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BUILDING ENERGY MODELING STEP-BY-STEP PROCEDURES FOR LEED CERTIFICATION

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ONLINE TRAINING BY KRISHNAJI PAWAR

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MODULE L25

Sample Measurement & Verification Plan

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BUILDING ENERGY MODELING : STEP-BY-STEP PROCEDURES FOR LEED CERTIFICATION

The integration of M&V and BEM creates a robust framework for assessing and optimizing energy performance. By using BEM to predict energy savings and subsequently employing M&V to verify those predictions, stakeholders can ensure that energy efficiency projects deliver tangible results. This synergy is particularly valuable for ongoing energy management, where continuous monitoring and feedback loops can lead to sustained improvements.

Learning Objectives

- Introduction and Course Outline
- Building Energy Modeling Checklists
- Scaling an imported drawing from AutoCAD
- ASHRAE Standards and Guidelines
- Zones Input Details in BEM Tools
- Setup and Running the Building Energy Modeling Simulation
- Review BEM Software Output Reports.
- Sample Measurement & Verification Plan
- Summary and Resources
- BEMP Practice Test V.4.1

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INTRODUCTION

- M&V is crucial for assessing energy efficiency projects.
- It ensures real, measurable, and verifiable energy savings.
- A well-structured M&V plan outlines procedures and methods for energy savings assessment.
- M&V is vital for accountability, financial transactions, and project informing.
- Key components include project description, baseline measurements, M&V approach, data collection and analysis, reporting, verification process, and contingency plans.
- Project description should detail technologies, baseline energy consumption, and expected savings.
- Reporting should be quarterly during the first year, followed by a comprehensive report at the end of the year.

MEASUREMENT AND VERIFICATION (M&V) AND BUILDING ENERGY MODELING (BEM)

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- M&V is a systematic process used to assess energy savings from energy efficiency projects.
- It provides reliable evidence that the anticipated energy savings have been achieved, justifying the investment in energy efficiency measures.
- M&V methodologies are guided by established protocols, such as the International Performance Measurement and Verification Protocol (IPMVP).
- The IPMVP outlines four options for M&V: Retrofit Isolation (Key Parameter Measurement), Retrofit Isolation (All Parameter Measurement), Whole-Building Measurement, and Calibrated Simulation.
- The difference in energy consumption, adjusted for any significant changes in occupancy or operational hours, is calculated to determine the energy savings attributable to the HVAC upgrade.

COMPONENTS OF A SAMPLE M&V PLAN

- Project Description: Details the specifics of the energy efficiency project, including technologies, baseline energy consumption, and expected energy savings.
- Baseline Measurements: Defines the methodology for establishing a baseline, including data collection methods, duration of the measurement period, and conditions under which measurements were taken.
- M&V Approach: Defines the methodology used to quantify energy savings, with four options provided by the International Performance Measurement and Verification Protocol (IPMVP).
- Data Collection and Analysis: Outlines how data will be collected, the frequency of collection, and the methods for analyzing the data.
- Reporting: Stipulates the format and frequency of reporting energy savings to stakeholders.
- Verification Process: Outlines the process for independent verification, including who will conduct it and the criteria for evaluation.
- Contingency Plans: Outlines steps to mitigate risks and ensure continuity in data collection.

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M/S WALLS & FLOORS ME FZCO

WAREHOUSE & OFFICE BUILDING
PLOT NO. S20905, JAFZA, DUBAI, U.A.E.

LEADERSHIP IN ENERGY AND ENVIRONMENTAL DESIGN
GREEN BUILDING RATING SYSTEM™ FOR NEW CONSTRUCTION
(LEED FOR NEW CONSTRUCTION VERSION 2.2)

Measurement & Verification Plan

11 NOVEMBER 2021

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MEASUREMENT & VERIFICATION PLAN

1. Introduction

This plan describes the activities involved in conducting measurement and verification for the new Warehouse & Office Building, M/S Walls & Floors ME FZCO. The project is conducting measurement and verification according to the US Green Building Council's LEED (Leadership in Energy and Environmental Design) standards. Monitoring and verification will be conducted to provide the building with the tools and information needed to:

- track energy use
- identify systems that are not functioning as intended, and;
- optimize energy performance

The project will establish a baseline for energy use, and measure energy savings in relation to that baseline. The baseline will be created using energy simulation software, and performance of building systems will be continuously monitored through the tracking energy & water consumption.

The International Performance Measurement & Verification Protocol (IPMVP) Volume III will be the guide for conducting M&V. The project will use IPMVP's Option D, Whole Building Calibrated Simulation, to measure savings.

