Measurement & Verification Plan
LEED-NC v2.2

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1.0 Overview

1.1 Project Background

The (*project name*) hotel in (*location*) has been designed and constructed according to LEED-NC v2.2 criteria. The project building is a new construction, four-story, 123-room hotel with no future expansion anticipated.

For addition information about the project design, please reference the following:

- Owner's Project Requirements
- Mechanical Systems Narrative and Basis of Design

1.2 M&V Objectives

This Measurement and Verification (M&V) plan is based on Option D: Calibrated Simulation of the *International Performance Measurement & Verification Protocol (IPMVP) Volume III: Concepts and Options for Determining Energy Savings in New Construction, April, 2003.* The plan is intended to verify the cost savings associated with energy efficiency measures incorporated into the design, and to provide a recalibrated energy model that will serve as a tool for building operators in identifying and remedying causes of underperformance. Energy conservation measures (ECMs) found to deliver anticipated savings will be considered by (*owner*) for inclusion in architecture and design standards for future builds of similar properties.

The plan describes the process and responsible parties for:

- Predicting energy use by end use in the project building
- Measuring energy use by end use in the project building
- Calculating actual cost savings
- Corrective action when underperformance occurs

1.2 Baseline and Expected Energy Savings

Anticipated annual savings are based on energy modeling performed during the design process using Trace 700 software, which showed a building-wide reduction in energy costs of 18.4% compared to ASHRAE 90.1-2004 efficiency levels. This projection was developed based on the Building Performance Rating Method in Appendix G of ASHRAE 90.1-2004, and is shown in the table below.

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Table 1: Expected Annual Energy Savings

Energy Type	Baseline Annual Consumption (kBtu)	Projected Annual Consumption (kBtu)	Projected Annual Savings (kBtu)	Projected Annual Cost Savings ($)	Percent Cost Savings
Electricity	4,722,867	3,658,210	1,064,657	$32,506	15.1%
Natural Gas	2,988,647	2,890,811	97,836	$1,105	3.3%
Total	7,711,514	6,549,021	1,162,493	$33,611	18.4%

The expected annual consumption values above will be adjusted based on weather data, occupancy levels, and system operating parameters realized during the year-long period during which energy consumption measurements are in place. The adjusted expected savings will then be compared to actual savings.

1.3 M&V Plan Summary

Through the use of utility invoices, permanently installed sub-metering and spot measurements, the facility's operations staff will work with the mechanical engineering design and commissioning firm, (*company name*), to measure the actual utility usage of the building and key end uses for one year of post-occupancy consumption.

Collected data will be used to verify the predicted energy performance of energy conservation measures (ECMs) integrated into the design as part of the LEED effort.

Table 2: M&V Plan Summary

ECM	Description	M&V Methods and Equipment
Lighting	Optimize activation using scheduling and occupancy sensors	Monitor lighting electricity usage through use of sub meters
Exterior Lighting	Optimize activation using scheduling through time clocks and photocell	Monitor lighting electricity usage through use of sub meters
Space Heating	Optimize activation using scheduling and remote thermostats	Monitor space heating electricity usage through use of sub meters
Space Cooling	Optimize cooling through electronic thermostats an space sensors to	Monitor space cooling electricity usage through use of sub meters

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	minimize ventilation air	

Table 2: M&V Plan Summary cont:

Space Cooling	Optimize cooling through electronic thermostats an space sensors to minimize ventilation air	Monitor gas usage through gas sub meters
Space Heating	Optimize space temperature heating	Monitor gas usage through gas sub meters
Water Heating	Reduce hot water storage temperature	Monitor gas usage through gas sub meters

1.4 Equipment Commissioning

Commissioning activities occurred in the project building for the following energy-related systems prior to occupancy in (*date*).

- Heating
- Ventilation
- Air conditioning
- Refrigeration
- Lighting
- Domestic hot water
- Controls

Commissioning was performed by (*company name*) in accordance to LEED EA Prerequisite 1, Fundamental Commissioning of the Building Energy Systems. The Commissioning Report is included in the LEED Certification Application, and records of deficiencies and their remediation of kept by (*company name*). Throughout the M&V period, minor additional commissioning activities will be performed as necessary by (*company name*) and the building operations staff.

