in Table 12. The transportation metric is required because of the ease of data collection and also because it will offer another occupant perspective.

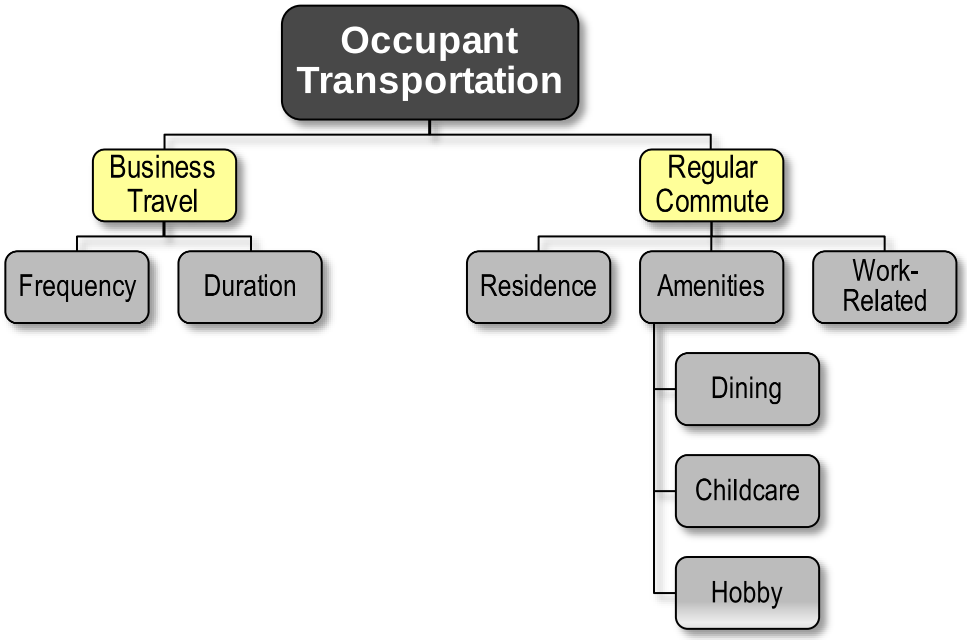


Figure 25. Transportation metrics hierarchy

5.6.1.1 Regular Commute

Regular commute includes all normal workday travel between residence, work, and required amenities, such as child care and dining.

Distance traveled and cost accrued in regular commute are measures of quality of life impacts that building location has on occupants. Carbon emissions, depletion of fossil fuel, air pollutants, and infrastructure needs resulting from regular occupant commute impact the environment. This metric uses the emissions reduction associated with alternative transportation options, such as carpooling, biking, and mass transit as the indicator of transportation impacts.

5.6.2 Data Collection and Calculations

5.6.2.1 Regular Commute

Transportation data can be collected using a survey of building occupants. During the protocol pilot test, transportation questions were included as part of the CBE survey.

5.6.3 Potential Issues and Lessons Learned

Through the pilot test of the metrics and technical review by transportation experts, the following potential data collection and analysis issues have been raised

- Occupant transportation choices are expected to reflect building site selection and occupant values rather than the operational performance of the building.
- Survey return rate needs to be high enough to provide statistically relevant results (transportation return rate was lower than IEQ return rate).
- For collection of survey data, recognize that there may be a need to address union officials, security, management, and/or senior organization officials.
- To ensure an accurate sample, confirm that all of the occupants permanently located at the building are offered the chance to take the survey.

6.0 Summary of Protocol Use

This report documents the development of and guidance for use of the building cost and performance protocol. The protocol was designed to offer a high-level comparative measurement of building performance that will help further the knowledge base of the sustainable design business case. This has been accomplished by

- identifying metrics that are indicators for sustainable building performance and cost (i.e., water, energy, maintenance and operations, waste generation, environmentally preferable purchasing, indoor environmental quality, and transportation),
- identifying building and site characteristics that can be used to normalize building performance and cost data for the comparative analysis,
- providing options for establishing a baseline for comparison, and
- offering data reporting options that could be used to communicate the data being collected.