2. Activities

This plan describes the process for collecting building operational data, and comparing actual systems performance with a baseline. The baseline for M&V will be a calibrated energy model based on energy models built during the design phase of the project. Monitoring building system performance and analyzing performance trends will enable the project to verify energy savings, and identify equipment or system malfunctions and opportunities for further energy savings. Monitoring and data collection will cover the following systems:

- Split Ducted AC Units
- Decorative AC Units
- Lighting
- Motors
- Pumps

The project will rely on building facility staff to collect and organize data. Data collection will be coordinated by an energy administrator within facility management, who will monitor results on a monthly basis. Quarterly reports will be prepared by the M&V consultant on overall energy performance in comparison to the baseline.

2.1 Process

The essential steps involved in M&V for this project are as follows:

1. Define baseline according to ASHRAE 90.1-2004
2. Develop energy simulation model to project energy savings
3. Prepare M&V Plan
4. Verify installation and commissioning of energy conservation measures (ECMs)
5. Collect operating performance data
6. Calibrate baseline model according to actual operating parameters
7. Calculate savings by comparing calibrated baseline and actual performance
8. Report results
9. Re-evaluate savings and performance for each Quarter over 1 year

Table 1: M&V Activities and Responsible Party

Activity	Primary Responsibility	Provide Input
M&V Plan Development	MECSD	Pacific Control Systems
M&V Plan Review and Approval	Facility Management Team, M/S Walls & Floors ME FZCO	Abhijit Jayswal
Post Construction Equipment Survey – Review of Cx Plan	Facility Management Team, M/S Walls & Floors ME FZCO	Pacific Control Systems
Data Collection for Trend Logging and Calibration	Facility Management Team, M/S Walls & Floors ME FZCO	Pacific Control Systems
Model Calibration	Facility Management Team, M/ Walls & Floors ME FZCO	Abhijit Jayswal
Trend Log, Utility Data and Energy Analysis	Facility Management Team, M/S Walls & Floors ME FZCO	Abhijit Jayswal
M&V Report: Post-Installation, Quarterly (Interval) Report, and at end of 1 year	Facility Management Team, M/S Walls & Floors ME FZCO	Pacific Control Systems
Corrective Action (if needed)	Facility Managers	MECSD, Pacific Control Systems

2.2 M&V Period and Schedule

The M&V period is for one year after construction is complete and the building has reached a reasonable level of occupancy and operational stability. After one year, long-term M&V can be conducted. Data collected during the first year will become the "base year" for measuring energy performance and trends over the long term. This plan covers only the first year.

Table 2: Schedule of Reporting Activities

Item	Recommended time of submission	Owner's review and acceptance period
Post-Installation Report	30 days after data collection	30 days
Quarterly Reports	30 days after data collection	30 days
Annual Report	30 days after final quarterly report	30 days

2.3 Project Team

Table 3: Team Members

Team Member	Company & Contact Names	Phone, fax, email address
Mr. Reza Nikzad	Managing Director, M/S Walls & Floors ME FZCO	Tel:00971-506254226 E-mail: rezanikzad@wallsandfloors.com
Mr. Samod Kanjoor	Pacific Controls	Tel: 00971-508756885 E-mail: samod@pacificcontrols.net
Mr. Krishnaji Pawar	MECSD	Tel:00971-501978731 E-mail: krishnaji@mecsd.com
Mr. Lytten Thomas	Electrical Engineer (Space Electromechanical)	Tel:00971-509023540 E-mail:spaceele@yahoo.com

3. Design Intent of Specific ECMs

During the design phase of the project, various high performance ECMs were modeled for the building to quantify possible energy efficiency improvements below ASHRAE 90.1-2004. ECMs are included in the building design as it is presently developed. ECMs chosen for the project include:

- High efficiency air conditioning units
- High efficiency energy recovery units
- Low-e glazing and skylights
- Lighting power density reduction
- Solar water heating system

The model predicted annual energy savings from these energy efficiency measures totaling 97,021 kWh.

Table 4: Baseline Building versus Proposed ECM Savings

Equipment Loads from Energy Conservation Measures (ECMs) (kWh)		
Equipment Description	ASHRAE Baseline (Average)	Proposed Design
Space Cooling	104,934	76,619
Hot Water	43,199	12,959
Space Heat	1,786	918
Ventilation Fans	45,162	45,710
Equipment	43,474	43,474
Process Load	80,543	80,543
Interior Lights	185,040	130,578
External Lights	46,503	31,811
Total Energy	550,641	422,612
Total Cost	166,108 (AED)	123,863 (AED)

4. LEED and M&V

Measurement and verification will be conducted according to the criteria described under Energy and Atmosphere, Credit 5.