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1.5 M&V Period

The M&V period is the timeframe during which monthly readings of energy consumption will occur. This period shall be at least one year in length, and is anticipated to commence on (*date*).

1.6 Expected M&V Accuracy

Occupancy data through guest room sales data is highly accurate and is done and documented daily by hotel operations reservation system. Hotel Operations has confirmed that they will assist with monitoring logs and provide information to MEP engineer (*company name*). It is not expected that issues with inaccurate guest room sales will compromise the M&V effort.

Permanent metering equipment will have Utility Grade Metering Accuracy and meet ANSI National Accuracy Standards.

Within the M&V program, it is expected that data collected during the period will be highly accurate. Limitations of the modeling program are expected to be the greatest potential source of inaccuracy. Adherence to ASHRAE 90.1-2004 Appendix G protocols will be used to minimize this potential.

1.7 Quality Assurance

The M&V strategy will be reviewed following the first month of implementation to ensure that procedures and processes are effective for capturing the required data. Monthly data recordings will be reviewed promptly for anomalous values that could signal data errors or underperforming equipment.

1.8 Budget and Resources

(*Owner*) is financially responsible for executing the M&V program costs. Materials and labor budgets are outlined below. These do not reflect soft costs associated with data recording on the part of operations staff.

Item	Budget
Submetering Equipment	$15,000-$25,000
M&V Labor	$20,000
Corrective Action	As needed

2.0 Data and Assumptions

2.1 Energy Rate Data

Electricity costs will be calculated using a rate of .13452 kWh for (*location*) based on (*utility provider*).

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Natural gas usage costs will be calculated using a rate of $1.292 per therm for (*location*) based on (*gas utility company*).

2.1 Energy Savings Calculations

Energy savings will be determined by comparing measured energy use to the projected based on the following equation:

Energy Savings = Projected Baseline Energy Use – Measured Post-Construction Energy Use

Measured Post-Construction Energy Use is the energy use of the as-built facility. This is in accordance with the Method 2, Option D: Savings Estimation protocol in the IPMVP standard.

2.2 Reporting Requirements

The M&V report shall be provided to (*owner*) within 45 days of the completion of the one-year M&V period. The owner or owner's representative shall then review the report with a subsequent 30 days. The report will include summaries of logged information for each ECM, log deviations from expected savings, provide recommendations for corrective actions and future savings, and record any significant O&M work performed on equipment associated with ECMs.

2.3 Responsible Parties

(*Company name*), the project's mechanical designer and energy analyst, is the entity primarily responsible for the M&V Plan's development, coordination and implementation. The project owner and building operations staff will support implementation of the plan.

Table 3: M&V Responsibilities

M&V Activity	Responsible Party
Baseline energy model	XX
Recalibrated baseline energy model to reflect as-built conditions	XX
Identification of ECMs for inclusion in the M&V plan	XX
Development of M&V plan	XX
Compilation of all occupancy, controls, and scheduling information during the M&V period	XX
Spot metering during M&V period	XX

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Installation of required sub-metering equipment	XX
M&V Report	XX
Corrective Action	XX

3.0 Electricity M&V Plan

3.1 Electricity Baseline Simulation

IPMVP Option D has been selected for the M&V plan because a) the integrated design process yielded efficiency strategies intended to work in concert with each other, making isolation of ECMs inappropriate, and b) a computer simulation was used during the design phase to predict whole building energy usage. The computer simulation was performed using Trane 700 to demonstrate achievement with LEED-NC v2.2 EA Credit 1: Optimize Energy Performance. Model inputs are recorded in the LEED Certification Application materials.

The energy analysis used climatic data for (*location*), which is proximate and climatically similar to (*project location*).

Building occupancy during the M&V period will be tracked based on guest room sales. Due to the nature of the building, operating hours are static.

3.2 Electricity Baseline and Expected Usage Projections

The projected baseline is based on the minimum requirements of ASHRAE 90.1-2004 for buildings with similar mechanical systems.

Projections reflect annual electricity consumption, and are summarize by end use in the table below.