This protocol offers sustainable design and development professionals a tool for the collection of consistent data across key sustainable design indicators. It can be used to further document the business case for sustainable design through measured building performance rather than by design intent. It is not intended to answer all questions regarding sustainably designed buildings, but rather offer indicators of cost and performance. Although the metrics were selected in part because of their relative ease of collection, there will be implementation challenges associated with consistent data collection across the metrics and challenges with the ability to identify sustainably designed buildings and a comparable baseline willing to contribute data for analysis.

Due in large part to the project's Technical Advisory Group, there are current plans to apply this protocol on Federal projects with the most notable being 14 Navy buildings. Since 1998 the U.S. Navy's Naval Facilities Engineering Command has had a policy to incorporate sustainable design principles into new building construction. The first cost considerations have been one of the biggest challenges for integrating sustainable design into Navy projects. Although considerable progress has been made, to make the next leap in progress the Navy needs to provide actual cost and performance data of their sustainably designed buildings to demonstrate the benefits they are reaping for their investments. To accomplish the goal, the protocol defined in this document is being used on seven Navy building sets (14 buildings). Each building set includes one sustainably designed building and a similar building on the same Navy site designed in a more 'typical' fashion. In addition to using the typically designed building for comparison, industry benchmarks and existing Navy data will be used when available. The building types that are included in the project are office buildings and barracks. The protocol is also being considered for use on other comparative analysis of Federal sustainably designed buildings.

A.1 Original Metric Criteria and Selection Process

The success of the project, however, was due to the contributions made by the project's Technical Advisory Group (TAG). Current and former members of the TAG include:

Lucia Athens, Seattle Public Utilities Sustainable Buildings Program *(former)*
Cathy Berlow, U.S. Environmental Protection Agency
James Carelock, Jr., General Service Administration
Anne Crawley, U.S. Department of Energy
Robert Fallis, Environmental Protection Agency *(former)*
Steve Glover, Department of the Army
Don Horn, General Services Administration
Charles Howell, Washington State University *(former)*
Arun Jhaveri, U.S. Department of Energy
Mary Ann Lazarus, Hellmuth, Obata + Kassabaum (HOK)
Chris Long, Environmental Protection Agency *(former)*
Megan Moser, Green Building Alliance
Tom Paladino, Paladino & Company, Inc.
Dennis Talton, Department of the Navy
Joel Todd, Environmental Consultant
Andy Walker, National Renewable Energy Laboratory
James White, Environmental Protection Agency *(former)*

The contributions of the volunteers for the metrics pilot test were also key to the completion of this project. They included Fort Lewis, Tacoma Washington personnel, Pacific Northwest National Laboratory staff, Social Security and General Services Administration personnel associated with the Woodlawn facility (Nancy Belt, Bette Hoffman, John McKewan, Debbie Paul, and John Shryock), and HOK building managers and consultants.

The Center for the Built Environment has been a significant contributor to this project as well. They provided the primary tool selected for addressing indoor environmental quality and transportation issues (Sahar Abbaszadeh and Leah Zagreus).

The final set of metric selection criteria were refined by the TAG (**Error! Reference source not found.**). These criteria were used to help identify and limit the number of metrics so that the final set met the intent of the project, which is a simple yet technically defensible method of measuring the performance of sustainably designed buildings.

Table A.1. Metric selection criteria

Ease of Collection
Availability: Information routinely collected for other purposes or by other entities.
Obtainability: Available via relatively simple measurement or collection procedures.
Cost: No cost or minimal cost to collect the data.
Time: Minimal time investment to collect the data.

Standardization: Frequently measured quantities with well-established collection procedures where feasible.
Public: Based on data that can be shared with the public.

Usefulness of Information
Relevance: Representative of sustainability.
Importance: Having a large sustainability impact potential.
Comparability: Amenable to normalization for comparisons over varying climates, years, and uses where feasible.
Utility: Usable for additional purposes where feasible.