The intent of measurement and verification is to provide for ongoing accountability of building energy consumption. EA credit 5 references the IPMVP Volume III guideline as the standard for verifying energy performance of new construction buildings. The credit requires development of a Measurement and Verification Plan using either Option B (ECM isolation) or Option D (calibrated simulation and savings estimation method 2) under the IPMVP Volume III.

5. Description of Baseline

The baseline for M&V is ASHRAE 90.1-2004. Once the building is operationally stable, the baseline model will be calibrated using Option D (calibrated simulation) to match actual occupancy and operational parameters. However, baseline elements such as insulation

levels, baseline HVAC System type and efficiency rating, etc, will not change in the calibrated baseline. The baseline represents building design and operation using ASHRAE 90.1 specifications, without ECMs. The ASHRAE 90.1-2004 compliant baseline and proposed design models have been built to meet LEED EAp2 and EAc1 requirements.
Option D is most suited to this project since whole-building simulation is being conducted for energy analysis, and since the building has numerous ECMs that are interactive in nature.

Table 5: Baseline and Proposed Design Inputs

Building Characteristics	ASHRAE Baseline Model	Proposed Design Model
Roof (U-value)	0.063	0.06
Windows	U – 1.22 , SHGC – 0.25	U – 0.52, SHGC – 0.26
Walls (U-value)	0.12 4	0.089
HVAC System (Split Ducted Units)	9.3	10.4 (average)
Lighting Power Density	0.96 (average)	0.75 (average)

6. M&V Option D

6.1 Simulation Software

Simulation software used for M&V is Visual DOE 4.1 which uses DOE 2.1 as the calculation engine. Visual DOE is an energy analysis tool capable of detailed building analysis.

Within Visual DOE, DOE 2.1 conducts hourly simulation of the building for a one-year period. The program calculates heating and cooling loads for each hour of the year, using inputs for the following:

- walls
- windows
- glass
- occupants
- plug loads
- ventilation

After inputting equipment type, size, and operating parameters, Visual DOE simulates the performance of:

- fans
- pumps
- HVAC Systems
- other energy-consuming devices

Results of the simulation are in the form of projected energy use for the following building loads:

- lighting
- plug loads (computers, appliances, copiers, etc.)
- heating
- cooling
- ventilation
- pumping

6.2 Method for Savings Estimation

This project will use "Method 2" for savings estimation (as described by the IPMVP). Method 2 involves subtracting the "metered post-construction energy use from the energy use of the calibrated baseline model (IPMVP Volume III, 2003, p.22)."

The alternative approach, Method 1, subtracts energy use of the calibrated as-built model from that of the calibrated baseline model. This approach would not identify any physical losses or malfunctions of building equipment and systems.

Method 2 will involve more detailed calibration and review of the baseline calibrated model to ensure accuracy and to reduce baseline simulation error. Savings estimation must be adjusted to account for error in the baseline model.

Note that under Method 2 the baseline simulation model will have to be adjusted for each M&V period. This is to account for any operational or equipment performance changes that occur between measurement periods.

6.3 Assumptions and any Unique Modeling Techniques/Methodologies

Simulation of the cooling system required some notable modifications to the baseline and proposed models. The proposed building's current design utilizes split ducted units, but according to ASHRAE 90.1-2004's performance rating approach, a packaged single system has to be used for the baseline model.

The pre-calibrated model also includes inputs based on some assumptions. The building's operating schedule is assumed to be 12 hours. That schedule is likely to be modified in the calibrated model based on actual use (e.g., adjustments to night time schedules to reflect reduced production activities). Finally, the model used DOE weather files for Abu Dhabi, UAE. Those files may not take into account microclimate differences in the Dubai area, which could create variance between predicted and actual energy performance.

Table 6: Weather/Climatic Inputs

Climatic Conditions	
Location	Abu Dhabi, UAE
Latitude	40.97°N
Longitude	28.82°W
Elevation (Feet)	764
Heating Deg Days (Baseline 65°F)	3,534
Cooling Deg Days (Baseline 50°F)	3,777
Heating Design Temp	26°F
Cooling Design Dry bulb	84°F
Cooling Design Wet bulb	69°F
ASHRAE Climate Zone	1A

6.4 Metering and Calibration

Data gathered from meters will be used during simulation calibration. System or equipment specific meters and sensors enable calibration down to the system level and provide information on operational performance of metered equipment.

Simulation Calibration Procedure

Upon completion of construction and after the building is entirely occupied and fully operational, data collected from monthly utility bills and instrumentation installed on specific equipment which the owner and design team may desire to monitor independently shall be used to calibrate the as-built and Baseline building simulation programs.

This initial M&V period should span no less than twelve months.

Weather data must be collected for this time period and be incorporated into both the Baseline and as-built building simulation models. Government weather agencies are acceptable sources for local weather data.

Both the as-built and Baseline building simulation models shall incorporate any changes made to the operation or occupancy schedules.