Table 4: Baseline an Expected Electricity Usage Projects by End Use

End Use	Baseline Annual Electricity (kWh)	Expected Annual Electricity (kWh)	Actual Annual Electricity (kWh)
Interior Lighting, Exterior Lighting (tradable and non tradable)	397,274	228,873	TBD
Space Heating	191,956	159,413	TBD

Space Cooling	160,231	117,992	TBD
Fans – Interior	120,403.8	68,973	TBD
Guestroom Power, lighting and HVAC	228,335	228,335	TBD

3.3 Post-Installation Equipment Monitoring

Following installation and before occupancy, commissioning activities were used to verify the proper fundamental operations of the building systems. Should a component of an ECM fail to work in the designed manner, maintenance will be performed to restore the equipment to its designed operation. Permanent and spot metering will be used to measure electrical consumption. Operation staff will use metered trend data and spot checks to identify underperforming systems so that corrective action can be taken.

The method of metering will be through sealed electronic sub meters, these meters will record the electrical loads indicated within this plan. These meters are intended to validate the anticipated energy savings previously indicated in LEED EAc1 and as indicated below. Recalibration of the meters can be done by sending these meters back to the factory, contacts with these vendors have indicated that this is typically done every five years. The table below shows the metering strategy that will be used to monitor electrical loads.

Recording of the guestroom occupancy will be done through the (*hotel name*) reservation system.

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Table 5: Electrical Metering Equipment

Meter	Location	Metered Panels/Loads	Load Type	Loads
M1	ELECTRICAL ROOM 129	PANEL EM-A – METER CIRCUIT BREAKER FEEDING PANEL OLP – METER TO BE RATED FOR 100AMPS	Electric - Exterior Lighting (tradable and non tradable)	OUTDOOR LIGHTING
M1-A Using meter M! add additional CTs to read the energy usage	ELECTRICAL ROOM 129	PANEL LP-1A, LP-1B, LP-2, LP-3, LP-4 AND DIMMING PANEL TO SUBTRACT LOAD FOR PANEL MECH 1B	Electric - Interior LIGHTING	INTERIOR LIGHTING
M1-B Using meter M1 add additional CTs to read the energy usage	ELECTRICAL ROOM 129	PANEL EM-1 – METER TO BE RATED AT 200AMPS	Electric - INTERIOR LIGHTING	LIGHTING

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Table 5: Electrical Metering Equipment cont:

M2	ELECTRICAL ROOM 129	PANEL MECH-1A – METER TO BE RATED FOR 1600AMPS. PROVIDE XTRA SET OF CT'S TO SUBTRACT LOAD FOR PANEL MECH 1B	Electric - Space Cooling	INTERIOR COOLING EQUIPMENT ROOF TOP UNITS AND SPLIT SYSTEMS
M3	ELECTRICAL ROOM 129	PANEL MECH-1B – METER TO BE RATED FOR 400AMPS. PROVIDE CT'S TO PICK UP SPACE HEATING	Electric - Space HEATING	INTERIOR WALL AND CABINET HEATERS
M4	ELECTRICAL ROOM 129	PANEL MECH-1B – METER TO BE RATED FOR 400AMPS. PROVIDE CT'S TO PICK UP SPACE COOLING	Electric - Space COOLING	SPLIT SYSTEM AC EQUIPMENT FED FROMTHIS PANEL

Table 5: Electrical Metering Equipment cont:

M5	ELECTRICAL ROOM 129	PANEL MECH-1B – METER TO BE RATED FOR 400AMPS. PROVIDE CT'S TO PICK UP SPACE HEATING	Electric - Space HEATING	INTERIOR WALL AND CABINET HEATERS
M6	ELECTRICAL ROOM 129	PANEL MDP, METER CIRCUIT BREEAKERS FEEDING PANEL 1GB, 2GA, 2GB, 3GA, 3GB,4GA AND 4GB – METER TO BE RATED AT 1200AMPS	Electric - Guestroom Power, lighting and HVAC	LIGHTING, POWER AND HVAC IN GUESTROOM

Please note that the exhaust fans run continuously (due to fire life safety codes); spot checking will occur on a monthly basis to validate energy usage. The usage of the fans is independent of the environment or guest room occupancy.

3.4 M&V Period Verification Activities

On a monthly basis, operations staff shall record the energy consumption of loads associated with ECMs. Also record any significant O&M activities performed on the systems during that time period, including any associated costs. At the end of the one-year M&V period, summarize the electrical consumption data for comparison with the recalibrated baseline and expected consumption. The metered equipment shall be inspected at the conclusion of the

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M&V period and as needed to verify proper operation. All collected information and comparison results will be included in the M&V report.