Quality of Data
Quantification: Numeric measurements facilitating both absolute and relative sustainability performance assessments where feasible.
Accuracy: Reflective of the actual state of the system.
Precision: Minimal error in metric measurement.
Clarity: Well-defined, easily communicated, and clearly understood among multiple parties.
Simplicity: Minimal normalization or manipulation of data.

Based on the experience of trying to collect and analyze data for each of the metrics, each metric chosen by the TAG was scored for how well it met each of the criteria (**Error! Reference source not found.**). If the metric is expected to easily meet the criterion in most cases, it is shaded green. If the metric did not meet the criterion, it is shaded orange. If the metric could meet the criterion in some but not all cases, it is shaded yellow.

Table A.2 Selection criteria: analysis by metric

Criteria	*Ease of Collection*						*Usefulness of Information*				*Quality of Data*				
	Availability	Obtainability	Cost	Time	Standardization	Public	Relevance	Importance	Comparability	Utility	Quantification	Accuracy	Precision	Clarity	Simplicity
Water															
Total Building Potable Water Use	Yellow	Yellow	Yellow	Yellow	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
Indoor Potable Water Use	Yellow	Yellow	Yellow	Yellow	Yellow	Green	Green	Yellow	Yellow	Green	Green	Green	Green	Green	Green
Outdoor Water Use	Yellow	Yellow	Yellow	Yellow	Yellow	Green	Green	Yellow	Yellow	Green	Green	Green	Green	Green	Green
Total Storm Sewer Output	Orange	Orange	Orange	Orange	Orange	Yellow	Yellow	Yellow	Orange	Yellow	Yellow	Yellow	Yellow	Yellow	Orange
Energy															
Total Building Energy Use	Green	Green	Yellow	Yellow	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
Source Energy	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Green	Yellow	Yellow	Orange	Yellow	Orange	Orange	Yellow	Yellow
Peak Electricity Demand	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Green	Green	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow
Maintenance and Operations															
Building Maintenance	Yellow	Yellow	Yellow	Yellow	Orange	Orange	Green	Green	Yellow	Yellow	Yellow	Orange	Orange	Orange	Orange
Grounds Maintenance	Yellow	Yellow	Yellow	Yellow	Orange	Orange	Yellow	Yellow	Yellow	Yellow	Yellow	Orange	Orange	Orange	Orange
Churn Cost	Yellow	Yellow	Yellow	Yellow	Orange	Orange	Green	Green	Yellow	Yellow	Yellow	Yellow	Orange	Yellow	Orange
Waste Generation															
Solid Sanitary Waste	Yellow	Yellow	Yellow	Yellow	Orange	Yellow	Green	Green	Green	Green	Yellow	Yellow	Yellow	Yellow	Yellow
Hazardous Waste	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Green	Green	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow
Recycled Materials	Yellow	Yellow	Yellow	Yellow	Orange	Orange	Green	Green	Yellow	Yellow	Yellow	Yellow	Orange	Yellow	Yellow
Purchasing															
Environmentally Preferable Purchasing (EPP)	Orange	Orange	Orange	Orange	Orange	Yellow	Green	Yellow	Orange	Orange	Yellow	Orange	Orange	Orange	Orange
Indoor Environmental Quality (IEQ)															
Occupant Turnover Rate	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Green	Yellow	Yellow	Yellow	Yellow	Yellow	Orange	Yellow	Yellow
Absenteeism	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Green	Yellow	Yellow	Yellow	Yellow	Yellow	Orange	Yellow	Yellow
Building Occupant Satisfaction	Yellow	Yellow	Yellow	Yellow	Yellow	Orange	Green	Yellow	Yellow	Yellow	Orange	Orange	Orange	Yellow	Yellow
Self-Rated Productivity	Yellow	Yellow	Yellow	Yellow	Yellow	Orange	Green	Green	Yellow	Yellow	Orange	Orange	Orange	Yellow	Yellow
Transportation															
Regular Commute	Yellow	Yellow	Yellow	Yellow	Orange	Orange	Green	Green	Orange	Yellow	Yellow	Orange	Orange	Yellow	Yellow