The energy consumption outputs for the as-built building simulation program shall be calibrated to a tolerance within plus or minus 10 % of the actual energy consumption of the building for the initial M&V period (per ASHRAE Guideline 14).

Calibrating the whole-building level shall be done using the following approach.

First, the model is developed and run using weather data that corresponds to the monthly utility billing periods as described above. Next, monthly simulated energy consumption and monthly measured data are plotted against each other for every month in the data set. Be sure to calculate the model's whole building energy usage over the same calendar days as for each month's utility bill. The error in the monthly and annual energy consumption is calculated by the following equations:

$$\mathrm{ERR}_{\mathrm{month}}(\%) = \frac{\mathrm{M} - \mathrm{S}_{\mathrm{month}}}{\mathrm{M}_{\mathrm{month}}} \times 100$$

$$\mathrm{ERR}_{\mathrm{month}} = \sum_{\mathrm{year}} \frac{\mathrm{ERR}_{\mathrm{month}}}{\mathrm{N}_{\mathrm{month}}}$$

where *M* indicates the measured kWh or fuel consumption and *S* the simulated kWh or fuel consumption. *N month* is the number of utility bills in the year.

Note that monthly differences in measured and simulated energy consumption may cancel each other, resulting in a smaller annual ERR. To ensure against cancellation of monthly errors, the coefficient of variation of the root-mean-squared monthly errors must also be checked.

The root-mean-squared monthly error is calculated by the following equation:

$$RMSE = \sqrt{\frac{\sum_{month} (M-S)_{month}^2}{N_{month}}}$$

The mean of the monthly utility bills is:

$$A_{month} = \frac{\sum_{year} M_{month}}{N_{month}}$$

The CV (RMSE) for the monthly billing data is:

$$CV(RMSE_{month}) = \frac{RMSE_{month}}{A_{month}} \times 100$$

The combination of ERR and the CV (RMSE) can determine how well the model predicts whole-building energy usage. The lower the ERR and CV (RMSE), the better the calibration.

After the as-built has been satisfactorily calibrated, to the greatest extent possible all applicable adjustments made to the as-built model should be incorporated into the Baseline simulation model.

Savings Estimation

Savings for the initial M&V period for this project shall be estimated using Method 2 as described in Section 4.5.8 of the IPMVP Volume III.

This method simply subtracts metered post-construction energy use from the energy use of the calibrated Baseline model.

Completion of the initial M&V period review will require a collaboration of the owner's personnel and the design team.

Subsequent Energy Analysis

Analysis of subsequent M&V periods will be the responsibility of the owner's personnel.

- Correlate power demand and energy data from equipment operation to refine operating procedures.

7.2.1 Utility Consumption Reporting

Utility data will be collected and analyzed at least once a month. However, power and load trends will be analyzed at much smaller intervals (e.g., per minute or hour) to allow for a higher level of analysis.

7.3 Reporting Format

Aggregate energy consumption will be reported for each of the utilities (excluding domestic water which is reported separately). To do this, each utility will be converted into common metrics, such as BTUH. For example, the results will be reported as BTUH per m^2 per month (e.g., 5,000 BTUH per m^2 per month for the office building).

Savings will also be reported for major building loads. See Appendix. A: Annual Measurement & Verification Report below for recommended reporting format for monthly and annual reports.

7.4 M&V Report

Quarterly M&V reports will include the above utility data and savings results. Quarterly reports will also provide a summary of performance data for major equipment and associated load profiles. The report will identify any discrepancies, actions taken to improve energy performance, and further optimization strategies. This report shall be submitted to Environmental Health & Safety (local government authority of Dubai) as per their requirement.

This plan was developed for the sole purposes of the Warehouse & Office Building, M/S Walls & Floors ME FZCO. It is modeled after IPMVP Volume III guidelines for measurement and verification of new construction buildings, to meet requirements of the LEED green building rating system with some excerpts reproduced from those two sources.

M/S Walls and Floors ME FZCO
Plot No. S20905, JAFZA, Dubai, UAE

ANNUAL MEASUREMENT & VERIFICATION REPORT

Energy Conservation Measurement to be Monitored	Units	Measurement	Review	Baseline DATA	Actual	Responsible person
Total Building energy consumption (HVAC & lighting)	kWH/yr	Single energy meter mounted on the main incoming grid	Monthly	550,641 (kWH/yr)	To be measured and filled-in.	Facility management team
Water Consumption System & Solar Water Heater						
Potable water consumption from DEWA	Gallons /yr	Water flow by permanent water flow meter	Monthly	74,995 (gl/yr)	To be measured and filled-in.	Facility management team

Submitted by:

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Facility Manager

Submitted to:

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EHS Officer
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