All efforts will be made to prevent the omission or loss of metered data. In the event that data is missing or lost, existing data from before and after the missing portion will be used to extrapolate if appropriate. Extension of the M&V period is also an option for mitigating the effect of lost data.

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Table 6: Electrical Monthly Consumption Reporting Form

Measurements Recorded By:			
Date of Measurements:			
Occupancy Levels:			
Meter	**Location**	**Electric Consumption (kWh)**	**O&M Activities / Costs / Comments**
M1	**Electrical Room 129**		
M2	**Electrical Room 129**		
M3	**Electrical Room 129**		
M4	**Electrical Room 129**		
M5	**Electrical Room 129**		
M6	**Electrical Room 129**		

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4.0 Natural Gas M&V Plan

3.1 Natural Gas Baseline Simulation

IPMVP Option D has been selected for the M&V plan because a) the integrated design process yielded efficiency strategies intended to work in concert with each other, making isolation of ECMs inappropriate, and b) a computer simulation was used during the design phase to predict whole building energy usage. The computer simulation was performed using Trane 700 to demonstrate achievement with LEED-NC v2.2 EA Credit 1: Optimize Energy Performance. Model inputs are recorded in the LEED Certification Application materials.

The energy analysis used climatic data for (*location*), which is proximate and climatically similar to (*project location*).

Building occupancy during the M&V period will be tracked based on guest room sales. Due to the nature of the building, operating hours are static.

3.2 Natural Gas Baseline and Expected Usage Projections

The projected baseline is based on the minimum requirements of ASHRAE 90.1-2004 for buildings with similar mechanical systems.

Projections reflect annual natural gas consumption, and are summarize by end use in the table below.

Table 4: Baseline an Expected Electricity Usage Projects by End Use

End Use	Baseline Annual Natural Gas (kBtu)	Expected Annual Natural Gas (kBtu)	Actual Annual Natural Gas (kBtu)
Space Heating	809,779.3	904979	TBD
Service Water Heating - Domestic	520,320.8	339910	TBD

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3.3 Post-Installation Equipment Monitoring

Following installation and before occupancy, commissioning activities were used to verify the proper fundamental operations of the building systems. Should a component of an ECM fail to work in the design manner, maintenance will be performed to restore the equipment to its designed operation. Permanent and spot metering will be used to measure electrical consumption. Operation staff will use metered trend data and spot checks to identify underperforming systems so that corrective action can be taken.

Gas meters will be turbine style. Recalibration of the meters can be done by sending these meters back to the factory, contacts with these vendors have indicated that this is typically done every five years. The table below shows the metering strategy that will be used to monitor natural gas loads.

Recording of the guestroom occupancy will be done through the (*company name*) reservation system.

Table 5: Natural Gas Metering Equipment

Meter	Location	Metered Loads	Load Type	Loads
Space Heating	Roof Top Equipment	RTU-1, RTU-2, RTU-3 and RTU-4	Gas	Roof Top Equipment
Service Water Heating - Domestic	Mechanical Room 128	GWH-1 (750mbh)	Gas	Hot Water

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3.4 M&V Period Verification Activities

On a monthly basis, operations staff shall record the energy consumption of loads associated with ECMs. Also record any significant O&M activities performed on the systems during that time period, including any associated costs. At the end of the one-year M&V period, summarize the natural gas consumption data for comparison with the recalibrated baseline and expected consumption. The metered equipment shall be inspected at the conclusion of the M&V period and as needed to verify proper operation. All collected information and comparison results will be included in the M&V report.

All efforts will be made to prevent the omission or loss of metered data. In the event that data is missing or lost, existing data from before and after the missing portion will be used to extrapolate if appropriate. Extension of the M&V period is also an option for mitigating the effect of lost data.

Table 6: Natural Gas Monthly Consumption Reporting Form

Measurements Recorded By:			
Date of Measurements:			
Occupancy Levels:			
Meter	**Location**	**Natural Gas Consumption (kBta)**	**O&M Activities / Costs / Comments**
G1	Roof Top Equipment		
G2	Mechanical Room 128		

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