Key

- (Green) Meets criterion majority of the time
- (Yellow) Meets criterion with effort or depending on building location or existing building systems
- (Orange) Does not obvioiusly meet criterion majority of the time

To ensure the metrics were dispersed across the principles of sustainable development and design, they were reviewed for their impact on economic, environmental, and social equity indicators. The economic indicators include design and construction cost, operating cost, occupant cost, and productivity. The environmental indicators include global climate change, resource use, waste generation, and toxicity. The social equity indicators include human health, occupant comfort and/or convenience, and community impact. **Error! Reference source not found.** shows which of the sustainability indicators each of the building cost and performance metrics will be addressing.

Table A.3 Sustainable development and design indicators: analysis by metric

Sustainability	Economic			Environment				Equity		
	Design & Construction Cost	Operating and/or Occupant Cost	Productivity	Global Climate Change	Resource Use	Waste Generation	Toxicity	Human Health	Community	Occupant Comfort/Convenience
Water										
Total Building Potable Water Use	X	X			X	X			X	
Indoor Potable Water Use	X	X			X	X				
Outdoor Water Use	X	X			X	X			X	
Total Storm Sewer Output	X	X			X	X		X	X	
Energy										
Total Building Energy Use	X	X		X	X				X	
Source Energy				X	X					
Peak Electricity Demand	X	X		X	X				X	
Maintenance and Operations										
Building Maintenance	X	X	X							X
Grounds Maintenance	X	X			X		X	X		
Churn Cost	X	X	X		X					X
Waste Generation										
Solid Sanitary Waste		X			X	X			X	
Hazardous Waste	X	X			X	X	X	X	X	
Recycled Materials	X	X			X	X			X	
Purchasing										
Environmentally Preferable Purchasing (EPP)		X			X		X	X	X	
Indoor Environmental Quality (IEQ)										
Occupant Turnover Rate		X						X	X	X
Absenteeism		X						X		X
Building Occupant Satisfaction	X	X	X							X
Self-Rated Productivity	X	X	X							
Transportation										
Regular Commute	X	X	X	X	X				X	X

The *metrics*, or measurable characteristics, were developed, reviewed, and tested to ensure they were technically feasible and defensible. The information that needs to be collected from each building to produce comparable measurements has been broken into two groups:

4. Building and Site Characteristics and
5. Building Cost and Performance Metrics.

The building and site characteristics are used to provide a valid comparison between buildings. The building cost and performance metrics are used to measure the actual performance of the building over time. The performance of the individual buildings will be measured with a minimum of 12 months of data.

A.2 Example On-site Data Collection Form

WBPM Site Data for ______________________________ Date:__________

Building Characteristics ☐	**Occupancy** ☐		
Type/Function:	Type of occupants:		
Age (year occupied):	Total number of occupants:		
Year of Mjr Rnv:	Male: Female:		
Gross Area:	Vistors:	Hours/visit:	
Landscaped Area:	Hours of operation:	Start	End
Total Site Area:	Weekday:		
Number of floors:	Saturday:		
Gross Conditioned Area:	Sunday:		
Number of PCs:	Notes/Exceptions:		
Address:			

FIRST COSTS ☐	
Design Cost ($):	Construction Cost ($):
Unusual first costs/funds - Activity:	Total Cost ($):

Primary Space: ____

LIGHTING ☐

Technology Type	Fixture Description (size, #lamps, wattage, reflectors, ballasts, application, etc.)	Use Area or % of building served	Mounting Method	Utilization

MISC. EQUIPMENT ☐

Atypical equipment (note: type, fuel, capacity, utilization), refrigeration, food prep, or other

Secondary Space: ______________________________________

LIGHTING ☐

Technology Type	Fixture Description (size, #lamps, wattage, reflectors, ballasts, application, etc.)	Use Area or % of building served	Mounting Method	Utilization

MISC. EQUIPMENT ☐

Atypical equipment (note: type, fuel, capacity, utilization), refrigeration, food prep, or other

HVAC			
Portion of building NOT heated:	HEATING		
Portion of building served:	**Type 1:**	**Type 2:**	**Type 3:**
Fuel Type:			
Equipment type: 0=Elec. Resist. baseboard 1=Forced air furnace			
2=Air-source HP 3=Ground-coupled HP 4= Radiator/cent. steam/hw 5=Fan coils/cent. steam/hw/elec. 6=AHU/cent steam/hw 7=Radiator/boiler 8=Fan coils/boiler 9=AHU/boiler 10=Radiant/central steam/hw 11=Radiant/single bldg boiler 12=Infrared			
Output Capacity (total):			
Number of pieces of equipment:			
Efficiency (%):			
Portion of building NOT cooled:	COOLING		
Portion of building served:	**Type 1:**	**Type 2:**	**Type 3:**
Fuel Type:			
Equipment type: 0=Evap. Cooler 1=Window/wall units			
2=Air-source HP 3=Ground-coupled HP 4=Package or split DX 5=Fan coils/central chilled water 6=AHU/central chilled water 7=Fan coils/absorption chiller 8=AHU/absroption chiller 9=Fan coils/conventional chiller 10=AHU/conventiona chiller			
Output Capacity (total):			
Number of units:			
Manufacturer & model #:			

SERVICE HOT WATER	
Portion of building served:	**Equipment vintage:**
Fuel Type:	**Tank Capacity (gal, #tanks):**
System Type: DISTRIBUTED LOOP	**Efficiency:**
Note presence of: bottom boards, pipe insul., tank wrap, heat traps, electronic pilots	

PARKING	
Number of spots:	**Lighting:**
Location:	**Heat/Cool:**

BASEMENT	LANDSCAPING
Conditioned? **Uses?**	**Type of Plants?** **Water features?**

ROOF	
Roof type:	BUILT-UP METAL PANEL SHINGLES/SHAKES
PV:	YES NO
Cooling Tower:	YES NO

ENVELOPE	
-floor-floor height:	**Windows:** # of panes: 1 2 3
-floor-ceiling height:	**-frame type** WOOD/VINYL METAL
-suspended ceiling? YES NO	THERMAL BREAK TINTING SHADING FILM
	-% of wall area that is glass:
Wall: WOOD SIDING MASONRY/WOOD MASONRY CURTAIN MET PANEL	

MAINTENANCE/JANITORIAL SERVICES					
Maintenance Costs:		**Janitorial Costs:**			
"Green" supplies purchased for :	JANITORIAL	BUILDING MAINT.	GROUNDS MAINT.	NONE	
Maintenance Logs available:	YES	NO			
Notes:					

WASTE/RECYCLING						
How is solid sanitary wate measured?	UTILITY BILL					
Units:	# OF PICKUPS	WEIGHT	VOLUME			
Do hazardous waste disposal manifests exist for the building?	YES	NO				
What are hazardous materials used for?	JANITORIAL	GROUNDS	BUILDING MAINT.			
How frequently is waste generation reported?						
What is recycled?	PAPER	CARDBOARD	ALUMINUM	TIN	PLASTIC	GLASS
Is it measured for the building?	YES	NO	How?			
Is the recycling program promoted?	YES	NO	If so, by whom?			
Costs?	YES	NO	If so, who pays?	BUILDING	ORGANIZATION	
What is the community attitude toward recycling?						
Notes:						

OCCUPANT SURVEY
What is the process for getting an occupant survey approved and distributed?
Who needs to be involved in the process for the building?

TRANSPORTATION					
Common commute method(s)?	DRIVE	TRANSIT	WALK	BIKE	CARPOOL
Is mass transit readily available?	YES	NO	What types?		
Is parking readily available?	YES	NO			
Incentives/Disincentives for:					
Walking:					
Biking:					
Carpooling:					
Using Mass transit:					
Driving:					
Telework:					
What is the community attitude toward driving?					

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